Climate Change, Coming Home

Global warming's effects on populations

by Sarah DeWeerdt

Since the 1970s, rainfall has been scarce in the Sahel, the wide belt of semi-arid land that stretches across Africa on the southern edge of the Sahara Desert. One of the worst-affected areas has been the Tigray region of northern Ethiopia, where a series of prolonged droughts exacerbated by war caused widespread famine in the 1970s and 1980s.

To help increase the productivity of farmers' fields, the local government decided in the late 1980s to build a series of small dams to trap the unreliable rainfall and connect these to simple irrigation systems. Sure enough, harvests increased and fewer people went hungry—but health researchers also found that children in villages near the dams were seven times as likely to suffer from malaria. The water stored behind the dams provided perfect breeding habitat for the mosquitoes that carry the disease.

The people of this isolated rural region of Ethiopia offer a glimpse into the human future—a view of how global climate change can play havoc with populations' lives and livelihoods, and how addressing one climate-related problem can sometimes cause another. The World Health Organization (WHO) has calculated that by 2020 human-triggered climate change could kill 300,000 people worldwide every year. By 2000, in fact, climate change was already responsible for 150,000 excess deaths annually—deaths that wouldn't have occurred if we humans weren't burning vast quantities of fossil fuels and loading up the air with carbon dioxide and other greenhouse gases.

Jonathan Patz, a professor with the University of Wisconsin/Madison's Center for Sustainability and the Global Environment, praises the WHO's sober accounting as the most comprehensive, scientific estimate available of the health effects of climate change. The agency combined models of recent and projected climate change with data on several health dangers that are known to be affected by climate (including malaria, diarrheal diseases, and malnutrition) to calculate the disease burden due to changes in climate. However, Patz says, "their estimate is *extremely* conservative." Not only are the underlying assumptions conservative, but the analysis only concerns a few of the relatively better-understood health risks of climate change.

Climate change might have a few pluses for our species—for example, warmer winters probably mean fewer cold-related deaths in North America and Europe, while in some parts of the tropics hotter and drier conditions could reduce the survival of disease-carrying mosquitoes. But most of the effects of climate change are likely to be harmful ones: declining agricultural production and more hungry people, increased spread of infectious diseases, dangerous heat waves and floods. Although no region of the globe will be entirely spared, the negative effects are likely to fall most heavily on poor nations in tropical and subtropical regions. In other words, the people most vulnerable to the effects of climate change are precisely those who are least responsible for causing it—and those who have the least resources with which to adapt to it.

FOOD

"Malnutrition will very likely be one of the biggest impacts in low-income countries," says Kristie Ebi, an environmental consultant who has served on the Intergovernmental Panel on Climate Change (IPCC) and several other climate-change-related scientific bodies. Globally, food production is likely to decrease only modestly at worst, but this overall pattern hides what many researchers see as a growing inequality between the haves and have-nots of the world.

Some relatively wealthy countries in temperate regions will likely see crop yields rise, mainly due to longer, warmer growing seasons. Even the excess carbon dioxide in the air that is the underlying cause of climate change can theoretically be a boon for agriculture, acting as a fertilizer when other conditions for plant growth are favorable. Though it's not yet clear whether or how this effect of carbon dioxide will play out in the real world, any beneficial effects are most likely to be seen at middle and high latitudes. The prospect

Neil Cooper/Peter Arnold, Inc.

Tigray region, Ethiopia: farmer building a terrace to capture runoff and water his crop.

of these changes causes skeptics of climate-change doom and gloom to envision vast stretches of northern tundra transformed into a future breadbasket.

