from *Plan B 4.0: Mobilizing to Save Civilization*, by Lester R. Brown

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Climate Change and the Energy Transition

Ever since civilization began, each generation has left the next a planet similar to the one it inherited. Our generation may be the first to abandon that tradition.

The earth's temperature is rising. It has gone up 0.6 degrees Celsius (1 degree Fahrenheit) since 1970, and it is projected to rise by up to 6 degrees Celsius (11 degrees Fahrenheit) by the end of this century. This rise will be uneven. It will be much greater at the higher latitudes than in the equatorial regions, greater over land than over oceans, and greater in continental interiors than in coastal regions.[1]

Sea level is rising too, as a result of the thermal expansion that takes place as ocean water warms and as ice sheets melt. Recent studies project a rise of 3–6 feet by the end of the century. During the entire twentieth century, sea level rose by 7 inches, but if it rises 6 feet by 2100, it will have risen an average of 7 inches per decade.[2]

Geographically, the oceans will expand and the continents will shrink. Low-lying island countries will disappear beneath the waves. Rising seas will inundate low-lying cities and rice-growing river deltas, generating hundreds of millions of refugees.

The rapidly rising temperature that is projected for this century with business as usual will alter every ecosystem on earth. Up to one third of all plant and animal species could be lost. Despite the fences we have built around parks and wildlife preserves, the ecosystems within them will not survive the thermal stress.[3]

Agriculture as we know it today evolved in a climate that was remarkably stable during its 11,000-year experience. As climate changes, agriculture will be increasingly out of sync with it.

At the same time that rising temperatures are reshaping the earth's ecology and geography, declining oil production will be reshaping the global economy. The twentieth century was the oil century. In 1900, the world produced 150 million barrels of oil. In 2000, it produced 28 billion barrels—a 185-fold jump. This was the century in which oil overtook coal to become the world's leading source of energy. It was also the century in which oil totally reshaped life for much of humanity.[4]

The rapidly expanding supply of cheap oil led to an explosive worldwide growth in food production, population, urbanization, and human mobility. But today's oil-based civilization is heavily dependent on a resource whose production will soon be falling. Since 1981, oil extraction has exceeded new discoveries by an ever-widening margin. In 2008, the world pumped nearly 31 billion barrels of oil but discovered only 7 billion barrels. World oil reserves are now in decline, dropping every year.[5]

As we look at the future of oil in a Plan B context, it is not only geological constraints but also escalating climate concerns that will reduce its use. Today roughly 43 percent of carbon dioxide (CO_2) emissions from burning fossil fuels comes from coal and 38 percent from oil. The remaining 19 percent comes from natural gas. Because coal is the most carbon-intensive fossil fuel, any effort to quickly cut CO_2 emissions means quickly cutting coal use[6]

Rising Temperature and Its Effects

We are entering a new era, one of rapid and often unpredictable climate change. In fact, the new climate norm is change. The 25 warmest years on record have come since 1980. And the 10 warmest years since global recordkeeping began in 1880 have come since 1996.[7]

The warming is caused by the accumulation of heat-trapping "greenhouse" gases and other pollutants in the atmosphere. Of the greenhouse gases, CO_2 accounts for 63 percent of the recent warming trend, methane 18 percent, and nitrous oxide 6 percent, with several lesser gases accounting for the remaining 13 percent. Carbon dioxide comes mostly from electricity generation, heating, transportation, and industry. In contrast, human-caused methane and nitrous oxide emissions come largely from agriculture—methane from rice paddies and cattle and nitrous oxide from the use of nitrogenous fertilizer.[8]

Atmospheric concentrations of CO_2, the principal driver of climate change, have climbed from nearly 280 parts per million (ppm) when the Industrial Revolution began around 1760 to 386 ppm in 2008. The annual rise in atmospheric CO_2 level, now one of the world's most predictable environmental trends, results from emissions on a scale that is overwhelming nature's capacity to absorb carbon. In 2008, some 7.9 billion tons of carbon were emitted from the burning of fossil fuels and 1.5 billion tons were emitted from deforestation, for a total of 9.4 billion tons. But since nature has been absorbing only about 5 billion tons per year in oceans, soils, and vegetation, the remainder stays in the atmosphere, pushing up CO_2 levels.[9]

Methane, a potent greenhouse gas, is produced when organic matter is broken down under anaerobic conditions, including the decomposition of plant material in bogs, organic materials in landfills, or forage in a cow's stomach. Methane can also be released with the thawing of permafrost, the frozen ground underlying the tundra that covers nearly 9 million square miles in the northern latitudes. All together, Arctic soils contain more carbon than currently resides in the atmosphere, which is a worry considering that permafrost is now melting in Alaska, northern Canada, and Siberia, creating lakes and releasing methane. Once they get under way, permafrost melting, the release of methane and CO_2, and a rising temperature create a self-reinforcing trend, what scientists call a "positive feedback loop." The risk is that the release of a massive amount of methane into the atmosphere from melting permafrost could simply overwhelm efforts to stabilize climate.[10]

Another unsettling development is the effect on climate of atmospheric brown clouds (ABCs) consisting of soot particles from burning coal, diesel fuel, or wood. These particles affect climate in three ways. First, by intercepting sunlight, they heat the upper atmosphere. Second, because they also reflect sunlight, they have a dimming effect, lowering the earth's surface temperature. And third, if particles from these brown clouds are deposited on snow and ice, they darken the surface and accelerate melting.[11]

