THE NEW YORKER
FACT

ANNALS OF SCIENCE

THE CLIMATE OF MAN—III

by ELIZABETH KOLBERT

What can be done?

Issue of 2005-05-09
Posted 2005-05-02

In February, 2003, a series of ads on the theme of inundation began appearing on Dutch TV. The ads were sponsored by the Netherlands' Ministry of Transport, Public Works, and Water Management, and they featured a celebrity weatherman named Peter Timofeeff. In one commercial, Timofeeff, who looks a bit like Albert Brooks and a bit like Gene Shalit, sat relaxing on the shore in a folding chair. "Sea level is rising," he announced, as waves started creeping up the beach. He continued to sit and talk even as a boy who had been building a sandcastle abandoned it in panic. At the end of the ad, Timofeeff, still seated, was immersed in water up to his waist.

In another commercial, Timofeeff was shown wearing a business suit and standing by a bathtub. "These are our rivers," he explained, climbing into the tub and turning on the shower full blast. "The climate is changing. It will rain more often, and more heavily." Water filled the tub and spilled over the sides. It dripped through the floorboards, onto the head of his screeching wife, below. "We should give the water more space and widen the rivers," he advised, reaching for a towel.

Both the beach-chair and the shower ads were part of a public-service campaign that also included radio spots, newspaper announcements, and free tote bags. Notwithstanding their comic tone—other commercials showed Timofeeff trying to start a motorboat in a cow pasture and digging a duck pond in his back yard—their message was sombre.

A quarter of the Netherlands lies below sea level, much of it on land wrested from either the North Sea or the Rhine or the River Meuse. Another quarter, while slightly higher, is still low enough that, in the natural course of events, it would regularly be flooded. What makes the country habitable is the world's most sophisticated water-management system, which comprises more than ten thousand miles of dikes, dams, weirs, flood barriers, and artificial dunes, not to mention countless pumps, holding ponds, and windmills. (People in Holland like to joke, "God made the world, but the Dutch made the Netherlands.")

Until recently, it was assumed that any threat to low-lying areas would be dealt with the same way such threats always had been: by raising the dikes, or by adding new ones. (The latest addition, the Maeslant barrier, which is supposed to protect Rotterdam from storm surges with the aid of two movable arms, each the size of a skyscraper, was completed in 1997.) But this is no longer the case. The very engineers who perfected the system have become convinced that it is unsustainable. After centuries of successfully manipulating nature, the Dutch, the ads warn, will have to switch course.

Eelke Turkstra runs a water-ministry program called Room for the River, which is just the sort of enterprise that Timofeeff was advocating when he climbed into the bathtub. A few months ago, I arranged to speak with Turkstra, and he suggested that we meet at a nature center along a branch of the Rhine known as the Nieuwe Merwede. The center featured an exhibit about the effects of climate change. One kid-friendly display allowed visitors to turn a crank and, in effect, drown the countryside. By 2100, the display showed, the Nieuwe Merwede could be running several feet above the local dikes.

From the nature center, Turkstra took me by car ferry across the river. On the other side, we drove through an area that was made up entirely of "polders"—land that has been laboriously reclaimed from the water. The polders were shaped like ice trays, with sloping sides and perfectly flat fields along the bottom. Every once in a while, there was a sturdy-looking farmhouse. The whole scene—the level fields, the thatched barns, even the gray clouds sitting on the horizon—could have been borrowed from a painting by Hobbema. Turkstra explained that the plan of Room for the River was to buy out the farmers who were living in the polders, then lower the dikes and let the Nieuwe Merwede flood when necessary. It was expected that the project would cost three hundred and ninety million dollars. Similar projects are under way in other parts of the Netherlands, and it is likely that in the future even more drastic measures will be necessary, including, some experts argue, the construction of a whole new outlet channel for the Rhine.

"Some people don't get it," Turkstra told me as we zipped along. "They think this project is stupid. But I think it's stupid to continue in the old way."

A few years ago, in an article in *Nature*, the Dutch chemist Paul Crutzen coined a term. No longer, he wrote, should we think of ourselves as living in the Holocene, as the period since the last glaciation is known. Instead, an epoch unlike any of those which preceded it had begun. This new age was defined by one creature—man—who had become so dominant that he was capable of altering the planet on a geological scale. Crutzen, a Nobel Prize winner, dubbed this age the Anthropocene. He proposed as its starting date the seventeen-eighties, the decade in which James Watt perfected his steam engine and, inadvertently, changed the history of the earth.

In the seventeen-eighties, ice-core records show, carbon-dioxide levels stood at about two hundred and eighty parts per million. Give or take ten parts per million, this was the same level that they had been at two thousand years earlier, in the era of Julius Caesar, and two thousand years before that, at the time of Stonehenge, and two thousand years before that, at the founding of the first cities. When, subsequently, industrialization began to drive up CO_2 levels, they rose gradually at first—it took more than a hundred and fifty years to get to three hundred and fifteen parts per million—and then much more rapidly. By the mid-nineteen-seventies, they had reached three hundred and thirty parts per million, and, by the mid-nineteen-nineties, three hundred and sixty parts per million. Just in the past decade, they have risen by as much—twenty parts per million—as they did during the previous ten thousand years of the Holocene.

For every added increment of carbon dioxide, the earth will experience a temperature rise, which represents what is called the equilibrium warming. If current trends continue, atmospheric CO_2 will reach five hundred parts per million—nearly double pre-industrial levels—around the middle of the century. It is believed that the last time CO_2 concentrations were that high was during the period known as the Eocene, some fifty million years ago. In the Eocene, crocodiles roamed Colorado and sea levels were nearly three hundred feet higher than they are today.

