**www.scorecard.org**
Environmental Defense Fund environmental "score card." Data-rich about environmental problems, even to the levels of counties in the United States, but sometimes dated.

## ENDNOTES

1. In the United States, for example, there are the Clean Air Act (1963), the Solid Waste Disposal Act (1965), the Water Quality Act (1965), and the National Environmental Protection Act (1960), which established the Federal Environmental Protection Agency.
2. According to the EPA, the worst cities in terms of air pollution in 1994, were:
   ***Extreme Pollution:*** Los Angeles Basin
   ***Severe Pollution:*** San Diego, Southeast desert region, Ventura County, California; Chicago, Baltimore New York–Long Island, Philadelphia, Houston, Milwaukee
   ***Serious Pollution:*** Sacramento, San Joaquin Valley, California; Greater Connecticut; Washington, DC; Atlanta; Baton Rouge, Louisiana; Boston, Springfield, Massachusetts; Portsmouth–Rochester, New Hampshire; Providence, Rhode Island; Beaumont–Port Arthur, Texas; El Paso, Texas

# CHAPTER THREE

# Global Climate Change

In the early months of 2006 the weather was bizarre. In January there were floods in Northern California, drought across a wide swath of the Southeast and Midwestern states, visibly melting snow in the Rocky Mountains and glacial ice. In Nebraska I remember the winter of 2005–2006 as the one that largely never appeared. I rarely used our snow blower, and I did not put my bicycle away all winter. At the North Pole, polar ice was melting in January. On the morning of April 18, radio news reported 100 degree weather in Houston, Texas, that was accompanied by "rolling" electrical blackouts, which usually didn't occur there until June or July (*Morning Edition*, 2006. National Public Radio, April 18, 2006).

Unlike the weather, the world's climate rarely sends clear signals. Climate is determined by the large-scale and long-term interaction of hundreds of variables—sunlight, ocean currents, precipitation, fires, volcanic eruptions, topography, human industrial emissions, and the respiration of living things—that produce a complex system that scientists are just beginning to understand—and which defy precise forecasts. Indeed, feedback relationships between the biosphere and global climate suggest that life and climate *coevolved*, a process in which the close interaction influenced the evolutionary paths of both systems in ways that would not have happened had they not been in each other's presence (Schneider and Londer, 1984; Alexander et al., 1997). But the weather in any given year is so variable that some regions are warmer than normal, some cooler, some wetter, some drier, and many riddled with "severe weather events" like floods, droughts, and hurricanes. Almost all of these can be understood as within the enormous range of climatic variability. Unlike weather, climate is impossible to directly experience, and is detected and measured only in global (or continental) averages.

Global temperature record keeping began in 1867, and since 1900, the world's mean temperature has risen, but since 1976 it has risen three times as much as for the century as a whole. Furthermore, the 10 warmest years on record have all occurred since 1990 (Goddard Center, National Aeronautics and Space Administration, cited in Sawin, 2005a). In fact, Antarctic ice core analysis suggests that the late twentieth century was warmer than at any time since at least 1400 C.E. Geophysical and biological signs of warming are visible in many ways. Mountain snow cover and ice caps are melting around the world, in the Rockies, the Andes, the European Alps, and on Mount Kilimanjaro in Africa. Most significantly, Greenland's northern ice cap, which contains so much of the world's water (as ice) that it could raise ocean levels around the world, is melting noticeably. In tropical areas warmer water has "bleached" the earth's coral reefs, which are all under stress. Horticulturalists and gardeners have noticed that growing seasons are becoming longer in Europe and North America. The sea ice around Antarctica has virtually disappeared since the 1950s.

The ecological and human consequences of global warming are profound. Higher temperatures and precipitation have driven species northward or to higher elevations, and have affected the timing of breeding and migratory seasons. Carbon cycling and storage processes have been altered. The shrinking of glaciers threatens water supplies for people and other species. Rising global temperatures are a factor in increasing drought worldwide. The World Health Organization estimated that at least 160,000 people die annually from things related to global warming (Sawin, 2005a).

**BOX 3.1 THE SUMMER OF 1988**

To get some idea of what a generally warmer climate might mean, consider the consequences of a warm summer—the summer of 1988—that represented a dramatic spike in generally increasing global mean temperatures. The North American corn crop was stunted by drought in the grain belt, and corn production fell below consumption (probably for the first time in U.S. history). No grain was added to the nation's reserves. Electricity use skyrocketed as people ran air conditioners around the clock, and public agencies distributed electric fans to the elderly, for whom heat exhaustion was a significant health threat. Water levels in thoroughfares like the Mississippi River dropped so low that barges and their cargoes were stranded for weeks. Forest fires burned uncontrollably in America's great natural parks, a super hurricane threatened the Gulf Coast, and around the world in Asia, floods in Bangladesh killed 2,000 and drove millions from their homes.



Of course, you *cannot infer* from particular events, or even decades, that a general global climate change is in process. But a warmer climate would increase the probabilities of increasingly severe weather events and for widely disruptive changes in ecosystems and human societies (Silver and DeFries, 1990: 63–64). Evidence consistent with a warming pattern continues to mount.

Climate change is very different than the environmental problems discussed in Chapter Two. Problems with soil, water supplies, deforestation, biodiversity, mineral resources, solid wastes, and water and air pollution do have global ramifications, but they are mainly visible as *ecosystem problems*. There are differences as well as similarities in the type and severity of these problems among ecosystems, but these are still problems that are visible *within* particular ecosystems. By contrast, atmospheric and climate change are *biospheric problems*. As energy and matter circulate in atmosphere around the globe, their consequences affect all individuals, societies, and ecosystems, though certainly not in the same way or with the same intensity. In Chapter One I noted that the environment has complex sets of limiting factors that determine the success and distribution of living things on earth. The physical and chemical nature of the envelope of gases surrounding the earth—the atmosphere—is among the most important, but also the most taken for granted, of these.

Problems like climate change also have a unique *phenomenology*[1] in that they are not really directly experienced by human senses, or studied very directly. Such *megaproblems* are unique in their vast scope, abstract nature, and the long-time horizon over which they develop. Furthermore, they present high-order risks in terms of their consequences. No one is exempt from their effects, and they exemplify a negative side to the rapidly burgeoning human interdependence in the modern world. Conventional scientific inference related to such megaproblems is always contentious, since it cannot be based on experimental research. A pattern of climate change, for instance, cannot be conclusively demonstrated from any particular measured weather data at a particular time and place. Moreover, such megaproblems are typically remote from the concrete experience of individuals and seemingly unaffected by anything that individuals do. The very existence of such problems and their remedies are so abstract and complex that people are dependent on cadres of experts and their scientific (social) constructions of the problem. That means that such problems and their remedies have a peculiar counterfactual nature: If the remedies work, we will never know whether the original diagnostic claims were right. With or without remedies, the experts who make diagnostic claims are likely to find themselves branded as doomsday merchants (Giddens, 1995: 219). Unless you have been living under a rock, you know that global warming (its reality and appropriate human responses) has certainly been debated frequently and often acrimoniously in contemporary mass media, by citizens, scientists, corporate leaders, and our politicians (I will have more to say about this throughout this chapter).

This chapter is about climate change as a geophysical problem of the planet, but also about its risks for humans and other species, about alternate strategies to respond to it, and about the difficulty of scientifically studying such problems. The chapter will discuss (1) recent *ozone depletion* in the upper atmosphere and its relationship to increasing levels of solar ultraviolet radiation, (2) the reality and predictions about *global warming*, (3)and ethical questions, strategy choices, and policy options about global warming.

## OZONE DEPLETION AND ULTRAVIOLET RADIATION

The destruction of significant portions of the stratospheric ozone layer graphically illustrates the unintended long-term consequences of a remarkable human technological achievement. It also illustrates how the nations of the world recognized the overshoot of a particular environmental limit, decided to back off, and gave up a profitable and useful industrial product before there was significant human or ecological damage. In that process, the scientific community and the United Nations effectively communicated to governments evidence of an undeniable international problem and negotiated with them to conclude treaties about the problem. In fact, the resolution of the ozone depletion crisis shows nations, international organizations, and scientific communities at their collective best. We may have resolved the problem in time to prevent drastic damage (O'Meara, 1999).