These effects are of particular concern in India and China, where a large ABC over the Tibetan Plateau is contributing to the melting of high-altitude glaciers that supply the major rivers of Asia. Soot deposition causes earlier seasonal melting of mountain snow in ranges as different as the Himalayas of Asia and the Sierra Nevada of California, and it is also believed to be accelerating the melting of Arctic sea ice. Soot particles have even been found in snow in Antarctica, a region once thought to be pristine and untouched by pollution.[12]

In contrast to CO_2, which may remain in the atmosphere for a century or more, soot particles in these clouds are typically airborne for only a matter of weeks. Thus, once coal-fired power plants are closed or wood cooking stoves in villages are replaced with solar cookers, atmospheric soot disappears rapidly.[13]

If we continue with business as usual, the projected rise in the earth's average temperature of 1.1–6.4 degrees Celsius (2–11 degrees Fahrenheit) during this century seems all too possible. These projections are the latest from the Intergovernmental Panel on Climate Change (IPCC), the world body of more than 2,500 leading climate scientists that in 2007 released a consensus report affirming humanity's role in climate change. Unfortunately, during the several years since the study was completed, both global CO_2 emissions and atmospheric CO_2 concentrations have exceeded those in the IPCC's worst-case scenario.[14]

With each passing year the chorus of urgency from the scientific community intensifies. Each new report indicates that we are running out of time. For instance, a landmark 2009 study by a team of scientists from the Massachusetts Institute of Technology concluded that the effects of climate change will be twice as severe as those they projected as recently as six years ago. Instead of a likely global temperature rise of 2.4 degrees Celsius, they now see a rise of 5.2 degrees.[15]

Another report, this one prepared independently as a background document for the December 2009 international climate negotiations in Copenhagen, indicated that every effort should be made to hold the temperature rise to 2 degrees Celsius above pre-industrial levels. Beyond this, dangerous climate change is considered inevitable. To hold the temperature rise to 2 degrees, the scientists note that CO_2 emissions should be reduced by 60–80 percent immediately, but since this is not possible, they note that, "To limit the extent of the overshoot, emissions should peak in the near future."[16]

The effects of rising temperature are pervasive. Higher temperatures diminish crop yields, melt the mountain glaciers that feed rivers, generate more-destructive storms, increase the severity of flooding, intensify drought, cause more-frequent and destructive wildfires, and alter ecosystems everywhere.

What we can anticipate with a warmer climate is more extreme weather events. The insurance industry is painfully aware of the relationship between higher temperatures and storm intensity. Soaring weather-related damage claims have brought a drop in earnings and a flurry of lowered credit ratings for insurance companies as well as the reinsurance companies that back them up.[17]

Companies using historical records as a basis for calculating insurance rates for future storm damage are realizing that the past is no longer a reliable guide to the future. This is a challenge not only for the insurance industry but for all of us. We are altering the earth's climate, setting in motion trends we do not always understand with consequences we cannot anticipate.

Crop-withering heat waves have lowered grain harvests in key food-producing regions in recent years. In 2002, record-high temperatures and drought-reduced grain harvests in India, the United States, and Canada dropped the world harvest 90 million tons, or 5 percent below consumption. The record-setting 2003 European heat wave contributed to a world harvest that again fell short of consumption by 90 million tons. Intense heat and drought in the U.S. Corn Belt in 2005 contributed to a world grain shortfall of 34 million tons.[18]

Such intense heat waves also take a direct human toll. In 2003, the searing heat wave that broke temperature records across Europe claimed more than 52,000 lives in nine countries. Italy alone lost more than 18,000 people, while 14,800 died in

France. More than 18 times as many people died in Europe in this 2003 heat wave as died during the terrorist attacks on the World Trade Center in 2001.[19]

There has also been a dramatic increase in the land area affected by drought in recent decades. A team of scientists at the National Center for Atmospheric Research (NCAR) reports that the area experiencing very dry conditions expanded from less than 15 percent in the 1970s to roughly 30 percent by 2002. The scientists attribute part of the change to a rise in temperature and part to reduced precipitation, with high temperatures becoming progressively more important during the latter part of the period. Most of the drying was concentrated in Europe, Asia, Canada, western and southern Africa, and eastern Australia.[20]

A 2009 report published by the U.S. National Academy of Sciences and led by Susan Solomon of the National Oceanic and Atmospheric Administration reinforces these findings. It concludes that if atmospheric CO_2 climbs from 385 ppm to 450–600 ppm, the world will face irreversible dry-season rainfall reductions in several regions of the world. The study likened the conditions to those of the U.S. Dust Bowl era of the 1930s.[21]

Researchers with the U.S. Department of Agriculture's Forest Service, drawing on 85 years of fire and temperature records, projected that a 1.6-degree-Celsius rise in summer temperature could double the area of wildfires in the 11 western states.[22]

The Pew Center on Global Climate Change sponsored an analysis of some 40 scientific studies that link rising temperature with changes in ecosystems. Among the many changes reported are spring arriving nearly two weeks earlier in the United States, tree swallows nesting nine days earlier than they did 40 years ago, and a northward shift of red fox habitat that has it encroaching on the Arctic fox's range. Inuits have been surprised by the appearance of robins, a bird they have never seen before. Indeed, there is no word in Inuit for "robin."[23]

