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In the last calendar year, 2020, what was called at first the novel coronavirus killed, according to the CDC, 350,000 Americans.[1] Air pollution from the burning of fossil fuels is not novel, but according to one recent estimate published in the journal *Environmental Research*, it also killed, in the last year for which data are available, 350,000 Americans.[2] A covid-level mortality event in the midst of what appeared to most of us, overlooking the cost of burning fossil fuels, an unexceptional year.

The numbers are so large they can seem almost hard to credit, and they may yet be revised—though it is a distressing fact of climate science that almost all revisions push estimates of damage, and therefore the cost of inaction, upward. This is a familiar paradox of climate science, which offers harrowing assessments and projections which we know — must know — also offer the clearest picture we have of the future that awaits us should we fail to act. In fact, we are already living with many of those impacts, often having insidiously normalized them. Globally, the same research suggested, 8.7 million deaths in 2018 can be attributed to pollution produced by the burning of fossil fuels.[3] That attribution is complex, and the deaths multi-factorial, meaning they are hard to untangle from other contributing factors we often call comorbidities and know reflect enduring disparities: poverty, poor health care and housing quality, underlying medical conditions. On all of these fronts, climate change and environmental degradation promise to worsen disparities, punishing those most intensely who are least able to endure and adapt.

Those punishments are harrowingly widespread. The *Lancet* puts the global annual death toll of all pollution at 9 million.[4] This is dying at the scale of the Holocaust every single year. In India, where 349,000 stillbirths and miscarriages have been attributed annually to the effects of air

[1] https://covid.cdc.gov/covid-data-tracker/#trends_totalandratedeathstotalrate
[2] Karn Vohra et al, "Global mortality from outdoor fine particle pollution from fossil fuel combustion: Results from GEOS-Chem," *Environmental Research* 195 (2021).
[3] Vohra 2021.
[4] *The Lancet Commission on Pollution and Health* 2017.

pollution[5], the average resident of Delhi has had his or her life expectancy shortened by more than 9 years from the repetitive inhalation of smog.[6] Globally, the average figure is two years.[7]

In the United States, thankfully, we have enviable air quality. The Clean Air Act of 1970 is still, according to the National Resources Defense Council, saving 370,000 American lives every single year.[8] As a result, the NRDC says, that single piece of legislation delivers annual economic benefits of more than $3 trillion, 32 times the cost of enacting it—benefits distributed disproportionately to the poor and marginalized, who had previously suffered most from pollution (as they always do).[9] That estimate of benefits is so large it could have covered the cost of the CARES act last year, and the Jobs Act this year, and paid for similarly-sized investments in the future well-being of Americans every single year hereafter. But, unfortunately, many of these gains could be undone by air pollution produced by growing American wildfires over the next few decades.

In 2020, wildfire smoke accounted for more than half of all air pollution in the western U.S., meaning that more particulate matter from fire infiltrated the lungs of Americans living in those states than from all other industrial and human activity combined.[10] The smoke reached the East Coast, too,[11] then traveled to Europe[12], which shouldn't surprise us, considering that smoke from the Australian fires from earlier in the year — which burned 46 million ares, stopping ferry service in Sydney harbor, setting off fire alarms in the city's downtown office buildings, and forcing beachside military evacuations in scenes reminiscent of both *Dunkirk* and *Mad Max* — could be seen via satellite traveling as far as South America.[13]

Now, at the tail end of a brutal pandemic year, those Australian fires may seem like a vague and distant memory, but they are also a harbinger of our global future. There are those who downplay the problem of wildfire in the American west by suggesting that the dramatic growth in acres burned — a quadrupling over four decades[14], with five of the six largest fires in the state's modern history all arriving in 2020[15] — is not the simple result of climate changes but also a half

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[5] Tao Xue et al, "Estimation of pregnancy losses attributable to exposure to ambient fine particles in south Asia: an epidemiological case-control study," *Lancet Planetary Health* 5 (2021).
[6] Michael Greenstone and Claire Qing Fan, "Air Quality Life Index 2020 Annual Update."
[7] Greenstone 2020.
[8] "Clearing the Air: The Benefits of the Clean Air Act," May 2020.
[9] "Clearing the Air: The Benefits of the Clean Air Act," May 2020.
[10] Marshall Burke et al, "The changing risk and burden of wildfire in the United States," *Proceedings of the National Academy of the Sciences* 118 (2021).
[11] Mike Baker, "Smoke from West Coast Wildfires Spreads to the East Coast," *New York Times*, September 15, 2020.
[12] Andrew Freedman, "Western wildfire smoke nearing Europe, may be on an around-the-world journey," *Washington Post*, September 16, 2020.
[13] "Australian bushfire smoke affecting South America, U.N. reports," *Reuters*, January 7 2020.
[14] Burke 2021.
[15] Michael McGough, "5 of the 6 largest California wildfires in history started in the past 6 weeks," *Sacramento Bee*, September 22, 2020.