For all practical purposes, the recent "carbonation" of the atmosphere is irreversible. Carbon dioxide is a persistent gas; it lasts for about a century. Thus, while it is possible to increase CO_2 concentrations relatively quickly, by, say, burning fossil fuels or levelling forests, the opposite is not the case. The effect might be compared to driving a car equipped with an accelerator but no brakes.

The long-term risks of this path are well known. Barely a month passes without a new finding on the dangers posed by rising CO_2 levels—to the polar ice cap, to the survival of the world's coral reefs, to the continued existence of low-lying nations. Yet the world has barely even begun to take action. This is particularly true of the United States, which is the largest emitter of carbon dioxide by far. (The average American produces some twelve thousand pounds of CO_2 emissions annually.) As we delay, the opportunity to change course is slipping away. "We have only a few years, and not ten years but less, to do something," the Dutch state secretary for the environment, Pieter van Geel, told me when I went to visit him in The Hague.

In climate-science circles, a future in which current emissions trends continue, unchecked, is known as "business as usual," or B.A.U. A few years ago, Robert Socolow, a professor of engineering at Princeton, began to think about B.A.U. and what it implied for the fate of mankind. Socolow had recently become co-director of the Carbon Mitigation Initiative, a project funded by BP and Ford, but he still considered himself an outsider to the field of climate science. Talking to insiders, he was struck by the degree of their alarm. "I've been involved in a number of fields where there's a lay opinion and a scientific opinion," he told me when I went to talk to him shortly after returning from the Netherlands. "And, in most of the cases, it's the lay community that is more exercised, more anxious. If you take an extreme example, it would be nuclear power, where most of the people who work in nuclear science are relatively relaxed about very low levels of radiation. But, in the climate case, the experts—the people who work with the climate models every day, the people who do ice cores—they are *more* concerned. They're going out of their way to say, 'Wake up! This is not a good thing to be doing.' "

Socolow, who is sixty-seven, is a trim man with wire-rimmed glasses and gray, vaguely Einsteinian hair. Although by training he is a theoretical physicist—he did his doctoral research on quarks—he has spent most of his career working on problems of a more human scale, like how to prevent nuclear proliferation or construct buildings that don't leak heat. In the nineteen-seventies, Socolow helped design an energy-efficient housing development, in Twin Rivers, New Jersey. At another point, he developed a system—never commercially viable—to provide air-conditioning in the summer using ice created in the winter. When Socolow became co-director of the Carbon Mitigation Initiative, he decided that the first thing he needed to do was get a handle on the scale of the problem. He found that the existing literature on the subject offered almost too much information. In addition to B.A.U., a dozen or so alternative scenarios, known by code names like A1 and B1, had been devised; these all tended to jumble together in his mind, like so many Scrabble tiles. "I'm pretty quantitative, but I could not remember these graphs from one day to the next," he recalled. He decided to try to streamline the problem, mainly so that he could understand it.

There are two ways to measure carbon-dioxide emissions. One is to count the full weight of the CO_2; the other, favored by the scientific community, is to count just the weight of the carbon. Using the latter measure, global emissions last year amounted to seven billion metric tons. (The United States contributed more than twenty per cent of the total, or 1.6 billion metric tons of carbon.) "Business as usual" yields several different estimates of future emissions: a mid-range projection is that carbon emissions will reach 10.5 billion metric tons a year by 2029, and fourteen billion tons a year by 2054. Holding emissions constant at today's levels means altering this trajectory so that fifty years from now seven billion of those fourteen billion tons of carbon aren't being poured into the atmosphere.

Stabilizing CO_2 emissions, Socolow realized, would be a monumental undertaking, so he decided to break the problem down into more manageable blocks, which he called "stabilization wedges." For simplicity's sake, he defined a stabilization wedge as a step that would be sufficient to prevent a billion metric tons of carbon per year from being emitted by 2054. Along with a Princeton colleague, Stephen Pacala, he eventually came up with fifteen different wedges—theoretically, at least eight more than would be necessary to stabilize emissions. These fall, very roughly, into three categories—wedges that deal with energy demand, wedges that deal with energy supply, and wedges that deal with "capturing" CO_2 and storing it somewhere other than the atmosphere. Last year, the two men published their findings in a paper in *Science* which received a great deal of attention. The paper was at once upbeat—"Humanity already possesses the fundamental scientific, technical, and industrial know-how to solve the carbon and climate problem for the next half-century," it declared—and deeply sobering. "There is no easy wedge" is how Socolow put it to me.

Consider wedge No. 11. This is the photovoltaic, or solar-power, wedge—probably the most appealing of all the alternatives, at least in the abstract. Photovoltaic cells, which have been around for more than fifty years, are already in use in all sorts of small-scale applications and in some larger ones where the cost of connecting to the electrical grid is prohibitively high. The technology, once installed, is completely emissions-free, producing no waste products, not even water. Assuming that a thousand-megawatt coal-fired power plant produces about 1.5 million tons of carbon a year—in the future, coal plants are expected to become more efficient—to get a wedge out of photovoltaics would require enough cells to produce seven hundred thousand megawatts. Since sunshine is intermittent, two million megawatts of capacity is needed to produce that much power. This, it turns out, would require PV arrays covering a surface area of five million acres—approximately the size of Connecticut.

Wedge No. 10 is wind electricity. The standard output of a wind turbine is two megawatts, so to get a wedge out of wind power would require at least a million turbines. Other wedges present different challenges, some technical, some social. Nuclear power produces no carbon dioxide; instead, it generates radioactive waste, with all the attendant problems of storage, disposal, and international policing. Currently, there are four hundred and forty-one nuclear power plants in the world; one wedge would require doubling their capacity. There are also two automobile wedges. The first requires that every car in the world be driven half as much as it is today. The second requires that it be twice as efficient. (Since 1987, the fuel efficiency of passenger vehicles in the U.S. has actually declined, by more than five per cent.)

