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The
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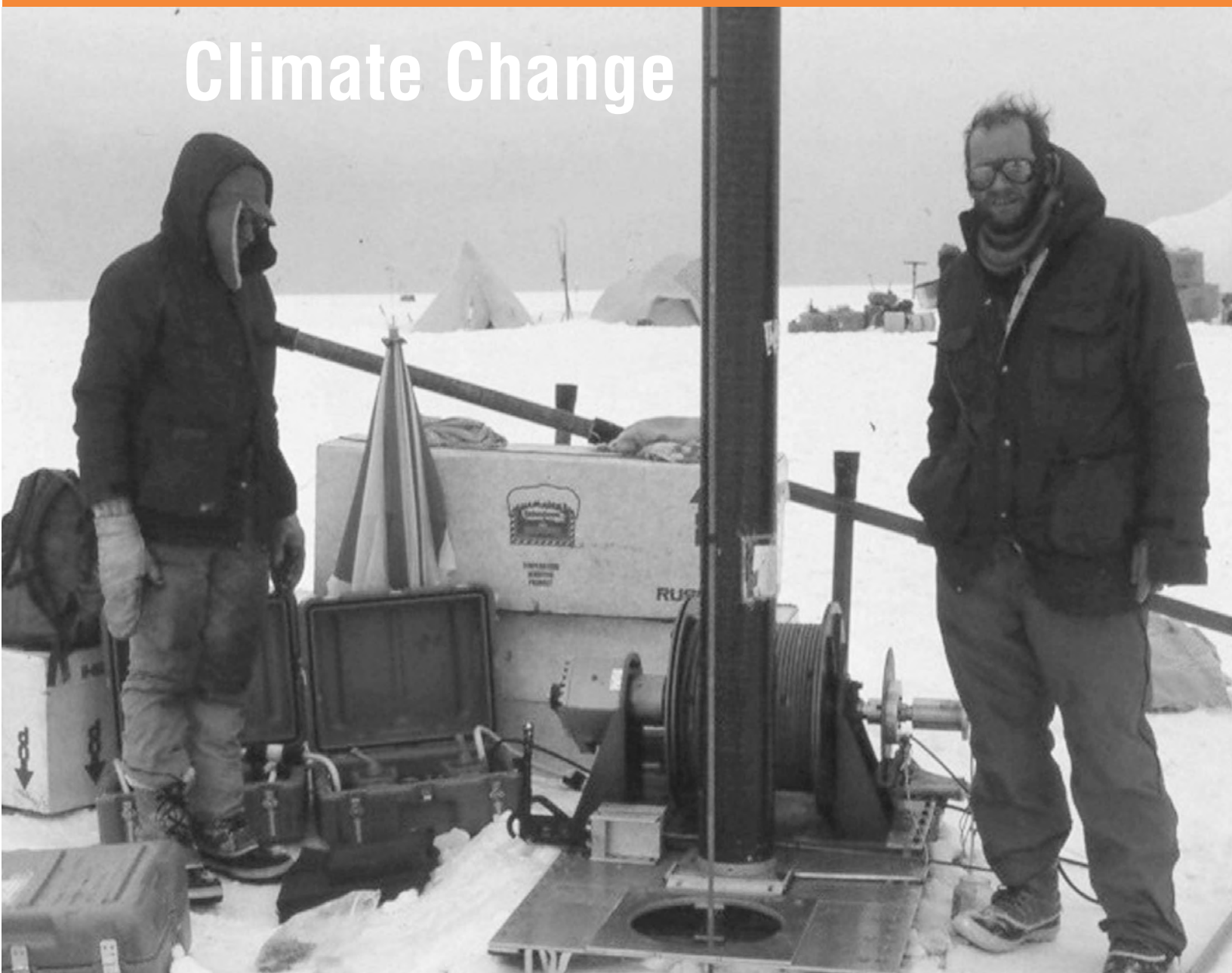
Climate Change



In Memory of

Dr. Jeff Jack, Director of the KIESD Center for Environmental Science, was tragically killed in an automobile accident January 1, 2007. Jeff was a tenured faculty member in the Department of Biology since 1998 and was named the Tom Wallace Chair in Conservation Biology in 2006. His work in micro- and macro-zooplankton, stream restoration, and large river ecology was recognized nationally. His expertise was highly regarded and he was frequently sought to work on water quality issues statewide. Masters and doctoral students interested in water quality issues selected him to be their advisor. He supervised 22 Masters and PhD students. Jeff understood the value of interdisciplinary research and collaborated with faculty from across campus.

He leaves a family of two girls, Amanda and Gracelyn, and his wife Elaine.

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The Kentucky Institute for the Environment and Sustainable Development (KIESD) was created in July 1992 within the Office of the Vice President for Research, University of Louisville.

The Institute provides a forum to conduct interdisciplinary research, applied scholarly analysis, public service and educational outreach on environmental and sustainable development issues at the local, state, national and international levels.

KIESD is comprised of eight thematic program centers: Environmental Education, Environmental Science, Environmental Law, Sustainable Urban Neighborhoods, Pollution Prevention, Environmental and Occupational Health Sciences, Environmental Policy and Management, and Environmental Engineering.

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Cover: An ice core is recovered from the summit of the Dunde Ice Cap on the Tibetan Plateau in western China. Keith Mountain (right) and colleague Bruce Koci operate the drill on the 18,000 foot summit. The ice core was returned to the Byrd Polar Research Center at the Ohio State University for analysis and yielded a 15,000 year climate record for the northern Tibetan Plateau.

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The Threat to the Planet

By Jim Hansen
Goddard Space Institute
National Aeronatic and Space Administration

1. Animals are on the run. Plants are migrating too. The Earth's creatures, save for one species, do not have thermostats in their living rooms that they can adjust for an optimum environment. Animals and plants are adapted to specific climate zones, and they can survive only when they are in those zones. Indeed, scientists often define climate zones by the vegetation and animal life that they support. Gardeners and bird watchers are well aware of this, and their handbooks contain maps of the zones in which a tree or flower can survive and the range of each bird species.

Those maps will have to be redrawn. Most people, mainly aware of larger day-to-day fluctuations in the weather, barely notice that climate, the average weather, is changing. In the 1980s I started to use colored dice that I hoped would help people understand global warming at an early stage. Of the six sides of the dice only two sides were red, or hot, representing the probability of having an unusually warm season during the years between 1951 and 1980. By the first decade of the twenty-first century, four sides were red. Just such an increase in the frequency of unusually warm seasons, in fact, has occurred. But most people —who have other things on their minds and can use thermostats—have taken little notice.

If human beings follow a business-as-usual course, continuing to exploit fossil fuel resources without reducing carbon emissions or capturing and sequestering them before they warm the atmosphere, the eventual effects on climate and life may be comparable to those at the time of mass extinctions.

Animals have no choice, since their survival is at stake. Recently after appearing on television to discuss climate change, I received an e-mail from a man in northeast Arkansas: "I enjoyed your report on Sixty Minutes and commend your strength. I would like to tell you of an observation I have made. It is the armadillo. I had not seen one of these animals my entire life, until the last ten years. I drive the same forty-mile trip on the same road every day and have slowly watched these critters advance further north every year and they are not stopping. Every year they move several miles."

Armadillos appear to be pretty tough. Their mobility suggests that they have a good chance to keep up with the movement of their climate zone, and to be one of the surviving species. Of course, as they reach the city limits of St. Louis and Chicago, they may not be welcome. And their ingenuity may be taxed as they seek ways to ford rivers and multiple-lane highways.

Problems are greater for other species, as Tim Flannery, a well-known Australian mammalogist and conservationist, makes clear in *The Weather Makers*. Ecosystems are based on interdependencies—between, for example, flower and pollinator, hunter and hunted, grazers and plant life—so the less mobile species have an impact on the survival of others. Of course climate fluctuated in the past, yet species adapted and flourished. But now the rate of climate change driven by human activity is reaching a level that dwarfs natural rates of change. And barriers created by human beings, such as urban sprawl and homogeneous agricultural fields, block many migration routes. If climate change is too great, natural barriers, such as coastlines, spell doom for some species.

Studies of more than one thousand species of plants, animals, and insects, including butterfly ranges charted by members of the public, found an average migration rate toward the North and South Poles of about four miles per decade in the second half of the twentieth century. That is not fast enough. During the past thirty years the lines marking the regions in which a given average temperature prevails ("isotherms") have been moving poleward at a rate of about thirty-five miles per decade. That is the size of a county in Iowa. Each decade the range of a given species is moving one row of counties northward.

As long as the total movement of isotherms toward the poles is much smaller than the size of the habitat, or the ranges in which the animals live, the effect on species is limited. But now the movement is inexorably toward the poles and totals more than a hundred miles over the past several decades. If emissions of greenhouse gases continue to increase at the current rate—"business as usual"—then the rate of isotherm movement will double in this century to at least seventy miles per decade. If we continue on this path, a large fraction of the species on Earth, as many as 50 percent or more, may become extinct.

The species most at risk are those in polar climates and the biologically diverse slopes of alpine regions. Polar animals, in effect, will be pushed off the planet. Alpine species will be pushed toward higher altitudes, and toward smaller, rockier areas with thinner air; thus, in effect, they will also be pushed off the planet. A few such species, such as polar bears, no doubt will be "rescued" by human beings, but survival in zoos or managed animal reserves will be small consolation to bears or nature lovers.

In the Earth's history, during periods when average global temperatures increased by as much as ten degrees Fahrenheit, there have been several "mass extinctions," when between 50 and 90 percent of the species on Earth disappeared forever. In each case, life survived and new species developed over hundreds of thousands of years. The most recent of these mass extinctions defines the boundary, 55 million years ago, between the Paleocene and Eocene epochs. The evolutionary turmoil associated with that climate change gave rise to a host of modern mammals, from rodents to primates, which appear in fossil records for the first time in the early Eocene.