High up in the stratosphere, twice as high as Mount Everest or as jet planes fly, is a gossamer veil of ozone with a crucial function. Ozone is made of three oxygen atoms stuck together ($O_3$) compared with ordinary atmospheric oxygen, which has two ($O_2$). Ozone is so unstable and reactive that it attacks and oxidizes almost anything it contacts. Low in the atmosphere, where it has a lot of things it can react with (including plant tissues and human lungs), ozone is a destructive but short-lived pollutant. High in the atmosphere, where ozone is created by the action of sunlight on ordinary oxygen molecules, there isn't much to react with, so the ozone layer lasts a long time. But there is enough ozone to absorb much of the most harmful ultraviolet wavelength from incoming sunlight (UV-B), which tears apart organic molecules that make up all living things. In humans it can produce corneal damage, reproductive mutations, and skin cancer while suppressing the immune system's ability to fight cancer. It damages single-celled organisms and could damage floating micro-organisms (plankton) that are at the base of ocean food chains. Exposure to UV-B light stunts the growth and photosynthesis of green plants; in two-thirds of the crop plants that have been studied, crop yields go down as UV-B goes up. The ozone layer is in fact a stratospheric sunscreen that protects humans and ecosystems from damage in ways that are difficult to predict (Meadows et al., 1992: 141–147).



### Destroying the Ozone Layer

In 1974, two scientific papers published independently stated that chlorine atoms in the stratosphere could be powerful ozone destroyers and that chlorine atoms could be increasing as chlorofluorocarbon molecules (CFCs) reach the stratosphere and break up to release them. Their hypothesis was controversial but treated seriously enough by nine countries, which banned the use of CFCs in spray cans in the late 1970s. The first unmistakable sign of the destruction of stratospheric ozone arrived in 1985, when a team of British scientists published findings that stunned the world community of atmospheric scientists. They presented evidence that between 1977 and 1984 the concentration of ozone above Antarctica had plunged more than 40 percent below the 1960 baseline measurements of the southern hemispheric spring season. Ground-level ozone measurements had not hinted at the decline, but the stratospheric depletion was confirmed by analyzing data from NASA satellites and a 1986–1987 Antarctic scientific expedition of the U.S. National Oceanic and Atmospheric Administration (NOAA).

CFCs, widely used as solvents, refrigerant chemicals, and in the production of plastic "foam," were manufactured mainly in Europe and North America, but they were mixed throughout the lower atmosphere so that there are as many CFCs over Antarctica as over Colorado or Washington, DC. Researchers surmised that upon reaching the stratosphere, CFCs encounter high-energy ultraviolet light, which breaks them down, releasing their chlorine atoms. These then engage with ozone in a catalytic reaction in which each chlorine fragment converts ozone to ordinary oxygen. But through a series of reactions, each chlorine atom can cycle through this process many times, destroying one ozone molecule each time and becoming like the "Pac-Man of the higher atmosphere, gobbling one ozone molecule after another and then being regenerated to gobble again" (Meadows et al., 1992: 148). Each chorine atom can destroy up to 100,000 ozone molecules before it is finally removed from the atmosphere. Chemicals thought most dangerous (CFC-11, CFC-12, and CFC-113) were increasing in the atmosphere by between 5 and 11% annually.

By the late 1980s, there was virtual agreement among the scientific community that CFCs were responsible for Antarctic ozone depletion. The most severe ozone depletion was limited to the Antarctic because the reaction requires the cold temperatures, stratospheric ice crystals, and sunlight characteristic of the early Antarctic spring and also because the circulation of winds (the *polar vortex*) tends to trap the depleted ozone over the Antarctic for several months. Less severe but record ozone losses have also occurred over the populous and agriculturally abundant mid- to high latitudes of both hemispheres. Scientists speculate that increases in sulfurous particles, water vapor, and various pollutants in the stratosphere may provide material surfaces for the ozone-depleting reactions to take place much as ice crystals do in the Arctic and Antarctic (O'Meara, 1999; Silver and DeFries, 1990: 103–112; Stern et al., 1992: 57–59).

## A Cautionary Tale: Technology, Progress, and Environmental Damage

Here's a brief detour from the physical facts of the problem into its social and historical contexts. In the first chapter, I argued that underlying modern environmental problems were the economic, social, cultural, and technological issues. Following is a dramatic example related to ozone depletion. It is also a classic illustration about how undeniable progress can result in unanticipated long-run problems. To really understand the causes of ozone depletion, you need to reach back through a century's history, long before CFCs were invented (the following discussion relies heavily on Stern et al., 1992: 54–59).

Until almost the end of the nineteenth century, refrigerating food and drink depended on ice from natural sources that was chopped from local ponds and stored in warehouses or pits for use in the summer. Households used this ice, but breweries and restaurants were the heaviest users, and stored winter ice was sometimes shipped hundreds of miles to provide refrigeration (Boston ice merchants shipped ice as far as South Carolina and the Caribbean). Because this system of using stored winter ice was difficult and expensive, most food was preserved by chemical additives (most commonly salt, sodium chloride). Pork became the most popular meat because its decay could be easily arrested by salt. Preserved beef was much less popular, and those who ate beef preferred to buy it freshly slaughtered from local butchers. To increase their profits, in the 1870s meatpackers began experimenting with ice-refrigerated railway cars to ship dressed beef, slaughtered and chilled in Chicago, to consumers hundreds of miles away. Soon this new ice storage and delivery technology was used to ship fruits and vegetables from California and Florida and dairy products from urban hinterlands to remote customers. This technology drastically lowered the rate at which food spoiled and made perishable crops available to consumers through much of the year. Eventually refrigeration changed the whole nature of the American diet. But natural ice was unreliable, and in two warm winters (1889 and 1890) the failure of the natural ice crop encouraged the packers to seek more reliable forms of refrigeration.

The principle of mechanical refrigeration—by which compressed gas was allowed to expand rapidly and lower temperature—had been known since the mid-eighteenth century. But mainly urban brewers used the first commercial adaptation of this process in the late nineteenth century. These early refrigerant systems used ammonia, sulfur dioxide, or methyl chloride as refrigerant gases, but they had serious problems. For efficiency, they required high pressures and powerful compressors, which increased the risk of equipment failures and explosions. They were toxic gases that caused a number of deaths. Toxicity and the need for expensive compressors kept mechanical refrigeration from making headway with retail customers, who represented a huge potential market. This led Thomas Midgely, working for General Motors Frigidaire division, in 1931 to develop a new chlorinated fluorocarbon (CFC), patented as Freon 12, as a perfect alternative to existing refrigerant gases. Freon was chemically stable, nonflammable, nonexplosive, nontoxic, and required less pressure to produce the cooling effect.



Because smaller compressors were required, American consumers could soon own their own "refrigerators," making it possible to sell chilled foods in retail-sized packages. Frozen foods were marketed in the 1950s, as were the fresh vegetables and dairy products that became rapidly accepted as ordinary parts of the American diet. Europeans followed Americans in adopting these technologies.

Equally important, the properties of Freon made it possible for the refrigeration technology to be applied to space cooling in buildings, thus creating another important market for it. Air-conditioning became common to offices and finally to residences. This development had an enormous impact on the American social pattern. Air-conditioning promoted urban growth in the American sunbelt—from Florida to California—and in tropical regions around the globe. For many Americans, it would be difficult to envision life in the summer months or warm climates without air-conditioning in their homes, autos, stores, and offices. It shifted the peak use of electricity from the winter (when its use for lighting and space heating peaked) to the summer, when air-conditioning systems use electricity at unprecedented rates. From the 1950s, the sales of CFCs were increased by other uses: as nontoxic propellants in aerosol sprays and as solvents for the manufacture of integrated electrical circuits. Taken together, these technologies had an enormous impact on improving the nutrition, comfort, and physical quality of life for many people. But the very *stability* of CFCs that made them so useful ultimately proved to be their greatest environmental hazard. As they leaked from refrigerators, air conditioners, and spray cans at an ever-increasing rate, they eventually found their way to the stratosphere, where they encountered ozone. The problem with ozone depletion was a direct but long-term consequence of a social pattern—the technical innovations; the search for profitable markets; the residential, consumption, and lifestyle patterns and expectations of people—that evolved in the MDCs.

## A Happy Ending?

Even with the scientific consensus about the relationship between CFCs and ozone deterioration, little would have happened without the United Nations Environmental Program, which hosted and prodded the international political process. Its staff assembled and interpreted evidence, created a neutral forum for high-level discussions, and patiently reminded all nations that no short-term selfish consideration was as important as the integrity of the ozone layer. In consequence, the DuPont company, which produced 25% of the world's CFCs, declared its intent to phase out CFC production and search for more environmentally benign refrigerant chemicals. In 1987, 49 signatory nations to the *Montreal Protocol* announced their intention to cut CFC production and consumption by 50% by the year 2000. An even more stringent protocol was subsequently signed in London. Firms are producing less damaging chemicals to power air conditioners, act as solvents to clean computer cleaning circuit boards, and make into insulating foam. Only time will tell whether the new compounds are more environmentally benign than CFCs. Hamburgers are being wrapped in paper or cardboard again, and many consumers are returning to washable ceramic coffee cups instead of foam ones.