Three of the possible options are based on a technology known as "carbon capture and storage," or C.C.S. As the name suggests, with C.C.S. carbon dioxide is "captured" at the source—presumably a power plant or other large emitter. Then it is injected at very high pressure into geological formations, such as depleted oil fields, underground. No power plants actually use C.C.S. at this point, nor is it certain that CO_2 injected underground will remain there permanently; the world's longest-running C.C.S. effort, maintained by the Norwegian oil company Statoil at a natural-gas field in the North Sea, has been operational for only eight years. One wedge of C.C.S. would require thirty-five hundred projects on the scale of Statoil's.

In a world like today's, where there is, for the most part, no direct cost to emitting CO_2, none of Socolow's wedges are apt to be implemented; this is, of course, why they represent a departure from "business as usual." To alter the economics against carbon requires government intervention. Countries could set a strict limit on CO_2, and then let emitters buy and sell carbon "credits." (In the United States, this same basic strategy has been used successfully with sulfur dioxide in order to curb acid rain.) Another alternative is to levy a tax on carbon. Both of these options have been extensively studied by economists; using their work, Socolow estimates that the cost of emitting carbon would have to rise to around a hundred dollars a ton to provide a sufficient incentive to adopt many of the options he has proposed. Assuming that the cost were passed on to consumers, a hundred dollars a ton would raise the price of a kilowatt-hour of coal-generated electricity by about two cents, which would add roughly fifteen dollars a month to the average American family's electricity bill. (In the U.S., more than fifty per cent of electricity is generated by coal.)

All of Socolow's calculations are based on the notion—clearly hypothetical—that steps to stabilize emissions will be taken immediately, or at least within the next few years. This assumption is key not only because we are constantly pumping more CO_2 into the atmosphere but also because we are constantly building infrastructure that, in effect, guarantees that that much additional CO_2 will be released in the future. In the U.S., the average new car gets about twenty miles to the gallon; if it is driven a hundred thousand miles, it will produce almost forty-three metric tons of carbon during its lifetime. A thousand-megawatt coal plant built today, meanwhile, is likely to last fifty years; if it is constructed without C.C.S. capability, it will emit some hundred million tons of carbon during its life. The overriding message of Socolow's wedges is that the longer we wait—and the more infrastructure we build without regard to its impact on emissions—the more daunting the task of keeping CO_2 levels below five hundred parts per million will become. Indeed, even if we were to hold emissions steady for the next half century, Socolow's graphs show that much steeper cuts would be needed in the following half century to keep CO_2 concentrations from exceeding that level. After a while, I asked Socolow whether he thought that stabilizing emissions was a politically feasible goal. He frowned.

"I'm always being asked, 'What can you say about the practicability of various targets?' " he told me. "I really think that's the wrong question. These things can all be done.

"What kind of issue is like this that we faced in the past?" he continued. "I think it's the kind of issue where something looked extremely difficult, and not worth it, and then people changed their minds. Take child labor. We decided we would not have child labor and goods would become more expensive. It's a changed preference system. Slavery also had some of those characteristics a hundred and fifty years ago. Some people thought it was wrong, and they made their arguments, and they didn't carry the day. And then something happened and all of a sudden it was wrong and we didn't do it anymore. And there were social costs to that. I suppose cotton was more expensive. We said, 'That's the trade-off; we don't want to do this anymore.' So we may look at this and say, 'We are tampering with the earth.' The earth is a twitchy system. It's clear from the record that it does things that we don't fully understand. And we're not going to understand them in the time period we have to make these decisions. We just know they're there. We may say, 'We just don't want to do this to ourselves.' If it's a problem like that, then asking whether it's practical or not is really not going to help very much. Whether it's practical depends on how much we give a damn."

Marty Hoffert is a professor of physics at New York University. He is big and bearish, with a wide face and silvery hair. Hoffert got his undergraduate degree in aeronautical engineering, and one of his first jobs, in the mid-nineteen-sixties, was helping to develop the U.S.'s antiballistic-missile system. Eventually, he decided that he wanted to work on something, in his words, "more productive." In this way, he became involved in climate research. Hoffert is primarily interested in finding new, carbon-free ways to generate energy. He calls himself a "technological optimist," and a lot of his ideas about electric power have a wouldn't-it-be-cool, Buck Rogers sound to them. On other topics, though, Hoffert is a killjoy.

"We have to face the quantitative nature of the challenge," he told me one day over lunch at the N.Y.U. faculty club. "Right now, we're going to just burn everything up; we're going to heat the atmosphere to the temperature it was in the Cretaceous, when there were crocodiles at the poles. And then everything will collapse."

Currently, the new technology that Hoffert is pushing is space-based solar power, or S.S.P. In theory, at least, S.S.P. involves launching into space satellites equipped with massive photovoltaic arrays. Once a satellite is in orbit, the array would unfold or, according to some plans, inflate. S.S.P. has two important advantages over conventional, land-based solar power. In the first place, there is more sunlight in space—roughly eight times as much, per unit of area—and, in the second, this sunlight is constant: satellites are not affected by clouds or by nightfall. The obstacles, meanwhile, are several. No full-scale test of S.S.P. has ever been conducted. (In the nineteen-seventies, NASA studied the idea of sending a photovoltaic array the size of Manhattan into space, but the project never, as it were, got off the ground.) Then, there is the expense of launching satellites. Finally, once the satellites are up, there is the difficulty of getting the energy down. Hoffert imagines solving this last problem by using microwave beams of the sort used by cell-phone towers, only much more tightly focussed. He believes, as he put it to me, that S.S.P. has a great deal of "long-term promise"; however, he is quick to point out that he is open to other ideas, like putting solar collectors on the moon, or using superconducting wires to transmit electricity with minimal energy loss, or generating wind power using turbines suspended in the jet stream. The important thing, he argues, is not *which* new technology will work but simply that *some* new technology be found. A few years ago, Hoffert published an influential paper in *Science* in which he argued that holding CO_2 levels below five hundred parts per million would require a "Herculean" effort and probably could be accomplished only through "revolutionary" changes in energy production.