If human beings follow a business-as-usual course, continuing to exploit fossil fuel resources without reducing carbon emissions or capturing and sequestering them before they warm the atmosphere, the eventual effects on climate and life may be comparable to those at the time of mass extinctions. Life will survive, but it will do so on a transformed planet. For all foreseeable human generations, it will be a far more desolate world than the one in which civilization developed and flourished during the past several thousand years.

2. The greatest threat of climate change for human beings, I believe, lies in the potential destabilization of the massive ice sheets in Greenland and Antarctica. As with the extinction of species, the disintegration of ice sheets is irreversible for practical purposes. Our children, grandchildren, and many more generations will bear the consequences of choices that we make in the next few years.

The level of the sea throughout the globe is a reflection primarily of changes in the volume of ice sheets and thus of changes of global temperature. When the planet cools, ice sheets grow on continents and the sea level falls. Conversely, when the Earth warms, ice melts and the sea level rises. In *Field Notes from a Catastrophe*, Elizabeth Kolbert reports on the work of researchers trying to understand the acceleration of melting, and in his new book and film *An Inconvenient Truth*, Al Gore graphically illustrates possible effects of a rising sea level on Florida and other locations.

Ice sheets waxed and waned as the Earth cooled and warmed over the past 500,000 years. During the coldest ice ages, the Earth's average temperature was about ten degrees Fahrenheit colder than today. So much water was locked in the largest ice sheet, more than a mile thick and covering most of Canada and northern parts of the United States, that the sea level was 400 feet lower than today. The warmest interglacial periods were about two degrees Fahrenheit warmer than today and the sea level was as much as sixteen feet higher.

Future rise in the sea level will depend, dramatically, on the increase in greenhouse gases, which will largely determine the amount of global warming. As described in the books under review, sunlight enters the atmosphere and warms the Earth, and then is sent back into space as heat radiation. Greenhouse gases trap this heat in the atmosphere and thereby warm the Earth's surface as we are warmed when blankets are piled on our bed. Carbon dioxide (CO2), produced mainly by burning fossil fuels (coal, oil, and gas), is the most important greenhouse gas made by human beings. Methane (CH4), which is "natural gas" that escapes to the atmosphere from coal mines, oil wells, rice paddies, landfills, and animal feedlots, is also an important greenhouse gas. Other significant warming agents are ground-level ozone and black soot, which arise mainly from incomplete combustion of fossil fuels and biofuels.

In order to arrive at an effective policy we can project two different scenarios concerning climate change. In the business-as-usual scenario, annual emissions of CO2 continue to increase at the current rate for at least fifty years, as do non-CO2 warming agents including methane, ozone, and black soot. In the alternative scenario, CO2 emissions level off this decade, slowly decline for a few decades, and by mid-century decrease rapidly, aided by new technologies.

The business-as-usual scenario yields an increase of about five degrees Fahrenheit of global warming during this century, while the alternative scenario yields an increase of less than two degrees Fahrenheit during the same period. Warming can be predicted accurately based on knowledge of how Earth responded to similar levels of greenhouse gases in the past. (By drilling into glaciers to analyze air bubbles trapped under layers of snow, scientists can measure the levels of each gas in the atmosphere hundreds of thousands of years ago. By comparing the concentrations of different isotopes of oxygen in these air bubbles, they can measure the average temperature of past centuries.) Climate models by themselves yield similar answers. However, the evidence from the Earth's history provides a more precise and sensitive measure, and we know that the real world accurately included the effects of all feedback processes, such as changes of clouds and water vapor, that have an effect on temperature.

How much will sea level rise with five degrees of global warming? Here too, our best information comes from the Earth's history. The last time that the

Earth was five degrees warmer was three million years ago, when sea level was about eighty feet higher.

Eighty feet! In that case, the United States would lose most East Coast cities: Boston, New York, Philadelphia, Washington, and Miami; indeed, practically the entire state of Florida would be under water. Fifty million people in the US live below that sea level. Other places would fare worse. China would have 250 million displaced persons. Bangladesh would produce 120 million refugees, practically the entire nation. India would lose the land of 150 million people.

A rise in sea level, necessarily, begins slowly. Massive ice sheets must be softened and weakened before rapid disintegration and melting occurs and the sea level rises. It may require as much as a few centuries to produce most of the long-term response. But the inertia of ice sheets is not our ally against the effects of global warming. The Earth's history reveals cases in which sea level, once ice sheets began to collapse, rose one meter (1.1 yards) every twenty years for centuries. That would be a calamity for hundreds of cities around the world, most of them far larger than New Orleans. Devastation from a rising sea occurs as the result of local storms which can be expected to cause repeated retreats from transitory shorelines and rebuilding away from them.

Satellite images and other data have revealed the initial response of ice sheets to global warming. The area on Greenland in which summer melting of ice took place increased more than 50 percent during the last twenty-five years. Meltwater descends through crevasses to the ice sheet base, where it provides lubrication that increases the movement of the ice sheet and the discharge of giant icebergs into the ocean. The volume of icebergs from Greenland has doubled in the last ten years. Seismic stations reveal a shocking increase in "icequakes" on Greenland, caused by a portion of an ice sheet lurching forward and grinding to a halt. The annual number of these icequakes registering 4.6 or greater on the Richter scale doubled from 7 in 1993 to 14 in the late 1990s; it doubled again by 2005. A satellite that measures minute changes in Earth's gravitational field found the mass of Greenland to have decreased by 50 cubic miles of ice in 2005. West Antarctica's mass decreased by a similar amount.

The effect of this loss of ice on the global sea level is small, so far, but it is accelerating. The likelihood of the sudden collapse of ice sheets increases as global warming continues. For example, wet ice is darker, absorbing more sunlight, which increases the melting rate of the ice. Also, the warming ocean melts the offshore accumulations of ice—"ice shelves"—that form a barrier between the ice sheets and the ocean. As the ice shelves melt, more icebergs are discharged from the ice sheets into the ocean. And as the ice sheet discharges more icebergs into the ocean and loses mass, its surface sinks to a lower level where the temperature is warmer, causing it to melt faster.

The business-as-usual scenario, with five degrees Fahrenheit global warming and ten degrees Fahrenheit at the ice sheets, certainly would cause the disintegration of ice sheets. The only question is when the collapse of these sheets would begin. The business-as-usual scenario, which could lead to an eventual sea level rise of eighty feet, with twenty feet or more per century, could produce global chaos, leaving fewer resources with which to mitigate the change in climate. The alternative scenario, with global warming under two degrees Fahrenheit, still produces a significant rise in the sea level, but its slower rate, probably less than a few feet per century, would allow time to develop strategies that would adapt to, and mitigate, the rise in the sea level.

3. Both the Department of Energy and some fossil fuel companies insist that continued growth of fossil fuel use and of CO2 emissions are facts that cannot be altered to any great extent. Their prophecies become self-fulfilling, with the help of government subsidies and intensive efforts by special interest groups to prevent the public from becoming well-informed.

In reality, an alternative scenario is possible and makes sense for other reasons, especially in the US, which has become an importer of energy, hemorrhaging wealth to foreign nations in order to pay for it. In response to oil shortages and price rises in the 1970s, the US slowed its growth in energy use mainly by requiring an increase from thirteen to twenty-four miles per gallon in the standard of auto efficiency. Economic growth was decoupled from growth in the use of fossil fuels and the gains in efficiency were felt worldwide. Global growth of CO2 emissions slowed from more than 4 percent each year to between 1 and 2 percent growth each year.

This slower growth rate in fossil fuel use was maintained despite lower energy prices. The US is still only half as efficient in its use of energy as Western Europe, i.e., the US emits twice as much CO2 to produce a unit of GNP, partly because Europe encourages efficiency by fossil fuel taxes. China and India, using older technologies, are less energy-efficient than the US and have a higher rate of CO2 emissions.

Available technologies would allow great improvement of energy efficiency, even in Europe. Economists agree that the potential could be achieved most effectively by a tax on carbon emissions, although strong political leadership would be needed to persuasively explain the case for such a tax to the public. The tax could be revenue-neutral, i.e., it could also provide for tax credits or tax decreases for the public generally, leaving government rev-

enue unchanged; and it should be introduced gradually. The consumer who makes a special effort to save energy could gain, benefiting from the tax credit or decrease while buying less fuel; the well-to-do consumer who insisted on having three Hummers would pay for his own excesses.

Achieving a decline in CO2 emissions faces two major obstacles: the huge number of vehicles that are inefficient in their use of fuel and the continuing CO2 emissions from power plants. Auto makers oppose efficiency standards and prominently advertise their heaviest and most powerful vehicles, which yield the greatest short-term profits. Coal companies want new coal-fired power plants to be built soon, thus assuring long-term profits.

The California legislature has passed a regulation requiring a 30 percent reduction in automobile greenhouse gas emissions by 2016. If adopted nationwide, this regulation would save more than $150 billion annually in oil imports. In thirty-five years it would save seven times the amount of oil estimated by the US Geological Services to exist in the Arctic National Wildlife Refuge. By fighting it in court, automakers and the Bush administra-tion have stymied the California law, which many other states stand ready to adopt. Further reductions of emissions would be possible by means of technologies now being developed. For example, new hybrid cars with larger batteries and the ability to plug into wall outlets will soon be available; and cars whose bodies are made of a lightweight carbon composite would get better mileage.

If power plants are to achieve the goals of the alternative scenario, construction of new coal-fired power plants should be delayed until the technology needed to capture and sequester their CO2 emissions is available. In the interim, new electricity requirements should be met by the use of renewable energies such as wind power as well as by nuclear power and other sources that do not produce CO2. Much could be done to limit emissions by improving the standards of fuel efficiency in buildings, lighting, and appliances. Such improvements are entirely possible, but strong leadership would be required to bring them about. The most effective action, as I have indicated, would be a slowly increasing carbon tax, which could be revenue-neutral or would cover a portion of the costs of mitigating climate change.