Although CFC production has declined steeply, the ozone layer has yet to recover, because these compounds take years to reach the upper atmosphere and last for decades, or even centuries, once there. In October 2001, researchers at the U.S. National Oceanic and Atmospheric Administration said the seasonal "hole" in the ozone layer above Antarctica appeared to have stabilized. About a year earlier scientists predicted that the hole in the ozone layer should begin to close within a decade, healing completely by 2050 (O'Meara, 2002).

In sum, dealing with the ozone problem represents a model for addressing environmental problems involving scientific consensus and its interpretation for policy, international mediation, responsible political and corporate behavior, and public education. Yet there are still reasons for concern about the broader applicability of this resolution. Most important, the encouraging resolution of the ozone depletion problem may depend upon special circumstances not applicable to many other environmental problems. There were, for instance, only about two dozen CFC producers worldwide, and banning production threatened few existing firms or long-developed technical infrastructures. So the Montreal Protocol is a risky predictor for how quickly and effectively other international negotiations may turn out. Even if there is scientific consensus, such changes will be much more difficult (1) if the need for change requires greater alterations in social behavior and lifestyle expectations, (2) when there are many millions of responsible actors, or (3) when the costs and benefits of change are less evenly distributed around the planet (Stern et al., 1992: 59). By these criteria, the impending problem of global warming will be *much* more difficult to address.



## TURNING UP THE HEAT: GLOBAL WARMING

Gases in the atmosphere play a critical role in trapping enough infrared solar radiation (heat) to keep the mean temperature of the earth fluctuating within relatively narrow limits that make life possible. The most important of such gases, present in trace amounts, are water vapor, carbon dioxide ($CO_2$), tropospheric (low altitude) ozone, methane, CFCs, and nitrogen oxides ($NO_x$). Water vapor and $CO_2$, the most important of these, account for probably 90 percent of the heat-trapping capacity. Water vapor is controlled by the water cycle discussed earlier, and $CO_2$ is regulated by a similar carbon cycle (discussed in Chapter One). But humans have added $CO_2$ to the atmosphere by burning fossil fuels and deforestation. Forests take in $CO_2$, thereby "sequestering" carbon from the atmosphere (Miller, 2005: 464).

Such gasses were collectively called *greenhouse gases* because the way they warm the atmosphere is analogous to the way that gardeners have long grown plants and germinated seeds in air warmed in glass greenhouses. Remember returning to your car on a sunny day with the windows all rolled up? In principle, the *greenhouse effect* explains the very cold climate of Mars, where water vapor, a highly efficient greenhouse gas, is virtually absent, as well as the hot climate of Venus, where the atmosphere is so thick with $CO_2$ and conditions are so hot that life—as we know it—could not exist (Silver and DeFries, 1990: 64).

After water vapor, $CO_2$ is the most plentiful and effective greenhouse gas. It occurs naturally as a consequence of the respiration of living things. (Remember the carbon cycle discussed in Chapter One?) The atmosphere has so much water vapor that human activity has little effect on it. By contrast, the concentration of $CO_2$ is so small (.036%) that human activity can significantly increase its concentration. $CO_2$ is produced in great quantities by the burning of fossil fuels—natural gas, petroleum, and particularly coal. Other greenhouse gases are much rarer, but molecule for molecule they trap more heat than $CO_2$. Methane is produced through bacterial activity in bogs and rice paddies and in the digestive tracts of ruminant animals (cows, sheep). Most atmospheric methane is from biological sources, although some is produced from decaying human garbage dumps. CFCs, discussed earlier, not only destroy stratospheric ozone, but are effective greenhouse gases at lower levels, trapping 17–20,000 times as much heat per molecule as $CO_2$. Nitrous oxide ($N_2O$) is produced naturally through microbes in soil and in the burning of timber, the decay of crop residues, and the combustion of fossil fuels.

Speculations about the implications of anthropogenic increases in greenhouse gases are not really new, and the role of such gases in maintaining the temperature of the earth has been known for more than 150 years. Fourier was the first to discuss the heat-trapping role of $CO_2$ in 1827. At the turn of the twentieth century, Swedish naturalist Arrhenius argued that increasing concentrations of $CO_2$ would raise the global mean temperature. In 1941 Flohn noted that anthropogenic $CO_2$ perturbs the carbon cycle, leading to a continual $CO_2$ accumulation in the atmosphere, and in 1957 Revelle and Suess concluded that "human activities were initiating a global geophysical experiment that would lead to detectable climatic changes in a few decades" (cited in Krause et al., 1992: 11). In 1957 the systematic measurement of $CO_2$ began at the Mauna Loa (Hawaii) observatory and at the South Pole. In 1979, the World Meteorological Organization convened a World Climate Conference in Geneva to discuss the issue. Following this conference were a host of national meetings about climate change issues that led to the first meeting in 1988 of the Intergovernmental Panel on Climate Change (IPCC), sponsored by the United Nations Environmental Program and the World Meteorological Organization.

Summarizing, the greenhouse effect and the possibility of global warming has been known for more than a century, but only since the 1950s has this threat begun to be taken seriously, and only in the 1990s did questions about "preventative" policy measures enter the international political arena (Krause et al., 1992: 15).

## General Circulation Models

All of our knowledge about greenhouse gases and climate change are based on *general circulation models* (GCMs) by which climatologists try to construct mathematical models to represent or "simulate" the complex workings of the earth–atmosphere interactions. As you might guess, these global interactions are very complex and involve many feedback loops that are only imperfectly understood. So like all models, GCMs represent a vastly simplified version of the real world. Despite this, these computerized mathematical models that predict the ways in which temperature, humidity, wind speed and direction, soil moisture, sea ice, and other climate variables evolve through three dimensions and over time are the only tools available for understanding global climate change. There are five existing GCMs, while their findings generally agree, the models are not identical.

With the limitations of simplified mathematical models, how can climatologists use them to simulate the actual dynamics of the earth's climate, with its complex interaction of variable nonlinear feedback loops? In three ways: (1) By starting with existing data, the model can be "run forward" to simulate "today's climate," especially the large temperature swings of the seasonal cycle, (2) by determining whether the model can realistically simulate an individual physical component of the climate system, such as cloudiness, and (3) by running the model backward in time to see whether it can reproduce the long-term changes climate of the ancient earth, about which, surprisingly, a great deal is known. See Box 3.2.



### BOX 3.2 ESTIMATING GLOBAL CLIMATE FROM LONG, LONG AGO

There are physical signs that make it possible to estimate the planet's climate throughout long geological history. The expansion and contraction of glaciers, for which there are many physical markers, is one fairly good measure of past temperature fluctuations. Other evidence comes from studies of fossilized pollen grains, annual growth rings of trees, and the changing sea levels—as measured by the presence of coral reefs, which live close to the ocean surface because they need light before they die. Cores of sediment extracted from the floor of the deep oceans are particularly important, because of their chemical composition and the presence of warm- or cold-water fossil species. Such sediment samples provide clues to changes in ocean temperature and the volume of polar ice caps. The *most* useful comes from analyzing ice cores extracted from ancient glaciers in Greenland and Antarctica for changes in the concentrations of gas bubbles (of $CO_2$ or methane) over millions of years.(Miller, 2005: 462-463; Silver and DeFries, 1992: 25)

The performance of GCMs has been appraised continuously and they are getting better at predicting climate change (Schneider, 1990a: 74; Miller, 2005: 470). What do they conclude? In broad strokes, based on the accumulated evidence GCMs and other research, there is a strong and growing consensus within scientific communities that global warming is a real phenomenon, that contemporary warming is importantly anthropogenic (caused by humans), and that it represents a significant threat to human well-being now and in the future. I will flesh out this consensus in more detail shortly, but first let me discuss some of its ambiguities.

## Some Ambiguities in the Evidence

Here is a short laundry list of some ambiguities about contemporary "greenhouse theory."

1. While the correlation between greenhouse gas concentration and temperature fluctuation works well for geological history, it works less well for shorter time spans.
2. Climate may not change in a "linear" fashion. The assumed gradualness of linear change underlies the assumption that societies will have time to adjust. Some evidence suggests that climate has changed in abrupt and chaotic fashion in the past (Cunningham et al., 2005: 320).
3. Beyond their role as carbon sinks, the role of the oceans in the warming process is not clearly understood, but it is likely to be large. The oceans store most of the

planet's heat and $CO_2$ and have deep circulation patterns that are not well modeled. The enormous oceanic mass will act as a thermal sponge slowing any initial increase in global warming while the oceans themselves heat up, but the magnitude of this increase in temperature will depend on ocean circulation, which may *itself* change as the earth warms (Miller, 2005: 472; Schneider, 1990a: 31).