"The idea that we already possess the 'scientific, technical, and industrial know-how to solve the carbon problem' is true in the sense that, in 1939, the technical and scientific expertise to build nuclear weapons existed," he told me, quoting Socolow. "But it took the Manhattan Project to make it so."

Hoffert's primary disagreement with Socolow, which both men took pains to point out to me and also took pains to try to minimize, is over the future trajectory of CO_2 emissions. For the past several decades, as the world has turned increasingly from coal to oil, natural gas, and nuclear power, emissions of CO_2 per unit of energy have declined, a process known as "decarbonization." In the "business as usual" scenario that Socolow uses, it is assumed that decarbonization will continue. To assume this, however, is to ignore several emerging trends. Most of the growth in energy usage in the next few decades is due to occur in places like China and India, where supplies of coal far exceed those of oil or natural gas. (China, which has plans to build five hundred and sixty-two coal-fired plants by 2012, is expected to overtake the U.S. as the world's largest carbon emitter around 2025.) Meanwhile, global production of oil and gas is expected to start to decline—according to some experts, in twenty or thirty years, and to others by the end of this decade. Hoffert predicts that the world will start to "recarbonize," a development that would make the task of stabilizing carbon dioxide that much more difficult. By his accounting, recarbonization will mean that as many as twelve wedges will be needed simply to keep CO_2 emissions on the same upward trajectory they're on now. (Socolow readily acknowledges that there are plausible scenarios that would push up the number of wedges needed.) Hoffert told me that he thought the federal government should be budgeting between ten and twenty billion dollars a year for primary research into new energy sources. For comparison's sake, he pointed out that the "Star Wars" missile-defense program, which still hasn't yielded a workable system, has already cost the government nearly a hundred billion dollars.

A commonly heard argument against acting to curb global warming is that the options now available are inadequate. To his dismay, Hoffert often finds his work being cited in support of this argument, with which, he says, he vigorously disagrees. "I want to make it very clear," he told me at one point. "We have to start working immediately to implement those elements that we know how to implement *and* we need to start implementing these longer-term programs. Those are not opposing ideas."

"Let me say this," he said at another point. "I'm not sure we can solve the problem. I hope we can. I think we have a shot. I mean, it may be that we're not going to solve global warming, the earth is going to become an ecological disaster, and, you know, somebody will visit in a few hundred million years and find there were some intelligent beings who lived here for a while, but they just couldn't handle the transition from being hunter-gatherers to high technology. It's certainly possible. Carl Sagan had an equation—the Drake equation—for how many intelligent species there are in the galaxy. He figured it out by saying, How many stars are there, how many planets are there around these stars, what's the probability that life will evolve on a planet, what's the probability if you have life evolve of having intelligent species evolve, and, once that happens, what's the average lifetime of a technological civilization? And that last one is the most sensitive number. If the average lifetime is about a hundred years, then probably, in the whole galaxy of four hundred billion stars, there are only a few that have intelligent civilizations. If the lifetime is several million years, then the galaxy is teeming with intelligent life. It's sort of interesting to look at it that way. And we don't know. We could go either way."

In theory, at least, the world has already committed itself to addressing global warming, a commitment that dates back more than a decade. In June of 1992, the United Nations held the so-called Earth Summit, in Rio de Janeiro. There, representatives from virtually every nation on earth met to discuss the U.N. Framework Convention on Climate Change, which had as its sweeping objective the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic"—man-made—"interference with the climate system." One of the early signatories was President George H. W. Bush, who, while in Rio, called on world leaders to translate "the words spoken here into concrete action to protect the planet." Three months later, Bush submitted the Framework Convention to the U.S. Senate, which approved it by unanimous consent. Ultimately, the treaty was ratified by a hundred and sixty-five countries.

What "dangerous anthropogenic interference," or D.A.I., consists of was not precisely defined in the Framework Convention, although there are, it is generally agreed, a number of scenarios that would fit the bill—climate change dramatic enough to destroy entire ecosystems, for instance, or severe enough to disrupt the world's food supply. The disintegration of one of the planet's remaining ice sheets is often held up as the exemplary climate disaster; were the Greenland or the West Antarctic Ice Sheet to be destroyed, sea levels around the world would rise by at least fifteen feet, inundating areas where today hundreds of millions of people live. (Were both ice sheets to disintegrate, global sea levels would rise by thirty-five feet.) It could take hundreds, perhaps even thousands, of years for either of the ice sheets to disappear entirely, but, once the disintegration was under way, it would start to feed on itself, most likely becoming irreversible. D.A.I. is understood, therefore, to refer not to the end of the process but to the very beginning, which is to say, to the point at which greenhouse-gas levels became high enough to set disaster in motion.

Among the stipulations of the Framework Convention was that the parties meet regularly to assess their progress. (These meetings became known as the Conference of the Parties, or C.O.P., sessions.) As it turned out, there was hardly any progress to assess. Article 4, paragraph 2, subparagraph b of the convention instructs industrialized nations to "aim" to reduce their greenhouse-gas emissions to 1990 levels. By 1995, the collective emissions from these nations were still rising. (Virtually the only countries that had succeeded in returning to 1990 levels were some former members of the Soviet bloc, and this was because their economies were in free fall.) Several rounds of often bitter negotiations followed, culminating in an eleven-day session at the Kyoto International Conference Hall in December, 1997.