The National Wildlife Federation (NWF) reports that if temperatures continue to rise, by 2040 one out of five of the Pacific Northwest's rivers will be too hot for salmon, steelhead, and trout. Paula Del Giudice, Director of NWF's Northwest Natural Resource Center, notes that "global warming will add an enormous amount of pressure onto what's left of the region's prime cold-water fish habitat."[24]

Douglas Inkley, NWF senior science advisor and senior author of a report to The Wildlife Society, notes, "We face the prospect that the world of wildlife that we now know—and many of the places we have invested decades of work in conserving as refuges and habitats for wildlife—will cease to exist as we know them, unless we change this forecast."[25]

Melting Ice, Rising Seas

Ice is melting so fast that even climate scientists are scrambling to keep up with the shrinkage of ice sheets and glaciers. The melting of the earth's largest ice sheets—Greenland and West Antarctica—would raise sea level dramatically. If the Greenland ice sheet were to melt entirely, it would raise sea level 23 feet. Melting of the West Antarctic ice sheet, the most vulnerable portion of the Antarctic ice because of its exposure to both warming air and warming ocean water, would eventually raise sea level 16 feet. Many of the world's coastal cities would be under water; over 600 million coastal dwellers would be forced to move.[26]

Assessing the prospects for the Greenland ice sheet begins with looking at the warming of the Arctic region. A 2005 study, *Impacts of a Warming Arctic*, concluded that the Arctic is warming almost twice as fast as the rest of the planet. Conducted by the Arctic Climate Impact Assessment (ACIA) team, an international group of 300 scientists, the study found that in the regions surrounding the Arctic, including Alaska, western Canada, and eastern Russia, winter temperatures have climbed by 3–4 degrees Celsius (5–7 degrees Fahrenheit) over the last half-century. Robert Corell, the ACIA chairman, says this region "is experiencing some of the most rapid and severe climate change on Earth."[27]

In testimony before the U.S. Senate Commerce Committee, Sheila Watt-Cloutier, speaking on behalf of the 155,000 Inuits who live in Alaska, Canada, Greenland, and the Russian Federation, described their struggle to survive in the rapidly changing Arctic climate as "a snapshot of what is happening to the planet." For example, as the sea ice shrinks it threatens the ice-dwelling seals, a basic food source for the Inuit. She called the warming of the Arctic "a defining event in the history of this planet."[28]

The ACIA report noted that the retreat of the sea ice has devastating consequences for polar bears, whose very survival may be at stake. A subsequent report indicated that polar bears, desperate for food, are turning to cannibalism. Two thirds of the polar bear population could be gone by 2050.[29]

There is new evidence that Arctic sea ice is melting faster than previously thought. Scientists from the National Snow and Ice Data Center and NCAR examining data on Arctic Ocean summer ice since 1953 concluded that the ice is melting much faster than climate models had predicted. They found that from 1979 to 2006 the summer sea ice shrinkage accelerated to 9.1 percent a decade. In the summer of 2007, a record melt year, Arctic sea ice shrank to an area some 20 percent smaller than the previous record set in 2005. Recent evidence that the multi-year sea ice is not recovering in winter and therefore thinning overall only adds to concern about the ice cap's future.[30]

Walt Meier, a researcher at the U.S. National Snow and Ice Data Center, views the winter shrinkage with alarm. He believes there is "a good chance" that the Arctic tipping point has been reached. Some scientists now think that the Arctic Ocean could be ice-free in summer as early as 2015, but in early 2009 Warwick Vincent, director of the Center for Northern Studies at Laval University in Quebec, reported that this could happen by 2013. Arctic scientist Julienne Stroeve observed that the shrinking Arctic sea ice may have reached "a tipping point that could trigger a cascade of climate change reaching into Earth's temperate regions."[31]

Scientists have long been concerned that a self-reinforcing trend may be starting to kick in as the sea ice shrinks. When incoming sunlight strikes the ice in the Arctic Ocean, up to 70 percent of it is reflected back into space. Only 30 percent is absorbed. As the Arctic sea ice melts, however, and the incoming sunlight hits the much darker open water, only 6 percent is reflected back into space and 94 percent is converted into heat. This albedo effect helps explain the accelerating shrinkage of the Arctic sea ice and the rapidly rising regional temperature.[32]

If all the ice in the Arctic Ocean melts, it will not affect sea level because the ice is already in the water. But it will lead to a much warmer Arctic region as more of the incoming sunlight is converted to heat. And since Greenland lies largely within the Arctic Circle, its ice sheet—up to 1.6 kilometers (1 mile) thick in places—is beginning to show the effects.[33]

Several recent studies report accelerated melting of the Greenland ice sheet. In September 2006, a University of Colorado team study published in *Nature* indicated that between April 2004 and April 2006 Greenland lost ice 2.5 times faster than during the preceding two years. In October 2006, a team of NASA scientists reported that the flow of glaciers into the sea was accelerating. Eric Rignot, a glaciologist at NASA's Jet Propulsion Laboratory, said that "none of this has been predicted by numerical models, and therefore all projections of the contribution of Greenland to sea level [rise] are way below reality."[34]

