Beyond Catastrophe: A New Climate Reality Is Coming Into View

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David Wallace-Wells October 26, 2022

Beyond Catastrophe *A New Climate Reality Is Coming Into View* By David Wallace-Wells

Photographs by Devin Oktar Yalkin
Captions by Charley Locke

You can never really see the future, only imagine it, then try to make sense of the new world when it arrives.

Just a few years ago, climate projections for this century looked quite apocalyptic, with most scientists warning that continuing “business as usual” would bring the world four or even five degrees Celsius of warming — a change disruptive enough to call forth not only predictions of food crises and heat stress, state conflict and economic strife, but, from some corners, warnings of civilizational collapse and even a sort of human endgame. (Perhaps you’ve had nightmares about each of these and seen premonitions of them in your newsfeed.)

Now, with the world already 1.2 degrees hotter, scientists believe that warming this century will most likely fall between two or three degrees. (A United Nations report released this week ahead of the COP27 climate conference in Sharm el Sheikh, Egypt, confirmed that range.) A little lower is possible, with much more concerted action; a little higher, too, with slower action and bad climate luck. Those numbers may sound abstract, but what they suggest is this: Thanks to astonishing declines in the price of renewables, a truly global political mobilization, a clearer picture of the energy future and serious policy focus from world leaders, we have cut expected warming almost in half in just five years.

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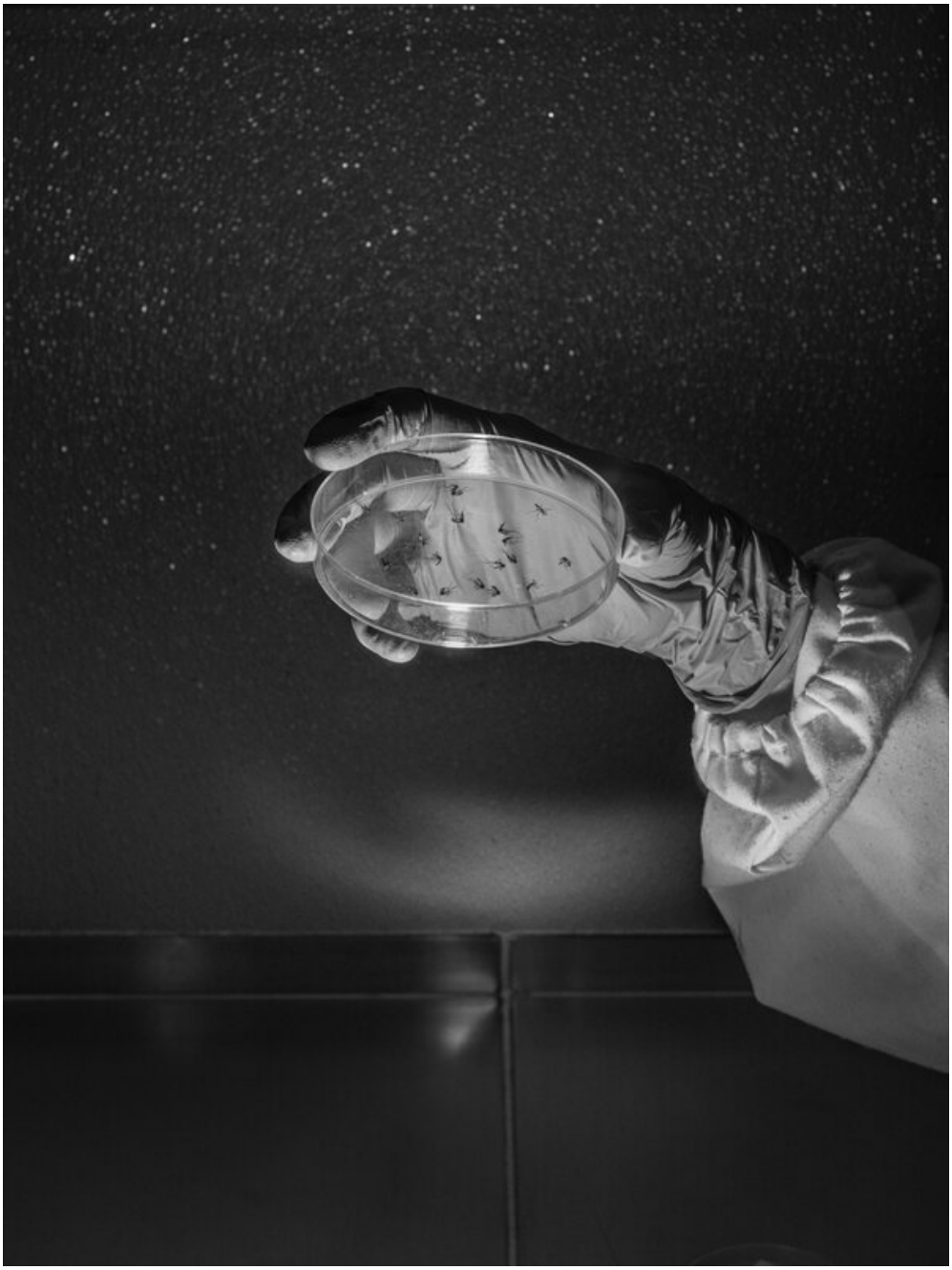
For decades, visions of possible climate futures have been anchored by, on the one hand, Pollyanna-like faith that normality would endure, and on the other, millenarian intuitions of an ecological end of days, during which perhaps billions of lives would be devastated or destroyed. More recently, these two stories have been mapped onto climate modeling: Conventional wisdom has dictated that meeting the most ambitious goals of the Paris agreement by limiting warming to 1.5 degrees could allow for some continuing normal, but failing to take rapid action on emissions, and allowing warming above three or even four degrees, spelled doom.



Genetically Modified Mosquitoes As rising temperatures force animals to migrate, vector-borne diseases like those caused by the yellow fever, dengue and Zika viruses will proliferate via mosquitoes. To stop the spread, the biotechnology company Oxitec has engineered a breed of Aedes aegypti mosquitoes that produce only viable male offspring, which are nonbiting. These mosquitoes are intended to mate with wild populations and lead, ultimately, to the collapse of those populations. The company led its first pilot project in 2021, releasing approximately four million mosquitoes into the Florida Keys. Here, a scientist transports genetically modified mosquitoes to release them.