Technically speaking, the agreement that emerged from that session is an addendum to the Framework Convention. (Its full title is the Kyoto Protocol to the United Nations Framework Convention on Climate Change.) For lofty exhortations, the Kyoto Protocol substitutes mandatory commitments. These commitments apply to industrialized, or so-called Annex 1, nations, a group that includes the United States, Canada, Japan, Europe, Australia, New Zealand, and several countries of the erstwhile Eastern bloc. Different Annex 1 nations have slightly different obligations, based on a combination of historical and political factors. The European Union nations, for example, are supposed to reduce their greenhouse-gas emissions eight per cent below 1990 levels. The U.S. has a target of seven per cent below 1990 levels, and Japan has a target of six per cent below. The treaty covers five greenhouse gases in addition to CO_2—methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride—which, for the purposes of accounting, are converted into units known as "carbon-dioxide equivalents." Industrialized nations can meet their targets, in part, by buying and selling emissions credits and by investing in "clean development" projects in developing, or so-called non-Annex 1, nations. This second group includes emergent industrial powers like China and India, oil-producing states like Saudi Arabia and Kuwait, and nations with mostly subsistence economies, like Sudan. Non-Annex 1 nations have no obligation to reduce their emissions during the period covered by the protocol, which ends in 2012.

In political terms, global warming might be thought of as the tragedy of the commons writ very, very large. The goal of stabilizing CO_2 concentrations effectively turns emissions into a limited resource, which nobody owns but everybody with a book of matches has access to.

Even as Kyoto was being negotiated, it was clear that the treaty was going to face stiff opposition in Washington. In July of 1997, Senator Chuck Hagel, Republican of Nebraska, and Senator Robert Byrd, Democrat of West Virginia, introduced a "sense of the Senate" resolution that, in effect, warned the Clinton Administration against the direction that the talks were taking. The so-called Byrd-Hagel Resolution stated that the U.S. should reject any agreement that committed it to reducing emissions unless concomitant obligations were imposed on developing countries as well. The Senate approved the resolution by a vote of 95-0, an outcome that reflected lobbying by both business and labor. Although the Clinton Administration eventually signed Kyoto, it never submitted the protocol to the Senate for ratification, citing the need for participation by "key developing nations."

From a certain perspective, the logic behind the Byrd-Hagel Resolution is unimpeachable. Emissions controls cost money, and this cost has to be borne by somebody. If the U.S. were to agree to limit its greenhouse gases while economic competitors like China and India were not, then American companies would be put at a disadvantage. "A treaty that requires binding commitments for reduction of emissions of greenhouse gases for the industrial countries but not developing countries will create a very damaging situation for the American economy" is how Richard Trumka, the secretary-treasurer of the A.F.L.-C.I.O., put it when he travelled to Kyoto to lobby against the protocol. It is also true that an agreement that limits carbon emissions in some countries and not in others could result in a migration, rather than an actual reduction, of CO_2 emissions. (Such a possibility is known in climate parlance as "leakage.")

From another perspective, however, the logic of Byrd-Hagel is deeply, even obscenely, self-serving. Suppose for a moment that the total anthropogenic CO_2 that can be emitted into the atmosphere were a big ice-cream cake. If the aim is to keep concentrations below five hundred parts per million, then roughly half that cake has already been consumed, and, of that half, the lion's share has been polished off by the industrialized world. To insist now that all countries cut their emissions simultaneously amounts to advocating that industrialized nations be allocated most of the remaining slices, on the ground that they've already gobbled up so much. In a year, the average American produces the same greenhouse-gas emissions as four and a half Mexicans, or eighteen Indians, or ninety-nine Bangladeshis. If both the U.S. and India were to reduce their emissions proportionately, then the average Bostonian could continue indefinitely producing eighteen times as much greenhouse gases as the average Bangalorean. But why should anyone have the right to emit more than anyone else? At a climate meeting in New Delhi three years ago, Atal Bihari Vajpayee, then the Indian prime minister, told world leaders, "Our per capita greenhouse gas emissions are only a fraction of the world average and an order of magnitude below that of many developed countries. We do not believe that the ethos of democracy can support any norm other than equal per capita rights to global environmental resources."

Outside the U.S., the decision to exempt developing nations from Kyoto's mandates was generally regarded as an adequate—if imperfect—solution. The point was to get the process started, and to persuade countries like China and India to sign on later. This "two-world" approach had been employed—successfully—in the nineteen-eighties to phase out chlorofluorocarbons, the chemicals responsible for depleting atmospheric ozone. Pieter van Geel, the Dutch environment secretary, who is a member of the Netherlands' center-right Christian Democratic Party, described the European outlook to me as follows: "We cannot say, 'Well, we have our wealth, based on the use of fossil fuels for the last three hundred years, and, now that your countries are growing, you may not grow at this rate, because we have a climate-change problem.' We should show moral leadership by giving the example. That's the only way we can ask something of these other countries."

The Kyoto Protocol finally went into effect on February 16th of this year. In many cities, the event was marked by celebration; the city of Bonn hosted a reception in the Rathaus, Oxford University held an "Entry Into Force" banquet, and in Hong Kong there was a Kyoto prayer meeting. As it happened, that day, an exceptionally warm one in Washington, D.C., I went to speak to the Under-Secretary of State for Global Affairs, Paula Dobriansky.

Dobriansky is a slight woman with shoulder-length brown hair and a vaguely anxious manner. Among her duties is explaining the Bush Administration's position on global warming to the rest of the world; in December, for example, she led the U.S. delegation to the tenth Conference of the Parties, which was held in Buenos Aires. Dobriansky began by assuring me that the Administration took the issue of climate change "very seriously." She went on, "Also let me just add, because in terms of taking it seriously, not only stating to you that we take it seriously, we have engaged many countries in initiatives and efforts, whether they are bilateral initiatives—we have some fourteen bilateral initiatives—and in addition we have put together some multilateral initiatives. So we view this as a serious issue."