The alternative scenario I have been referring to has been designed to be consistent with the Kyoto Protocol, i.e., with a world in which emissions from developed countries would decrease slowly early in this century and the developing countries would get help to adopt "clean" energy technologies that would limit the growth of their emissions. Delays in that approach—especially US refusal both to participate in Kyoto and to improve vehicle and power plant efficiencies—and the rapid growth in the use of dirty technologies have resulted in an increase of 2 percent per year in global CO2 emissions during the past ten years. If such growth continues for another decade, emissions in 2015 will be 35 percent greater than they were in 2000, making it impractical to achieve results close to the alternative scenario.

The situation is critical, because of the clear difference between the two scenarios I have projected. Further global warming can be kept within limits (under two degrees Fahrenheit) only by means of simultaneous slowdown of CO2 emissions and absolute reduction of the principal non-CO2agents of global warming, particularly emissions of methane gas. Such methane emissions are not only the second-largest human contribution to climate change but also the main cause of an increase in ozone—the third-largest human-produced greenhouse gas—in the troposphere, the lowest part of the Earth's atmosphere. Practical methods can be used to reduce human sources of methane emission, for example, at coal mines, landfills, and waste management facilities. However, the question is whether these reductions will be overwhelmed by the release of frozen methane hydrates—the ice-like crystals in which large deposits of methane are trapped—if permafrost melts.

If both the slowdown in CO2 emissions and reductions in non-CO2 emissions called for by the alternative scenario are achieved, release of "frozen methane" should be moderate, judging from prior interglacial periods that were warmer than today by one or two degrees Fahrenheit. But if CO2 emissions are not limited and further warming reaches three or four degrees Fahrenheit, all bets are off. Indeed, there is evidence that greater warming could release substantial amounts of methane in the Arctic. Much of the ten-degree Fahrenheit global warming that caused mass extinctions, such as the one at the Paleocene-Eocene boundary, appears to have been caused by release of "frozen methane." Those releases of methane may have taken place over centuries or millennia, but release of even a significant fraction of the methane during this century could accelerate global warming, preventing achievement of the alternative scenario and possibly causing ice sheet disintegration and further long-term methane release that are out of our control.

Any responsible assessment of environmental impact must conclude that further global warming exceeding two degrees Fahrenheit will be dangerous. Yet because of the global warming already bound to take place as a result of the continuing long-term effects of greenhouse gases and the energy systems now in use, the two-degree Fahrenheit limit will be exceeded unless a change in direction can begin during the current decade. Unless this fact is widely communicated, and decision-makers are responsive, it will soon be impossible to avoid climate change with far-ranging undesirable consequences. We have reached a critical tipping point.

4. The public can act as our planet's keeper, as has been shown in the past. The first human-made atmospheric crisis emerged in 1974, when the chemists Sherry Rowland and Mario Molina reported that chlorofluorocarbons (CFCs) might destroy the stratospheric ozone layer that protects animal and plant life from the sun's harmful ultraviolet rays. How narrowly we escaped disaster was not realized until years later.

CFC appeared to be a marvelous inert chemical, one so useful as an aerosol propellant, fire suppressor, and refrigerant fluid that CFC production increased 10 percent per year for decades. If this business-as-usual growth of CFCs had continued just one more decade, the stratospheric ozone layer would have been severely depleted over the entire planet and CFCs themselves would have caused a larger greenhouse effect than CO2.

Instead, the press and television reported Rowland and Molina's warning widely. The public, responding to the warnings of environmental groups, boycotted frivolous use of CFCs as propellants for hair spray and deodorant, and chose non-CFC products instead. The annual growth of CFC usage plummeted immediately from 10 percent to zero. Thus no new facilities to produce CFCs were built. The principal CFC manufacturer, after first questioning the scientific evidence, developed alternative chemicals. When the use of CFCs for refrigeration began to increase and a voluntary phaseout of CFCs for that purpose proved ineffective, the US and European governments took the lead in negotiating the Montreal Protocol to control the production of CFCs. Developing countries were allowed to increase the use of CFCs for a decade and they were given financial assistance to construct alternative chemical plants. The result is that the use of CFCs is now decreasing, the ozone layer was damaged but not destroyed, and it will soon be recovering.

Why are the same scientists and political forces that succeeded in controlling the threat to the ozone layer now failing miserably to deal with the global warming crisis? Though we depend on fossil fuels far more than we ever did on CFCs, there is plenty of blame to go around. Scientists present the facts about climate change clinically, failing to stress that business-as-usual will transform the planet. The press and television, despite an overwhelming scientific consensus concerning global warming, give equal time to fringe "contrarians" supported by the fossil fuel industry. Special interest groups mount effective disinformation campaigns to sow doubt about the reality of global warming. The government appears to be strongly influenced by special interests, or otherwise confused and distracted, and it has failed to provide leadership. The public is understandably confused or uninterested.

I used to spread the blame uniformly until, when I was about to appear on public television, the producer informed me that the program "must" also include a "contrarian" who would take issue with claims of global warming. Presenting such a view, he told me, was a common practice in commercial television as well as radio and newspapers. Supporters of public TV

WHAT WE MUST DO

Flannery concludes, as I have, that we have only a short time to address global warming before it runs out of control. However, his call for people to reduce their CO2 emissions, while appropriate, oversimplifies and diverts attention from the essential requirement: government leadership. Without such leadership and comprehensive economic policies, conservation of energy by individuals merely reduces demands for fuel, thus lowering prices and ultimately promoting the wasteful use of energy. I was glad to see that in a recent article in these pages, he wrote that an effective fossil energy policy should include a tax on carbon emissions.[2]

A good energy policy, economists agree, is not difficult to define. Fuel taxes should encourage conservation, but with rebates to taxpayers so that the government revenue from the tax does not increase. The taxpayer can use his rebate to fill his gas-guzzler if he likes, but most people will eventually reduce their use of fuel in order to save money, and will spend the rebate on something else. With slow and continual increases of fuel cost, energy consumption will decline. The economy will not be harmed. Indeed, it will be improved since the trade deficit will be reduced; so will the need to protect US access to energy abroad by means of diplomatic and military action. US manufacturers would be forced to emphasize energy efficiency in order to make their products competitive internationally. Our automakers need not go bankrupt.

Would this approach result in fewer ultraheavy SUVs on the road? Probably. Would it slow the trend toward bigger houses with higher ceilings? Possibly. But experts say that because technology has sufficient potential to become more efficient, our quality of life need not decline. In order for this to happen, the price of energy should reflect its true cost to society.

Do we have politicians with the courage to explain to the public what is needed? Or may it be that such people are not electable, in view of the obstacles presented by television, campaign financing, and the opposition of energy companies and other special interests? That brings me to Al Gore's book and movie of the same name: An Inconvenient Truth. Both are unconventional, based on a "slide show" that Gore has given more than one thousand times. They are filled with pictures—stunning illustrations, maps, graphs, brief explanations, and stories about people who have important parts in the global warming story or in Al Gore's life. The movie seems to me powerful and the book complements it, adding useful explanations. It is hard to predict how this unusual presentation will be received by the public; but Gore has put together a coherent account of a complex topic that Americans desperately need to understand. The story is scientifically accurate and yet should be understandable to the public, a public that is less and less drawn to science.

or advertisers, with their own special interests, require "balance" as a price for their continued financial support. Gore's book reveals that while more than half of the recent newspaper articles on climate change have given equal weight to such contrarian views, virtually none of the scientific articles in peer-reviewed journals have questioned the consensus that emissions from human activities cause global warming. As a result, even when the scientific evidence is clear, technical nitpicking by contrarians leaves the public with the false impression that there is still great scientific uncertainty about the reality and causes of climate change.

The executive and legislative branches of the US government seek excuses to justify their inaction. The President, despite conclusive reports from the Intergovernmental Panel on Climate Change and the National Academy of Sciences, welcomes contrary advice from Michael Crichton, a science fiction writer. Senator James Inhofe, chairman of the Committee on Environment and Public Works, describes global warming as "the greatest hoax ever perpetrated on the American people" and has used aggressive tactics, including a lawsuit to suppress a federally funded report on climate change, to threaten and intimidate scientists.

Policies favoring the short-term profits of energy companies and other special interests are cast by many politicians as being in the best economic interests of the country. They take no account of the mounting costs of environmental damage and of the future costs of maintaining the supply of fossil fuels. Leaders with a long-term vision would place greater value on developing more efficient energy technology and sources of clean energy. Rather than subsidizing fossil fuels, the government should provide incentives for fossil-fuel companies to develop other kinds of energy.

Who will pay for the tragic effects of a warming climate? Not the political leaders and business executives I have mentioned. If we pass the crucial point and tragedies caused by climate change begin to unfold, history will judge harshly the scientists, reporters, special interests, and politicians who failed to protect the planet. But our children will pay the consequences.

The US has heavy legal and moral responsibilities for what is now happening. Of all the CO2 emissions produced from fossil fuels so far, we are responsible for almost 30 percent, an amount much larger than that of the next-closest countries, China and Russia, each less than 8 percent. Yet our responsibility and liability may run higher than those numbers suggest. The US cannot validly claim to be ignorant of the consequences. When nations must abandon large parts of their land because of rising seas, what will our liability be? And will our children, as adults in the world, carry a burden of guilt, as Germans carried after World War II, however unfair inherited blame may be?

The responsibility of the US goes beyond its disproportionate share of the world's emissions. By refusing to participate in the Kyoto Protocol, we delayed its implementation and weakened its effectiveness, thus undermining the attempt of the international community to slow down the emissions of developed countries in a way consistent with the alternative scenario. If the US had accepted the Kyoto Protocol, it would have been possible to reduce the growing emissions of China and India through the Protocol's Clean Development Mechanism, by which the developed countries could offset their own continuing emissions by investing in projects to reduce emissions in the developing countries. This would have eased the way to later full participation by China and India, as occurred with the Montreal Protocol. The US was right to object to quotas in the Kyoto Protocol that were unfair to the US; but an appropriate response would have been to negotiate revised quotas, since US political and technology leadership are essential for dealing with climate change.

It is not too late. The US hesitated to enter other conflicts in which the future was at stake. But enter we did, earning gratitude in the end, not condemnation. Such an outcome is still feasible in the case of global warming, but just barely.