4. It is difficult for GCMs to factor in effects of vegetation and forests and their impact on ground surface *reflectiveness* (or *albedo*), their function as carbon sinks, or the significance of their release of water vapor and cloud formation.
5. Interactions and feedbacks between temperature change and cloud formation are not clear. Will heating of the atmosphere create more or fewer clouds? If more clouds, would they trap more heat at the earth's surface or reflect more solar radiation into space?

You surely know how contentious and controversial global warming is in the United States, and since it became a widely understood problem in the late 1980s, many people, powerful corporations, and foundations have become powerful social and political forces directed at getting global warming *not* seen as a real problem. One side of the contemporary debate is the massive and growing consensus among scientific communities that global warming is a real and significant problem, and on the other, a tiny minority of scientists with real credentials, some talented writers and media personalities, who are luxuriously supported by large corporations (mainly in mining, lumber, and petroleum industries) to produce and publicize widely the view that global warming is a pseudoproblem, just a "lot of hot air." Noting the real scientific complexity of the climate change, global warming skeptics argued that global warming is not a real problem at all—but one manufactured by networks of radical environmentalists and political liberals for money and political gain. It is a thinly disguised attack on American capitalism and consumerism. To the extent that global warming is real, they argued, it would be beneficial. For instance, in a $CO_2$-enriched atmosphere plants could grow exuberantly and produce more food for the hungry, and people would spend less on clothes and heating. Warming skeptics, who rarely publish in legitimate scientific journals, work with conservative foundations that seek to influence public opinion and lobby congressmen and the Bush administration not to take global warming seriously (Kennedy, 2005; McCright and Dunlap, 2000; 2003; Pope and Rauber, 2004). Since they have effectively dominated U.S. public opinion and politics about the issues, I will return to them toward the end of the chapter, in the discussion about sources of uncertainty in risk in science and in society.

## Evolving Science and Consensus

Systematic observations about climate conditions that began about 1985 produced interesting and curious observations about climate change. Then there was considerable scientific uncertainty about the "global warming" thesis,



understood by climatologists to be important but highly speculative. Reflecting this, the earliest edition of this book emphasized the uncertainty and speculative character of the evidence in those early years. But that changed, as more sophisticated techniques and research provided more convincing evidence. Founded in 1988 the Intergovernmental Panel on Climate Change (IPCC), comprising 2,000 leading climatologists, was charged with assessing the weight of evidence from scientific studies of climate change. The IPCC published reports in 1990, 1995, and 2001 (Miller, 2005: 469). Panels of scientists from the U.S. National Academy of Scientists (NAS) and the American Geophysical Union also examined the weight of evidence from scientific studies of climate change.

### BOX 3.3 GREENHOUSE POLITICS IN THE UNITED STATES

A powerful "countermovement" of industry association, private organization, and parts of the national government have worked to portray global warming as "not problems" (McCright and Dunlap, 2000). More recent research documents that prior to 1994, congressional expert testimonies about global warming were dominated by conventional and respected climate scientists, but after 1994 when more conservative Republicans gained control of congress, prominent "climate change skeptics" among scientists were more likely to be asked to testify. That change in congressional testimonials had an effect. After 1994 media articles about climate change were far more likely to give as much attention to the views of the small number of climate change skeptics as those representing the established consensus of the scientific community (McCright and Dunlap, 2003). Others documented that during the 1990s the fossil fuel industry, along with allies in manufacturing and labor unions, mounted a dual campaign of public relations and congressional lobbying public initiatives to address global warming (Gelbspan, 1997; Newel, 2000). In response to Al Gore's documentary about global warming (*An Inconvenient Truth*), the *Wall Street Journal* ran an editorial entitled "Hockey Stick hokum," citing the same few well known global warming "nay sayers" (*Wall Street Journal*, 2006: A12). Conservative movement ortanizations and think tanks with neatly packaged counterclaims flooded the media with press releases and held forums that provided their credentialed climate change skeptics with substantial resources and vensue for promoting their ideas. In January 2006 the top scientist at the National Aeronautics and Space Administration (Dr. James Hansen) publicly claimed that the administration of George Bush tried to stop him from peaking out since he called for prompt reductions in the emissions of greenhouse gasses (Revkin, 2006).

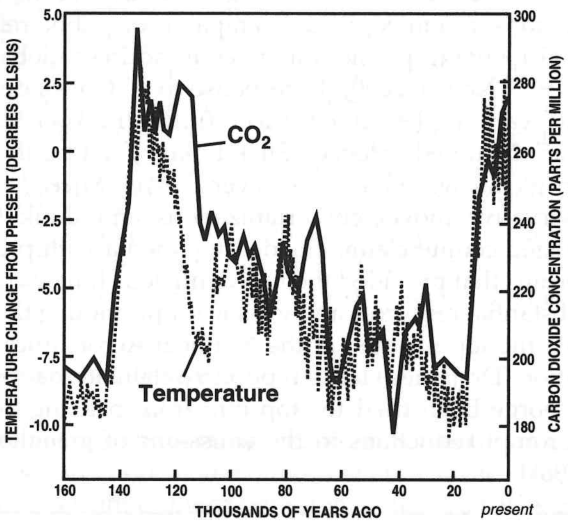
The uncertainty about global warming of earlier years has been progressively replaced by a strong consensus within the world community of climatologists that global warming is real and a significant threat to human well-being. In the present century as well as longer geological history there have been *strong positive correlations* between atmospheric concentrations of greenhouse gases and fluctuation in the earth's mean temperatures. Atmospheric concentrations of $CO_2$ have risen from preindustrial levels of 280 parts per mission by volume (ppm) to 360 ppm today. Since the momentum of emissions is inexorable, and $CO_2$ persists in the atmosphere for centuries, climate change cannot be avoided, but in can be moderated (Raskin et al., 2002). See Figures 3.1 and 3.2.

Here are three major findings of the IPCC 2001 report:

- Despite uncertainties, the latest climate models match the records of global temperature changes since 1850 very closely.
- "There is new and stronger evidence that most of the warming observed over the last fifty years is attributable to human activities."
- It is very likely (90–99% probability) that the earth's means surface temperature will increase by 1.4–5.8 degrees centigrade (2.5–10.4 degrees Fahrenheit) between 2000 and 2100.

(Miller, 2005:469)

**Figure 3.1** Carbon Dioxide and Temperature, Long-Term Record
*Source:* Adapted from S. H. Schneider, "The Changing Climate," in Editors of Scientific American, *Managing the Planet Earth,* 1990a: 29. New York: W. H. Freeman Co. Used with permission.





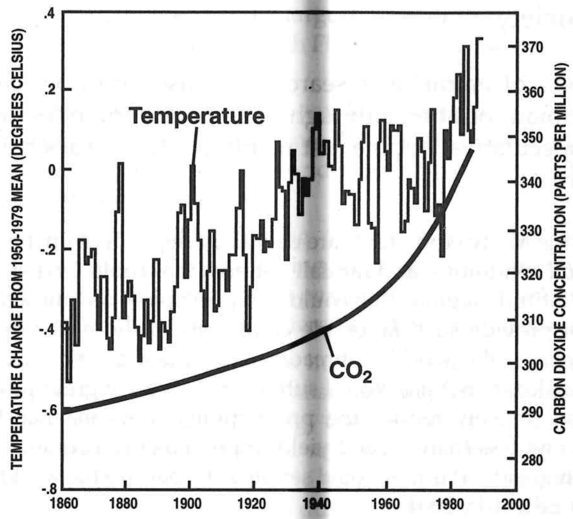




**Figure 3.2** Carbon Dioxide and Temperature, Industrial Era
*Source:* Adapted from S. H. Schneider, "The Changing Climate," in Editors of Scientific American, *Managing the Planet Earth,* 1990a: 29, New York: W. H. Freeman Co. Used with permission.

It is not just that temperature changes threaten us, regardless of the causes, but how rapidly they occur. Past temperature change often took place over 1000 to 100,000 years. The problem we face is a fairly sharp projected increase of the temperature of the troposphere in this century. In 2002 the NAS issued a study raising the possibility that the temperature could rise drastically in only a decade or two, and in 2006 at the request of Congress, which had requested a broad review of scientific work, the NAS report concluded that "recent warmth is unprecedented for the last several millennia" (Associated Press, 2006).

To grasp the enormity of these probable changes, compare them to the climate history of the earth. A global average warming of 1.5 degrees would represent a climate not experienced since the beginning of agricultural civilization some 6,000 years ago; three to five degrees would represent a climate not experienced since human beings appeared on the earth some two million years ago. The last time the earth was this warm was in the Pliocene period (some 3 to 5 million years ago). Furthermore, more than five degrees' warming would mean a climate not experienced since 40 million years ago, before the evolution of birds, flowering plants, and mammals, when there were no glaciers in the Antarctic, Iceland, or Greenland (Krause et al., 1992: 28). The projected rate of warming is 15 to 40 times faster than after the major ice ages. Such warming could far outstrip the ability of ecosystems to adapt or migrate (Silver and DeFries, 1990: 71).