In late summer 2007 scientists at a symposium in Ilulissat, Greenland, said that the Greenland icecap is melting so fast that it is triggering minor earthquakes as pieces of ice weighing millions of tons break off and slide into the sea. ACIA chairman Corell reported that "we have seen a massive acceleration of the speed with which these glaciers are moving into the sea." The Ilulissat (Jakobshavn Isbrae) glacier, a large outlet glacier on Greenland's southwest coast, is moving at 2 meters per hour on a front 8 kilometers (5 miles) wide and 900 meters deep.[35]

Data gathered by NASA satellites indicated that Greenland's floating ice shelves shrank by 24 square miles in 2007. In the summer of 2008 this loss jumped to 71 square miles, nearly tripling. Part of this loss was observed directly by an Ohio State University research team, which saw a massive 11-square-mile chunk of ice break off from the Petermann Glacier in northern Greenland. An upstream crack in the glacier suggested an even larger chunk would be breaking off soon.[36]

What scientists once thought was a simple linear process—that at the surface an ice sheet melts a fixed amount each year, depending on the temperature—is now seen to be much more complex. As the surface ice begins to melt, some of the water filters down through cracks in the glacier, lubricating the surface between the glacier and the rock beneath it. This accelerates the glacial flow and the calving of icebergs into the surrounding ocean. The relatively warm water flowing through the moulins (deep holes) and cracks in the ice sheet also carries surface heat deep inside it far faster than it would otherwise penetrate by simple conduction.[37]

At the other end of the earth, the 2-kilometer-thick Antarctic ice sheet, which covers an area one and a half times the size of the United States and contains 70 percent of the world's fresh water, is also beginning to melt. Ice shelves formed by the flow of glaciers from the continent into the surrounding seas are breaking up at an alarming rate.[38]

The flow of ice, fed by the continuous formation of new ice on land and culminating in the breakup of the shelves on the outer fringe and the calving of icebergs, is not new. What is new is the pace of this process. Even veteran ice watchers are amazed at how quickly the disintegration is occurring. "The speed of it is staggering," said David Vaughan, a glaciologist at the British Antarctic Survey, which has been monitoring the Larsen ice shelf closely. Along the Antarctic Peninsula, in the vicinity of Larsen, the average temperature has risen 2.5 degrees Celsius over the last five decades.[39]

When Larsen A, a huge ice shelf on the eastern side of the Antarctic Peninsula, broke up in 1995, it was a signal that all was not well in the region. Then in 2000, a huge iceberg nearly the size of Connecticut—11,000 square kilometers (4,250 square miles)—broke off the Ross Ice Shelf on the south side of the continent.[40]

After Larsen A broke up, it was only a matter of time, given the rise in temperature in the region, before neighboring Larsen B would do the same. So when the northern part of the Larsen B Ice Shelf collapsed into the sea in March 2002, it was not a total surprise. At about the same time, a Rhode Island–sized chunk of ice broke off the Thwaites Glacier.[41]

In May 2007, a team of scientists from NASA and the University of Colorado reported satellite data showing widespread snow-melt on the interior of the Antarctic ice sheet over an area the size of California. This melting in 2005 was 900 kilometers inland, only about 500 kilometers from the South Pole. Team member Konrad Steffen observed, "Antarctica has shown little to no warming in the recent past with the exception of the Antarctic Peninsula, but now large regions are showing the first signs of the impacts of warming."[42]

Ice sheets are now breaking up at a remarkable rate. At the end of February 2008, a NASA satellite caught a Manhattan-sized piece of the Wilkins ice shelf breaking up. Within 10 days, the 5,000-square-mile ice shelf lost 160 square miles of ice.[43]

Just over a year later, a NASA satellite image showed the collapse of an ice bridge that signaled the final demise of the Wilkins ice shelf. Yet another chunk of the West Antarctic ice sheet is disappearing. NASA reports that the Wilkins breakup is the tenth major Antarctic ice sheet to collapse in recent times.[44]

When ice shelves already largely in the water break off from the continental ice mass, this does not have much direct effect on sea level per se. But without the ice shelves to impede the flow of glacial ice, typically moving 400–900 meters a year, the flow of ice from the continent can accelerate, leading to a thinning of the ice sheet on the edges of the Antarctic continent, thus contributing to sea level rise.[45]

The accelerated melting of both the Greenland and West Antarctic ice sheets is leading to much higher projected rises in sea level for this century. The IPCC projections of 18–59 centimeters during this century do not fully include the dynamic processes accelerating ice melt on the Greenland and West Antarctic ice sheets. As scientists take these into account, they are revising their projections. In 2008, a report by the U.S. Climate Change Science Program indicated that the IPCC sea level rise is likely an underestimate. A team led by W. Tad Pfeffer of the Institute of Arctic and Alpine Research at the University of Colorado concluded in September 2008 that with melting continuing to accelerate, the world could see a sea level rise of 0.8–2 meters (3–6 feet) by 2100.[46]

The International Institute for Environment and Development (IIED) has analyzed the effect of a 10-meter rise in sea level, providing a sense of how humanity would be affected if the two ice sheets started to disappear. The IIED study begins by pointing out that 634 million people currently live along coasts at or below 10 meters above sea level, most of them in cities and rice-growing river deltas.[47]

One of the most vulnerable countries is China, with 144 million potential climate refugees. India and Bangladesh are next, with 63 million and 62 million respectively. Viet Nam has 43 million vulnerable people, and Indonesia 42 million. Others in the top 10 include Japan with 30 million, Egypt with 26 million, and the United States with 23 million.[48]

It is difficult to imagine the displacement of so many people.