As explained above, we have at most ten years—not ten years to decide upon action, but ten years to alter fundamentally the trajectory of global greenhouse emissions. Our previous decade of inaction has made the task more difficult, since emissions in the developing world are accelerating. To achieve the alternative scenario will require prompt gains in energy efficiencies so that the supply of conventional fossil fuels can be sustained until advanced technologies can be developed. If instead we follow an energy-intensive path of squeezing liquid fuels from tar sands, shale oil, and heavy oil, and do so without capturing and sequestering CO2 emissions, climate disasters will become unavoidable.

5. When I recently met Larry King, he said, "Nobody cares about fifty years from now." Maybe so. But climate change is already evident. And if we stay on the business-as-usual course, disastrous effects are no further from us than we are from the Elvis era. Is it possible for a single book on global warming to convince the public, as Rachel Carson's Silent Spring did for the dangers of DDT? Bill McKibben's excellent book The End of Nature is usually acknowledged as having been the most effective so far, but perhaps what is needed is a range of books dealing with different aspects of the global warming story.

Elizabeth Kolbert's Field Notes, based on a series of articles she wrote for The New Yorker, is illuminating and sobering, a good book to start with. The reader is introduced to some of the world's leading climate researchers who explain the dangers in reasonably nontechnical language but without sacrificing scientific accuracy. The book includes fascinating accounts of how climate changes affected the planet in the past, and how such changes are occurring in different parts of the world right now. If Field Notes leaves the reader yearning for more experience in the field, I suggest Thin Ice by Mark Bowen, which captures the heroic work of Lonnie Thompson in extracting unique information on climate change from some of the most forbidding and spectacular places on the planet.[1]

Tim Flannery's The Weather Makers puts needed emphasis on the effects of human-made climate change on other life on the planet. Flannery is a remarkable scientist, having discovered and described dozens of mammals in New Guinea, yet he writes for a general audience with passion and clarity. He considers changes in climate that correspond to what I have defined as the business-as-usual and alternative scenarios. Flannery estimates that when we take account of other stresses on species imposed by human beings, the alternative scenario will lead to the eventual extinction of 20 percent of today's species, while continuing with business-as-usual will cause 60 percent to become extinct. Some colleagues will object that he extrapolates from meager data, but estimates are needed and Flannery is as qualified as anyone to make them. Fossil records of mass extinctions support Flannery's shocking estimate of the potential for climate change to extinguish life.

The reader might assume that I have long been close to Gore, since I testified before his Senate committee in 1989 and participated in scientific "roundtable" discussions in his Senate office. In fact, Gore was displeased when I declined to provide him with images of increasing drought generated by a computer model of climate change. (I didn't trust the model's estimates of precipitation.) After Clinton and Gore were elected, I declined a suggestion from the White House to write a rebuttal to a New York Times Op-Ed article that played down global warming and criticized the Vice President. I did not hear from Gore for more than a decade, until January of this year, when he asked me to critically assess his slide show. When we met, he said that he "wanted to apologize," but, without letting him explain what he was apologizing for, I said, "Your insight was better than mine."

Indeed, Gore was prescient. For decades he has maintained that the Earth was teetering in the balance, even when doing so subjected him to ridicule from other politicians and cost him votes. By telling the story of climate change with striking clarity in both his book and movie, Al Gore may have done for global warming what Silent Spring did for pesticides. He will be attacked, but the public will have the information needed to distinguish our long-term well-being from short-term special interests.

An Inconvenient Truth is about Gore himself as well as global warming. It shows the man that I met in the 1980s at scientific roundtable discussions, passionate and knowledgeable, true to the message he has delivered for years. It makes one wonder whether the American public has not been deceived by the distorted images of him that have been presented by the press and television. Perhaps the country came close to having the leadership it needed to deal with a grave threat to the planet, but did not realize it.

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[1] Henry Holt, 2005. See the review by Bill McKibben, "The Coming Meltdown," The New York Review, January 12, 2006.

[2] See "The Ominous New Pact," The New York Review, February 23, 2006.

The Geopolitics of Global Climate Change

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For decades, scientists have known that human activity – primarily the consumption of fossil fuels and the clearing or burning of forested areas — is significantly increasing the volume of carbon dioxide and other so-called "greenhouse gases" emitted into the atmosphere. Since the beginning of the industrial age, CO2 concentrations have increased by more than 30% and they are forecast to double or even quadruple throughout the current century, depending upon population and economic growth rates. Even while this "large scale geophysical experiment" has been conducted – a label ominously applied by oceanographer Roger Revelle some fifty years ago – scientists have become more-and-more certain that the greenhouse gas increases are contributing to global climate changes that will likely have devastating consequences.[1] The February 2007 "Summary for Policymakers" released by the Intergovernmental Panel on Climate Change confirms key linkages between human activity and climate change. Indeed, the IPCC's fourth assessment, which has already been criticized for being too cautious about the causes and consequences of climate change, provides a sobering reminder that humans are profoundly transforming the Earth's environment. The 2500 scientists from over 130 countries signed on to a report declaring a "very high confidence" (defined as "at least 9 out of 10 chance of being correct") "that the globally averaged net effect of human activities since 1750 has been one of warming." Climate system temperature increases are described as "unequivocal."[2]

Consequently, the planet potentially faces the melting of much of its polar ice caps and glaciers, the unprecedented flooding of its coastal areas and islands, mass extinction of innumerable plant and animal species, worrying shifts in agricultural patterns, and the creation of tens of millions of human environmental refugees. To understand some of the horrific social and economic implications of these changes, imagine dozens of world cities and even entire nations facing prolonged catastrophes as shocking as the 2004 Asian tsunami or the 2005 hurricanes that obliterated much of the southern gulf coast of the United States. Those natural disasters may merely hint at the potential consequences of the weather-related disasters yet to come.

To prevent calamitous global climate change, the world will simply have to reduce its greenhouse gas emissions. Fundamentally, this means altering energy consumption patterns because the burning of fossil fuels is responsible for three-quarters of CO_2 releases. Technologically and economically, changing energy habits will not be easily achieved. The world is heavily dependent upon oil, coal, and natural gas and current infrastructures associated with energy systems reflect a significant financial commitment to the current methods of extracting, processing and utilizing fossil fuels. Nearly seven hundred million passenger cars and trucks, for example, account for about 10% of global greenhouse gas emissions. No single vehicle emits a globally significant amount of pollution, meaning that a worldwide transformation will be required to make meaningful emission reductions in the transportation sector. Furthermore, most of the world's electricity is generated by fossil fuel combustion in power plants. This use will not be readily replaced and accounts for about 40% of total emissions. The agricultural sector, air and sea vessels, and factories also rely extensively upon fossil fuels and will need to be retooled at great expense if humans are to move from these energy sources to others across the next decades.

In many ways, however, the political undertaking may be even more difficult than the technical and economic, despite the fact that the international community has been working towards limiting emissions for more than two decades. Perhaps the greatest barrier is raised by the world's wealthiest and most powerful nation-state, which has essentially abandoned the international effort to prevent climate change. Rather than take a lead role, the United States has clearly been responsible for slowing global cooperative efforts and overtly rebuffs binding international commitments to reduce emissions. For a variety of reasons, a number of other reluctant nations have joined the US in refusing to accept global standards on emissions. Additionally, the entire developing world is currently exempt from those same regulations. In several important ways, unfortunately, the global politics of climate change occurs in a competitive rather than a cooperative negotiation context. Even the existing agreement to reduce emissions – known as the Kyoto Protocol – may fail on its own terms, as many of the industrialized states that have committed to the treaty stand poised to break their promises. Perhaps worst of all, Kyoto must at best be viewed as merely a beginning since it requires only modest reductions in emissions that will not long forestall the worst effects of climate change. Far greater reductions in greenhouse gases must be achieved.

International Politics: the Problem of Anarchy

While 168 countries and the European Union were able to negotiate and put into effect a formal treaty requiring significant reductions in greenhouse gas emissions, the agreement does not oblige the world's largest polluter to cut its discharges. The United States produces about one-fourth of the planet's greenhouse gases and is responsible for about one-third of the

emissions among the developed countries now regulated under the Kyoto Protocol by the Framework Convention on Climate Change (FCCC). However, America's unwillingness to ratify that treaty means that the US is not bound by the terms. This is not at all atypical, as environmental agreements, arms control deals, human rights accords, and virtually all other international treaties apply only to those nation-states that agree to obey. International political life is not governed by a central authority that can pass and enforce universal laws. Indeed, scholars use the term "anarchy" to describe the relations among states. The world's territory is divided into sovereign nation-states that are not subservient to anything like a world government. Each state has virtual free reign to design its own energy policy, to clear-cut its own forested areas, or even to refuse to observe pollution emission rules favored by the other states.

Hypothetically, of course, the countries of the world could decide to act together to overcome a common security threat like climate change. In reality, however, the most powerful states, which burn most of the world's fossil fuels and produce most greenhouse emissions, have a long history of rivalry, competition, and even conflict with one another that would seem to belie their working together to solve many communal problems. The past hundred years has been scarred by two world wars, nearly a half century of divisive cold war, and a large number of lesser struggles and disagreements. The collapse of the Soviet Union and the end of bipolar rivalry did not trigger a new friendly era of global cooperation. During the 1990s, the United States and its European allies could not convince Russia that the United Nations should act militarily in the Balkans over Kosovo's fate. Likewise, the UN's strongest states were unable to agree to act preventively in Rwanda to stop a foreseeable genocide that ultimately killed hundreds of thousands of people. The US in the 1990s refused to join many of its closest western allies in a variety of international treaties that they strongly favored. These accords would have prohibited the deployment of anti-personnel landmines, created an International Criminal Court to prosecute crimes against humanity, and banned all nuclear test explosions. In each instance, the US cited strategic American interests and concerns that kept if from going along with much of the rest of the world.