Neither of those futures looks all that likely now, with the most terrifying predictions made improbable by decarbonization and the most hopeful ones practically foreclosed by tragic delay. The window of possible climate futures is narrowing, and as a result, we are getting a clearer sense of what’s to come: a new world, full of disruption but also billions of people, well past climate normal and yet mercifully short of true climate apocalypse.

Over the last several months, I've had dozens of conversations — with climate scientists and economists and policymakers, advocates and activists and novelists and philosophers — about that new world and the ways we might conceptualize it. Perhaps the most capacious and galvanizing account is one I heard from Kate Marvel of NASA, a lead chapter author on the fifth National Climate Assessment: "The world will be what we make it." Personally, I find myself returning to three sets of guideposts, which help map the landscape of possibility.

First, worst-case temperature scenarios that recently seemed plausible now look much less so, which is inarguably good news and, in a time of climate panic and despair, a truly underappreciated sign of genuine and world-shaping progress.

Second, and just as important, the likeliest futures still lie beyond thresholds long thought disastrous, marking a failure of global efforts to limit warming to "safe" levels. Through decades of only minimal action, we have squandered that opportunity. Perhaps even more concerning, the more we are learning about even relatively moderate levels of warming, the harsher and harder to navigate they seem. In a news release accompanying its report, the United Nations predicted that a world more than two degrees warmer would lead to "endless suffering."

Third, humanity retains an enormous amount of control — over just how hot it will get and how much we will do to protect one another through those assaults and disruptions. Acknowledging that truly apocalyptic warming now looks considerably less likely than it did just a few years ago pulls the future out of the realm of myth and returns it to the plane of history: contested, combative, combining suffering and flourishing — though not in equal measure for every group.

It isn't easy to process this picture very cleanly, in part because climate action remains an open question, in part because it is so hard to balance the scale of climate transformation against possible human response and in part because we can no longer so casually use those handy narrative anchors of apocalypse and normality. But in narrowing our range of expected climate futures, we've traded one set of uncertainties, about temperature rise, for another about politics and other human feedbacks. We know a lot more now about how much warming to expect, which makes it more possible to engineer a response. That response still begins with cutting emissions, but it is no longer reasonable to believe that it can end there. A politics of decarbonization is evolving into a politics beyond decarbonization, incorporating matters of adaptation and finance and justice (among other issues). If the fate of the world and the climate has long appeared to hinge on the project of decarbonization, a clearer path to two or three degrees of warming means that it also now depends on what is built on the other side. Which is to say: It depends on a new and more expansive climate politics.

"We live in a terrible world, and we live in a wonderful world," Marvel says. "It's a terrible world that's more than a degree Celsius warmer. But also a wonderful world in which we have so many ways to generate electricity that are cheaper and more cost-effective and easier to deploy than I would've ever imagined. People are writing credible papers in

scientific journals making the case that switching rapidly to renewable energy isn't a net cost; it will be a net financial benefit," she says with a head-shake of near-disbelief. "If you had told me five years ago that that would be the case, I would've thought, wow, that's a miracle."

How did it happen? To begin with, the world started to shift away from coal.

In 2014, the energy researcher and podcast producer Justin Ritchie was a Ph.D. student wondering why many climate models were predicting that the 21st century would look like a coal boom. Everyone knew about the decades of coal-powered economic growth in China, but those working closely on the future of energy had already grown somewhat skeptical that the same model would be deployed across the developing world — and even more skeptical that the rich nations of the world would ever return to coal in a sustained way.

But that perspective was nowhere to be seen in the huge set of models, mixing economic and demographic and material assumptions about the trajectory of the future, which climate scientists used to project impacts later this century, including for the United Nations Intergovernmental Panel on Climate Change (I.P.C.C.). The most conspicuous example was an emissions pathway called RCP8.5, which required at least a fivefold growth of coal use over the course of the 21st century. Because it was the darkest available do-nothing path, RCP8.5 was reflexively called, in the scientific literature and by journalists covering it, "business as usual." When Ritchie and his doctoral adviser published their research in Energy Economics in 2017, they chose a leading subtitle: "Are Cases of Vastly Expanded Future Coal Combustion Still Plausible?" The world's current path appears to offer a quite simple answer: no.

Questions about the future course of coal had been circulating for years, often raised by the same people who would point out that projections for renewable energy kept also comically underestimating the growth of wind and solar power. But to a striking degree, broad skepticism about high-end emissions scenarios has come from a small handful of people who read Ritchie's work and took to Twitter with it: Ritchie's sometime co-author Roger Pielke Jr., a professor of environmental studies and frequent Republican witness at congressional climate hearings; the outspoken British investor Michael Liebreich, who founded a clean-energy advisory group bought by Michael Bloomberg, and who spent a good deal of 2019 yelling on social media that "RCP8.5 is bollox"; and the more mild-mannered climate scientists Zeke Hausfather and Glen Peters, who together published a 2020 comment in Nature declaring that "the 'business as usual' story is misleading." (I published a piece the previous year picking up the same bread crumbs.)

Adjustments to the input assumptions of energy models are perhaps not the sexiest signs of climate action, but Hausfather estimates that about half of our perceived progress has come from revising these trajectories downward, with the other half coming from technology, markets and public policy.

Let's take technology first. Among energy nerds, the story is well known, but almost no one outside that insular world appreciates just how drastic and rapid the cost declines of renewable technologies have been — a story almost as astonishing and perhaps as consequential as the invention within weeks and rollout within months of new mRNA vaccines to combat a global pandemic.

Since 2010, the cost of solar power and lithium-battery technology has fallen by more than 85 percent, the cost of wind power by more than 55 percent. The International Energy Agency recently predicted that solar power would become "the cheapest source of electricity in history," and a report by Carbon Tracker found that 90 percent of the global population lives in places where new renewable power would be cheaper than new dirty power. The price of gas was under $3 per gallon in 2010, which means these decreases are the equivalent of seeing gas-station signs today advertising prices of under 50 cents a gallon.

The markets have taken notice. This year, investment in green energy surpassed that in fossil fuels, despite the scramble for gas and the "return to coal" prompted by Russia's invasion of Ukraine. After a decade of declines, supply-chain issues have nudged up the cost of renewable manufacturing, but overall the trends are clear enough that you can read them without glasses: Globally, there are enough solar-panel factories being built to produce the necessary energy to limit warming to below two degrees, and in the United States, planned solar farms now exceed today's total worldwide operating capacity. Liebreich has taken to speculating about a "renewable singularity," beyond which the future of energy is utterly transformed.