## Impacts on Society

A growing body of empirical research is focused on how climate change might affect human societies, although with the uncertainties just mentioned, much of it is speculative. Let me just mention a few issues being addressed in this research:

1. *Food security:* Many crop yields are delicately dependent on a particular mix of temperatures, soil conditions, and rainfall patterns that could be disrupted by global warming. High latitude regions that could—in principle—become available for agriculture may not provide such favorable conditions. If the midlatitude continental dryness materializes, the world's "breadbasket" (such as the U.S. Midwest, and Ukraine and Kazakstan in Asia) would suffer a 50% drop in grain productivity. Heat stress could also severely reduce the productivity of Asian "rice bowl" regions. Reduced yields and less-than-needed yield improvements, combined with growing population and higher food prices, could seriously jeopardize the world's food security (Devereaux and Edwards, 2004).

2. *Regional impacts:* The amount of warming is expected to be greatest in the northern latitudes, harming some growing areas and expanding others, but computer models suggest that the effect on crops is likely to be more uniformly severe in the southern latitudes. In short, the impact is likely to increase the price of grain on a worldwide basis, but the impact is likely to be especially severe in the LDCs (largely in the southern hemisphere). In general, those economic sectors and nations depending heavily on unmanaged ecosystems—on rainfall, runoff, or temperature—will suffer the greatest impact of climate change. MDCs like Japan or the United States will be relatively insulated from impacts, while LDCs (which have 70% of the world's people) will suffer greater impacts. Rising global temperatures have been a key factor in increasing drought worldwide, threatening water supplies for millions of people and species. The World Health Organization estimates that at least 160,000 people die annually due to climate change (Bhuttacharya, 2003). Greenhouse gases will have the greatest impact on agriculture, forestry, tourism, and coastal activities (Nordhaus, 2002: 499).

3. *Land use and human settlements:* A modest rise in sea level would threaten the coastal settlements in which *half* of humanity lives. They include Boston, New York, Miami, New Orleans, Los Angeles, Seattle, and Vancouver as well as Tokyo, Osaka, Manila, Shanghai, Guangshou, Calcutta, Lagos, London, Copenhagen, and Amsterdam. The entire Maldives Republic and much of Bangladesh, Indonesia, the Netherlands, and Denmark would be under water. Rich farmland in river deltas would be lost, salinity would move upstream, and high tides and storm surges would penetrate further inland. The economic costs of adapting to this change—of population relocation and protecting coastal infrastructures—would be enormous, with cumulative costs of billions for MDCs and probably prohibitive costs for LDCs. In the United States, for instance, economic analyses estimate that a 50 cm rise in sea level by the year 2100 would cost between $20.4 and $138 billion in lost property and damage to economic infrastructures (Alexander et al., 1997: 86). A one meter rise would flood most of New York City, including the entire subway system and all three major airports. A five degree Fahrenheit rise in average temperature would melt the Greenland ice cap, the world's largest mass of frozen water. That would raise the sea level enough that most of South Florida (including Miami) would simply disappear into the Atlantic.



4. *Freshwater supplies:* Global warming would reduce stream flows and increase pressure on groundwater while worsening the pollution discharge into smaller flows. This effect could exacerbate the world's existing water problems, which, as Chapter Two noted, are substantial.

5. *Planning uncertainty:* In the planning of human resettlement, flood control, revamping agriculture for changing growing seasons, society might find itself in a constant treadmill, trying to catch up with perpetual change in an environment that is changing rapidly, unpredictably, and differently in different regions.

6. *Other impacts:* Global warming could involve increased human health risks as a result of heat stress and more vigorous transmission of tropical diseases over larger areas. Warming could lead to increasing energy consumption for air-conditioning, losses in hydropower availability, and losses in revenue from tourism and fisheries. If ecosystems collapse suddenly, low-lying cities are flooded, forests are consumed in vast fires, grasslands die out and turn into dust bowls, and tropical waterborne and insect-transmitted diseases spread rapidly beyond their current ranges, this would represent a truly a catastrophic "worst-case-scenario." It also represents a significant security threat. A 2003 Defense Department analysis projected widespread rioting and regional conflict in some countries faced with dwindling food, water, and energy supplies, and argued that global warming must "be viewed as a serious threat to global stability and should be elevated beyond a scientific debate to a national security concern" (Miller, 2005: 471–472). For more studies of the social consequences of warming, see Alexander et al., 1997; Cairncross, 1991; Kates et al., 1985; Miller, 2005: 473; Parry, 1988; Rosa and Krebill-Prather, 1993; Rosenzweig and Parry, 1993; and Smith and Tirpak, 1988, which specifically focuses on the United States.

## DO WE KNOW ENOUGH TO ACT?

There are different schools of thought about what (if anything) could or should be done. Let me examine some different assumptions.

1. Don't act until you are certain, or *wait and see.* Those holding this view, including some scientists, economists, corporate leaders and politicians, argue that more research is needed before making far-reaching economic decisions (like phasing out the carbon-based fossil fuel system), and they argue that uncertainties are still to large to warrant costly remedial or preventative measures.

2. *Act now to minimize risks.* Those with this view (a growing number of scientists, and business and political leaders) believe that uncertainty cuts both ways: If major climate change, for example, should occur, inaction could have catastrophic consequences, and the problem may prove more difficult and costly later. The world's nations should pursue investments and policies now to address the problem (Krause et al., 1992: 3). This is widely known as a "precautionary principle" meaning that when there is a potential threat (even with some uncertainty) to humans or ecosystems decision makers should take action.

3. Act to slow global warming, with *no regrets*, even if the threat of global warming does not materialize. This rationale is widely used in other realms. I insure my house against fire, even though it has never happened, but would prove catastrophic if it did. Similarly, the United States spent billions of dollars during the cold war preparing for a thermonuclear war that never occurred.

I am more persuaded by the last two assumptions. By the time we "wait and see" or scientific knowledge improves, the full brunt of climatic change may be upon us. There are enormous risks and a huge gamble in the wait-and-see-while-collecting-more-data option (Krause et al., 1992: 5). The prudent course is to take some action early in the hopes of forestalling worst possible outcomes. It seems to me that the imprudent course is to do nothing, awaiting a complete confirmation of the models. As a World Bank paper stated: "When confronted with risks which could be menacing, cumulative and irreversible, uncertainty argues strongly in favor of prudent action against complacency" (MacNeill et al., 1991: 17–18). Note that this was written before the scientific consensus was as strong as it is today.

If we act and the threat is real, we win. If we act and the treat is not so real, we lose something, but only the investments and "insurance premiums." If, on the other hand, the threat is real and we don't do anything about it unit it is too late, we risk losing on a catastrophic scale.

*But wait.* Even if the threat of global warming really doesn't materialize, addressing it would not be all cost. Such efforts would have side benefits for human well-being and ecological threats, which make them worth doing on other grounds. They could, for example, improve problems of urban air pollution and acid rain, enhance energy efficiency, and wean us away from the last decades of the carbon-based energy system. They could promote international global cooperation in programs about reforestation, sustainable agriculture, soil conservation, land reform, and probably the alleviation of the most wretched global poverty. In other words, addressing global warming could be a way to unify a basket of separate measures addressing human–environment problems and preserving the "global commons."

## POLICY OPTIONS: WHAT COULD BE DONE ABOUT GLOBAL WARMING?

Human action and responses about global warming fall into three broad categories: *adaptation, mitigation,* and *geoengineering.* They are not mutually exclusive.

Those who urge *adaptation* believe that the large uncertainties in climate projections make it unwise to spend large sums trying to avert outcomes that may never materialize (Schneider, 1990a: 34). They believe that



human systems can adapt to climate change much faster than they occur. Those advocating adaptation do not eschew all active policies (such as anticipating flood control or water supply problems), but they generally argue that human individuals, organizations, and communities will quickly adjust to such changes so that much organized governmental response will be superfluous and unnecessary. This is a favorite argument of neoclassical economists. They maintain that while the projected doubling of $CO_2$ will take place over the next century, financial markets adapt in minutes, labor markets in several years, and the planning horizon for significant economic and technological change is at most two or three decades (Stern et al., 1992: 110). So there is plenty of time to adapt to whatever happens.