All too often, in fact, narrow self interests preclude meaningful international cooperation. Unfortunately, the prospects of global cooperation are not especially high even when states agree about the need for common action to reduce a shared threat. After the September 11, 2001, al Qaeda attacks on the World Trade Center and Pentagon, most nation-states rallied behind the US in an apparently unified global "war on terrorism." Indeed, the surprise assault sparked virtually all of the world's key states to form a "coalition of the willing" to combat terrorism. Practically no states protested when the coalition first directed its attention at Afghanistan in a battle to root out the Taliban government. However, the common cause was short-lived as major powers were soon openly clashing when the prospect of fighting Iraq and toppling Saddam Hussein was elevated to the top of the international agenda. Long-time close American allies like France and Germany worked openly to try to stop the US from starting such a war. These states interpreted the situation very differently and favored their own proposed solutions. Again, these are typical roadblocks to cooperation in international political life.

Unfortunately for the planet, it is nearly impossible to imagine any successful international agreement addressing the problem of global warming without American cooperation. The Kyoto Protocol and any follow-on agreement is likely doomed to fail without a significant change in American policy. To repeat, this is largely because the US, with less than 5% of the world's population, emits about a quarter of greenhouse gases.

For virtually any problem, especially one as complex as climate change, states are likely to have different understandings of the circumstances and may have unique interests that either preclude their working together or compel them to advocate proposals that others will reject. Countries might disagree, for instance, about the level of sacrifice each would need to make towards achieving a common end. Collective action typically cannot be achieved without someone paying at least some costs and not even a shared fear of a mounting threat can assure that every state will voluntarily pay those costs. The problem is especially acute if any single state is asked to make a contribution larger than it is willing to pay – or greater, proportionally, than other states are asked to supply.

In the case of the Kyoto Protocol, neither Bill Clinton, who was President when the deal was struck in 1997, nor his successor George W. Bush, has ever asked the US Senate to consider the climate change treaty. Indeed, shortly after taking office in 2001, President Bush condemned the Kyoto Protocol as "fatally flawed" and Vice President Dick Cheney called it a "dead proposition" that the United States "would not be bound by."[3] Unfortunately for the planet, it is nearly impossible to imagine any successful international agreement addressing the problem of global warming without American cooperation. The Kyoto Protocol and any follow-on agreement is likely doomed to fail without a significant change in American policy. To repeat, this is largely because the US, with less than 5% of the world's population, emits about a quarter of greenhouse gases.

Why does the US oppose the Kyoto Protocol? Has the US consistently worked in opposition to a convention limiting greenhouse gas emissions? Have the climate change negotiators been undercut by selfishness?

The History of American Intransigence

While the US has long been reluctant to join other states in regulating greenhouse gases, it has not always overtly obstructed the international political process. After a series of informal global conferences in the 1980s about the so-called "greenhouse effect," which often included US representatives and scientists, the United Nations Environment Program and World Meteorological Organization established the Intergovernmental Panel on Climate Change. The IPCC was formed in 1988 to provide a comprehensive and expert assessment of this phenomenon as scientists and policymakers alike wanted to understand the causes of climate change, the potential impacts, and the available options for mitigating the causes and/or effects. The three IPCC Working Groups – the US chaired one on responses to global warming – reported their initial findings to the UN General Assembly and to a World Climate Conference in fall 1990. These first reports reflected a scientific consensus that the greenhouse effect was real and was being worsened by human activity. Thanks partly to this input, the UN General Assembly adopted a resolution in December 1990 that established an Intergovernmental Negotiating Committee (INC) that could meet and bargain towards a formal international treaty to address the problem.

Many optimistic observers hoped that negotiators intended to achieve a climate change pact by traversing the political pathway blazed during the 1980s to address another atmospheric environmental concern. With the active participation and leadership of a US negotiating team appointed by President Ronald Reagan, nations agreed in a series of bargaining sessions to mitigate the environmental hazards linked to a class of man-made chemicals known as chlorofluorocarbons (CFCs). After their use on earth, these chemicals were eventually migrating to the atmosphere and thinning the ozone layer. Sadly, adding CFCs to O_3 was a double whammy because the chemical changes reducing the concentration of ozone yielded CO_2 as one unfortunate byproduct! Simply by limiting production and consumption of these harmful man-made chemicals, the so-called Montreal Protocol could preserve the ozone layer and thereby prevent ultra-violet radiation from causing untold numbers of future skin cancers. It is only a small exaggeration to suggest that the international agreement protected in some fashion virtually all life on the earth, from phytoplankton to humans. In any case, for extremely sound reasons, the 1987 Montreal is viewed as the gold standard for formulating international environmental agreements. Under the pact, a baseline emissions year was established. Next, production and use of CFCs vis-à-vis this base year was reduced — and then CFCs were almost completely banned. States also created a multilateral fund to help poor countries adopt alternative technologies so that they would not be tempted to purchase CFC products prohibited in the industrialized world.

Proponents of international action on climate change, however, must acknowledge that the Montreal Protocol was in many ways unique. The manufacture and use of CFCs was primarily limited to a relatively small number of affluent states. Developing countries as a whole produced less than 5 percent of the chemicals. CFCs had functional purposes – as a refrigerant, a cleaning solvent for electronics, a propellant in aerosol containers, and as the gas that puffed plastic into Styrofoam – but these ultimately proved amenable to relatively inexpensive replacement. The corporations that produced CFCs derived substantial revenues from their goods, but some key manufacturers like DuPont declared quite early on that they were willing and likely able to make viable substitutes. Moreover, CFC consumption did not constitute a significant portion of the global economy. The multibillion dollar CFC production industry was concentrated in only about 20 companies. Finally, the Environmental Protection Agency had already banned nonessential CFC use in 1978 and the US assumed a genuine leadership role in the negotiations. In all, this was a welcoming context in which to negotiate a deal.

Knowledgeable onlookers realize that it would be very difficult to duplicate the success of the Montreal Protocol, with or without active American leadership. The evidence about global warming may be backed by fairly strong scientific consensus, but the US and other states have periodically contested the need to act upon information they viewed as simply too uncertain given the great costs likely associated with a transformation of the world's energy use patterns. Scientists willing to challenge the assembled evidence quickly assumed prominent positions in the American public debate. Numerous transnational corporations, including the world's major oil companies, and many nation-states have a much greater economic interest in the stakes and these actors worked aggressively to stall negotiations. In the US, ExxonMobil played a particularly vigorous role in financing a long-term public relations campaign designed to cast doubt on the science and raised many questions about the economic and technical feasibility of cutting fossil fuel use.

Nonetheless, countries completed a Framework Convention on Climate Change (FCCC) in advance of the UN Conference on Environment and Development, which was held in June 1992, in Rio de Janeiro, Brazil. Because negotiators knew that the "Earth Summit" was a symbolically important event, they effectively operated under a deadline and made remarkably rapid progress in the sessions leading up to the June conference. During the negotiations, however, the US under the administration of George Herbert Walker Bush refused to allow the proposed agreement to establish either targeted emission reductions or a legally binding timetable. As the world's lead-

ing emitter of gases, the US was already viewed as vital to any solution. It could thus effectively use its position and establish informal veto power by blocking emission reduction requirements. Though the FCCC signed at the Rio "Earth Summit" included no provisions requiring states to reduce emission of greenhouse gases and thus reflected minimal agreement, parties preferred this to inaction.

Under the 1992 treaty, industrialized nations (included in Annex I of the Convention) agreed merely to "aim" to return their emissions to 1990 levels by the year 2000. Annex I countries were also charged with developing national policies to mitigate greenhouse gas emissions, though they were allowed the option of "joint implementation." In practice, this meant obtaining credit for emission reductions by helping other states, potentially including those in the developing world, reduce their pollution. The convention also created measures requiring states to provide inventories of greenhouse gas discharges and to report on their development of national emission reduction plans. Poor developing states of the Global South tried to obtain pledges of increased development assistance in order that they too might be able to achieve emission reductions, but the final version of the original treaty did not include a provision for this purpose. Yet, the world's richest states agreed in the treaty to "provide new and additional financial resources to meet the agreed full costs" for developing countries to meet their reporting requirements.[4] This would at least allow states a way to calculate accurately the rate of emission growth – and would provide baseline data for joint implementation. At the Earth Summit, a pilot Global Environment Facility was named the interim agency that would pool and distribute these financial resources. In 1999, after a significant restructuring that more clearly distinguished its mission from that of the relatively unpopular World Bank, the GEF became the convention's permanent financial mechanism.

More than 150 states signed the FCCC in Rio and it entered into force in March 1994, three months after the fiftieth ratification. The US was the first industrialized state to ratify the convention. As of February 2007, 189 countries have joined the treaty. Most importantly, given the failure to require emissions reductions, the FCCC established a Conference of the Parties (COP) to continue negotiations. The COP, which is comprised of all state members to the pact, met formally on a number of occasions over the next few years to discuss the key unresolved issues. At the COP-1 in Berlin in spring 1995, an Alliance of Small Island States (AOSIS) pressed mightily for a convention protocol that would require emission reductions. The leaders of AOSIS had very strong interests in global warming since their nations were potentially quite vulnerable to future increases in sea level caused by melting ice caps. No agreement on emissions reductions emerged from COP-1 as very few states were prepared to take that step and the AOSIS states were simply too weak to have influence on their more powerful peers. The COP-2 meeting in Geneva in 1996 also failed to reach an agreement on this issue. One important concession was attained, however, as President Clinton's negotiators did agree that the US would commit to legally binding reductions on emissions. The devil was in the details, as is so often said, because precise cuts were yet to be settled.

After some additional heated negotiations, participants in 1997 ultimately approved specific binding emission reductions in the Kyoto Protocol. This deal established 1990 as the baseline year for emissions and set the years 2008-2012 as the target dates for reductions. The developed states, again known as Annex I countries, commit on average to 5.2% emission reductions from the 1990 base. However, states were assigned different responsibilities and developing countries were exempted altogether from the requirements. By agreement, the US was assigned a target of 7% reduction in greenhouse gas emissions from the 1990 base year, though its actual obligations were mitigated significantly by the acceptance of an American plan to credit states for the successful management of so-called "carbon sinks" by employing environmentally friendly land use techniques and innovative forestry practices. Article 12 of the Kyoto Protocol additionally creates a Clean Development Mechanism to allow Annex I states to gain credits for emission reductions in developing states not bound by the treaty. The major negotiating parties had been deeply divided about many proposed provisions and the Protocol actually reflected only limited agreement. To its credit, the Protocol overcame most national divisions about the specific emission reductions to be required and the various gases that would be covered by the treaty.