century of poor forest management, which has left behind a state full of what Californians have tragically learned to call "fuel." Those people are right, to a degree: better forest management can help mitigate the damage from future fires, though even the prescribed burns favored by experts to "thin" that fuel load would produce air pollution just as wildfires do—and would require perhaps 20 million acres, or 20 percent of the state, to be burned or thinned.[16] And while it is also the case, as skeptics sometimes point out, that California once saw much bigger fires in its distant pre-Columbian past, it is also true — critically true, since on all of these questions we are not just dealing with natural systems but the matter of human response and human consequences — that there weren't 40 million people living there, then, either, breathing all that toxic air, and pushed by the state's housing crisis to live further and further into what's called the "wildland urban interface," where fire risk is highest. Since 1990, sixty percent of all new residential development in the state has come in wildfire-prone areas.[17] Nationally, we are adding a million new homes to the "WUI" every three years.[18] When the Camp Fire incinerated Paradise, California, evacuees settled in nearby Chico—straining an already-strained housing supply, driving up homelessness, and sparking a political backlash to those new arrivals whom locals began calling "refugees," and "unwanted," though they came from less than fifteen miles away, chased by flames.[19]

This is where we are today, with birds falling from the sky by the thousands in the American southwest, emaciated by climate change[20]; and clouds of locusts eight thousand times bigger than they would have been without warming descending on croplands in the horn of Africa, chewing through enough food to feed millions[21]; with a category 5 hurricane making landfall in Nicaragua just two weeks after, and just fifteen miles from, a previous category 4[22]; and Houston hit by five of what were once called "five hundred year storms" in just five years.[23]

This term has lost much of its meaning in a time of rapid warming, and was often invoked imprecisely before. But its vernacular use is a powerful reminder of just how far we have come from what our grandparents, or even our parents, would have recognized as "normal." Five hundred years ago, there were no European settlements in North America. Hernando Cortez had just landed in Mexico. A "500-year storm" is therefore a storm of such severity it would be

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[16] Rebecca K. Miller et al, "Barriers and enablers for prescribed burns for wildfire management in California," *Nature Sustainability* 3 (2020).
[17] Patrick Sisson, "Maps show where wildfires have burned over and over again in LA county," *Curbed*, January 22, 2019.
[18] Burke 2021.
[19] Naomi Klein, "Forged in Fire: California's Lessons for a Green New Deal," *The Intercept*, November 7, 2019.
[20] Phoebe Weston, "Mass die-off of birds in southerwestern U.S. 'caused by starvation,'" *The Guardian*, December 26, 2020.
[21] Rina S. Khan, "Record Locust Swarms Hint at What's to Come With Climate Change," *EOS*, July 14 2020.
[22] Associated Press, "Dangerous Hurricane Iota Makes Landfall on Nicaragua Cost," November 16, 2020.
[23] Amal Ahmed, "Tropical Storm Imelda Will Likely Be Southeast Texas' Fifth 500-Year Flood in Five Years," September 20, 2019.

expected to hit, on average, just once during that entire history—the arrival of Europeans on American soil, the waging of a genocide against its native peoples, the building of colonies and the fighting of a revolution, the building of a slave empire and the fighting of a civil war, industrialization and the Great Depression, World War I and World War II, Jim Crow and the Civil Rights movement, the Women's movement and gay rights movement, the Cold War, the end of the Cold War, the "end of history," the internet, September 11 and 2008. One storm of that scale in all that time, is what we were told to expect. The area of Houston was hit by five of them in five years—literally millennia of extreme weather, compressed into the span of just half a decade. The immediate cost of just one of those storms, Hurricane Harvey, has been calculated at $90 billion—three times higher than the estimate of climate damages offered by William Nordhaus' Nobel-prize winning DICE model for the entire country that entire year.[24] Continued warming does not herald a "new normal," however often the phrase has been deployed, but the end of normal—never normal again.

Now, Houston is still standing, of course, and most of California is, too, and we are still here today, debating what measures to take to stall the growth and blunt the force of climate change—all a sign that the impacts of warming aren't the whole of our destiny, but instead form the natural landscape on which our future will be built, and indeed contested. Humans are adaptable, and resilient, and innovative—though we can also be cruel, ruthlessly nationalistic and punishingly prejudiced. And while society offers countervailing forces, of course — benevolence, generosity, solidarity in times of crisis — it is easy to fear that other set of impulses growing more intense over time, as intuitions about resource scarcity and the threat of extreme weather drive mass migration and give credence to a zero-sum view of the world. Already, as we live only with the known knowns of present warming, the climate obstacles to equitable human flourishing — and to promises of justice and prosperity and global cooperation we would hope to extend to future generations — are of an unprecedented scale.