The world looks almost as different for politics and policy. Five years ago, almost no one had heard of Greta Thunberg or the Fridays for Future school strikers, Extinction Rebellion or the Sunrise Movement. There wasn't serious debate about the Green New Deal or the European Green Deal, or even whispers of Fit for 55 or the Inflation Reduction Act or the Chinese promise to peak emissions by 2030. There were climate-change skeptics in some very conspicuous positions of global power. Hardly any country in the world was talking seriously about eliminating emissions, only reducing them, and many weren't even talking all that seriously about that. Today more than 90 percent of the world's G.D.P. and over 80 percent of global emissions are now governed by net-zero pledges of various kinds, each promising thorough decarbonization at historically unprecedented speeds.

Sustainable ‘Supercrops’ A tropical “supertree” used in reforestation, pongamia grows beans similar to soy, producing protein and oil. It can be cultivated in almost any soil with limited use of pesticides or irrigation, and it sucks nitrogen out of the air. It has grown wild in Southeast Asia, Australia and the Pacific Islands for hundreds of years, but Terviva, a company based in Alameda, Calif., has begun to plant it widely for the first time in the United States. It now grows across 1,500 acres in Hawaii and Florida, including groves in St. Lucie County, Fla., where this photo was taken. The twin goals of cutting agricultural emissions while producing food for more and more people presents a formidable challenge; “supercrops” like pongamia offer promising solutions.

At this point, they are mostly paper pledges, few of them binding enough in the short term to look like real action plans rather than strategies of smiling delay. And yet it still marks a new era for climate action that a vast majority of world leaders have felt pressed to make them — by the force of protest, public anxiety and voter pressure, and increasingly by the powerful logic of national self-interest. What used to look like a moral burden is now viewed increasingly as an opportunity, so much so that it has become a source of geopolitical rivalry. As prime minister, Boris Johnson talked about making the United

Kingdom the “Saudi Arabia of wind power,” and the Inflation Reduction Act was written to supercharge American competitiveness on green energy. China, which is already installing nearly as much renewable capacity as the rest of the world combined, is also manufacturing 85 percent of the world’s solar panels (and selling about half of all electric vehicles purchased worldwide). According to one recent paper on the energy transition published in Joule, a faster decarbonization path could make the world trillions of dollars richer by 2050.

You can’t take these projections to the bank. But they have already put us on a different path. The Stanford scientist Marshall Burke, who has produced some distressing research about the costs of warming — that global G.D.P. could be cut by as much as a quarter, compared with a world without climate change — says he has had to update the slides he uses to teach undergraduates, revising his expectations from just a few years ago. “The problem is a result of human choices, and our progress on it is also the result of human choices,” he says. “And those should be celebrated. It’s not yet sufficient. But it is amazing.”

Matthew Huber of Purdue University, the climate scientist who helped introduce the idea of a temperature and humidity limit to human survival, likewise describes himself as considerably less worried than he used to be, though he believes, drawing on inferences from the deep history of the planet, that a future of two degrees warming is less likely than a world of three. “Some of my colleagues are looking at three degrees and going, oh, my God, this is the worst thing ever — we’re failing!” he says. “And then someone like me is saying, well, I used to think we were heading to five. So three looks like a win.”

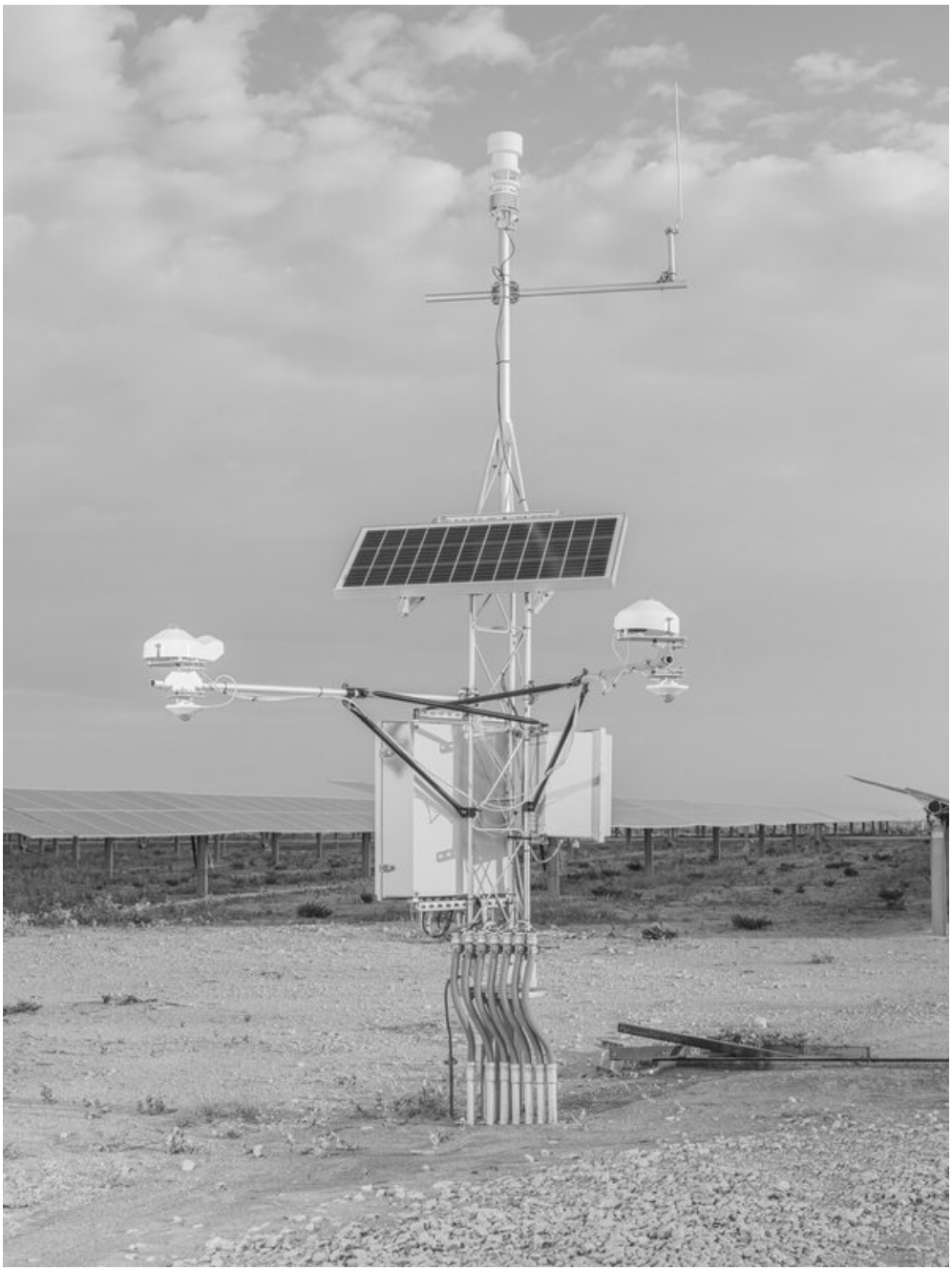
A very bruising win. “The good news is we have implemented policies that are significantly bringing down the projected global average temperature change,” says the Canadian atmospheric scientist Katharine Hayhoe, a lead chapter author on several National Climate Assessments and an evangelical Christian who has gained a reputation as a sort of climate whisperer to the center-right. The bad news, she says, is that we have been “systematically underestimating the rate and magnitude of extremes.” Even if temperature rise is limited to two degrees, she says, “the extremes might be what you would have projected for four to five.”