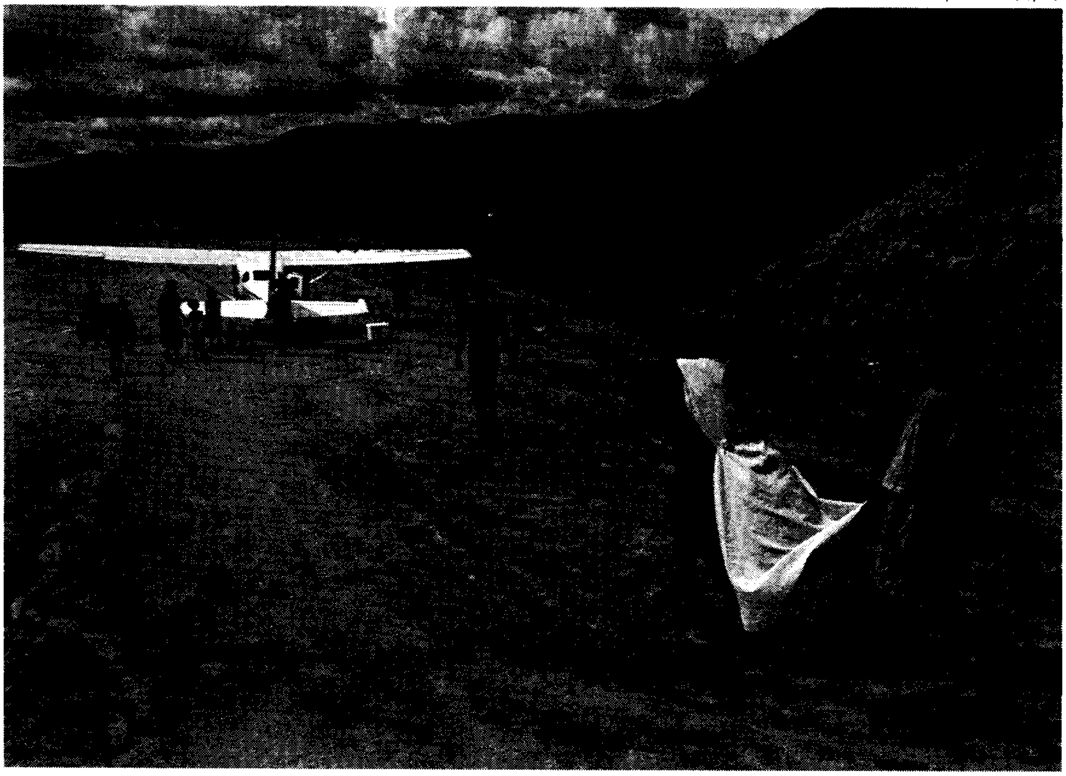
Meanwhile, however, crop yields are likely to fall in the tropical and subtropical world, latitudes with many poorer countries where most of the world's hungry and malnourished live today. There, many crops are already growing near the upper bound of their temperature tolerance, so further warming would push them beyond their limits. In some areas, precipitation may increase, causing crops to rot; elsewhere, rainfall may diminish and become more erratic, arriving unpredictably as intense downpours that will run off the parched earth instead of nourishing the soil. And since the economies of many poorer countries are heavily dependent on agriculture, the failure of crops at home will leave them unable to buy surplus grain abroad.

For the last decade and a half, Martin Parry of the U.K. Met (formerly Meteorological) Office (and current co-chair of the IPCC working group on impacts of climate change), Cynthia Rosenzweig of the Goddard Institute for Space Studies, and a large group of other researchers from various institutions have been modeling the possible effects of climate change on production of the world's staple grain crops: wheat, rice, maize, and soybeans. Their work integrates several complex computer models—of global climate, crop yields, world food trade, and various patterns of economic development and population growth—to predict future global agricultural production and the risk of hunger. One set of their calculations indicates that, accounting for future population growth, continued "business as usual" greenhouse gas emissions would increase the ranks of the hungry by 80 million by 2080, mostly in Africa and southern Asia.

Already there are hints that such projections are beginning to come true. Recently, Ebi worked on a U.S. Agency for International Development study of possible adaptations to climate change in Zignasso, a town of about 3,000 people in the main agricultural area of southern Mali. "It's gotten hotter. It's gotten drier," she says of the area's climate. "Farmers are seeing the rains come at somewhat different times of year," and sometimes there are dry spells during the rainy season. To combat declining soil quality farmers have started adding more fertilizer to their fields of potatoes, the main cash crop, but nevertheless climate shifts mean that harvests are getting smaller.

If average temperatures in this area of Mali increase, as expected, another 2–3°C by the 2060s, potato yields could further decrease by about a quarter. It's not clear whether rainfall in the area will increase or decrease. In general, scientists simply don't understand this part of the climate system very well, so different models often disagree in their predictions. But in either case, says Ebi, the soil will probably be drier, because warm temperatures cause soil moisture to evaporate more quickly—and that could spell trouble for rice, the area's staple grain crop.

Mark Edwards/Peter Arnold, Inc.



Sierra Parima, Venezuela: a Yanomami indian girl, suffering from malaria and unconscious, is carried to a plane for airlift to a hospital for treatment. The Yanomami have been decimated by malaria, to which they have not developed resistance.