Some of the refugees could simply retreat to higher ground within their own country. Others—facing extreme crowding in the interior regions of their homeland or a total inundation of their low-lying island countries—would seek refuge elsewhere. Rising-sea refugees in already crowded Bangladesh would likely try to do this, which helps explain why neighboring India has built a fence along its border.

Not only would some of the world's largest cities, such as Shanghai, Kolkata, London, and New York, be partly or entirely inundated, but vast areas of productive farmland would also be lost. The rice-growing river deltas and floodplains of Asia, including the Gangetic and Mekong deltas, would be covered with salt water, depriving Asia of part of its food supply.

Melting Glaciers, Shrinking Harvests

If all the earth's mountain glaciers melted, they would raise sea level only a matter of inches. But it is the summer ice melt from these glaciers that sustains so many of the world's rivers during the dry season. Thus, as temperature rises there will be a shrinkage of river-based irrigation water supplies. In early 2009 the University of Zurich's World Glacier Monitoring Service reported that 2007 marked the eighteenth consecutive year of glacier retreat. And glaciers are melting at double the rate of a decade ago.[49]

Mountain glaciers are melting in the Andes, the Rocky Mountains, the Alps, and elsewhere, but nowhere does this melting threaten world food security more than in the Himalayas and on the Tibet-Qinghai Plateau, where the melting of glaciers could soon deprive the major rivers of India and China of the ice melt needed to sustain them during the dry season. In the Indus, Ganges, Yellow, and Yangtze River basins, where irrigated agriculture depends heavily on rivers, this loss of dry-season flow will shrink harvests and could create unmanageable food shortages.[50]

The world has never faced such a predictably massive threat to food production as that posed by the melting mountain glaciers of Asia. As noted in Chapter 1, China and India are the world's leading wheat producers, and they totally dominate the rice harvest.[51]

The IPCC reports that Himalayan glaciers are receding rapidly and that many could melt entirely by 2035. If the giant Gangotri Glacier—whose ice melt supplies 70 percent of the Ganges flow during the dry season—disappears, the Ganges could become a seasonal river, flowing during the rainy season but not during the dry season when irrigation needs are greatest.[52]

In China, which is even more dependent than India on river water for irrigation, the situation is particularly challenging. Chinese government data show that the glaciers on the Tibet-Qinghai Plateau that feed the Yellow and Yangtze Rivers are melting at a torrid pace. The Yellow River, whose basin is home to 147 million people, could experience a large dry-season flow reduction. The Yangtze River, by far the larger of the two, is threatened by the disappearance of glaciers as well. The basin's 369 million people rely heavily on rice from fields irrigated with its water.[53]

Yao Tandong, one of China's leading glaciologists, predicts that two thirds of China's glaciers could be gone by 2050. "The full-scale glacier shrinkage in the plateau region," Yao says, "will eventually lead to an ecological catastrophe."[54]

Agriculture in the Central Asian countries of Afghanistan, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan depends heavily on snowmelt from the Hindu Kush, Pamir, and Tien Shan mountain ranges for irrigation water. Nearby Iran gets much of its water from the snowmelt in the 5,700-meter-high Alborz Mountains between Tehran and the Caspian Sea.[55]

In Africa, Tanzania's snow-capped Kilimanjaro may soon be snow- and ice-free. Ohio State University glaciologist Lonnie Thompson's studies of Kilimanjaro show that Africa's tallest mountain lost 84 percent of its ice field between 1912 and 2007. He projects that its snowcap could disappear entirely by 2015. Nearby Mount Kenya has lost 7 of its 18 glaciers. Local rivers fed by these glaciers are becoming seasonal rivers, generating conflict among the 2 million people who depend on them for water supplies during the dry season.[56]

Bernard Francou, research director for the French government's Institute of Research and Development, believes that 80 percent of South American glaciers could disappear within the next decade. For countries like Bolivia, Ecuador, and Peru, which rely on glacial melt for household and irrigation use, this is not good news.[57]

Peru, which stretches some 1,600 kilometers along the vast Andean mountain range and is the site of 70 percent of the earth's tropical glaciers, is in trouble. Some 22 percent of its glacial endowment, which feeds the many Peruvian rivers that supply water to the cities in the semi-arid coastal regions, has disappeared. Lonnie Thompson reported in 2007 that the Quelccaya Glacier in southern Peru, which was retreating by 6 meters per year in the 1960s, was then retreating by 60 meters annually. In an interview with *Science News* in early 2009, he said, "It's now retreating up the mountainside by about 18 inches a day, which means you can almost sit there and watch it lose ground."[58]

Many of Peru's farmers irrigate their wheat and potatoes with the river water from these disappearing glaciers. During the dry season, farmers are totally dependent on irrigation water. For Peru's 29 million people, shrinking glaciers will eventually mean a shrinking food supply.[59]

Lima's 8 million residents get most of their water from three rivers high in the Andes, rivers that are fed partly by glacial melt. While the glaciers are melting, the rivers swell, but once they are gone, the river flows will drop sharply, leaving Lima with a swelling population and a shrinking water supply.[60]