President Clinton signed the Kyoto accord in November 1998, but pointed to an unwelcoming Senate resolution from 1997 (which passed 95-0) and indicated that he would not submit the agreement to that body for its "advice and consent" until a subsequent additional deal more satisfactory to US interests was concluded. Specifically, the Senate resolution identified two key American policy concerns that were not successfully resolved in the Kyoto deal. The Senate recommended that the U.S. not become a signatory to any international protocol that would "result in serious harm to the economy" or that would "mandate new commitments to limit or reduce greenhouse gas emissions for the Annex I Parties, unless the protocol or other agreement also mandates new specific scheduled commitments to limit or reduce greenhouse gas emissions for Developing Country Parties within the same compliance period."[5]

American Economic Interests

To keep Kyoto-related costs down, the US very much favored market-friendly emissions trading plans, along the lines of joint implementation. Economists often argue that such

approaches are the preferred method of pollution abatement because they encourage much greater efficiency as compared to fixed regulatory standards. In other words, such mechanisms would meet environmental goals at lower costs. Critics of environmental regulations have long claimed that standards can be too costly if they require every company to meet requirements. While newer industries might already meet and exceed a new standard thanks to their use of the latest technologies, older industries might not be able to meet a toughened standard without making prohibitively expensive changes. Under a trading plan, every company in every participating country could be allotted a specific number of pollution credits under the law. The number of total credits would be pegged to the target goal of emission reduction. The greenest companies (or nation-states), with credits to spare, could sell some of theirs to the most polluting industries (or nation-states) who might prefer buying credits to closing shop. The overall standard would therefore be met at the lowest feasible cost, as set in the marketplace. Moreover, the market could be open to environmentalists as well, since they too could buy pollution credits. By purchasing and retiring credits, environmental groups could effectively toughen international pollution standards without additional regulatory action.

For fairly obvious reasons, American businesses vulnerable to environmental standards often strongly prefer these kind of market-based mechanisms. The US Clean Air Act, in fact, has for many years allowed pollution trading. However, other countries have been greatly divided as to whether to embrace these mechanisms. Influential environmental groups from around the world especially fear that industrialized states will not make any technological or resource use changes if granted the option to comply merely through emissions trading or joint implementation. These advanced states might simply build new factories in the Global South or buy pollution credits from states with surpluses to offset their own obligations. Effectively, opponents argued, the richest states and their industries would be allowed to pay to pollute. In the end, resolution of this particular dispute was deferred until future COP negotiations.

Likewise, the Kyoto agreement did not address the US demand that developing countries should be required to reduce their emissions. The US claimed that industrialized states might make significant and costly reductions in pollution, but that countries like China and India would offset even effective changes by substantially increasing their own fossil fuel consumption and emissions. China already emits 15% of the world's greenhouse gases and has one of the world's fastest growing economies to go along with an enormous population. Its future may include tens of millions of new automobiles and hundreds of new coal-fired power plants. While US officials often called for Chinese and Indian inclusion as a means to strengthen the treaty, they were also well aware that the exclusion of these states effectively provided them with advantages in the global marketplace. Transnational and domestic companies could build new factories in China and not have to worry about the overall level of greenhouse gas emissions. If some likewise closed more polluting plants in Annex I countries, emissions credits would even be granted. While economists may be correct about the relative efficiency of such a plan, this does not relieve politicians from fears about trade deficits and lost manufacturing jobs.

Poorer countries, including China and India, argued that they should be exempted from making reductions since they had not contributed very much to the atmospheric buildup of greenhouse gases from the start of the industrial revolution and even now expel only a small fraction of the emissions of wealthier countries on a per capita basis. They often framed their opposition around the issue of international justice. Would it be fair to require citizens of the world's poorest states to reduce their greenhouse gas emissions even if each American, on average, released five to ten times as much CO_2? Many nongovernmental organizations, who are increasingly influential on this and other environmental topics, agreed that it was unjust for wealthy states to demand reductions in fossil fuel usage by the world's most impoverished inhabitants.

While states individually debated whether or not to ratify Kyoto, the parties kept meeting to address unresolved issues. In several successive COP meetings through the late 1990s, in fact, representatives from the US and other states engaged in ongoing talks about enforcement of the Kyoto-mandated emissions reductions, emissions trading proposals, and possible credits for greenhouse gas "sinks." In the various meetings, the US continued to bargain for both adoption of market mechanisms and regulation of developing countries. The parties were apparently close to a deal that would satisfy some US concerns in late 2000, but they were unable to finalize an agreement before the Clinton administration ended.

Unsurprisingly, given that her boss had already renounced Kyoto, international environmental diplomats meeting in Bonn in 2001 booed the new chief US Delegate, Paula Dobriansky, when she proclaimed a continuing US commitment to action on climate change. In short order, the mantle of leadership was grabbed by the European Union in hopes of assuring the survival of the FCCC process. Tough bargaining lead to new standards describing how industrial states would limit greenhouse emissions, and a last-minute decision by Japanese Prime Minister Junichiro Koizumi to go along saved the treaty. The Europeans achieved a new deal, the Marrakesh Accords, largely by accepting the Japanese position on carbon-trapping sinks, or forested areas that absorb CO_2, and by compromising on a Russian desire for emissions trading. While these concessions would have greatly pleased many Clinton-era negotiators representing US and private busi-

ness interests as recently as November 2000, the Bush administration still worried that binding reduction targets would harm the US economy, and its representatives reiterated complaints that the treaty did not go far enough to require action by developing countries such as China and India. On many occasions, President Bush and some Republican members of Congress even questioned the strength of the scientific evidence.

Recent Developments

The Kyoto Protocol became binding on the member states in February 2005 once it was ratified by 55 nation-states, including enough industrialized countries to account for at least 55% of all 1990 emissions. Most crucially, a set of "likeminded" affluent states led the way. The European Union, Japan and Canada ratified the Kyoto Protocol in 2002, primarily because these states genuinely favored the agreement. Russia was convinced to join them two years later, but geopolitics figured prominently in an odd end game. Because it was impossible to reach the 55% threshold without either the US or Russia's acceptance of the accord, the latter held a remarkably advantageous bargaining position vis-à-vis the member states, which desperately wanted Russia to join them. President Vladimir Putin was therefore able to extract Europe's backing for Russian accession to the World Trade Organization in exchange for a commitment to ratify Kyoto. This was a win-win outcome for Putin as Russia was already in compliance with the deal after closing many of its most polluting and inefficient factories in the early 1990s. In fact, rather than paying costs associated with emissions reductions, Russia would have emission credits to sell on a global market and knew this long before gaining the WTO side deal.

The United States has been joined in vocal opposition to Kyoto by Australia's relatively conservative government under Prime Minister John Howard. Additionally, a number of African and Middle Eastern states have more quietly ignored the treaty. Member states of the Organization of Petroleum Exporting Countries (OPEC) have overtly raised a critical problem that will inevitably influence the global politics of climate change. While publicly stating their general support for Kyoto goals, OPEC states argued that they should receive assistance if climate-related policy changes significantly undermine the international market for their oil. Though OPEC economies are heavily dependent upon petroleum export revenues, their calls for aid commitments have not found a receptive audience. Indeed, many other key pivotal states have significant fossil fuel reserves and other natural resources that may well become central issues in future bargaining rounds. China has vast coal supplies, Canada retains enormous reserves of petroleum in oil sands, Russia is already tapping its significant oil supplies, and Brazil controls the largest remaining forested areas. If the international community is going to slow the dramatic increase of greenhouse gas emissions through this century, many of these natural resources may have to remain unused. The only alternative would be remarkable technological change that would somehow limit carbon emissions.

International negotiators have continued to meet and discuss climate change since the Kyoto deal was agreed in 1997, but the only successful follow-up agreement to Kyoto was the COP-7 Marrakesh Accords, which were agreed in 2001. That deal set detailed rules for implementation of the Kyoto Protocol and was politically necessary to make Kyoto work better, but it was not a substantial step towards a more comprehensive plan to reduce emissions. Given the years that have now passed, it seems apparent that states are not strictly following the Montreal Protocol model, which relatively quickly reduced and ultimately banned CFC production. The most recent COP-12 meetings were held in Nairobi, Kenya, in November 2006 and those talks continued to focus extensively on implementation issues. Parties to the convention discussed questions about the capacity of developing countries to meet many of the adverse impacts of global climate change, the development of clean technology projects in Africa and other poorer regions, and the future of financial mechanisms to help assist these states. There is no deal to require additional emission cuts, nor even a timetable for bargaining about such reductions. Independently, however, European Union countries have announced plans to reduce emissions by 20% by 2020.

Meanwhile, numerous reports suggest that many affluent state parties to the Kyoto deal are not making significant strides towards reducing emissions, even though the target dates are now imminent. Thanks to the various market mechanisms included in the treaty, a state like Japan, which has seen increased emissions since the 1990 base year, can "buy its way out" of noncompliance by trading emissions or by financing environmentally-friendly projects in the developing world. This is just as many environmentalists feared. Technically, this would mean that these states are meeting their international commitments, but the world will not be able to slow and reduce the effects of climate change until even the most affluent states bring their emissions under control. This is especially important given the most recent findings from an array of scientific reports, including the IPCC's latest consensus assessment, which suggest that emissions reductions far in excess of Kyoto will ultimately be needed if the most disastrous consequences of climate change are to be avoided. The European Union states, for instance, want to see total global emissions peak within the next two decades, followed by a 15 to 50% reduction in total emissions by 2050. Those kinds of ambitious targets, as already noted, will require remarkable transformation of the world's energy systems. Developing states, including China and India, eventually must make commitments and changes to reduce their net emissions.