As drier conditions shrink growing seasons in tropical and subtropical environments, farmers have been encouraged by governments and aid agencies to turn to new, fast-growing crop varieties: rice that matures in 90 days, for example, rather than 120 days. But this solution may beget its own set of problems, Ebi says: "The fast-growing cultivars, because they grow faster, have less time to absorb micronutrients" from the soil, so they might provide people with sufficient calories but leave them vulnerable to vitamin and mineral deficiencies. "We need to pay attention to the quality of the food, not just the quantity."

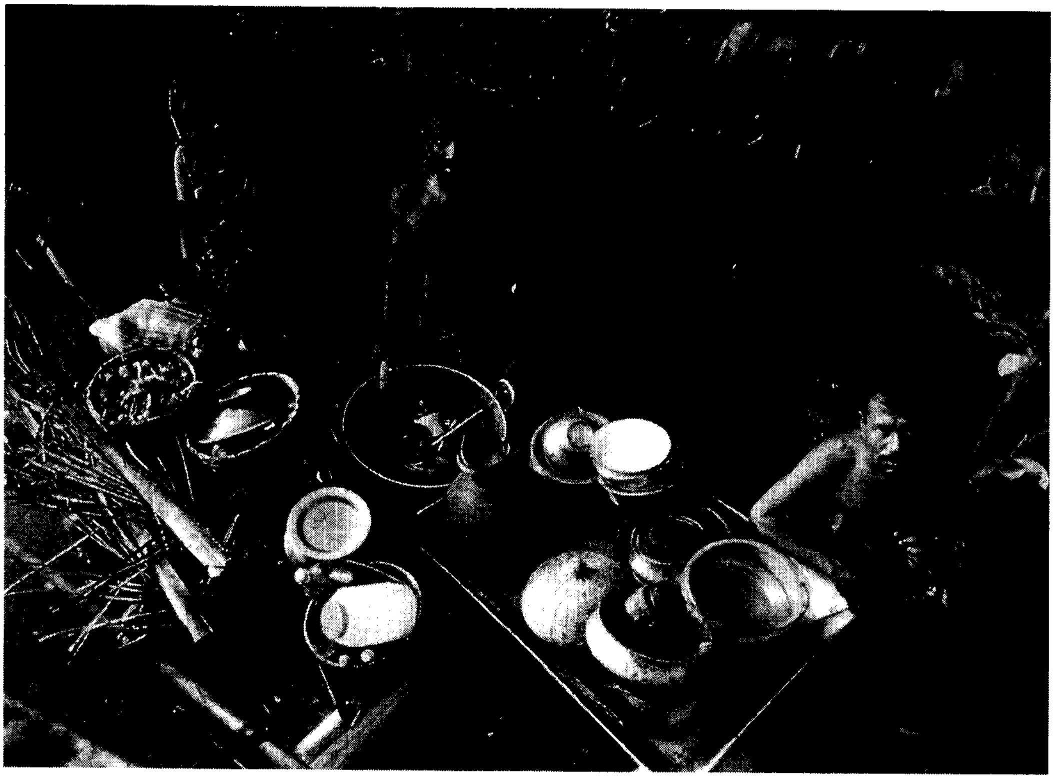
DISEASE

Much research on climate change and infectious disease has focused on vector-borne diseases, in which a pathogen is carried from one human host to another by a third species, often a mosquito or other type of insect. Common vector-borne diseases in developing countries include malaria and dengue fever, both transmitted by mosquitoes, and in developed countries Lyme disease, transmitted by ticks. Many vector-borne diseases are sensitive to shortterm climate variations and show seasonal patterns of transmission and year-to-year differences depending on the weather. Warmer weather (at least up to a certain maximum) increases the rate of mosquito reproduction, increases the number of blood meals a mosquito takes, prolongs the mosquito breeding season, and makes disease-causing microorganisms reproduce or mature more quickly.

However, linking observed increases in vector-borne diseases to changing weather patterns has so far proved difficult. "If we look over time, to see whether the changing distribution of malaria, for example, is due to climate change, it's difficult if not impossible to demonstrate that because many other things have changed over the same period," says Andrew Haines, director of the London School of Hygiene and Tropical Medicine. In the highlands of East Africa, for example, the onset of warmer weather has also been accompanied by other factors that can increase malaria, including drug resistance of the malaria parasite, human migration and changes in immunity, and the failure of mosquito-control programs. "The other problem is that we often don't have very good data over long time periods, particularly in those parts of the world where one might expect an impact from climate change," Haines adds.