In early 2009 Wilfried Haeberli, head of the World Glacier Monitoring Service, reported that some 90 percent of the glacial ice in Spain's Pyrenees Mountains has disappeared over the last century. These glaciers feed the Gállego, Cinca, and Garona Rivers that flow southward, supplying summertime water in the region's foothills and plains.[61]

The story is the same everywhere. Daniel Fagre, U.S Geological Survey ecologist at Glacier National Park, reported in 2009 that the park's glaciers, which had been projected to disappear by 2030, may in fact be gone by 2020.[62]

In the southwestern United States, the Colorado River—the region's primary source of irrigation water—depends on snowfields in the Rockies for much of its flow. California, in addition to depending heavily on the Colorado, also relies on snowmelt from the Sierra Nevada range in the eastern part of the state. Both the Sierra Nevada and the coastal range supply irrigation water to California's Central Valley, the country's fruit and vegetable basket.[63]

With a business-as-usual energy policy, global climate models project a 70-percent reduction in the amount of snow pack for the western United States by mid-century. A detailed study of the Yakima River Valley, a vast fruit-growing region in Washington State, conducted by the Pacific Northwest National Laboratory of the U.S. Department of Energy shows progressively heavier harvest losses as the snow pack shrinks, reducing irrigation water flows.[64]

The snow and ice masses in the world's leading mountain ranges and the water they store are taken for granted simply because they have been there since agriculture began. As the earth gets hotter, we risk losing these "reservoirs in the sky" on which both farmers and cities depend.

Rising Temperatures, Falling Yields

Since farming began thousands of years ago, crops have been developed to maximize yields in a relatively stable climatic regime. Now that regime is changing.

Since crops typically are grown at or near their thermal optimum, even a relatively minor increase during the growing season of 1 or 2 degrees Celsius can shrink the grain harvest in major food-producing regions, such as the North China Plain, the Gangetic Plain of India, or the U.S. Corn Belt.[65]

Higher temperatures can halt photosynthesis, prevent pollination, and lead to crop dehydration. Although the elevated concentrations of atmospheric CO_2 that raise temperature can also raise crop yields, after a certain point the detrimental effect of higher temperatures on yields overrides the CO_2 fertilization effect for the major crops.

Two scientists in India, K. S. Kavi Kumar and Jyoti Parikh, assessed the effect of higher temperatures on wheat and rice yields. Basing their model on data from 10 sites, they concluded that in north India a 1-degree Celsius rise in mean temperature did not meaningfully reduce wheat yields, but a 2-degree rise lowered yields at almost all sites. When they looked at temperature change alone, a 2-degree Celsius rise led to a decline in irrigated wheat yields ranging from 37 percent to 58 percent. When they combined the negative effects of higher temperature with the positive effects of CO_2 fertilization, the decline in yields among the various sites ranged from 8 percent to 38 percent. For a country projected to add 400 million people by mid-century, rising temperatures are a troubling prospect.[66]

In a study of local ecosystem sustainability, Mohan Wali and his colleagues at Ohio State University noted that as temperature rises, photosynthetic activity in plants increases until the temperature reaches 20 degrees Celsius (68 degrees Fahrenheit). The rate of photosynthesis then plateaus as the temperature climbs until it hits 35 degrees Celsius (95 degrees Fahrenheit), whereupon it begins to decline, until at 40 degrees Celsius (104 degrees Fahrenheit), photosynthesis ceases entirely.[67]

Within the last few years, crop ecologists in several countries have been focusing on the precise relationship between temperature and crop yields. One of the most comprehensive of these studies was conducted at the International Rice Research Institute (IRRI) in the Philippines. A team of eminent crop scientists using crop yield data from experimental field plots of irrigated rice confirmed the rule of thumb emerging among crop ecologists—that a 1-degree Celsius rise in temperature above the norm lowers wheat, rice, and corn yields by 10 percent. The IRRI finding was consistent with those of other recent research projects. The scientists concluded that "temperature increases due to global warming will make it increasingly difficult to feed Earth's growing population."[68]

The most vulnerable part of a plant's life cycle is the pollination period. Of the world's three food staples—rice, wheat, and corn—corn is particularly vulnerable. In order for corn to reproduce, pollen must fall from the tassel to the strands of silk that emerge from the end of each ear of corn. Each of these silk strands is attached to a kernel site on the cob. If the kernel is to develop, a grain of pollen must fall on the silk strand and then journey to the kernel site. When temperatures are uncommonly high, the silk strands quickly dry out and turn brown, unable to play their role in the fertilization process.

The effects of temperature on rice pollination have been studied in detail in the Philippines. Scientists there report that the pollination of rice falls from 100 percent at 34 degrees Celsius to near zero at 40 degrees Celsius, leading to crop failure.[69]

High temperatures can also dehydrate plants. When a corn plant curls its leaves to reduce exposure to the sun, photosynthesis is reduced. And when the stomata on the underside of the leaves close to reduce moisture loss, CO_2 intake is also reduced, thereby restricting photosynthesis. At elevated temperatures, the corn plant, which under ideal conditions is so extraordinarily productive, goes into thermal shock.