Obviously, a successful global plan will require participation by the United States. Is there any reason to believe that the US will finally embrace the world's efforts to limit climate

change? Actually, there are many reasons to believe that Americans are starting to think seriously about global warming. The aftermath of Hurricane Katrina shocked the nation's psyche and many scientists publicly blamed the phenomenon of increasingly powerful hurricanes on climate change and human activity. Former Vice President Al Gore's critically acclaimed film, "An Inconvenient Truth," won the Academy Award for Best Documentary. At the box office, it is the third highest grossing documentary released since 1982. Public opinion poll results reveal that the overwhelming majority of Americans consider global warming a threat to future generations. Indeed, nearly 70% of Americans think that their government should do more to address global warming.[6] Even President Bush called global climate change a "serious challenge" in the 2007 State of the Union speech, which marked the first time he had referenced the problem in his annual agenda-setting address.[7]

Previously, the Bush administration had merely announced a series of related efforts that encouraged voluntary public-private partnerships to reduce emissions. Meanwhile, US greenhouse gas emissions have increased about 1% per year through the Bush presidency – just as they did throughout the 1990s. While the new Democratic majority in Congress hints at new energy and climate policies, and many cities have committed to the Kyoto Protocol goals, the US still has a long road to travel before it catches the leading green states.

Conclusions

Currently, fossil fuel production and consumption seems integral to the economic livelihood of the global community. After all, these energy sources power a substantial portion of electricity generation and heating, nearly all automobiles, and a great deal of worldwide industrial activity. Therefore, they provide prosperity to innumerable individuals, many giant corporations and dozens of nation-states. Significantly reducing either energy demand or fossil fuel consumption will require a concerted effort unlike any other environmental achievement to date. Indeed, meeting the challenges posed by global warming will require extraordinary political effort and will – perhaps the apt comparison is the collective exertion put forth by the allied states during the second World War, when the leaders of the United States and United Kingdom joined the forces under their respective commands with those of the Soviet Union to defeat a common and dangerous foe. Halting global warming is not literally equivalent to war, of course, but it will require costly and prolonged commitments by diverse and powerful political actors. Proponents of greener policies will confront well-entrenched forces that will not yield their economic position without a political fight. Enormous barriers must be surmounted for the US alone to make the necessary transformations – and such progress would necessarily have to be matched all over the world. The great hope for the planet will, as it did in the 1940s, rest upon the prospect of a basic common interest that must become the motivating impetus for collective action. Scientists warn that the costs and negative consequences will be devastating if the world does not attempt to meet this challenge.

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Rising Temperatures, Rising Stakes: Global Warming In the Courts

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Back in 1997, when the Kyoto Protocol was negotiated and the United States agreed to reduce its emissions of greenhouse gases (GHGs) to 7 percent below 1990 levels by 2008-2012, there were high hopes that soon the U.S. would adopt mandatory programs to reduce GHG emissions. True, there were harbingers of doubt – the Clinton administration was badly bruised by the fight over imposing a "BTU tax" early in its tenure and the Senate passed, by a 97-0 vote the summer before Kyoto, a resolution that seemed to disavow the essential principles embodied in the Kyoto Protocol: that the developed countries should take action to reduce GHG emissions before the developing world. Nevertheless, the U.S. has an impeccable history of living up to international environmental agreements and the scientific evidence of global warming has only grown stronger since 1997. Yet, here we are ten years later with U.S. GHG emissions 16% above 1990 levels and no national regulation of carbon.

Since the executive and legislative branches of the U.S. government have failed to enact or implement mandatory programs to reduce U.S. GHG emissions, environmental groups and many states and localities have turned to the judicial branch to force the federal government and industry to reduce GHG emissions.[2] The use of the judicial system to promote good public policy is not new: for example, school segregation was challenged in *Brown v. Board of Education*, and courts have ordered cigarette companies to pay millions of dollars in damages. In the environmental arena, people have sought relief from the courts to stop pollution from industry, either when the pollution is inadequately regulated or, as in the case of GHG emissions, not regulated at all. The courts are also a venue for compelling the government to act when people believe the government is failing to use its existing authority to protect public health. For example, the Natural Resources Defense Council in the early 1970s sued EPA to regulate lead content in gasoline and to list lead as a criteria pollutant under the Clean Air Act.

So it is no surprise to see a phenomenal growth in climate change litigation in the past few years. This article discusses some of the issues raised in the most significant lawsuits (but it is not intended to be a complete accounting of all litigation). The most important case by far is the one decided by the Supreme Court this spring of 2007.

***Massachusetts v. EPA:* Greenhouse Gases Are Air Pollutants So Why Doesn't EPA Regulate Them Under the Clean Air Act?**

The questions presented in *Massachusetts v. EPA*[3] are whether EPA has authority under the Clean Air Act to regulate GHG emissions from motor vehicles and, if the agency does, did it rely on permissible grounds in rejecting a petition calling for it to regulate these emissions.

The lawsuit stems from a petition filed back in 1999 asking EPA to regulate GHG emissions from motor vehicles under section 202(a)(1) of the Clean Air Act (CAA). The petition asked EPA to regulate these emissions because GHG emissions are air pollutants, as defined under the Act, that "may reasonably be anticipated to endanger public health and welfare."[4] EPA denied the petition in 2003 for two reasons.[5] First, it said it lacked authority to regulate GHG emissions. This contradicted an opinion issued by EPA's general counsel in 1998[6] that reached the opposite conclusion. EPA said that global warming was such an important issue touching on almost all aspects of life, since energy production releases GHG emissions and energy production is integral to economic development, so, in "the absence of any direct or even indirect indication that Congress intended to authorize regulation under the CAA to address global climate change, it is unreasonable to conclude that the CAA provides the Agency with such authority."[7] It also noted its view that such regulation would interfere with fuel economy standards set by the Department of Transportation under the Energy Policy and Conservation Act (EPCA).

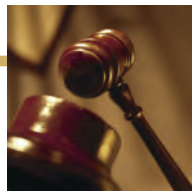
This is a remarkable position for an agency to take and belies the agency's willingness to interpret environmental statutes expansively in other areas. For example, the EPA under this administration has found

authority in the Clean Air Act to set up a national cap-and-trade scheme for mercury, a toxic air pollutant, even though all other hazardous air pollutants are instead subject to mandatory source-by-source reduction requirements. It has also found authority in the Act to establish a regional cap-and-trade system for sulfur dioxide and nitrogen oxide emissions from power plants in the eastern half of the U.S., even though such a scheme is not spelled out in the CAA.[8] Granted, one might argue that these expansive interpretations concern pollutants EPA has already regulated under the Clean Air Act, not GHGs. However, EPA liberally interpreted another act – the Safe Drinking Water Act – to cover underground injection of carbon dioxide (CO_2) into geological formations.[9] The Safe Drinking Water Act (SDWA) was passed in 1974 and amended in 1986 and 1996. It strains credulity to believe that Congress in promulgating the SDWA contemplated that this law, designed to protect the public's water supply, would cover injection of CO_2 into geological formations as part of carbon capture and sequestration strategies to deal with global warming.

The second reason EPA gave for rejecting the petition was that, even if it had the authority to regulate GHG emissions under the Clean Air Act, it refused to exercise this authority for policy reasons and instead was pursuing the President's voluntary approach of reducing GHG intensity and conducting more research.

EPA's decision was challenged in court, resulting in a fractured decision by the U.S. Court of Appeals for the D.C. Circuit.[10] By a 2-1 vote, the court dismissed the petition, but the judges' views were all over the map. The judge who wrote the majority opinion, Raymond Randolph, assumed that EPA had authority under the CAA to regulate GHG emissions, without deciding this issue, but said the EPA was within its discretion not to regulate GHG emissions from motor vehicles. Judge David Sentelle concurred with the result of Randolph's opinion – upholding EPA's rejection of the petition – but for an entirely different reason: he said that the plaintiffs in the suit lacked standing (more on that below). The third judge in the case, David Tatel, issued a strong dissent, finding that EPA has authority to regulate, that petitioners do have standing and that EPA relied on impermissible policy reasons that are not in section 202(a)(1) in rejecting the petition.

The petitioners, which include several states, appealed to the Supreme Court, which heard oral arguments on November 29, 2006. The majority of the oral argument time was spent on the question of standing. Standing in essence means, do the people who are suing have the right to sue and is the court in a position to help resolve the issue? Standing is a way for courts to manage cases, so that the courts only address issues that directly impact the person suing (injury in fact) and ones that the courts are capable of redressing (redressability). In addition, the injury suffered by the person suing must be traceable to an act of the defendant (traceability). Each of these three elements was probed by the justices.[11] With respect to redressability, Chief Justice John Roberts and Justice Antonin Scalia queried



Massachusetts Assistant Attorney General James Milkey as to whether a decision leading to a 2.5% reduction in GHG emissions (the possible impact of regulating GHG emissions from new U.S. automobiles) would really reduce the impact of global warming on states' coastlines. On the other hand, Justices Stephen Breyer, Anthony Kennedy, David Souter and John Paul Stevens seemed troubled by Deputy Solicitor General Gregory Garre's implication that harm needed to be "pinpointed mathematically" (i.e., the exact miles of state coastline that will be lost because of GHGs emitted by cars in the U.S.) to show standing. Justice Scalia also probed on the issue of timing: is anyone being harmed now? "When is the predicted cataclysm?" he asked.

Interestingly, the questions directed at what may seem to non-lawyers to be a sticky procedural issue also happen to be the same ones that make tackling global warming so tricky. How much will regulating only new cars/only power plants/only sources in the U.S./only sources in developed countries really reduce global warming? Aren't the worst impacts of global warming decades away, so no one is really being harmed now, and if so why should we act now? Shouldn't we wait until we have better technological solutions or until we have better scientific information? Who is really responsible for global warming – power plants, car companies, industry as a whole, countries (which ones) or do we have only ourselves and our lifestyle choices to blame?