The real question is not whether climate change will occur, but how rapidly it will occur. If moderate change takes place gradually over several hundred years, adaptation is a perfectly feasible and adequate response. But if global change reaches a threshold where the earth warms suddenly and rapidly, ushering in "large, abrupt, and unwelcome shifts in climate," as hypothesized by a report issued by the NAS in 2004, then the costs of adaptation would be substantial and accompanied by considerable social, economic, and political turmoil (see Haimson, 2002b). Such catastrophic and rapid climate change would also reduce the earth's biodiversity because many species couldn't adapt (Miller, 2005: 471).

*Mitigation* means curtailing the greenhouse gas buildup to prevent, minimize, or at least slow global warming. Advocates of taking action now to mitigate warming argue that because of the time lags in the global environmental system, it may be too late to prevent catastrophe by the time it becomes clear that a response is needed. Even if catastrophe is unlikely, mitigation that slows the rate of change means that successful adaptation would be easier and less costly. They argue that mitigation actions begun now allow for more modifications in process, and even blunders, than if begun at a later time when the situation may be more critical. Mitigation is like insuring against disaster: The costs of the "premiums" are onerous though bearable, but the costs of a world-scale catastrophe may not be. It seeks to avoid the high-risk uncontrolled experiment now taking place with the global environment. Furthermore, the advocates of mitigation believe that the economic arguments against mitigation, citing high costs, are specious in the general case. This is because the costs and benefits of postponing action are not always comparable. If current economic activity destroys the life support systems on which humans depend, what future market adjustments or investments could ever recoup this cost? Neither do economic arguments include some environmental goods (such as biodiversity), which have both economic and intrinsic or spiritual benefits that people value. Furthermore, economic accounting undervalues "common property," which cannot be privately owned (the vast atmosphere is a case in point), and for which prices and property rights are fictitious and only potential (Stern et al., 1992: 111–113).

Mitigation strategies could curtail greenhouse gas buildup by various energy conservation measures, switching to alternative energy sources such as a switch from coal and petroleum fuels to natural gas and other fuels with a lower $CO_2$ content, or by abandoning fossil fuels entirely and promoting societies powered by noncarbon sources. All of these would reduce or slow the atmospheric accumulation of $CO_2$, as would reforestation programs. A wide variety of mitigation techniques have been suggested. As with adaptation, a panel of the National Academy of Sciences has collected and categorized them. Table 3.1 lists a sample of such proposals.

The third type of policy options are *geoengineering strategies,* which use technical measures to counteract climate change. Proposals have included several ways of reducing temperature increases by screening sunlight (e.g., space mirrors, stratospheric dust or soot, reflective stratospheric balloons, stimulating cloud condensation) as well as stimulation plankton growth to increase the uptake of $CO_2$ by the oceans. Reforestation, already mentioned, is really a *sort* of geoengineering. You can see several proposed geoengineering technologies in Table 3.2.

Geoengineering options have a potential to affect global warming on a substantial scale, and some are relatively inexpensive, but all have large unknowns concerning possible environmental side effects (for example, particles introduced into the atmosphere or the ocean might alter the ocean chemistry—and food chains—in an effort to stimulate plankton growth) (National Academy of Sciences, 1991: 60). If we don't understand planetary dynamics completely, do we really know enough to reengineer the earth on such a scale? Yet the NAS panel argued that we need to know more about these options, because they may be crucial if global warming occurs, particularly at the upper range of temperature projections. If adaptive efforts fail, and efforts to restrain greenhouse gas production on a global basis fail—for either technical or political reasons—such geoengineering options might be the only effective ones available (National Academy of Sciences, 1991: 62–63).

## Strategies, Social Change, and Inequality

Adaptation and mitigation strategies would both involve significant social change. In terms of mitigation, the IPCC estimated that a reduction in greenhouse gases of between 60% and 80% below 1990 levels would be required to stabilize global mean temperature (Flavin, 1998: 14; Miller, 2002: 464–465). Achieving such results *would not be easy.* Improving energy efficiency would be the fastest, cheapest, and surest way to slash emissions of $CO_2$ and most other air pollutants within two decades. Since the real energy efficiency of



**Table 3.1** Sample Mitigation Options

| | |
|---|---|
| *Residential and Commercial Energy Management* | |
| • *White surfaces and vegetation:* | Reduce air-conditioning use and the "urban heat island effect" by 25% by planting vegetation and painting half of the residence roofs white. |
| • *Residential water heating* | Improve efficiency by 40–70% by efficient tanks, increased insulation, low-flow devices, and alternative water heating systems. |
| • *Residential appliances:* | Improve efficiency of refrigeration and dishwashers by 10–30% by implementation of new appliance standards for refrigeration and no-heat drying cycles in dishwashers. |
| • *Residential space heating* | Reduce energy consumption by 40–60% by improved/increased insulation, window glazing, and weatherstripping along with increased use of heat pumps and solar heating. |
| • *Residential and commercial lighting* | Reduce lighting energy consumption by 30–60% by replacing incandescent lighting with compact fluorescent bulbs; use reflectors, occupancy sensors, and daylighting. |
| • *Industrial energy management:* | Cogeneration—Replace existing industrial energy systems with an additional 25,000 MW of cogeneration plants that produce heat and power simultaneously. |
| • *Fuel efficiency* | Reduce fuel consumption up to 30% by improving energy management, waste heat recovery, boiler modification, and other industrial enhancements. |
| • *New process technology* | Increase recycling and reduce energy consumption primarily in the primary metals, pulp and paper, chemical, and petroleum refining industries by new, less energy-intensive process innovations. |
| *Transportation Energy Management* | |
| • *Vehicle efficiency (autos):* | Use technology to improve fuel economy to 25 mpg with no changes in existing fleet, and to 36 mpg by gradually downsizing the existing fleet (to 33 and 47 mpg, respectively, in CAFE terms).[a] |
| • *Alternative fuels:* | Over time, replace gasoline vehicles with those that use methanol produced from biomass, hydrogen created from solar electricity, or fuel cells. |
| • *Transportation demand management* | Reduce solo commuting by eliminating 25% of employer-provided parking spaces and placing a tax on the remaining spaces. |
| • *Electricity and fuel supply* | Replace fossil fuel-fired plants with ones powered by either hydroelectric or energy alternative sources (geothermal, biomass, solar photovoltaic, or solar thermal sources). Collectively this could account for 13 quads of energy, or about half of the energy used by U.S. electric utilities.[b] |

*Continued*

**Table 3.1** *Continued*

| *Nonenergy Emission Reduction* | |
|---|---|
| • *CFCs* | Find benign substitutes, alter production, and gradually retrofit existing stock of refrigerators, air conditioners, etc. |
| • *Agriculture* | Eliminate all paddy rice production; reduce ruminant animal production by 25%; reduce nitrogenous fertilizer use by 5%. |
| • *Landfill gas collection* | Reduce landfill gas generation by 60–65% by collecting and burning in a flare or energy recovery system. |
| • *Reforestation* | Reforest 28.7 million Ha of economically or environmentally marginal crop and pasture lands to sequester 10% of U.S. $CO_2$ emissions. |

[a]CAFE, or "corporate average fuel economy."

[b]1 quad = 1 quadrillion BTUs (British Thermal Units)–$10^{15}$ BTUs. Data about U.S. electric utility energy consumption from U.S. Energy Information Administration, cited in Craig et al., 1988: 75.

*Source:* National Academy of Sciences, *Policy implications of greenhouse warming,* pp. 54–57. National Academy Press. Copyright © 1991. Used with permission.

industrial economies is probably less than 5%, that leaves an enormous potential for increased efficiency to meet increased energy demand without new drilling or digging (Ayers, 2001: 34).

But other changes—such as car pooling, shifting to cycling or mass transit, and evolving away from the energy-wasteful low-density residential patterns characteristic of American cities—would involve significant changes in social behavior, consumption patterns, and urban growth, and established preferences. Producing the cultural consensus and political mechanisms to develop, market, coordinate, monitor, and control such changes among the multitude of diverse communities, corporations, and households on a societal scale is a *daunting* prospect.

**Table 3.2** Some Geoengineering Options

| | |
|---|---|
| • *Sunlight screening* | Place 50,000 100 $km^2$ space mirrors in the earth's orbit to reflect incoming sunlight. |
| • *Stratospheric dust* | Use guns or balloons to maintain a dust cloud in the stratosphere to increase sunlight reflection. |
| • *Stratospheric bubbles* | Place billions of aluminized, hydrogen-filled balloons in the stratosphere to provide a reflective screen. |
| • *Low stratospheric dust* | Use aircraft to maintain a cloud of dust in the low stratosphere to reflect sunlight. |
| • *Ocean biomass stimulation* | Place iron in the oceans to stimulate the production of $CO_2$ absorbing plankton. |

*Source:* Adapted from National Academy of Sciences, *Policy implications of greenhouse warming,* p. 58. National Academy Press. Copyright 1991. Used with permission.