Besides the U.S., the only other major industrialized nation that has rejected Kyoto—and, with it, mandatory cuts in emissions—is Australia. I asked Dobriansky how she justified the U.S.'s stance to its allies. "We have a common goal and objective as parties to the U. N. Framework Convention on Climate Change," she told me. "Where we differ is on what approach we believe is and can be the most effective."

Running for President in 2000, George W. Bush called global warming "an issue that we need to take very seriously." He promised, if elected, to impose federal limits on CO_2. Soon after his inauguration, he sent the head of the Environmental Protection Agency, Christine Todd Whitman, to a meeting of environment ministers from the world's leading industrialized nations, where she elaborated on his position. Whitman assured her colleagues that the new President believed global warming to be "one of the greatest environmental challenges that we face" and that he wanted to "take steps to move forward." Ten days after her presentation, Bush announced that not only was he withdrawing the U.S. from the ongoing negotiations over Kyoto—the protocol had left several complex issues of implementation to be resolved later—he was now opposed to any mandatory curbs on carbon dioxide. Explaining his change of heart, Bush asserted that he no longer believed that CO_2 limits were justified, owing to the "state of scientific knowledge of the causes of, and solutions to, global climate change," which he labelled "incomplete." (Former Treasury Secretary Paul O'Neill, who backed the President's original position, has speculated publicly that the reversal was engineered by Vice-President Dick Cheney.)

The following year, President Bush came forward with the Administration's current position on global warming. Central to this policy is a reworking of the key categories. Whereas Kyoto and the original Framework Convention aim at controlling greenhouse-gas emissions, the President's policy targets greenhouse-gas "intensity." Bush has declared his approach preferable because it recognizes "that a nation that grows its economy is a nation that can afford investments and new technology."

Greenhouse-gas intensity is not a quantity that can be measured directly. Rather, it is a ratio that relates emissions to economic output. Say, for example, that one year a business produces a hundred pounds of carbon and a hundred dollars' worth of goods. Its greenhouse-gas intensity in that case would be one pound per dollar. If the next year that company produces the same amount of carbon but an extra dollar's worth of goods, its intensity will have fallen by one per cent. Even if it doubles its total emissions of carbon, a company—or a country—can still claim a reduced intensity provided that it more than doubles its output of goods. (Typically, a country's greenhouse-gas intensity is measured in terms of tons of carbon per million dollars' worth of gross domestic product.)

To focus on greenhouse-gas intensity is to give a peculiarly sunny account of the United States' situation. Between 1990 and 2000, the U.S.'s greenhouse-gas intensity fell by some seventeen per cent, owing to several factors, including the shift toward a more service-based economy. Meanwhile, over-all emissions rose by some twelve per cent. (In terms of greenhouse-gas intensity, the U.S. actually performs better than many Third World nations, because even though we consume a lot more energy, we also have a much larger G.D.P.) In February of 2002, President Bush set the goal of reducing the country's greenhouse-gas intensity by eighteen per cent over the following ten years. During that same decade, the Administration expects the American economy to grow by three per cent annually. If both expectations are met, over-all emission of greenhouse gases will rise by about twelve per cent.

The Administration's plan, which relies almost entirely on voluntary measures, has been characterized by critics as nothing more than a subterfuge—"a total charade" is how Philip Clapp, the president of the Washington-based National Environmental Trust, once put it. Certainly, if the goal is to prevent "dangerous anthropogenic interference," then greenhouse-gas intensity is the wrong measure to use. (Essentially, the President's approach amounts to following the path of "business as usual.") The Administration's response to such criticism is to attack its premise. "Science tells us that we cannot say with any certainty what constitutes a dangerous level of warming and therefore what level must be avoided," Dobriansky declared recently. When I asked her how, in that case, the U.S. could support the U.N. Framework Convention's aim of averting D.A.I., she answered by saying—twice—"We predicate our policies on sound science."

Earlier this year, the chairman of the Senate Environment and Public Works Committee, James Inhofe, gave a speech on the Senate floor, which he entitled "An Update on the Science of Climate Change." In the speech, Inhofe, an Oklahoma Republican, announced that "new evidence" had come to light that "makes a mockery" of the notion that human-induced warming is occurring. The Senator, who has called global warming "the greatest hoax ever perpetrated on the American people," went on to argue that this important new evidence was being suppressed by "alarmists" who view anthropogenic warming as "an article of religious faith." One of the authorities that Inhofe repeatedly cited in support of his claims was the fiction writer Michael Crichton.

It was an American scientist, Charles David Keeling, who, in the nineteen-fifties, developed the technology to measure CO_2 levels precisely, and it was American researchers who, working out of Hawaii's Mauna Loa Observatory, first showed that these levels were steadily rising. In the half century since then, the U.S. has contributed more than any other nation to the advancement of climate science, both theoretically, through the work of climate modellers, and experimentally, through field studies conducted on every continent.

At the same time, the U.S. is also the world's chief purveyor of the work of so-called global-warming "skeptics." The ideas of these skeptics are published in books with titles like "The Satanic Gases" and "Global Warming and Other Eco-Myths" and then circulated on the Web by groups like Tech Central Station, which is sponsored by, among others, ExxonMobil and General Motors. While some skeptics' organizations argue that global warming isn't real, or at least hasn't been proved—"Predicting *weather* conditions a day or two in advance is hard enough, so just imagine how hard it is to forecast what our *climate* will be," Americans for Balanced Energy Choices, a lobbying organization funded by mining and power companies, declares on its Web site—others maintain that rising CO_2 levels are actually cause for celebration.