Still, scientists have observed many warm-adapted species of plants and animals moving to higher altitudes and latitudes as temperatures have climbed in recent years. "To think that bugs and mosquitoes are immune to [this migration] is wishful thinking," says Paul Epstein, associate director of the Center for Health and the Global Environment at Harvard Medical School. In fact, the mosquitoes that carry malaria and dengue fever have recently been spotted in highland areas of Africa, Asia, and Latin America where temperatures are increasing, glaciers are retreating, and plant communities are moving upward, and the Lyme disease tick has migrated to

Abir Abdullah/Peter Arnold, Inc.



Bangladesh: a flood in 2004 causes this family to float their entire belongings on makeshift rafts.

higher latitudes in Sweden and higher altitudes in the Czech Republic as the climate has warmed. About 45 percent of the world's population currently lives in areas where the climate is potentially suitable for malaria transmission, and as the planet continues to warm that proportion could increase to 60 percent by century's end.

There is a difference, though, between the expanding range of a vector *species* and the expanding range of a vector-borne *disease*. Duane Gubler, former director of the U.S. Centers for Disease Control Division of Vector-Borne Infectious Diseases, points out that malaria was once endemic in large portions of the United States. In fact the mosquitoes that carry the disease are still present and the climate today is already suitable for transmission of the disease during the summer months. "Unless our public health system and our standard of living tank, we're not going to see those huge outbreaks," he says. He also cautions that temperature is not the only factor that influences the survival of disease-carrying mosquitoes, and elsewhere in the world many other factors in addition to climate contribute to recent disease outbreaks.

Indeed, many scientists agree with Gubler that good public health systems and the ready availability of medical care, assuming they are not neglected, are likely to protect the United States and many other wealthy nations from widespread outbreaks of malaria and other vector-borne tropical diseases. By contrast, malaria may be more likely to take hold in temperate regions where the public health infrastructure has deteriorated in recent years, such as southern portions of the former Soviet Union.

The populations most at risk from the spread of malaria may be those at the margins of the disease's present distribution in developing countries without good access to health care. As malaria invades these new areas, its effects may become more severe. "When you have an outbreak in an area where people are not immune, they've not been exposed to malaria regularly, mortality can be 20 or 30 percent," Kristie Ebi says—compared to about 3 percent in areas where the disease is long established. Moreover, because malaria is such a common disease—infecting half a billion people each year and killing 1 to 2 million—a very slight increase in the relative risk of the disease can translate into hundreds of thousands of additional cases.

Many other climate/disease links have also been noted. Higher-than-average temperatures often lead to higher-than-average rates of food poisoning. Where access to clean water is scarce, droughts often trigger outbreaks of diseases associated with poor hygiene, such as diarrheal diseases, scabies, conjunctivitis, and trachoma. Floods, too, can increase the risk of diarrheal diseases by contaminating waterways and drinking-water supplies with human and animal wastes. Storms often leave infectious disease in their wake; in 2000, a series of heavy rains and three cyclones over the course of six weeks quintupled malaria infections in Mozambique.

Additional research on climate and infectious disease has focused on El Niño events, periods of higher sea-surface temperature in the southern Pacific that affect weather throughout the world. Health consequences linked to El Niño events include cholera outbreaks in Bangladesh; malaria in South America, the Punjab region of India, and elsewhere in Asia; rift valley fever in East Africa; Ross River virus in Australia; and hantavirus pulmonary syndrome in the southwestern United States. During the 1997–8 El Niño event, winter temperatures were about 5°C warmer than normal in Lima, Peru, and hospital admissions for diarrhea increased by 200 percent. Some climate-change models predict that El Niño events will become more frequent and more intense in the future, so this phenomenon is not only a model of how short-term climate variation affects infectious disease, but also a potential effect of climate change itself.

WEATHER EXTREMES AND SEA LEVELS

"Climate change has two parts—it's the warming and then the extremes," Paul Epstein says. The planet's weather is expected to become not only warmer on average, but more variable, with more frequent and intense heat waves, droughts, and torrential rains. Warmer air holds more moisture, so the global hydrologic cycle is expected to accelerate and intensify, leading to violent storms and stronger hurricanes. In addition to their effects on infectious diseases, such extremes of weather pose direct physical risks to the humans in their path—heat stroke, drowning, dehydration, injury.

