from Lester R. Brown, *Outgrowing the Earth: The Food Security Challenge in an Age of Falling Water Tables and Rising Temperatures* (NY: W.W. Norton & Co., 2005).

7

Stabilizing Climate

In July of 2004, the U.S. National Academy of Sciences released a research report by a team of nine scientists from China, India, the Philippines, and the United States who had measured the precise effect of rising temperatures on rice yields under field conditions. They concluded that yields typically fall by 10 percent for each 1-degree Celsius rise in temperature during the growing season. This confirmed what had seemed obvious to many agricultural analysts, namely that high temperatures can shrink harvests.[1]

In recent years, numerous heat waves have lowered grain harvests in key food-producing countries. In 2002, record-high temperatures and associated drought reduced grain harvests in India, the United States, and Canada, dropping the world harvest 89 million tons below consumption. In 2003, Europe was hit by high temperatures. The record-breaking late summer heat wave that claimed 35,000 lives in eight nations shrank harvests in every country from France eastward through the Ukraine. It contributed to a world harvest shortfall of 94 million tons—5 percent of world consumption.[2]

The new research results from agricultural scientists, along with the grain production performance of various

countries recently exposed to record temperatures, underscore the close relationship between energy policy and food security. Farmers already struggling to feed 70 million or more people each year will find it even more difficult as the earth's temperature rises.[3]

Rising Temperatures, Falling Yields

Within just the last few years, crop ecologists in several countries have been focusing on the precise relationship between temperature and crop yields. In an age of rising temperatures, their findings are disturbing. One of the most comprehensive of these studies was the one just cited, which focused on rice yields. This study was conducted at the International Rice Research Institute (IRRI) in the Philippines, the world's premier rice research organization. The IRRI team of eminent crop scientists noted that from 1979 to 2003, the annual mean temperature at the research site rose by roughly 0.75 degrees Celsius.[4]

Using crop yield data from the experimental field plots for irrigated rice under optimal management practices for the years 1992–2003, the team's finding confirmed the rule of thumb emerging among crop ecologists—that a 1-degree-Celsius rise in temperature lowers wheat, rice, and corn yields by 10 percent. The IRRI finding was consistent with those of other recent research projects. They concluded that "temperature increases due to global warming will make it increasingly difficult to feed Earth's growing population."[5]

While this study analyzing rice yields was under way, an empirical historical analysis of the effect of temperature on corn and soybean yields was being conducted in the United States. It concluded that higher temperatures had an even greater effect on yields of these crops. Using data for 1982–98 from 618 counties for corn and 444 counties for soybeans, David Lobell and Gregory Asner concluded that for each 1-degree Celsius rise in temperature, yields declined by 17 percent. Given the projected temperature increases in the U.S. Corn Belt, where a large share of the world's corn and soybeans are produced, these findings should be of grave concern to those responsible for world food security.[6]

The most vulnerable part of the crop cycle is the pollination period that immediately precedes seed formation. One of the IRRI projects, for example, showed that at 34 degrees Celsius (93 degrees Fahrenheit), nearly 100 percent of the tiny flowers on a rice head turn into kernels of rice. But at 40 degrees Celsius (104 degrees Fahrenheit), only a few kernels develop, leading to crop failure.[7]

Wheat and corn are similarly vulnerable. Earlier research showed that higher carbon dioxide (CO_2) levels in the atmosphere led to higher grain yields, assuming that there are no constraints imposed by soil moisture, nutrient availability, or other limiting factors. What the new research shows is that the negative effect of higher temperature on crop yields overrides the positive effect of higher CO_2 levels. Indeed, if pollination fails and there is no seed formation, then the CO_2 effect on grain yield is lost entirely.[8]

Abnormally high temperatures directly affect yields by stressing crops. Anyone who has been in a cornfield in mid-summer with temperatures above 35 degrees Celsius has seen how tightly the leaves curl in order to reduce moisture loss. But this also reduces photosynthesis, often to the point where the corn plant is merely maintaining itself. Under conditions of intense heat, plant growth ceases entirely.[9]

As temperatures rise, crop-withering heat waves are becoming more and more common. On August 12, 2003, when the U.S. Department of Agriculture released its monthly estimate of the world grain harvest, it reported

a 32-million-ton drop from the July estimate. This drop, equal to half the U.S. wheat harvest, was concentrated in Europe, where record-high temperatures had withered crops in virtually every country in the region.[10]