"Carbon dioxide emissions from fossil fuel combustion are beneficial to life on earth," the Greening Earth Society, an organization created by the Western Fuels Association, a utility group, states. Atmospheric levels of seven hundred and fifty parts per million—nearly triple pre-industrial levels—are nothing to worry about, the society maintains, because plants like lots of CO_2, which they need for photosynthesis. (Research on this topic, the group's Web site acknowledges, has been "frequently denigrated," but "it's exciting stuff" and provides an "antidote to gloom-and-doom about potential changes in earth's climate.")

In legitimate scientific circles, it is virtually impossible to find evidence of disagreement over the fundamentals of global warming. This fact was neatly demonstrated last year by Naomi Oreskes, a professor of history and science studies at the University of California at San Diego. Oreskes conducted a study of the more than nine hundred articles on climate change published in refereed journals between 1993 and 2003 and subsequently made available on a leading research database. Of these, she found that seventy-five per cent endorsed the view that anthropogenic emissions were responsible for at least some of the observed warming of the past fifty years. The remaining twenty-five per cent, which dealt with questions of methodology or climate history, took no position on current conditions. Not a single article disputed the premise that anthropogenic warming is under way.

Still, pronouncements by groups like the Greening Earth Society and politicians like Senator Inhofe help to shape public discourse on climate change in this country. And this is clearly their point. A few years ago, the pollster Frank Luntz prepared a strategy memo for Republican members of Congress, coaching them on how to deal with a variety of environmental issues. (Luntz, who first made a name for himself by helping to craft Newt Gingrich's "Contract with America," has been described as "a political consultant viewed by Republicans as King Arthur viewed Merlin.") Under the heading "Winning the Global Warming Debate," Luntz wrote, "The scientific debate is closing (against us) but not yet closed. There is still a window of opportunity to challenge the science." He warned, "Voters believe that there is *no consensus* about global warming in the scientific community. Should the public come to believe that the scientific issues are settled, their views about global warming will change accordingly." Luntz also advised, "The most important principle in any discussion of global warming is your commitment to sound science."

It is in this context, and really only in this context, that the Bush Administration's conflicting claims about the science of global warming make any sense. Administration officials are quick to point to the scientific uncertainties that remain about global warming, of which there are many. But where there is broad scientific agreement they are reluctant to acknowledge it. "When we make decisions, we want to make sure we do so on sound science," the President said, announcing his new approach to global warming in February, 2002. Just a few months later, the Environmental Protection Agency delivered a two-hundred-and-sixty-three-page report to the U.N. which stated that "continuing growth in greenhouse gas emissions is likely to lead to annual average warming over the United States that could be as much as several degrees Celsius (roughly 3 to 9 degrees Fahrenheit) during the 21st century." The President dismissed the report—the product of years of work by federal researchers—as something "put out by the bureaucracy." The following spring, the E.P.A. made another effort to give an objective summary of climate science, in a report on the state of the environment. The White House interfered so insistently in the writing of the global-warming section—at one point, it tried to insert excerpts from a study partly financed by the American Petroleum Institute—that, in an internal memo, agency staff members complained that the section "no longer accurately represents scientific consensus." (When the E.P.A. finally published the report, the climate-science section was missing entirely.) Just two months ago, a top official with the federal Climate Change Science Program announced that he was resigning, owing to differences with the White House. The official, Rick Piltz, said that he was disturbed that the Administration insisted on vetting climate-science reports, "rather than asking independent scientists to write them and let the chips fall where they may."

The day after the Kyoto Protocol took effect, I went to the United Nations to attend a conference entitled, appositely, "One Day After Kyoto." The conference, whose subtitle was "Next Steps on Climate," was held in a large room with banks of curved desks, each equipped with a little plastic earpiece. The speakers included scientists, insurance-industry executives, and diplomats from all over the world, among them the U.N. Ambassador from the tiny Pacific island nation of Tuvalu, who described how his country was in danger of simply disappearing. Britain's permanent representative to the U.N., Sir Emyr Jones Parry, began his remarks to the crowd of two hundred or so by stating, "We can't go on as we are."

When the U.S. withdrew from negotiations over Kyoto, in 2001, the entire effort nearly collapsed. According to the protocol's elaborate ratification mechanism, in order to take effect it had to be approved by countries responsible for at least fifty-five per cent of the industrialized world's CO_2 emissions. All on its own, America accounts for thirty-four per cent of those emissions. European leaders spent more than three years working behind the scenes, lining up support from the remaining industrialized nations. The crucial threshold was finally crossed this past October, when the Russian Duma voted in favor of ratification. The Duma's vote was understood to be a condition of European backing for Russia's bid to join the World Trade Organization. ("RUSSIA FORCED TO RATIFY KYOTO PROTOCOL TO BECOME W.T.O. MEMBER," read the headline in *Pravda*.)

As speaker after speaker at the U.N. conference noted, Kyoto is only the first step in a long process. Even if every country—including the U.S.—were to fulfill its obligations under the protocol before it lapses in 2012, CO_2 concentrations in the atmosphere would still reach dangerous levels. Kyoto merely delays this outcome. The "next step on climate" requires, among other things, substantive commitments from countries like China and India. So long as U.S. emissions continue to grow, essentially unchecked, obtaining these commitments seems next to impossible. In this way, the U.S., having failed to defeat Kyoto, may be in the process of doing something even more damaging: ruining the chances of reaching a post-Kyoto agreement. "The blunt reality is that, unless America comes back into some form of international consensus, it is very hard to make progress" is how Britain's Prime Minister, Tony Blair, diplomatically put it at a recent press conference.