“Things are coming through faster and more severely,” agrees the British economist Nicholas Stern, who led a major 2006 review of climate risk. In green technology, he says, “we hold the growth story of the 21st century in our hands.” But he worries about the future of the Amazon, the melting of carbon-rich permafrost in the northern latitudes and the instability of the ice sheets — each a tipping point that “could start running away from us.” “Each time you get an I.P.C.C. report, it’s still worse than you thought, even though you thought it was very bad,” he says. “The human race doesn’t, as it were, collapse at two degrees, but you probably will see a lot of death, a lot of movement of people, a lot of conflict over space and water.”

“I mean, we’re at not even one and a half now, and a third of Pakistan is underwater, right?” says the Nigerian American philosopher Olufemi O. Taiwo, who has spent much of the last few years writing about climate justice in the context of reparations for slavery and colonialism. “What we’re seeing now at less than two degrees — there’s nothing optimistic about that.”

All of which suggests an entirely different view of the near future, equally true. The world will keep warming, and the impacts will grow more punishing, even if decarbonization accelerates enough to meet the world’s most ambitious goals: nearly halving global emissions by 2030 and getting to net-zero just two decades later. “These dates — 2030, 2050 — they are meaningless,” says Gail Bradbrook, one of the British founders of Extinction Rebellion. “What matters is the amount of carbon in the atmosphere, and there is already way too much. The dates can be excuses to kick the problem into the long grass. But the important thing is that we’re doing harm, right now, and that we should stop absolutely as soon as possible with any activities that are making the situation worse.”

A lot, then, depends on perspective: The climate future looks darker than today but brighter than many expected not that long ago. The world is moving faster to decarbonize than it once seemed responsible to imagine, and yet not nearly fast enough to avert real turbulence. Even the straightest path to two degrees looks tumultuous, with disruptions from the natural world sufficient to call into question many of the social and political continuities that have been taken for granted for generations.



Solar Energy Spread across 2,770 acres in West Texas, the Roadrunner Solar and Storage Plant is expected to generate 1.2 terawatt-hours per year, which would displace the emission of over 800,000 tons of carbon dioxide. Solar capacity in the United States has risen nearly 300-fold since 2008, to 130.9 gigawatts in 2022, enough to power 23 million homes. In a model from the Department of Energy envisioning a fully decarbonized grid by 2050, solar energy could account for as much as 45 percent of the U.S. electricity supply.

For me, the last few years provide arguments for both buoyant optimism and abject despair. They have made me more mindful of the inescapable challenge of uncertainty when it comes to projecting the future, and the necessity of nevertheless operating within it.

In 2017, I wrote a long and bleak magazine article about worst-case scenarios for the climate, focused on a range of possible futures that began at four degrees Celsius of warming and went up from there. In 2019, I published a book about the disruptions and transformations projected by scientists for lower but still “catastrophic” levels of warming — between two degrees and four. I was called an alarmist, and rightly so — like a growing number of people following the news, I was alarmed.

I am still. How could I not be? How could you not be? In Delhi this spring, there were 78 days when temperatures breached 100 degrees Fahrenheit, a monthslong heat event made 30 times more likely by climate change. Drought across the Northern Hemisphere was made 20 times more likely, resulting in dried-up riverbeds from the Yangtze to the Danube to the Colorado, exposing corpses dumped in Lake Mead and dinosaur footprints in Texas and live World War II munitions in Germany and a “Spanish Stonehenge” in Guadalperal, and baking crops in agricultural regions on multiple continents to the point of at least partial failure. Hundreds died of heat just in Phoenix, more than a thousand each in England and Portugal and Spain.

Monsoon flooding in Pakistan covered a third of the country for weeks, displacing tens of millions of people, destroying the country’s cotton and rice yields and producing conditions ripe for migration, conflict and infectious disease within an already struggling state — a state that has generated in its entire industrial history about the same carbon emissions as the United States belched out this year alone. In the Caribbean and the Pacific, tropical storms grew into intense cyclones in under 36 hours.

In China, there were months of intense heat for which, as one meteorologist memorably put it, “there is nothing in world climatic history which is even minimally comparable.” As it did through the pandemic, China tried to hide most of the disruptions to daily life, but industrial shutdowns meant the rest of the world felt the effects in the supply chains for semiconductors, pharmaceuticals, photovoltaic cells, iPhones and Teslas — all pinched briefly closed by warming of just 1.2 degrees.

What will the world look like at two degrees? There will be extreme weather even more intense and much more frequent. Disruption and upheaval, at some scale, at nearly every level, from the microbial to the geopolitical. Suffering and injustice for hundreds of millions of people, because the benefits of industrial activity have accumulated in parts of the world that will also be spared the worst of its consequences. Innovation, too, including down paths hard to imagine today, and some new prosperity, if less than would have been expected in the absence of warming. Normalization of larger and more costly disasters, and perhaps an exhaustion of empathy in the face of devastation in the global south, leading to the kind of sociopathic distance that enables parlor-game conversations like this one.