Today, the planet is, by most estimates, about 1.2 degrees Celsius warmer than the pre-industrial average we use as a baseline. That number, 1.2, doesn't sound like much, but it already places us outside the window of temperatures that enclose the entire history of human civilization, which means that everything we have ever known as a species — from the invention of agriculture through the making of the modern nation state and the forging of an international order — was erected upon climate conditions which no longer prevail. The last time there was as much carbon in the atmosphere as there is today, NOAA recently reported, was 3.6 million years ago.[25] There were no humans then. The planet wasn't 1.2 degrees warmer, but 3. The arctic was full of forest. The seas weren't rising by centimeters; they were almost 80 feet higher.

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[24] Gernot Wagner, "In a summer of extreme weather, climate costs remain unclear," *Bloomberg Green*, June 17, 2020.
[25] "Despite pandemic shutdowns, carbon dioxide and methane surged in 2020," *NOAA Research News*, April 7, 2021.

The crudest prediction would be that what happened then will, more or less, happen now—though some impacts, like sea level rise, would take centuries to unfold. But the science is considerably more cautious, offering a picture of unchecked warming that, while unmistakably distressing, is also shrouded by several layers of uncertainty. There is some uncertainty in the science itself—whether 2 degrees of warming will destroy all the planet's coral reefs, depriving a billion people of a major food source, for instance, or just the vast majority of those reefs. There is also some uncertainty about the sensitivity of the climate—whether, given a doubling of pre-industrial carbon concentrations, say, the planet warms by 2 degrees or 5. And there is twofold uncertainty about the human response, as well: how quickly will we draw down our use of carbon, and how capably, how equitably, how justly and how ambitiously we adapt to the devastating impacts of climate, which will hit the poor and the marginalized much more intensely, exacerbating and intensifying existing disparities and injustices, both within countries and globally.

But uncertainty is not — should not be, cannot be — an argument for inaction, as our slow-footed pandemic response shows all too well. And we do know in which direction the climate is headed. We also know the terrifying speed. Today, carbon is being added to the atmosphere at a faster rate than at any point in the history of the planet, which includes several mass extinctions powered by such dramatic carbon-driven climate change that the overwhelming majority of life on earth died out. By most estimates, the present rate of increase is at least ten times faster.

Climate change isn't only fast when viewed from the perspective of deep time. You may think that global warming is a long process, initiated at the beginning of the industrial revolution, with impacts accruing slowly over centuries—this was how I long understood it, as the work of ignorant grandparents whose impacts would be felt by innocent grandchildren. But half of all the emissions produced from the burning of fossil fuels in all of human history have come in just the last 25 years. That is since Al Gore published his first book on warming, and since the U.N. established its I.P.C.C. climate change body. It is since the premiere of *Friends*. Climate responsibility — for the present crisis, and for preventing its worsening in the future — is alive on the planet today. It is in this room. I am not an old man—38 years old. Almost two thirds of all carbon emissions ever produced in the history of humanity have been produced in my lifetime. A quarter of all that damage has been done since Joe Biden was elected Vice President in 2008. About a third has come since Senator Graham first joined the Senate. To pull us up short of what has often been characterized as a catastrophic level of warming — 2 degrees — requires decarbonization at least as fast, and perhaps faster.

If we don't? The landscape of possibility projected by science is, while uncertain, inarguably alarming. At just two degrees of warming, the IPCC has suggested, flooding events that

would've once happened once a century could arrive instead every single year.[26] The land burned annually by fires in the American west is expected to at least double, and perhaps grow six-fold.[27] And because there is a natural limit on the amount of heat and humidity the human body can endure — the measure is known as "wet-bulb temperature" — cities across the Middle East and South Asia that are today home to millions would routinely be so hot during summer you couldn't safely go outside, and certainly couldn't work outside for long periods, without risking heat-stroke or possibly death.[28] In Calcutta, according to work published in *Nature Climate Change*, the number of days featuring what we now consider lethal heat could grow by between a quarter and a third from a baseline fifty years ago, to almost 200 days every year by 2050. In Miami, the number could double from a baseline drawn just in the year 2000, to 100 days annually; in Jakarta, 240.[29] At two degrees, the number of deaths from air pollution could grow by 150 million.[30]