The heat wave in Europe began in early summer 2003, when Switzerland experienced the hottest June since recordkeeping began 140 years ago. In July, the heat engulfed nearly the whole continent. In late summer, soaring temperatures were rewriting the European record book. On August 10th, the temperature in London reached 38 degrees Celsius (100 degrees Fahrenheit). France had 11 consecutive days in August with temperatures above 35 degrees Celsius. In Italy, temperatures reached 41 degrees Celsius.[11]

Crops suffered the most in Eastern Europe, which harvested its smallest wheat crop in 30 years. The wheat crop in the Ukraine, already severely damaged by winterkill, was reduced further by the heat, plummeting from 21 million tons the year before to a mere 5 million tons. As a result, the Ukraine—a leading wheat exporter in 2002—was forced to import wheat in late 2003 and early 2004 as bread prices threatened to spiral out of control. Romania, which was particularly hard hit by heat and drought, harvested the smallest wheat crop on record. And the Czech Republic had its poorest grain harvest in 25 years.[12]

During this life-threatening heat wave, Europeans may have felt that the temperature could not rise much more. But the increases projected for the decades ahead mean that such events will become more frequent and more intense. Just as Europeans could not have imagined the severity of the heat wave in the summer of 2003 that claimed 35,000 lives and shrank grain harvests in virtually every country, so too we have difficulty visualizing the extreme heat waves yet to come.[13]

Temperature Trends and Effects

Since 1970, the earth's average temperature has risen by 0.7 degrees Celsius, or nearly 1.3 degrees Fahrenheit. Each decade the rise in temperature has been greater than in the preceding one. (See Figure 7–1.) Four of the six warmest years since recordkeeping began in 1880 have come in the last six years. Two of these, 2002 and 2003, were years in which, as just described, the major food-producing regions saw their crops wither in the presence of record or near-record temperatures.[14]

As atmospheric concentrations of CO_2 rise, so does the earth's temperature. Since atmospheric CO_2 permits sunlight to freely penetrate the earth's atmosphere but restricts the radiation of heat back into space, it creates a "greenhouse effect."

Atmospheric concentrations of CO_2, estimated at 280 parts per million when the Industrial Revolution began, have been rising ever since people in Europe began burning coal. (See Figure 7–2.) They have risen every year

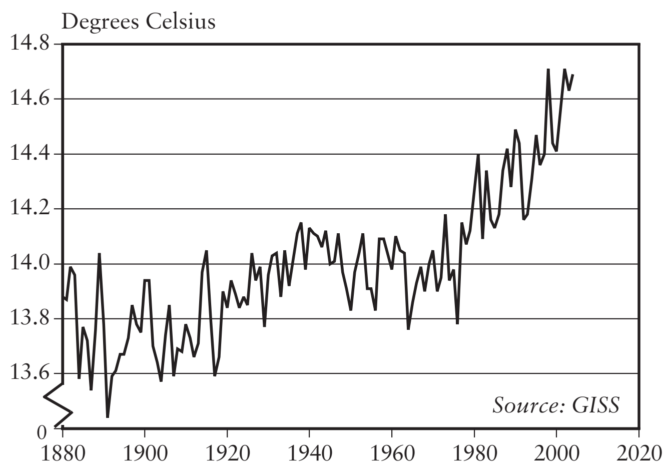

Figure 7–1. *Average Global Temperature, 1880–2003*

since precise measurements began in 1959, making this one of the world's most predictable environmental trends. As shown in Figure 7–2, atmospheric CO_2 concentrations turned sharply upward around 1960. Roughly a decade later, around 1970, the temperature too began to climb; the rise since then is quite visible in Figure 7–1. Projections by the Intergovernmental Panel on Climate Change (IPCC) show temperatures rising during this century by 1.4–5.8 degrees Celsius. The accelerating rise in temperature in recent years appears to have the world headed toward the upper end of that projected range of increase.[15]

Perhaps even more important than the average temperature rise is where the increase is likely to be concentrated. The warming will be greater over land than over the oceans, in the higher latitudes than in the equatorial regions, and in the interior of continents than in the coastal regions. One of the higher increases is expected to be in the interior of North America—an area that