Carbon Capture When carbon dioxide enters the water through rainfall, it eventually converts into calcium carbonate, or limestone, by a process called rock weathering. Carbon capture and enhanced weathering can drastically speed up the natural process. For example, Vesta, a public-benefit corporation with headquarters in San Francisco, grinds the sometimes green volcanic mineral olivine into sand. When the sand reacts with seawater, the olivine gradually dissolves into bicarbonate, just as any sand or rock does, reducing ocean acidity and storing carbon permanently.

At two degrees, in many parts of the world, floods that used to hit once a century would come every single year, and those that came once a century would be beyond all historical experience. Wildfire risk would grow, and wildfire smoke, too. (The number of people exposed to extreme smoke days in the American West has already grown 27-fold in the last decade.) Extreme heat events could grow more than three times more likely, globally, and the effects would be uneven: In India, by the end of the century, there would be 30 times as many severe heat waves as today, according to one estimate. Ninety-three times as many people would be exposed there to dangerous heat.

This is what now counts as progress. Today, at just 1.2 degrees, the planet is already warmer than it has been in the entire history of human civilization, already beyond the range of temperatures that gave rise to everything we have ever known as a species. Passing 1.5 and then two degrees of warming will plot a course through a truly foreign climate, bringing a level of environmental disruption that scientists have called "dangerous" when they are being restrained. Island nations of the world have called it "genocide," and African diplomats have called it "certain death." It is that level that the world's scientists had in mind when they warned, in the latest I.P.C.C. report, published in February, that "any further delay in concerted global action will miss a brief and rapidly closing window to secure a livable future."

What would we get if that window closes? The temptations of apocalyptic thinking aside, it would nevertheless be a world in which we would still be living — navigating larger and more damaging climate intrusions, and doing so with some yet-to-be-determined mix of success and failure, grief and opportunity.

"The West has always had a problem with millenarianism — the fall, Christianity, all that," says Tim Sahay, a Mumbai-born climate-policy wonk and co-founder of the new Polycrisis journal. "It's ineradicable — all we see are the possibilities for doom and gloom." The challenges are real and large and fall disproportionately on the developing world, he says, but they are not deterministic, or need not be. "We're riding down the dark mountain," he says. "That's scary in ways, of course, but there are also so many possible outcomes. I find it all exciting. What kind of cities will Brazil build? What will Indonesia be?"

In some places, climate rhetoric has begun to soften — or perhaps it is better to say harden, with existential abstractions thickening into something more like high-stakes realism. Mohamed Nasheed, the former president of Maldives who asked, at the Copenhagen climate conference in 2009, "How can you ask my country to go extinct?" has been lately talking in more practical terms. He has raised the need to secure climate finance — support from development banks and institutions of the global north to enable a green transition and local resilience — and theorized about the possible need for debt strikes to extract meaningful relief. He has also encouraged the work of scientists to genetically modify local coral to make it more resilient in the face of warming water.

Mia Mottley, the prime minister of Barbados, is fighting in the weeds with the International Monetary Fund and the World Bank, and trying to get other vulnerable nations to play hardball too. Greta Thunberg, the unyielding face of climate alarm, recently affirmed her support for at least existing nuclear power, and Rupert Read, once the spokesman for Extinction Rebellion, has taken to calling for a "moderate flank" of the climate movement. In the United States, the climate bill that emerged finally into law was not a Green New Deal, a punitive carbon tax or a program of demand reduction but an expansive, incentive-based approach to decarbonizing that included support for nuclear power and even carbon capture, long an anathema to the climate left.

This may look like a growing consensus, which to a certain extent it is. But the world it points to is still a quite unresolved mess. Over the last year, the economic historian Adam Tooze has popularized the word “polycrisis” to describe the cascade of large-scale challenges to the basic stability and continuity of the global order. President Emmanuel Macron of France, who embodies the slim-fit optimism of neoliberalism, has declared the current period of tumult “the end of abundance.” Josep Borrell, the former head of the European Parliament, chose the phrase “radical uncertainty,” later comparing Europe to a “garden” and the rest of the world to a “jungle” and warning that “the jungle could invade the garden.” John Kerry, the American climate envoy, has acknowledged, perhaps inadvertently, that the cost of climate damage in the global south is already in the “trillions” — a number he cited not to illustrate the need for support but to explain why nations in the global north wouldn’t pay. (He added that he refused to feel guilty about it.) The author and activist Bill McKibben worries that although the transition is accelerating to once-unimaginable speeds, it still won’t come fast enough. “The danger is that you have a world that runs on sun and wind but is still an essentially broken planet.” Now the most pressing question is whether it can be fixed — whether we can manage those disruptions and protect the many millions of people who might be hurt by them.

Vertical Farming Roughly 11 percent of greenhouse-gas emissions come from the agriculture industry. Vertical farms use far less land and water than typical outdoor farms, which enables them to grow greens more efficiently. Since their environment is manufactured, they can also grow food in dense urban areas and otherwise unsuitable climates, as with these sprouts at the Brooklyn-based Upward Farms. The company, which plans to open a 250,000-square-foot vertical farm in Luzerne County, Pa., in 2023, integrates aquaculture into its system, raising hybrid striped bass in tanks, along with its stacks of microgreens. The fish waste goes through a biodigester, where bacteria converts it into fertilizer for the plants; the fish themselves, along with the greens, head to market.

Next month, at the United Nations climate conference in Sharm el Sheikh, Egypt, known as COP27, world leaders will take up that question, which often goes by the name “adaptation.” Having engineered global ecological disruption, can we engineer our way out of its path?

The tools are many — in fact, close to infinite. Given that most of the world's infrastructure was built for climate conditions we have already left behind, protecting ourselves against new conditions would require something like a global construction project: defenses against flooding — both natural, like mangrove and wetland restoration, and more interventionist, like dikes and levees and sea walls and sea gates. We'll need stronger housing codes; more resilient building materials and more weather-conscious urban planning; heat-resistant rail lines and asphalt and all other kinds of infrastructure; better forecasting and more universal warning systems; less wasteful water management, including across very large agricultural regions like the American West; cooling centers and drought-resistant crops and much more effective investments in emergency response for what Juliette Kayyem, a former official at the Department of Homeland Security, calls our new "age of disasters."