At three degrees, yields of key crops could fall by 20% or more without intervention and adaptations[31]; some have warned of reductions as high as 50%[32]. Droughts used to hit once a century could hit every two to five years, , and those that used to last months could now last years.[33] Those who study the relationship between temperature and conflict suggest that, at three degrees, war could double[34]—and as Vice President Kamala Harris recently said, while past wars were often fought over oil, future ones may be fought over water. (Actually, she said "will.")[35] Estimates of the aggregate economic impact of unmitigated climate change vary widely, with some older models suggesting an impact of just a few percentage points, and others offering much higher estimates: compared with a world without warming, between 15-25% of per capita global output would be lost, according to one much-cited paper, between 2.5 degrees and 3 degrees of warming.[36] That is an impact bigger than the Great Depression, and, effectively, permanent, and the authors suggest that keeping warming to 1.5 degrees — as opposed to 3 —

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[26] "Special Report on the Ocean and the Cryosphere in a Changing Climate," U.N. IPCC, 2018.
[27] "Fourth National Climate Assessment," 2018.
[28] Fahad Saeed, "Deadly heat stress to become commonplace across South Asia already at 1.5C of global warming," *Geophysical Research Letters*, March 10, 2021.
[29] Camilo Mora et al, "Global risk of deadly heat," *Nature Climate Change* 7 (2017).The authors prepared an interactive tool to explore heat risks anywhere on the globe for Carbon Brief. The data described here show days of deadly heat under a "moderate mitigation" (or RCP4.5) scenario for 2050, and the tool can be found at carbonbrief.org/billions-face-deadly-threshold-heat-extremes-2100-study.
[30] Shindell et al, "Quantified, localized health benefits of accelerated carbon dioxide emissions reductions," *Nature Climate Change 8* (2018).
[31] Chuang Zhao et al, "Temperature increase reduces global yields of major crops in four independent estimates," *Proceedings of the National Academy of the Sciences* 114 (2017).
[32] David S. Battisti and Rosamond L. Naylor, "Historical Warnings of Future Food Insecurity with Unprecedented Seasonal Heat," *Science* 5911 (2009).
[33] G. Naumann et al, "Global Changes in Drought Conditions Under Different Levels of Warming," *Geophysical Research Letters* (2018).
[34] Marshall Burke et al, "Climate and Conflict," *Annual Review in Economics* 7 (2015).
[35] Mary Rose Corkery, "Kamala Harris Says Wars Will Be Fought Over Water 'In a Short Amount of Time,'" *Daily Caller*, April 7, 2021.
[36] Marshall Burke et al, "Large potential reduction in economic damages under U.N. mitigation targets," *Nature* 557 (2018).

would save 10-12% of global GDP. In the United States, another estimate runs as follows: "With continued growth in emissions at historic rates, annual losses in some economic sectors are projected to reach hundreds of billions of dollars by the end of the century—more than the current gross domestic product of many U.S. states."[37] That estimate isn't drawn from the r/collapse subreddit, or the talking points of Extinction Rebellion, or even the policy briefs of Sunrise. It is from the National Climate Assessment, intended to guide the climate policy of this body, and this country.

Just a few years ago, it seemed prudent to plan for scenarios at higher temperatures than three degrees—four degrees, five degrees. Thanks to a global political awakening, growing cultural pressure, and rapid, once-unthinkable improvements in the cost of renewables, those scenarios now appear, most scientists believe, considerably less likely. According to analysis by Climate Action Tracker, current global policies and trajectories will probably bring about 3 degrees of warming; factoring in new pledges lowers the figure about half a degree from there.[38] This is good news, though those are just paper pledges, at this point, and much more must be done, and much faster, to bring the world below two degrees. And even that new, measured optimism is shrouded in uncertainty, as well: we could decarbonize rapidly and still end up unfortunately north of two degrees, if the climate proves more sensitive than we expect. If we don't accelerate our ambition, we could get "unlucky," and end up at four degrees, perhaps even more. In that world, global mortality rates from climate change could be five times those of COVID-19—even when "adaptation" is factored in.[39]

And our adaptive response is just as clouded by uncertainty as the sensitivity of the climate system: though we flatter our own predictive powers with precise models of future economic growth, we have very limited ways of modeling technological progress, public investment and policy, especially deep into the future. In fact, adapting to two degrees may ultimately prove a taller, more disruptive, and more expensive task than limiting warming to that level. Even today, we are paying much more to respond to disasters than to prevent them, and the farther north we get, beyond two degrees, the more the needs and the costs will grow, too, along with the level of human suffering: more sea walls; more migration, both managed and unmanaged; more air filters and cooling centers, more hospitals and firefighters and flood insurance and farm insurance, all efforts to protect humanity and project prosperity equitably into an uncertain future.