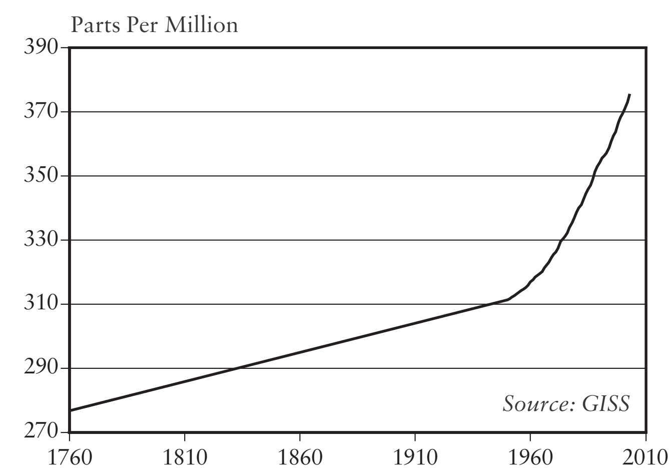

Figure 7–2. *Global Atmospheric Concentrations of Carbon Dioxide, 1760–2003*

includes the grain-growing Great Plains of the United States and Canada and the U.S. Corn Belt, the very region that makes this continent the world's breadbasket.[16]

The earth's rising temperature affects food security in many ways. Much of the world's fresh water is stored in ice and snow in mountainous regions. These "reservoirs in the sky" supply water for irrigation. But the reservoirs are now shrinking. A modest rise in temperature of 1 degree Celsius in mountainous regions can substantially alter the precipitation mix between rain and snow, increasing rainfall and decreasing snowfall. This leads to more runoff during the rainy season and less snowmelt to feed rivers during the dry season, when farmers need irrigation water.[17]

The melting glaciers and shrinking snowfields of the Himalayas are a concern to countries throughout Asia because this is where virtually all the major rivers in the region originate—the Indus, Ganges, Mekong, Yangtze, and Yellow. In Asia, where half the world's people live and where irrigated agriculture looms large, any reduction in river flow during the summer directly affects food security. The prospect of diminished river flows during the dry season at a time when water tables are already falling in most Asian countries raises basic questions about food security in the region.[18]

In addition to the direct effects of temperature on yield, higher temperatures mean more evaporation and thus more rainfall. Elevated temperatures can lead both to more extreme drought and to more severe flooding. Drought can be caused by below-normal rainfall or above-normal temperatures. Most often the two combine to create crop-withering droughts. Increased temperatures also mean more powerful, more destructive storms.[19]

Higher temperatures can worsen or create new crop disease and insect problems. The combination of heat and humidity, which makes an ideal environment for many plant diseases, makes it almost impossible to produce wheat profitably in the tropics. Higher temperatures would simply expand the region that is inhospitable to wheat from the equator toward the higher latitudes.[20]

One of the most serious long-term effects of climate change is rising sea level, which is driven both by the thermal expansion of the oceans as temperatures rise and by the melting of glaciers. The last IPCC report projected that sea level could rise by up to one meter during the current century, but papers published since then indicate that the melting is proceeding much faster than IPCC scientists had estimated. One study of glaciers in Alaska and Western Canada, for example, suggests that ice melting there is now raising sea level by 0.32 millimeters per year, more than double the 0.14 millimeters per year assumed by IPCC.[21]

One of the major concerns among scientists today is the accelerated melting of the Greenland ice sheet. If the ice sheet on Greenland—an island three times the size of Texas—were to melt entirely, sea level would rise 7 meters (23 feet), inundating not only Asia's rice-growing river deltas and floodplains but most of the world's coastal cities as well. This kind of massive melting, even in the case of the most rapid warming scenario, would occur over centuries, however, not years.[22]

The World Bank has published a map of Bangladesh, which shows that a 1-meter rise in sea level would inundate half of the country's riceland. It would also displace some 40 million Bangladeshis. Where would these people go? Which countries would be willing to accept even a million refugees fleeing the effects of rising sea level?[23]

A warmer earth means that agricultural zones in the northern hemisphere would move northward within Canada and Russia, for example, as the growing season lengthens. This assumes, of course, that there are high-quality soils that could sustain a productive agriculture in these regions. In Canada, however, the glaciated soils north of the Great Lakes cannot begin to match the productivity of the deep, fertile U.S. Corn Belt soils south of the Great Lakes.[24]

One advantage of a longer growing season would be that the winter wheat belt could move northward, replacing the lower-yielding spring wheat now grown in the northernmost agricultural regions. This would affect primarily Canada and Russia, the leading producers of spring wheat.[25]

On balance, however, agriculture would be a heavy loser if temperature continues to rise. The notion that the world's farmers would be better off with more atmospheric CO_2 and higher temperatures is a view based more on wishful thinking than on science. It may soon become apparent that the costs of climate change are unacceptably high.

Raising Energy Efficiency

If rising temperatures continue to shrink harvests and begin driving up food prices, public pressure to stabilize climate by cutting the carbon emissions that cause the greenhouse effect could become intense. The goal is to cut these emissions enough to stabilize climate and eliminate the threat to world food security from rising temperatures. Cutting emissions enough to stabilize atmospheric CO_2 levels is an ambitious undertaking, but given the technologies now available to both raise energy efficiency and develop renewable sources of energy, it can be done—and quickly, if need be.