Damage from storms is increasing, in large part because we keep building and moving right into what is often called the expanding bull's-eye of extreme weather, with the same distressing pattern observed in boom towns along the Florida coast and in the floodplains of Bangladesh. More and more people are flocking into harm's way, not all of them out of true ignorance.

Some more sanguine climate observers often point out that even as we put ourselves in the path of extreme weather, deaths from natural disasters are not, in fact, growing — indeed, they have fallen, by an astonishing degree, from as much as an average of 500,000 deaths each year a century ago to about 50,000 deaths each year today (even as climate- and weather-related natural disasters have increased fivefold, according to the World Meteorological Organization).

But whether those mortality trends would continue in a two-degree world is unclear. With Hurricane Ian, for instance, a wealthy and well-prepared corner of the global north just endured its deadliest hurricane since 1935. Most of that drastic drop in disaster mortality happened, in fact, between the 1920s and the 1970s, when such deaths fell to just under 100,000. The declines have been smaller over the last 50 years, as global warming began to destabilize our weather, and even smaller — perhaps even nonexistent, depending on the data set and how you want to look at it — over the last three decades, as temperature rise became more pronounced and warming pushed the world outside the "Goldilocks" climate range that had governed all of human history.

Perhaps this means the world has harvested much of the obvious low-hanging fruit of adaptation. Better meteorology and early warning systems, for instance, which have drastically reduced the death toll of recent monsoons in Bangladesh and hurricanes in Florida, are already in place. The cost of global climate damage has already run into the trillions, and the bill for adaptation in the developing world could reach $300 billion annually by 2030. Galveston, Texas, is undertaking the construction of a $31 billion "Ike Dike" project to protect its harbor; New York City is considering a system of storm-surge gates, priced at $52 billion. In other words, warming is already making adaptation harder and more expensive, and extending the gains achieved last century into the next one may prove difficult or even impossible.

The latest I.P.C.C. report, published in February, emphasized that “progress in adaptation planning and implementation” had been made but also warned that “many initiatives prioritize immediate and near-term climate risk reduction which reduces the opportunity for transformational adaptation,” meaning that resources devoted to repair and retrofitting aren’t being spent on new infrastructure or resettlement. “Hard limits to adaptation have already been reached in some ecosystems,” the I.P.C.C. wrote, adding that “with increasing global warming, losses and damages will increase and additional natural and human systems will reach adaptation limits.”

“For me, what we are witnessing at the present level of warming, it is already challenging the limits to adaptation for humans,” says Fahad Saeed of Climate Analytics. Over the last six months, Saeed, a Pakistani scientist based in Islamabad, has watched the country endure months of extreme heat, crop failures and monsoon flooding that submerged a third of the nation, destroyed a million homes, displaced 30 million people and inflicted damage estimated at $40 billion or above — 11 percent of Pakistan’s 2021 G.D.P. “One can’t believe what would happen at 1.5 degrees,” he says. “Anything beyond that? It would even be more devastating.”

“Two degrees is a lot better than four degrees,” says the climate scientist Michael Oppenheimer, one of those who delivered now-legendary warnings about the risks of warming to the U.S. Senate in 1988. “And one-and-a-half degrees is even better than two degrees. But none of those levels means there’s nothing to do.”

Oppenheimer has spent the last few years increasingly focused on the question of what to do, and how to judge our progress on adaptation. “How good are we today at dealing with the situation where hundred-year floods happen?” he asks. “Not very good.” He argues that we should try to hold ourselves to higher standards than normalizing more than a hundred deaths in a Florida hurricane. Extreme events are arriving now much more quickly, meaning that “the measure of success is no longer just how well you did in preparing for some bad event and then recovering from it. It’s also how quickly you do it.” He mentions the I.P.C.C.’s 2019 report on the oceans, which found that what were once called “hundred-year flood levels” would be reached, in many parts of the world, every single year by 2050. “And so you’ve got to get back in shape before the next one happens, when the next one might happen the same year — in the worst cases, the same month. Eventually, in some places, it happens just with the high tide.”

“You’re not going to just recover the way we think of recovery now,” Oppenheimer says. “You have to either be living in a totally different situation, which accepts something close to perpetual flooding in some places, or you fulfill the dreams some people have about adaptation, where the regularity of life is just totally different. The very structure of infrastructure and manufacturing, it’s all different.”

Geothermal Energy About 70 miles north of San Francisco in the Mayacamas Mountains, the Geysers Geothermal Resource Area is the largest complex of geothermal power plants in the world. At the complex, superheated steam is piped from underground reservoirs to steam turbines, like the one pictured here, to produce electricity; in 2020, that steam produced about 9 percent of California's renewable energy. Geothermal power plants like the Geysers hold enormous promise as a renewable source: They emit 99 percent less carbon dioxide than similar-size fossil-fuel power plants, and the United States holds more than five terawatts of heat resources, enough to power electricity for the entire world. The U.S. Department of Energy is investing in geothermal research and has set a goal to cut the cost of enhanced geothermal systems by 90 percent by 2035.

Talk enough about adaptation, and you drift into technical-seeming matters: Can new dikes be built, or the most vulnerable communities resettled? Can crop lands be moved, and new drought-resistant seeds developed? Can cooling infrastructure offset the risks of

new heat extremes, and early warning systems protect human life from natural disaster? How much help can innovation be expected to provide in dealing with environmental challenges never seen before in human history?

But perhaps the more profound questions are about distribution: Who gets those seeds? Who manages to build those dikes? Who is exposed when they fail or go unbuilt? And what is the fate of those most frontally assaulted by warming? The political discourse orbiting these issues is known loosely as “climate justice”: To what extent will climate change harden and deepen already unconscionable levels of global inequality, and to what degree can the countries of the global south engineer and exit from the already oppressive condition that the scholar Farhana Sultana has called “climate coloniality”?

“The big thing politically that’s going to happen on a massive scale is movement,” says Taiwo, the philosopher. “The numbers I’ve seen for displacement — both internal displacement and cross-border displacement at two degrees — are at least in the tens if not the hundreds of millions. And I don’t think we have a political context for what that means.”