Astonishingly, standing in the way of progress seems to be Bush's goal. Paula Dobriansky explained the Administration's position to me as follows: While the rest of the industrialized world is pursuing one strategy (emissions limits), the U.S. is pursuing another (no emissions limits), and it is still too early to say which approach will work best. "It is essential to really implement these programs and approaches now and to take stock of their effectiveness," she said, adding, "We think it is premature to talk about future arrangements." At C.O.P.-10, in Buenos Aires, many delegations pressed for a preliminary round of meetings so that work could start on mapping out Kyoto's successor. The U.S. delegation opposed these efforts so adamantly that finally the Americans were asked to describe, in writing, what sort of meeting they would find acceptable. They issued half a page of conditions, one of which was that the session "shall be a one-time event held during a single day." Another condition was, paradoxically, that, if they were going to discuss the future, the future would have to be barred from discussion; presentations, they wrote, should be limited to "an information exchange" on "existing national policies." Annie Petsonk, a lawyer with the advocacy group Environmental Defense, who previously worked for the Administration of George Bush, Sr., attended the talks in Buenos Aires. She recalled the effect that the memo had on the members of the other delegations: “They were ashen.”

European leaders have made no secret of their dismay at the Administration’s stance. “It’s absolutely obvious that global warming has started,” France’s President, Jacques Chirac, said after attending last year’s G-8 summit with Bush. “And so we have to act responsibly, and, if we do nothing, we would bear a heavy responsibility. I had the chance to talk to the United States President about this. To tell you that I convinced him would be a total exaggeration, as you can imagine.” Blair, who currently holds the presidency of the G-8, recently warned that only “timely action” on climate change will avert “disaster.” He has promised to make the issue one of the top items on the agenda of this year’s summit, to be held in Scotland in July, but no one seems to be expecting a great deal to come of it. While attending a meeting in London this spring, the head of the White House Council on Environmental Quality, James Connaughton, announced that he wasn’t yet convinced that anthropogenic warming was a problem. “We are still working on the issue of causation, the extent to which humans are a factor,” he said.

The town of Maasbommel, sixty miles southeast of Amsterdam, is a popular tourist destination along the banks of the River Meuse. Every summer, it is visited by thousands of people who come to go boating and camping. Thanks to the risk of flooding, building is restricted along the river, but a few years ago one of the Netherlands’ largest construction firms, Dura Vermeer, received permission to turn a former R.V. park into a development of “amphibious homes.” The first of these were completed last fall, and a few months later I went to see them.

The amphibious homes all look alike. They are tall and narrow, with flat sides and curved metal roofs, so that, standing next to one another, they resemble a row of toasters. Each one is moored to a metal pole and sits on a set of hollow concrete pontoons. Assuming that all goes according to plan, when the Meuse floods the homes will bob up and then, when the water recedes, they will gently be deposited back on land. Dura Vermeer is also working to construct buoyant roads and floating greenhouses. While each of these projects represents a somewhat different engineering challenge, they have a common goal, which is to allow people to continue to inhabit areas that, periodically at least, will be inundated. The Dutch, because of their peculiar vulnerability, can’t afford to misjudge climate change, or to pretend that by denying it they can make it go away. “There is a flood market emerging,” Chris Zevenbergen, Dura Vermeer’s environmental director, told me. Half a dozen families were already occupying their amphibious homes when I visited Maasbommel. Anna van der Molen, a nurse and mother of four, gave me a tour of hers. She said that she expected that in the future people all over the world would live in floating houses, since, as she put it, “the water is coming up.”

Resourcefulness and adaptability are, of course, essential human qualities. People are always imagining new ways to live, and then figuring out ways to remake the world to suit what they’ve imagined. This capacity has allowed us, collectively, to overcome any number of threats in the past, some imposed by nature, some by ourselves. It could be argued, taking this long view, that global warming is just one more test in a sequence that already stretches from plague and pestilence to the prospect of nuclear annihilation. If, at this moment, the bind that we’re in appears insoluble, once we’ve thought long and hard enough about it we’ll find—or maybe float—our way clear.

But it’s also possible to take an even longer view of the situation. We now have detailed climate records going back four full glacial cycles. What these records show, in addition to a clear correlation between CO_2 levels and global temperatures, is that the last glaciation was a period of frequent and traumatic climate swings. During that period, which lasted nearly a hundred thousand years, humans who were, genetically speaking, just like ourselves wandered the globe, producing nothing more permanent than isolated cave paintings and large piles of mastodon bones. Then, ten thousand years ago, at the start of the Holocene, the climate changed. As the weather settled down, so did we. People built villages, towns, and, finally, cities, along the way inventing all the basic technologies—agriculture, metallurgy, writing—that future civilizations would rely upon. These developments would not have been possible without human ingenuity, but, until the climate coöperated, ingenuity, it seems, wasn't enough.

Climate records also show that we are steadily drawing closer to the temperature peaks of the last interglacial, when sea levels were some fifteen feet higher than they are today. Just a few degrees more and the earth will be hotter than it has been at any time since our species evolved. Scientists have identified a number of important feedbacks in the climate system, many of which are not fully understood; in general, they tend to take small changes to the system and amplify them into much larger forces. Perhaps we are the most unpredictable feedback of all. No matter what we do at this point, global temperatures will continue to rise in the coming decades, owing to the gigatons of extra CO_2 already circulating in the atmosphere. With more than six billion people on the planet, the risks of this are obvious. A disruption in monsoon patterns, a shift in ocean currents, a major drought—any one of these could easily produce streams of refugees numbering in the millions. As the effects of global warming become more and more apparent, will we react by finally fashioning a global response? Or will we retreat into ever narrower and more destructive forms of self-interest? It may seem impossible to imagine that a technologically advanced society could choose, in essence, to destroy itself, but that is what we are now in the process of doing. ✦

(*This is the third part of a three-part article.*)