This is not the place to lay out a detailed global plan to cut carbon emissions, but a few examples of how to cut the use of oil and coal, the principal sources of carbon emissions, will illustrate the possibilities. One simple step that motorists can take to reduce oil use dramatically is to shift to cars with hybrid gas-electric engines. Automobiles such as the Toyota Prius and the hybrid Honda Civic that are already on the market are remarkably fuel-efficient. The 2004 Prius averages 55 miles per gallon in combined city and highway driving—double or even triple that of other midsize cars. If the United States were to raise the fuel efficiency of its automobile fleet over the next 10 years to that of today's Toyota Prius, U.S. gasoline consumption could be cut in half. This would not require any reduction in the number of cars used or in miles driven, only the use of more-efficient engines.[26]

But this is not the end. The hybrid gas-electric cars, which embody the most sophisticated automotive engineering on the road today, open up two exciting additional possibilities. The first is to modestly expand the electrical storage capacity of the hybrids by adding a second battery. The second is to include a plug-in recharge capacity so that owners can recharge their car batteries at night, when electricity demand drops, leaving surplus generating capacity. Given the typical U.S. daily commute of 12 miles roundtrip, these two steps would allow commuting and local driving, such as shopping, to be done almost entirely with electricity, saving gasoline for the occasional longer trip. Adding a second battery and a plug-in capacity could reduce gasoline use by perhaps another 20 percent, for a total reduction in U.S. gas use of 70 percent.[27]

These two modest technological modifications lead to an exciting possibility on the supply side, namely the use of cheap wind-generated electricity to power automobiles. Does the United States have the wind power potential to do this? As described later in this chapter, it has enough harnessable wind power to meet its electricity needs several times over.[28]

There are similarly exciting possibilities for cutting coal use. If, for example, the world were besieged by high temperatures and rising food prices, it would be a simple matter to replace the widely used old-fashioned, highly inefficient, incandescent light bulbs with compact fluorescent lamps that provide the same light but use less than a third as much electricity. A worldwide decision to phase out incandescent light bulbs would allow literally hundreds of coal-fired power plants to be closed. Not only would this help stabilize climate, but the return on investment in the new bulbs in the form of lower electricity bills is roughly 30 percent a year.[29]

These are but two of the obvious things that can be done on the demand side to cut carbon emissions. Reducing U.S. gasoline use for automobiles by 70 percent and dramatically cutting electricity use for lighting are exciting prospects for reducing dependence on imported oil, lowering the trade deficit, and stabilizing climate. We simply need a bit of imagination, some leadership, and a modest additional investment.

Turning to Renewable Energy Sources

There are also many options for cutting carbon emissions by harnessing renewable sources of energy, including wind energy, solar energy, geothermal energy, and biomass. Each of these can be developed in many ways. On the solar front, there are solar electric cells, solar thermal power plants, and the direct use of solar energy for water and space heating. The most immediately promising short-term source of new energy is wind. It is a vast resource, one that could meet all the world's electricity needs. As this chapter aims simply to give a sense of the possibilities for cutting carbon emissions, the discussion here will focus only on wind as a renewable source of energy.

The use of wind power is growing fast because it is abundant, cheap, inexhaustible, widely distributed, clean, and climate-benign—a set of attributes that no other energy source can match. Consider the U.S. potential. In 1991, the U.S. Department of Energy published a national wind-resource inventory. It concluded that North Dakota, Kansas, and Texas alone had enough harnessable wind energy to satisfy national electricity needs. For many people this was a surprise. They had no idea wind was such a vast resource.[30]

In retrospect, this was a gross underestimate because it was based on the wind energy that could be harnessed by the wind turbine technologies of 1991. Design advances since then enable turbines to operate at lower speeds, to convert wind into electricity more efficiently, and to harvest a much larger wind regime. Whereas the average wind turbine in 1991 might have been 40 meters tall, today turbines are closer to 100 meters, reaching heights where winds are stronger and steadier than they are at the earth's surface. While in 1991 the government concluded that wind power in just three states could satisfy national *electricity* needs, it may now be that these three states have enough harnessable wind energy to meet national *energy* needs. Although it is helpful to use these three wind-rich states to illustrate the scale of U.S. wind resources, many of the other 47 states are also richly endowed with wind energy.[31]