A broad "carbon tax" has been suggested as an elegantly simple solution to this difficult problem. Advocates argue that it would provide the incentives to impel us to adopt energy conservation and efficiency measures, both industrially and at the household level (Amano, 1990; Reddy and Goldemberg, 1990). But the burdens would fall unevenly on different socioeconomic classes. Higher-income households tend to purchase energy-efficient technology and to make building changes, while lower-income households tend to curtail consumption and do without (Dillman et al., 1983; Lutzenhiser and Hackett, 1993). I noted in earlier chapters that environmental problems and their remedies are often related to inequality and social stratification so that their burdens and benefits are not shared equitably. Without programs more evenly to distribute the burden sharing (in housing and transportation, for example), such a carbon tax would have highly inequitable and regressive effects that would burden low-income households much more than more affluent ones.

There is a similar difficulty regarding international inequality between nations. The United States alone produces about 28% of global $CO_2$, China about 23%, Russia and other Eastern European nations produce about 14%, West Europe about 12%, and the remaining 23% is distributed among all other nations (World Resources Institute, 2001, cited in Cunningham, 2005: 324). The richest fifth of the world contributes 63% of total global emissions, while the poorest fifth contributes just 2%. Putting it in individual terms, the average emissions of one American equal those of 7 Chinese, 24 Nigerians, 31 Pakistanis, or hundreds of Somalis (Dunn, 1999: 60).

## Greenhouse Diplomacy: Kyoto and Beyond

The 1992 United Nations World Conference on Environment and Development in Rio de Janeiro intended to initiate a global greenhouse treaty, much like the successful Montreal ozone treaty, but as suggested earlier, it proved much more contentious and difficult. In spite of the urgings of the National Academy of Sciences, the U.S. government refused to sign, sabotaging an initial agreement because it had quantitative national targets for emission reduction. What emerged from the Rio meeting was a statement that nations signed pledging "voluntary reductions" in greenhouse emissions, with no quantitative targets or sanctions for noncompliance. As you might guess, not much happened.

As evidence continued to mount, political mobilization around the issue continued in the 1990s. Scientific and environmental organizations, along with insurance liability carriers, urged action. But some industry groups, sensing greater restrictions, regulations, and reduced profits campaigned against doing anything about global warming. Earlier I noted foundations related to such industries as an anti–global warming movement, which started spending millions on "sponsored research" lobbying and advertising to derail effective mitigation treaties and policies. Examples include the American Enterprise Institute, the Cato Institute, The Heritage Foundation, and the George C. Marshall Institute. In addition to depicting global warming as not real, they maintained that policies dealing with global warming would do more harm than good (McCright and Dunlap, 2000). Some labor groups, fearing loss of jobs, joined them.

Responding to global alarm, some 10,000 government officials, lobbyists, representatives of environmental organizations and industry-related organizations gathered for a high-profile world climate conference at the ancient Japanese city of Kyoto to negotiate a better treaty than the Rio accord. After 10 days of chaotic, complex, redundant, and contentious negotiations, 160 nations formally adopted a Kyoto Protocol, legally committing industrial countries to reduce their emissions of greenhouse gases early in the twenty-first century. Why only the industrial nations? Because LDCs objected, noting that their greenhouse emissions are far lower than those of MDCs, even though they are rapidly growing. Led by India and China, they argued that meeting targeted reductions early in the twenty-first century would destroy their fragile developing economies—without financial and technical help from the MDCs. The Kyoto centerpiece was an agreement by all "Annex I" nations (MDCs and former East bloc countries) to cut their output of climate-altering gases collectively by 5.2% below their 1990 levels between 2008 and 2012. While that may not seem significant, it represents emissions levels that were about 29% lower than they would be by 2008–2012 without the treaty (United Nations 1998c). Most contentious was the target and timetable negotiated for each nation's contribution to the collective goal, which was resolved after many concessions and protracted debate (Dunn, 1998b: 33). Again, the U.S. did not sign the climate accord, partly on the grounds that LDCs were exempted from quantitative goals or timetables. Annual meetings different cities continued to strengthen and clarify the accord began in Kyoto, and by 2001 over 150 nations had ratified it. In October 2004 Russia ratified it, enabling it to come into force in February 2005 (Sawin, 2005a). Though an impressive accomplishment, even in the most ideal terms Kyoto only started the global political process, and has several kinds of weaknesses:

1. *Weak commitments:* Its goal of 5.2% reduction in emissions was anemic compared to between 60% and 80% reductions below 1990 levels that the IPCC says are necessary to stop global warming. Little noticed outside climate policy circles was the curious fact that total $CO_2$ emissions by MDCs were already below 1990 levels, due to steep declines in the former Soviet Union. Furthermore, when emissions by the LDCs are added, the global emission total was projected to increase some 30 percent *above* the 1990 level by 2010. The most hopeful thing that can be said about the Kyoto Protocol echoes Lao Tse's comment that a journey of a thousand miles begins with a single step. Though it will not affect global mean temperatures, it moves the world political process.



2. *Searching for "flexibility":* Some countries, particularly the United States, were anxious to find provisions—critics call them loopholes—that would make it less expensive to meet the protocol's goals and avoid the need to take a big bite out of domestic $CO_2$ emissions. They targeted a "basket" of emissions rather than focusing on each individually, which would arouse a hornet's nest of industry outrage. At the insistence of the United States, Canada, and New Zealand, countries could count—and subtract—carbon absorption by forests and peat bog sinks (Flavin, 1998: 14–16).

3. *Hot air trading:* Another form of flexibility is the concept of emissions trading. It is modeled on the U.S. Clean Air Act that allows power companies to "trade" their sulfur dioxide reduction obligations for cash, on the theory that this will encourage cuts to be made wherever it is least expensive to do so. Related to global climate change, nations would have the option of buying greenhouse gas emission allowances from other countries that have more than met their own requirements. An emissions trading scheme was viewed as a way of not only trimming emissions costs as efficiently as possible, but also distributing the burden of addressing the problem among various countries. But the idea opens the door for possible loopholes. For example, under the protocol signed, Russia and Ukraine had reduced emissions, given their depressed economies. Even if their economies rebound robustly, experts do not expect either country to come close to 1990 levels, allowing the United States and Russia to "make a deal," letting the United States purchase its credits for emissions reductions—without reducing U.S. emissions by one molecule (Flavin, 1998: 14–16).

In the United States, continuing opposition to ratification by the Congress and the presidential administrations of both Herbert Walker Bush and George W. Bush reflects real problems about making policy about a megaproblem, but, more important I think, the ongoing power, pervasiveness, and media effectiveness of the "anti-global warming movement" of conservatives, U.S. conservative foundations and some corporations noted earlier (McCright and Dunlap, 2000; 2003). In November 2006 the United Nations Environmental Programme convened another meeting of the world's nations in Nairobi, Kenya about global warming, and making the Kyoto accord more effective, with higher targets for reduction of greenhouse gases and more effective monitoring and enforcement among signatory nations.

Ironically, while international political processes stagnated, opportunities for economically cutting emissions have blossomed. Some nations did not completely fail in cutting $CO_2$ emissions. The United Kingdom, for instance, had already rolled them back to 1990 levels by 2000, and vowed to reduce them 60% more by 2050. Plans are to "decarbonize" British society and decouple gross national produce growth from $CO_2$ emissions. Germany reduced $CO_2$ emissions at least 10% by switching from coal to natural gas and encouraging energy efficiency throughout society, an illustration of the "no regrets" strategy mentioned earlier (Cunningham et al., 2005: 324). But the biggest surprise was China. Research by the Natural Resources Defense Council found that China reduced its $CO_2$ emissions by 17% between 1997 and 2000, a period when emissions in the U.S. rose by 14%. The Chinese government did this by reducing our coal subsidies, closing inefficient coal-fired electric plants, accelerating its commitment to increase energy efficiency, and structuring its economy to increase the use of renewable energy resources (Miller, 2005: 482).

Besides nations, some corporations joined the effort to address global warming. In 1998, the Pew Center on Global Climate Change announced that Weyerhaeuser lumber company, one of the world's biggest, formally joined the center's effort to combat the problems of climate change. The "green hybrid" auto, the Toyota Prius, has twice the fuel economy and half the $CO_2$ emissions of conventional autos (Haimson, 2002b: 4). A growing number of transnational corporations, including Alcoa, DuPont, IBM, Toyota, BP Amoco, and Shell, established targets to reduce their greenhouse gas emissions by 10 to 65% from 1990 to 2010 (Miller, 2005: 482). Thus, while many national governments appear to be stalled, efforts by corporations and a surprising number of local and city governments are addressing the problem of global warming. See Box 3.4.