In general, while patterns of weather can be linked to climate change, it's difficult to ascribe any one extreme event to that cause. For example, Hurricane Katrina, the August 2005 storm that slammed into the U.S. Gulf Coast and inundated New Orleans, is the *kind* of storm we would expect to see more frequently with climate change, but scientists can't say for certain that climate change caused that *particular* event.

Despite that general difficulty, Peter Stott and colleagues at the Hadley Centre for Climate Prediction and Research and from Oxford University have taken a careful statistical approach to demonstrate the links between climate change and the European summer heat wave of 2003. That summer is thought to have been the hottest in Europe since 1500, and in August over 20,000 people died in France and thousands more elsewhere in Europe. Stott and his colleagues demonstrated that the magnitude and timing of the heat wave were consistent with computer models of climate change, and calculated that the probability of such a heat wave was doubled by the amount of global warming to date.

Many deaths during heat waves occur among the very old, the very young, and frail individuals, especially those with underlying cardiovascular and respiratory diseases. However, Stott's team also found that mortality rates in hard-hit areas did not dip below normal after the 2003 heat wave. In other words, the victims represented excess deaths, not merely deaths that would likely have occurred soon anyhow.

Rising sea levels also represent a direct physical threat from climate change. Some coastal populations will be threatened by inundation from the water's slow, inexorable rise, while even larger areas will be subject to periodic danger from intensified storm surges. The Intergovernmental Panel on Climate Change, which includes scientists from 113 countries, is charged with reviewing and synthesizing research on climate change and its effects. The IPCC predicts that global sea levels will rise 18–59 centimeters over the next century. Most of that calculation represents the expansion of water as sea surface temperatures warm; melting of polar ice will also contribute, but the panel says the details of this process are not understood well enough to quantify.

Small, low-lying Pacific island nations are likely to be the first affected by rising seas. Already the citizens of Tuvalu, a group of small reef islands and atolls in the Pacific, are making plans to evacuate en masse over the next decade. A sea-level rise of one meter—an extreme case, but not outside the realm of possibility over the long term—could drive 18.6 million people in China, 13 million in Bangladesh, 3.5 million in Egypt, and 3.3 million in Indonesia from their homes.

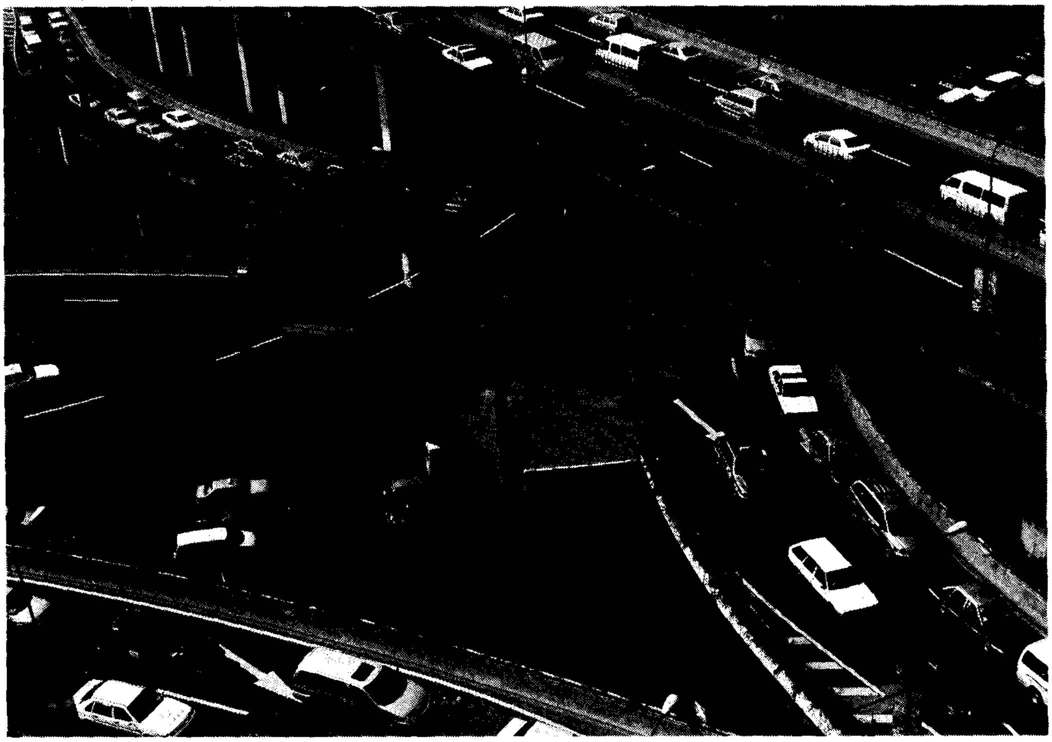
The best estimates so far suggest that climate change will cause many excess deaths but not slow population growth. (A study due from the IPCC in April reportedly projects "millions" starving from food shortages by 2080.) The planet's population will continue to rise, to perhaps 9 billion sometime this century, according to a middle-of-the-road United Nations projection.