As any investor or economist would tell you, uncertainty itself is a cost—and I'm very glad that Bob Litterman is here today to discuss the risk management, and risk mitigation, costs of warming. Investors and economists would also tell you that foregone benefits are a cost,

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[37] "Fourth National Climate Assessment," 2018.
[38] climateactiontracker.org/global/temperatures
[39] Tamma Carleton et al, "Valuing the Global Mortality Consequences of Climate Change Accounting for Adaptation and Benefits," *National Bureau of Economic Review* Working Paper No. 27599 (2020).

too—and this is, I think, the biggest news on climate, that the benefits of decarbonization, once considered trivial by contrast, are in fact enormous.

On this, we have passed a tipping point. For a generation, climate action was too often seen as a purely moral or humanitarian burden. It will be that: a challenge to all the world's nations to be good stewards of the planet, of their citizens, and indeed of the citizens of other nations, who may be made, by the impact of warming, more desperately in need. But it no longer makes sense to talk about decarbonization as an expensive undertaking to be weighed against that moral burden. In fact, quite the opposite: the cost of climate action is now almost certainly negative. Last year, Duke's Drew Shindell testified before the House of Representatives that a total decarbonization of the American electricity sector would be entirely paid for by the public health benefits of cleaner air.[40] The IMF has calculated that the unpaid environmental costs of fossil fuels amount to an annual global subsidy of over $5 trillion[41]—we don't need to keep paying that. The International Energy Association recently called solar power the "cheapest electricity in history,"[42] and in many parts of the world it is already cheaper to build out new clean energy capacity than to continue running existing dirty-energy infrastructure; by 2030, new renewables are expected to be cheaper than 96% of existing coal power.[43] In the short term, simply decarbonizing the country's electricity sector, it's been estimated, could create millions of jobs we'd be effectively losing by sitting on our hands. America's coal industry today employs 43,000 workers[44]; our oil and gas business employs 135,000.[45] One report, perhaps optimistic, puts the number of jobs created by a rapid program of electricity decarbonization at 25 million.[46] New infrastructure, new industry—these will bear fruit for decades, as will the necessary innovation in solar cells and batteries and perhaps even nuclear power and negative emissions, all of which can be effectively exported globally, as well, delivering an American share in a new, greener, global economy. We know now, in ways we didn't just a few years ago, that that economy is coming, and fast, because this same logic seems to apply all around the world, with ambitious new net-zero commitments being made this last year, during the pandemic and independent of any international pressure, by South Korea, Japan, the E.U., and, most significantly, China. They all see the gains to be seized; do we? I'm very glad that Joe Stiglitz is here today to discuss the limits of conventional economic accounting of climate impacts. Personally, I don't believe most of those models adequately reflect the costs of inaction, either, biased towards easily quantifiable outcomes and historical precedent and away from extreme events and the unprecedented risks of

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[40] Testimony of Drew Shindell, "The Devastating Health Effects of Climate Change," House Committee on Oversight and Reform, August 5, 2020.
[41] David Coady et al, "Global Fossil Fuel Subsidies Remain Large: An Update Based on Country-Level Estimates," IMF 2019.
[42] *World Energy Outlook 2020*, IEA 2020.
[43] "Powering Down Coal," Carbon Tracker, 2018.
[44] https://www.bls.gov/oes/current/naics4_212100.htm
[45] https://www.bls.gov/iag/tgs/iag211.htm
[46] Saul Griffith and Sam Calish, *Rewiring America*, 2020.

an unprecedented climate. And yet, even using those models, rapid decarbonization still comes out very much on top and in the black.

That bargain will only last for so long. Climate change is not binary; each tenth of a degree matters. But the opportunity to pull up short of catastrophic warming, and help deliver the world to a relatively comfortable landing, is closing quickly. This is a generational responsibility, and an immediate one. If the world had begun decarbonization in the year 2000, carbon emissions would only have had to fall by a couple of percentage points a year to safely avoid two degrees of warming. Now, the number is almost ten percent. Wait a decade and it will grow to 25% or more. How little would we have to feel we owed future generations to not act now? How blind would we have to be to our own best interest, to calculate only the costs of decarbonization and not its benefits? How short-sighted and how narrow-minded would we have to be, to overlook returns arriving as soon as later this decade, to accept the intensification by climate of already painful inequalities, or to define the suffering of those living elsewhere in the world as so insignificant we remained unmoved by it, even though moving would be in our best interest, too? I hope we aren't forced to learn the answers to those questions.

Thank you.