The range of estimates is huge, and its size is among the best indicators we have that, however much we know about the climate future, an enormous amount of the complex and cascading effects of warming remains shrouded in the inevitable uncertainty of human response. Indeed, the I.P.C.C. says that, in the near term, migration will most likely be driven more by socioeconomic conditions and governance issues. “There will be, let’s say, socioecological pressure on a scale that is an order of magnitude larger than the scale of what we’re seeing now,” Taiwo says. “Whether that translates into movement within borders and across borders, whether it translates into large-scale adaptation strategies that we don’t have a political context for, whether it translates into simply mass death we don’t have a context for, either, or some mix of those things — it’s anybody’s guess. And I wouldn’t trust a climate model to tell me which of those things, or which mix of those things, is going to happen.”

Taiwo says his mind drifts intuitively toward one scenario. “If the far right wins,” he says, “I see copycat agencies that are much like ICE operating in much of the global north and in some emerging states. I see a gradual integration of domestic policing and, for lack of a better term, border policing — which I think we’re seeing now anyway, a much more openly authoritarian development of those institutions, increasingly operating autonomously. I expect the militaries of nation states to increasingly be wedded to those operations. And I expect that to become ‘government’ for a substantial percentage of the world’s population. I likewise expect that to be a political shift that we do not have a context for.” Unless you’ve studied colonialism, he laughs.

“But maybe there’s another version of what that mix of pressures looks like at two degrees Celsius,” Taiwo says, one that produces more local resilience and sustainability, along with innovation in energy and politics, agriculture and culture. “And partially because of the success of a few of these measures,” he says, “you get markedly lower than predicted displacement numbers.”

For a generation now, climate-vulnerable countries have issued a series of variations on a simple exhortatory theme: For this damage, the rich world must pay. The call has gone by different names, each describing slightly different forms of support: “climate finance,” “loss and damage,” “reparations” and now “debt relief.” In 2009, in Copenhagen, the rich nations of the world formalized a promise to deliver $100 billion annually in climate funding to the global south, a promise that has yet to be fulfilled, even as climate-vulnerable nations have raised their request to $700 billion or more.

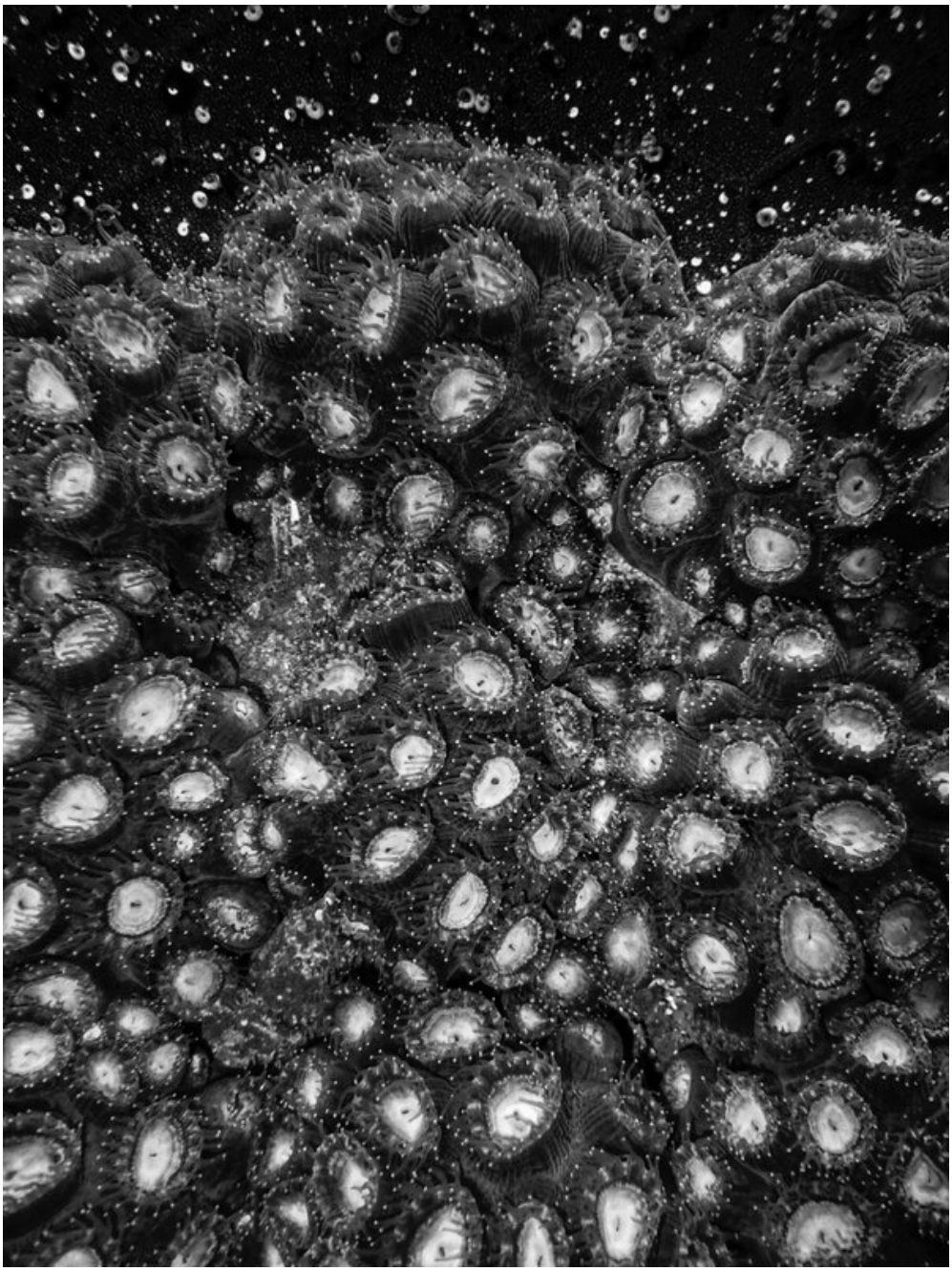
“It’s not only about adapting,” says the Kenyan climate activist Elizabeth Wathuti, “because you cannot ask people to adapt to losing their homes — their homes are being washed away, their livestock and their children are being carried away. They’re dying — how would they adapt to that? And crop failure — how would you adapt to that? How would you adapt to starvation? If you have not had a meal in two days, you will not adapt to that.”