Climate change and population are interlinked in complex ways. Most obviously, population growth worsens climate change—more people on the planet means more carbon dioxide emissions. And Parry and Rosenzweig's modeling of food security indicates that reducing the rate of global population growth would do more to reduce the number of hungry people in the world than would limiting climate change.

At the same time, climate change makes clear that an overcrowded planet isn't a matter of numbers alone. By reducing the planet's ability to feed us, stretching already overburdened public health resources, and making parts of the globe uninhabitable altogether, climate change will make a given level of population "feel" more crowded.

These ironies only deepen when you consider that the level of development that will help many wealthy countries avoid some of the adverse effects of climate change itself depends on fossil fuels. "A substantial fraction of what we call development is in fact adaptation to climate," explains Gerry Stokes, vice president of international partnerships for Battelle Memorial Institute. The clothes we wear, how we build our houses, what crops we plant, the public health systems we design—all vary from place to place, depending on the climate patterns we've observed in the past. People in the poorest, least developed countries "are incredibly vulnerable to the current climate, and the principle of minimum astonishment says they're probably not particularly well adapted to future climate either."

Scientists think about some of these tradeoffs and interconnections with the help of the Kaya equation (named ullstein-Hiss/Möller/Peter Arnold, Inc.



Shanghai, China: the effluence of affluence. In 2006 China increased its production of vehicles by 29 percent to 6.7 million cars and trucks.

for the Japanese scientist Yoichi Kaya):

CO_2 emissions = Population × Wealth (gross domestic product/population) × Energy-intensiveness of wealth creation (energy/unit GDP) × Carbon-intensiveness of energy production (CO_2/energy)

Currently, the major factor contributing to increased emissions is not population growth but growth in affluence, particularly in rapidly modernizing countries such as India and China. During the 20th century the global population quadrupled, but carbon emissions increased 12-fold. Of course, it's morally dicey—not to mention politically impossible—to suggest that countries should reduce their populations or that poor countries should remain poor. (And although it is beyond the scope of this article, some have argued that immigration patterns can be critical as well, when people move from poor countries to rich ones and eventually become integrated as members of those high-consuming societies; this topic is equally complex and delicate.) Scientists and policymakers primarily focus on the other two terms of the equation to reduce carbon dioxide emissions and thus mitigate climate change—that is, improving the energy-efficiency of economies, and finding low-carbon sources of energy.

Many technologies already exist to accomplish both of these goals, although they are often more expensive than fossil-fuel intensive forms of energy (in part because of longterm government subsidies to fossil fuel industries and because fossil fuel prices do not reflect the associated costs of climate change and other environmental ills). Often, it makes the most economic sense to apply these technologies first in developing countries—it's better to build a super-efficient power plant in a new area than to tear down or retrofit an existing one. Stokes says wealthy nations could atone for some of their carbon emissions by helping developing countries bear the extra cost of such climate-friendly development.

Focusing such efforts on developing countries could also produce the greatest gains in resilience, or ability to adapt to climate change. About 2 billion of the world's people lack access to electricity—but if this energy could be made available to them in cleanly generated form, they could, for example, prevent food from spoiling, store vaccines, and purify water. "By providing cleaner energy for populations...you can also get near-term benefits to health by reducing air pollution," Haines adds.

Maybe that explains why many scientists who have studied the health effects of climate change seem optimistic in the end. "I believe that this climate crisis is going to lead us to a clean energy transition, and that this can be the engine of growth for the 21st century and help people develop cleanly and sustainably," Epstein says.

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