Ironically, in the summer of 2002, the Bush administration found itself in the position of reacting to the weight of scientific evidence and pressure from other nations by recognizing that global warming is a real problem and caused by human impacts, while rejecting the Kyoto accord and proposing a vague "voluntary" approach to the problem.

## Can We Afford the Costs?

Mitigating global warming and shifting to a low carbon economy would be very costly. But doing nothing about the problem would be much more costly over the longer time frame. In October 2006 Nicholas Stern, formerly chief economist for the World Bank, produced a report for the British government that was the first detailed analysis of the impact of climate change and efforts to address it on the global economy. His report has demolished some of economists' argument that it is better to adapt to global warming than to mitigate it. The report notes that the damage from climate change in this century alone could be 20 times the costs of solving it for all time.

Stern's report forecasts huge disruption to African economies as drought hits food production; up to a billion people losing water supplies as glaciers disappear; hundreds of millions being displaced by sea-level rises; and more serious hurricane damage as storms grow fiercer. The cost of failing to act could approach $4 trillion by 2100. Up to a fifth of the world's wealth could disappear, cutting living standards by 20%, and plunging the world into a recession worse than that of the 1930s. By comparison, the costs of investing in the right technologies would be trivial compared with the potential damage. Investing about 1% of the global GDP over the next 50 years should stabilize greenhouse gas concentrations at about 500 to 550 parts per million of $CO_2$, 25% above current levels—"high but acceptable"—according to Stern. The report may disappoint science, because it does not talk about science (with talk about global temperature change, ocean circulation, and atmospheric composition). Although scientists have done their best to convince people and governments of the urgency of the problem, largely they have failed. Stern's report carried a lot more clout. Most politicians are more attuned to economics than natural science, and Stern's report went for the political jugular.

But how do we do that? Humanity can afford to emit another 100 billion or so tons of carbon into the atmosphere before the global economy suffers serious damage. Everyone, from the world's richest to the poorest, has to be a part of a global mitigation strategy. This could be based on the size of populations and the average amount emitted per person, and clearly some emit a lot more than others. How should we allocate rights for remaining carbon pollution? The only equitable way to share such entitlements is to



### BOX 3.4 ARE CITIES MOVING FASTER THAN NATIONS ON CLIMATE?

While national governments often dither, a surprising number of cities are moving forward with active efforts to reduce their emissions. Seattle, for instance, has committed to meet the cuts agreed to in Kyoto and reduce its greenhouse emissions by 7 percent from 1990 levels mainly through conservation and increased wind power, while San Franciscans passed a $100 million bond issue to fund the nation's biggest solar project. Solar and wind will eventually supply 25 percent of the city's electricity. The International Council on Local Environmental Initiatives (ICLEI) was founded in 1993 to facilitate city-to-city networking, and as of October 2001 some 500 cities responsible for about 8 percent of global carbon emissions had signed up. Although goals vary from place to place, some cities are aiming higher than their national governments. The first cities to join the ICLEI already have measurable progress. One hundred and ten cities and counties in the United States had eliminated 2.5 million tons of carbon by June 2001, and Copenhagen, Denmark has reduced emissions by 22 percent from 1990 levels. Though local governments are not party to the Kyoto treaty, the ICLEI sends city officials to key meetings to endorse strong targets, receive press coverage, and raise public consciousness (O'Meara-Sheehan, 2002: 39). In 2005 environmental movements in the United States were organizing a similar "Cool Cities" network involving a larger number of cities (and many smaller communities) in similar efforts to combat global warming.

share the quota among the global population, and reduce it by about 80% over the coming century. Nations, communities, corporations, and perhaps even individuals should be able to trade their entitlements (Editors, *NewScientist*, 2006a, 2006b; 5–7).

## PERSONAL CONNECTIONS

### Consequences and Questions

**1.** Ask some of your acquaintances of different ages, education, or circumstances what they think about global warming. The diversity of opinions may surprise you. You also have read about the scientific consensus. Who do you trust the most?

**2.** Assume that projections about global warming are right, and that a general and significant rise in mean global temperatures will happen during the next 40 to 50 years. You would probably experience some consequences during your lifetime. You can't predict them specifically, but can make informed guesses about their probable consequences. Think about how you will bear a share of the costs of coping with these consequences of global warming.

**3.** In 1990 the federal government estimated costs of mitigating greenhouse gases at about $10 billion a year. By now, that is surely a conservative estimate, but it is certainly not a trivial tax or economic surcharge on normal social and economic functioning. What are some ways the costs or taxes might show up for you as a typical consumer or taxpayer?

**4.** A huge number of North Americans live in coastal regions. Look at the location of the really big American cities and metropolitan areas in this light. If ocean levels rise because of climate warming, you will be affected. If ocean levels rise modestly, dense human settlements will have to be protected and people relocated or evacuated inland. Think about the costs and chaos of doing this, particularly for America's large coastal cities like New York, Los Angeles, Seattle, and Miami. Increasing sea levels would flood scores of estuaries, freshwater aquifers, and other resources on which societies depend. You will bear a share of those costs which cannot be precisely calculated, but they are enormous! Some of them will be shifted to you even if you don't live in a coastal region, like higher costs for goods and services, higher property insurance premiums, and taxes for state and federal disaster relief programs. Think how people bore such costs due to Hurricane Katrina, even people and communities in non-coastal regions.



**5.** Climate zones and vegetation may shift unpredictably. Global warming would increase both evaporation and precipitation, and atmospheric models suggest that regional effects would be extremely uneven. In 2006 the Midwestern and Great Plains states were plagued by a severe and prolonged drought. Soil moisture was deficient and crop production was down. If this becomes chronic, how might it affect food prices, world grain markets, and food security? How do you think you would change your lifestyle to adapt to these circumstances? What kinds of adaptive measures could be taken?

**6.** *You may already be beginning to absorb such costs.* One likely consequence of global warming is rapid weather changes and more frequent severe weather patterns. A warmer atmosphere and warmer seas may result in greater exchange of energy and momentum to the vertical change processes important to the development of cyclones, tornadoes, thunderstorms, and hailstorms. Certainly, you absorbed such costs in 2005 if you lived in New Orleans area during Katrina, or in Florida, when the state was crisscrossed by five hurricanes in one season. *How?*

The insurance industry has not exhibited the same skepticism about global warming as have some others, when paying losses for flooded farmlands, crops, hurricanes, tornados, and other disaster losses. Indeed, in its own long-term interest, the insurance industry is joining efforts to find ways of mitigating or adapting to global warming.

### What You Can Do

### Real Goods

**1.** *Ceiling fans.* Eco-friendly technology's answer to air-conditioning, ceiling fans, cool tens of millions of people in LDCs. Air conditioning, found in about two-thirds of U.S. homes, is a real electrical "juice hog" of electrical energy. Ceiling fans, on the other hand, are simple, durable, repairable, and take little energy to run. They run at very low speeds (summer and winter) and help even out the "layers" of room temperature. A fan over your bed circulates enough air that you may not have to run your air conditioner as much.

**2.** *The reel-type push lawnmower (without a gas engine).* They're back! And, they cost about one-fourth of the cost of a self-propelled power mower, and probably a sixth of the cost of a riding mower. They are made with lighter metal alloys that are easier to push than historic versions. One is easy to push up a 45-degree incline on my front yard (where my previous power mower would stall because it drained oil into the engine, and where I always feared that it would tip over and slice my foot off). No gas, tune-ups, smoke, pollution, or noise. There is only a quiet clik, clik, clik as it moves, which brings back nostalgic childhood memories. The kids in the neighborhood had never seen one before, and came over to ask, "What is that thing?"

**3.** *Compact fluorescent light bulbs.* They are three or four times as efficient as regular incandescent bulbs. One 18-watt compact fluorescent light bulb provides the light of a 75-watt incandescent bulb and lasts 10 times as long. Currently they are pretty pricey but should get cheaper as more people use them. Even so, over the life of its use, an 18-watt compact bulb can keep more than 80 pounds of coal in the ground and about 250 pounds of $CO_2$ out of the atmosphere.

## MORE RESOURCES

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## ELECTRONIC RESOURCES

**www.epa.gov/globalwarming/news/**
EPA site about global warming

**www.tellusinstitute.org/**
Website of The Stockholm Environment Institute. Material and reports about large-scale social and environmental change, and sustainability.



**www.mountwashington.org/climatechange**
Links about regional, national, and global climate change (to NASA, NOAA, IPCC, and others; links about the human impacts of global warming, and to web sites of global warming skeptics).

**www.climatecrisis.net**
The web site that goes with Al Gore's movie about climate change (*An Inconvenient Truth*). It has an interesting "carbon counter" to compute how much carbon you put in the atmosphere that is fun to play with.

## ENDNOTES

1. *Phenomenology* is a philosophical term that means how humans experience something.