“For years and years — decades and decades — people have been begging,” Taiwo says. “The deciding thing will be, what is it that global south countries are prepared to do if these demands aren’t met.”

Sahay, of the Polycrisis journal, offers one answer, describing a world in which climate-exacerbated great power rivalry means that alliances of underdeveloped states could play rich nations against one another, in a sort of spiritual extension of the nonalignment movement, led by Indonesia, in the last decades of the Cold War. Sahay calls the emerging nonalignment alliance built around Brazil, Russia, India and China (BRIC) a “new bargaining chip,” floating the possibility that a new group of “electro-states” could succeed the last century’s petro-states and aggressively broker access to their own mineral resources. The scholar Thea Riofrancos has similarly imagined a “Lithium OPEC,” and though she doubts it will come entirely to pass, she believes that a harder and more nationalistic resource geopolitics surely will.

“Westerners take it for granted that people in the global south, if they’re badly hit by some climate-change event, will attack fossil fuels,” says the Indian novelist Amitav Ghosh, also the author of several piercing meditations on the injustices of warming. “But that’s a complete fantasy. In the global south, everybody understands that energy access is the difference between poverty and not poverty. Nobody sees fossil fuels as the basic problem. They see the West’s profligate use of fossil fuels as the basic problem.”

“Throughout this whole crisis in Pakistan, have you heard of anyone talking about attacking fossil fuels? No — it’s laughable to even ask. Everything I see being mentioned about Pakistan is about reparations, it’s about global inequality, it’s about historic government injustices. It’s not at all about fossil fuels. This is one of the really big divides between the global south and the global north,” Ghosh says. “If people are going to attack anything — let’s say in Pakistan or India after a heat wave or some other catastrophic event — it won’t be the fossil-fuel infrastructure. It will be the consulates of the rich countries, just as it’s been over many other things in the past.”



Fortifying Coral Reefs Two additional degrees of warming would kill virtually all of the world's living coral reefs, threatening the survival of roughly a quarter of global ocean biodiversity and affecting the protein supply for hundreds of millions of people. Some species of coral are somewhat less susceptible to warming waters, like elkhorn coral, which can be encouraged to grow relatively quickly via a method called microfragmentation. The process involves cutting the coral, which then grows faster while healing. Here, in partnership with the National Oceanic and Atmospheric Administration, scientists at the Mote Marine Laboratory and Aquarium are growing elkhorn coral in a lab in the Florida Keys before introducing them into the wild.

"We live in an unimaginable future," says the writer Rebecca Solnit, who has grown increasingly focused on the political and social challenges of climate change. "Things thought impossible or inconceivable or unlikely not very long ago are accepted norms

now.” Today, as a result, “a lot of my hope is just radical uncertainty,” she says. “You see that the world can’t go on as it is — that is true. But it doesn’t mean the world can’t go on. It means that the world will go on, not as it is but in some unimaginably transformed way.”

In 2017, looking back at decades of ineffectual organizing, I didn’t think the political mobilization of the last five years was even possible, and if you had told me then about the radical acceleration of renewable technology to come, I would’ve been more credulous but still surprised. But signs of optimism are not arguments for complacency — quite the opposite, because the new range of expectations is not just a marker of how much has changed over the last five years but of how much might over the next five, the next 25 or the next 50.

Two degrees is not inevitable; both better and worse outcomes are possible. Most recent analyses project paths forward from current policy about half a degree warmer, meaning much more must be done to meet that goal, and even more to keep the world below the two-degree threshold — as was promised under the Paris agreement. (Even the I.P.C.C. scenarios designed to limit warming to that level now predict we’ll trespass it as soon as next decade.) And because decarbonization might stall and the climate may prove more sensitive than expected, temperatures above three degrees, though less likely than they recently seemed, remain possible, too.

Overall emissions have not yet begun to decline, and it’s a long way from peak down to zero, making all these changes to expectations mostly notional, for now — a different set of lines being drawn naïvely on a whiteboard and waiting to be made real. New emissions peaks are expected both this year and next, which means that more damage is being done to the future climate of the planet right now than at any previous point in history. Things will get worse before they even stabilize.

But we are getting a clearer map of climate change, and however intimidating it looks, that new world must be made navigable — through action to limit the damage and adaptation to defend what can’t be stopped. At four degrees, the impacts of warming appeared overwhelming, but at two degrees, the impacts would not be the whole of our human fate, only the landscape on which a new future will be built.

Normalization is a form of adaptation, too, however cruel and unfortunate a form it may appear in theory or ahead of time. Indeed, already we can say a given heat wave was made 30 times more likely by climate change, or that it was a few degrees hotter than it would have been without climate change, and both would be true. We’ll be able to talk about the contributions of warming to disasters that buckle whole nations, as the recent monsoon flooding in Pakistan has, or about the human contributions to such vulnerability. And as we do today, we will often reach for the past when trying to judge the present, reckoning with how the world got where it is and who was responsible and whether the result of the fight against warming counts as progress or failure or both. History is our handiest counterfactual, however poor a standard it sets for a world that could have been much better still. “We’ve come a long way, and we’ve still got a long way to go,” says Hayhoe, the Canadian scientist, comparing the world’s progress to a long hike. “We’re

halfway there. Look at the great view behind you. We actually made it up halfway, and it was a hard slog. So take a breather, pat yourself on the back, but then look up — that's where we have to go. So let's keep on going."

Opening photo: With more than 3,000 turbines, the Tehachapi Pass wind farms around Mojave, Calif., are some of the largest wind-energy generators in the state.

Drone assistance for aerial photograph of solar farm by Jordan Vonderhaar.

Additional design and development by Jacky Myint.

David Wallace-Wells is a columnist for the magazine and an Opinion writer for The New York Times, as well as the author of the international best seller "The Uninhabitable Earth: Life After Warming," published in 2019.

Charley Locke is a writer who often covers youth, including for The New York Times for Kids. She last wrote about the $190 billion in Covid aid that went to American schools.

Devin Oktar Yalkin is a photographer based in Los Angeles who has previously covered Joe Biden, dirt-track racing, live music and falcons for the magazine. He currently has a solo exhibition, Obsidian, at Evin Sanat Gallery in Istanbul.