Countless global climate models show that as temperature rises, some parts of the world will become more vulnerable to drought. Among these are the southwestern United States and the Sahelian region of Africa, where heat plus drought can be deadly. The Sahel, a wide savannah-like region that stretches across Africa from Mauritania and Senegal in the west to Sudan, Ethiopia, and Somalia in the east, already suffers devastating periodic droughts and high temperatures. Now the low rainfall in this region is becoming even more sparse.[70]

For tens of millions in this region across Africa, lower rainfall and higher temperatures threaten their survival. For them time is running out. Cary Fowler, head of the Global Crop Diversity Trust, says, "If we wait until it's too hot to grow maize in Chad and Mali, then it will be too late to avoid a disaster that could easily destabilize an entire region and beyond."[71]

The Decline of Oil and Coal

Climate change poses a threat to our civilization that has no precedent. A business-as-usual energy policy is no longer an option. At issue is whether we can quickly transition from fossil fuels to renewables. If we wait until massive climate change forces us to make the shift, it may be too late.

For oil, geological constraints are leading to production declines in many oil-producing countries. Paralleling the oil field depletions are security concerns in oil-importing countries, since so much oil comes from the politically volatile Persian Gulf region. For the United States, which imports 60 percent of its oil and where 88 percent of the labor force travels to work by car, this is not a trivial matter.[72]

Reducing oil use is not at all farfetched. For several reasons, including record high gasoline prices, consumption of oil in the United States—the world's leading oil consumer—dropped 6 percent in 2008. This decline appears to be continuing in 2009 as motorists turn to public transit, bicycles, and more fuel-efficient cars.[73]

With oil supply, the geological handwriting on the wall is clearly visible. Discoveries of conventional oil total roughly 2 trillion barrels, of which 1 trillion have been extracted so far. By themselves, however, these numbers miss a central point. As security analyst Michael Klare notes, the first trillion barrels was easy oil: "oil that's found on shore or near to shore; oil close to the surface and concentrated in large reservoirs; oil produced in friendly, safe, and welcoming places." The other half, Klare notes, is tough oil: "oil that's buried far offshore or deep underground; oil scattered in small, hard-to-find reservoirs; oil that must be obtained from unfriendly, politically dangerous, or hazardous places."[74]

Another clue to the oil production prospect is the actions of the major oil companies themselves. To begin with, the collective production of the eight leading independents has peaked and is declining. This decline notwithstanding, there have not been any dramatic increases in exploration and development, suggesting that the companies agree with the petroleum geologists who say that 95 percent of all the oil in the earth has already been discovered. "The whole world has now been seismically searched and picked over," says independent geologist Colin Campbell. "Geological knowledge has improved enormously in the past 30 years and it is almost inconceivable now that major fields remain to be found."[75]

Matt Simmons, a prominent oil investment banker, says in reference to new oil fields: "We've run out of good projects. This is not a money issue...if these oil companies had fantastic projects, they'd be out there [developing new fields]." Both Walter Youngquist, author of *GeoDestinies*, and the late A.M. Samsam Bakhtiari of the Iranian National Oil Company projected that oil production would peak in 2007.[76]

Yet another way of gauging the oil prospect is simply to look at the age of the major oil fields. Of the 20 largest oil fields ever found, 18 were discovered between 1917 (Bolivar in Venezuela) and 1968 (Shaybah in Saudi Arabia). The two most recent large ones, Cantarell in Mexico and East Baghdad Field in Iraq, were discovered during the 1970s, but none have been found since then. Neither Kazakhstan's discovery of the Kashagan oil field in the Caspian Sea in 2000 nor Brazil's discovery of the Tupi oil field in 2006—both good-sized finds—make the all-time top 20. With so many of the largest oil fields aging and in decline, offsetting this with new discoveries or more-advanced extraction technologies is increasingly difficult.[77]

The big news in 2008 was the announcement by Russia, the world's leading oil producer in recent years, that its oil output had peaked in the late 2007 and would henceforth be declining. Data through mid-2009 confirm the decline, supporting those who think world oil production has already peaked.[78]

Aside from conventional petroleum, which can easily be pumped to the surface, vast amounts of oil are stored in tar sands and in oil shale. The Athabasca tar sand deposits in Alberta, Canada, total an estimated 1.8 trillion barrels, but only about 300 billion barrels of this may be recoverable. Venezuela also has a large deposit of extra heavy oil, estimated at 1.2 trillion barrels. Perhaps a third of it could be recovered.[79]

Oil shale concentrated in Colorado, Wyoming, and Utah in the United States holds large quantities of kerogen, an organic material that can be converted into oil and gas. In the late 1970s the United States launched a major effort to develop the oil shale on the western slope of the Rocky Mountains in Colorado. When oil prices dropped in 1982, the oil shale industry collapsed. Exxon quickly pulled out of its $5-billion Colorado project, and the remaining companies soon followed suit.[80]

The one large-scale project that is moving ahead is the tar sands project in Canada. Launched in the early 1980s, it was producing 1.3 million barrels of oil a day in 2008, an amount equivalent to nearly 7 percent of current U.S. oil consumption. This tar sand oil is not cheap, becoming economical only when oil is priced at $70 per barrel. Some think it may take $90 oil to spur new investments.[81]

There is growing doubt as to whether oil in tar sands and shale should be tapped at all because of the many damaging effects, including climate disruption. Since getting oil out of tar sands requires "cooking" the sands to separate the oil, the carbon emissions from producing a barrel of tar sands oil are at least three times those from pumping a barrel of conventional oil. As oil analyst Richard Heinberg notes, "Currently, two tons of sand must be mined in order to yield one barrel of oil." Beyond this, the quantity of water needed to extract oil from shale or tar sands can be prohibitive, particularly in the western United States, where virtually all water is spoken for. Considering carbon emissions, water requirements, local water pollution, and the overall environmental devastation from processing billions of tons of tar sands or oil shale, civilization would be better off if this oil were simply left in the ground.[82]