Europe is the model for developing wind power. Although its wind resources are modest compared with those of the United States, it is moving much faster to harness them. In its late 2003 projections, the European Wind Energy Association (EWEA) shows Europe's wind-generating capacity expanding from 28,400 megawatts in 2003 to 75,000 megawatts in 2010 and then 180,000 megawatts in 2020. By 2020, just 16 years from now, projections show that wind-generated electricity will be able to satisfy the residential needs of 195 million Europeans, half of the region's population.[32]

Europe is tapping its offshore wind resources as well as those on land. A 2004 assessment of Europe's offshore potential by the Garrad Hassan wind energy consulting group concluded that if governments move aggressively to develop their vast offshore resources, wind could be supplying all of the region's residential electricity by 2020.[33]

Wind-generating capacity worldwide, growing at over 30 percent a year, has jumped from less than 5,000 megawatts in 1995 to 39,000 megawatts in 2003—nearly an eightfold increase. (See Figure 7–3.) In comparison, natural gas use leads the fossil fuels, with an annual growth rate topping 2 percent during the same period, followed by oil at less than 2 percent and coal at less than 1 percent. Nuclear generating capacity expanded by 2 percent.[34]

The modern wind-generating industry was born in California during the early 1980s, but the United States, which now has 6,400 megawatts of generating capacity, has fallen behind Europe in adopting this promising new technology. Germany overtook the United States in 1997; within Europe, it leads the way with 14,600 megawatts of generating capacity. Spain, a rising wind power in southern Europe, may overtake the United States in 2004. Tiny Denmark, which led Europe into the wind era with the development of its own wind resources, now gets an impressive 20 percent of its electricity from wind. It is also the world's leading manufacturer and exporter of wind turbines.[35]

When the wind industry first began to develop in California, wind-generated electricity cost 38¢ per kilowatt-hour. Since then it has dropped to 4¢ or below in prime

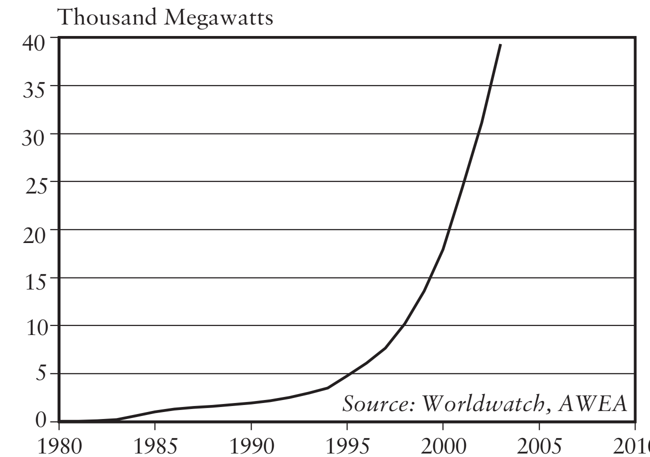

Figure 7–3. *World Wind Electric Generating Capacity, 1980–2003*

wind sites. And some long-term supply contracts have been signed for 3¢ per kilowatt-hour. EWEA projects that by 2020 many wind farms will be generating electricity at 2¢ per kilowatt-hour, making it cheaper than other sources of electricity.[36]

The United States is lagging in developing wind energy not because it cannot compete technologically with Europe in manufacturing wind turbines but because of a lack of leadership in Washington. The wind production tax credit of 1.5¢ per kilowatt-hour, which was adopted in 1992 to establish parity with subsidies to fossil fuel, has lapsed three times in the last five years—most recently at the end of 2003, when Congress failed to pass a new energy bill. The uncertainty about when it would be renewed disrupted planning throughout the wind power industry.[37]

The United States—with its advanced technology and wealth of wind resources—should be a leader in this field. Unfortunately the country continues to rely heavily on coal, a nineteenth-century energy source, for much of its electricity at a time when European countries are replacing coal with wind. Europe is not only leading the world into the wind age, it is also leading the world into the post-fossil-fuel age—the age of renewable energy and climate stabilization. By demonstrating the potential for harnessing the energy in wind, Europe is unveiling the new energy economy for the rest of the world.

The impetus for that new energy economy to unfold quickly may come from an unexpected source: agriculture. The effect of rising temperatures on crop yields fundamentally broadens the responsibility for food security. Historically, food security was the sole responsibility of the Ministry of Agriculture, but now the Ministry of Energy also bears responsibility. Decisions made by ministries of energy on whether to stay with carbon-based, climate-disrupting fossil fuels or to launch a crash program to develop renewables may have a greater effect on food security than do any of the decisions made in ministries of agriculture.

Data for figures and additional information can be found at www.earth-policy.org/Books/Out/index.htm.