With coal, worldwide supply depletion is not imminent, but any strategy to stabilize climate must have the phaseout of coal as its centerpiece. Coal is carbon-intensive, with CO_2 emissions per unit of energy produced double those from natural gas and half again those from oil.[83]

Coal is also the most damaging to human health. Black lung disease among coal miners is all too common. Beyond this, an estimated 3 million people die each year, more than 8,000 a day, from breathing polluted air—much of it from burning coal. Coal burning is also the leading source of mercury pollution, a potent neurotoxin, one that is particularly dangerous to children.[84]

Mercury emitted from coal smokestacks literally blankets the earth's land and water surfaces. In the United States, virtually every state warns against eating too much fish taken from fresh water, lakes, and streams because of dangerously high mercury content.[85]

In China, where cancer is now the leading source of death, coal pollution is a growing concern. A Ministry of Health survey of 30 cities and 78 counties that was released in 2007 reveals a rising tide of cancer. Populations of some "cancer villages" are being decimated by the disease.[86]

Coal is only part of the problem, but in a country that was building a new coal-fired power plant every week, it is a large part. The new reality is that each year China grows richer and sicker. The Chinese leadership is becoming increasingly concerned not only with the cancer epidemic but with the sharp rise in birth defects. Concern about the health effects of coal burning may help explain why China is making a massive push with wind and solar energy, planning to soon be the world leader in both.[87]

A sign of the emerging changes in China came when the *New York Times* reported in July 2009 that the Ministry of Environmental Protection has temporarily prohibited three of the country's five biggest power companies from building coal-fired power plants because they had not complied with environmental regulations on their existing plants. This is a major step for China, and one that would not have been made without approval at the highest level.[88]

In addition to coal's disproportionate contribution to climate disruption and damage to human health, it also is the most easily replaced of the three fossil fuels. Electricity is electricity, whether it comes from coal-fired power plants or wind farms, solar thermal power plants, and geothermal power plants. In contrast, replacing oil is more complicated because it is so pervasive in the economy.

The third fossil fuel, natural gas, accounts for only 19 percent of CO_2 emissions from fossil fuels. Because it is so much less carbon-intensive than coal and cleaner-burning than oil, it is emerging as the transition fuel as the world shifts from fossil fuels to renewable sources of energy. Its use, too, will be reduced, although not nearly as fast as that of coal.[89]

A Challenge Without Precedent

Given the need to simultaneously stabilize climate, stabilize population, eradicate poverty, and restore the earth's natural systems, our early twenty-first-century civilization is facing challenges that have no precedent. Rising to any one of these challenges would be taxing, but we have gotten ourselves into a situation where we have to effectively respond to each of them at the same time, given their mutual interdependence. And food security depends on reaching all four goals. There is no middle ground with Plan B.

As political stresses from oil shortages, food shortages, and climate change intensify, the number of failing states is growing. Beyond this, there are dangerous signs that the strong system of international cooperation that evolved after World War II, and on which global economic progress is based, is weakening. For example, concern about access to oil led the United States to convert part of its grain harvest to fuel for cars regardless of its effect on world food prices and low-income consumers.

More recently, we have seen how grain-exporting countries faced with soaring food prices restricted or banned exports in order to control internal food price rises, thereby creating a growing sense of insecurity in food-importing countries. As importing countries lost confidence in the market to supply their needs, the more affluent among them began buying or leasing massive tracts of land in other countries, many of them land-scarce, hunger-ridden countries. How do we reverse this trend toward each country fending for itself rather than working together for the common good?

Plan B is shaped by the urgent need to halt the rise in atmospheric CO_2 concentrations, to reverse the decline in world food security, and to shorten the list of failing states. In setting the climate goal of cutting net carbon emissions 80 percent by 2020, we did not ask what sort of cut was politically feasible. Instead we asked how much and how fast do we have to cut carbon emissions if we want to have a decent chance of saving the Greenland ice sheet and avoiding a politically destabilizing sea level rise. How fast do we have to cut carbon emissions if we want to save at least the larger glaciers in the Himalayas and on the Tibetan Plateau, the glaciers whose ice melt irrigates wheat and rice fields in China and India?

With energy, our goal is to close all coal-fired power plants by 2020, replacing them largely with wind farms. In the Plan B economy the transportation system will be electrified with a broad-based shift to plug-in hybrids, all-electric cars, and high-speed intercity rail. And in the Plan B world, cities are designed for people, not for cars.

Plan B is shaped not by what we have done in the past but by what we need to do for the future. We are offering a vision of what that future might look like, a road map of how to get from here to there, and a timetable for doing so. Plan B is not based on conventional thinking. That is what got us into this mess. It takes a different kind of thinking, a new mindset, to get us out.

Plan B is obviously ambitious and, to some, impossibly so. Recognizing the enormity of the challenge the world faces, Paul Hawken, corporate entrepreneur and environmentalist, counseled the graduates at the University of Portland in May 2009: "Don't be put off by people who know what is not possible. Do what needs to be done, and check to see if it was impossible only after you are done."[90]

II

THE RESPONSE