On April 2, 2007, the Supreme Court released its decision.[12] By a vote of 5-4, the Court found that the appellants had standing, that EPA has authority to regulate GHG emissions from new motor vehicles under the Clean Air Act and that the reasons EPA gave for not regulating these emissions were "divorced from the statutory text."[13] The majority opinion was authored by Justice Stevens and joined by Justices Breyer, Ginsburg, Kennedy and Souter.

With respect to standing, interestingly, the majority said that Massachusetts "is entitled to special solicitude" in the court's standing analysis.[14] The Court noted that a state, while a sovereign power, surrendered certain of these powers when it joined the Union: "Massachusetts cannot invade Rhode Island to force reductions in [GHGs], it cannot negotiate an emissions treaty with China or India, and in some circumstances the exercise of its police powers to reduce in-state motor vehicle emissions might well be pre-empted."[15] The court then concluded that Massachusetts meets all the tests required by standing:[16] Massachusetts owns a substantial portion of coastal property that has already been harmed by sea level rise caused by global warming and will be harmed by further sea level rises, "[t]he risk of catastrophic harm, though remote, is nevertheless real [and this] risk would be reduced to some extent if petitioners received the relief they seek."[17]

The Court dismissed several arguments on standing that deserve mention. The fact that climate change risks are widely shared, it said, "does not minimize Massachusetts' interest in the outcome of this litigation."[18] A decision otherwise could have

severely affected the ability of anyone to sue where there are broad but diffuse environmental impacts. For example, in a case in Oregon in 2006 about a company's GHG emissions, the company argued that plaintiffs lacked standing because global warming will affect everyone, not just the defendants. The district judge eloquently rebuffed these arguments:

> "If Defendant's theory of standing were correct, no person could have standing to maintain an action aimed at averting harm to the Grand Canyon or Yellowstone National Park, or threats to the giant sequoias and blue whales, as the loss of those treasures would be felt by everyone."[19]

The court also said that, while EPA's regulation of GHG emissions from new motor vehicles in the U.S. wouldn't be enough to reverse global warming, a reduction in U.S. GHG emissions would slow the pace of global emissions increase. (This goes to the issue of "redressability.") The Supreme Court could have decided that, since GHG emissions from new U.S. motor vehicles constitute only 2.5% of worldwide emissions, regulating these sources is insufficient to redress the harm to states for global warming. Then, Massachusetts would have lacked standing to sue. Such a decision would have meant that, the more sources of pollution there are, the harder it would be to sue any one of them because a source could always say it is but a small part of the problem and so is not harming any one person all that much. Therefore, no one has standing to sue.

Turning to the merits, the court strongly criticized EPA's decision and reasoning in refusing to regulate GHG emissions from new motor vehicles. First, it examined EPA's argument that GHGs are not "air pollutants" as defined in the Act. The Court said the statute contains a "sweeping definition" of air pollutant that "embraces all airborne compounds of whatever stripe," and CO_2 and other GHGs "without a doubt" fit the statutory definition of "air pollutant" in the Act.[20] Furthermore, the court rejected EPA's contention that regulation of CO_2 emissions from motor vehicles would require the agency to tighten fuel efficiency standards, which falls under the purview of the Department of Transportation (DOT). That "DOT sets mileage standards in no way licenses EPA to shirk its environmental responsibilities" – the obligations of the two agencies may overlap, "but there is no reason to think the two agencies cannot both administer their obligations and yet avoid inconsistency."[21]

Thus finding that GHGs clearly fall within the definition of "air pollutant," the Court then addressed whether EPA acted arbitrarily and capriciously in rejecting the petition calling for it to regulate GHG emissions from new motor vehicles. The Court found that EPA had so acted. The CAA gives EPA discretion on regulating, but that discretion is cabined, the court said: EPA "must ground its reasons for action or inaction in the statute." Instead, EPA provided "a laundry list of reasons not to regulate . . . [and] it is evident they have nothing to do with whether [GHG] emissions contribute to climate change." The court said that if scientific uncertainty on global warming "is so profound it precludes EPA from making a reasoned judgment as to whether GHG emissions contribute to global warming, EPA must say so." That EPA prefers not to regulate because of some "residual uncertainty ... is irrelevant," the court said. The court remanded the matter for further proceedings consistent with its opinion, thus sending the petition back to EPA for action.

Chief Justice Roberts wrote a dissent, joined by the other three dissenters, rejecting the case on standing grounds. While he provided a detailed legal explanation of his reasoning, in essence his argument was that this was really a matter for Congress and the executive branch to resolve, not the courts. Roberts said there is a "mismatch" between catastrophic global warming and the "narrow subject matter of the Clean Air Act provision at issue in this suit[, which] suggests that petitioners' true goal for this litigation may be more symbolic than anything else."[22] Justice Scalia wrote a separate dissent, also joined by the three other dissenters, arguing that it was within EPA's discretion to defer a decision to regulate GHG emissions under the Act. (He also argued that EPA was correct in concluding that GHGs are not air pollutants and that enough scientific uncertainty existed about global warming for EPA to conclude that scientific uncertainty is so profound as to preclude EPA from concluding that GHGs contribute to global warming.)

What are the implications of this decision? First, it frees this EPA or a future EPA to regulate GHG emissions from any and all sources covered by the CAA. And, in fact, it does more than that – it appears to *require* that EPA make a decision and not simply defer a decision, and it sharply limits which reasons the agency can cite in deciding not to regulate.[23] The only points of discretion afforded EPA are in determining 1) whether GHG emissions contribute to global warming and 2) whether sufficient information exists to make a finding that global warming "may reasonably be anticipated to endanger public health and welfare," as provided in section 202(a)(1). If EPA concludes that GHG emissions contribute to climate change and makes a finding of endangerment,[24] then the agency's only option appears to be, under the court's ruling, to regulate GHG emissions from new motor vehicles.

Second, the ruling that GHGs are air pollutants as defined in the CAA lifts the cloud of uncertainty surrounding state efforts to regulate emissions of air pollutants from new motor vehicles. Under the CAA section 209(a), only the federal government or California (with a waiver from EPA) may regulate emissions from air pollutants from new motor vehicles. (The rest of the U.S. may choose to either adopt the California or EPA standards.) Arguably, if the Supreme Court ruled that EPA cannot regulate GHG emissions from motor vehicles under the CAA, no other jurisdiction in the United States could do so either because of the restriction in CAA section 209(a). California in 2004 promulgated regulations limiting GHG emissions from new cars and light duty trucks beginning in 2009, and eleven states[25] (in addition to California) have

adopted these standards, with three states[26] actively considering following suit. These state efforts are being challenged on various other grounds, which I will describe in more detail below.

Third, the court's statements about the overlapping obligations of EPA (under the CAA) and DOT (under the EPCA) may have implications for cases challenging California's GHG emission standards for motor vehicles, described below. One of the arguments raised is that regulating GHG emissions from motor vehicles by necessity means increasing fuel efficiency standards, and so EPA regulation of GHG emissions from motor vehicles conflicts with DOT's statutory authorities. The Supreme Court, however, didn't see any conflict and in fact said that EPA couldn't use this argument to "shirk its environmental responsibilities."[27]

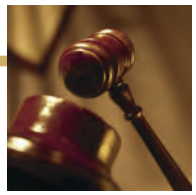
Finally, the case expounds further on the Supreme Court's views on standing doctrine, in a favorable way for plaintiffs, which will prove helpful in future environmental cases.

Other Lawsuits Against the Federal Government

There are several other lawsuits wending their way through courts attempting to either compel the U.S. government to explicitly regulate GHG emissions or to take global warming into account in U.S. government decisions or actions. These lawsuits include challenges to:

- EPA's decision, under CAA section 111, not to establish a new source performance standard (NSPS) for CO_2 emissions from new, modified or reconstructed power plants[28]—EPA stated it did not have authority to "set NSPS to regulate CO_2 or other [GHGs] that contribute to global climate change;"[29]
- National gas mileage standards set in 2006 for light trucks, because the Department of Transportation failed to consider global climate change and to consider the overall environmental impact of GHG emissions from light trucks;[30]
- Investment decisions of the Overseas Private Investment Corporation and the Export-Import Bank because they failed to conduct any assessment of the impact on global warming of the loans and financial guarantees they have made for projects resulting in GHG emissions, including oil and gas fields, pipelines, oil refineries and power plants;[31] and
- Regulations that allow the oil and gas industry to incidentally take polar bears and walruses while engaging in activities in the Arctic, because the Department of the Interior allegedly failed to consider the impact that global warming, in addition to oil and gas exploration activities, will have on these species.[32]

The Supreme Court decision in *Massachusetts* will have the most direct impact on the first case, since EPA can no longer argue that it lacks authority to regulate GHG emissions under the CAA. However, setting a CO_2 NSPS is hardly straightforward. For example, for coal, would integrated gasification combined cycle (IGCC) technology be considered the "best demonstrated technology,"[33] even though it could be, as several power plant companies have argued, considered a wholly different form of generating electricity and so is changing the character of the project from one that burns coal to one that gasifies it instead? IGCC's full benefits aren't realized unless the carbon is sequestered, so would sequestration be an element of the NSPS? Technologies are being developed to capture CO_2 from traditional pulverized coal plants, but they are evolving and much more costly currently than IGCC.[34] Stay tuned.



Environmental groups and others have also sought to compel the federal government to:

- list the polar bear as an threatened or endangered species under the Endangered Species Act because global warming is imperiling the polar bears' habitat;[35] and
- produce a new National Assessment of Climate Change Impacts on the United States; the last assessment was released in 1999 and by law one is supposed to be produced every four years.[36]

Lawsuits Against Companies

The two largest sources of GHG emissions in the United States are the electric utility sector and the transportation sector,[37] and organizations have pursued lawsuits against utility and car companies. These suits raise complex legal, policy and political considerations. How can one attribute the harms of global warming to any one company, group of companies or any industrial sector, when global warming is a global pollution problem with impacts diverse and diffuse? Are the courts the right arena for this kind of policymaking, or are the issues better resolved by the legislative branch, which can weigh competing concerns and pass comprehensive or targeted legislation as needed? A court can only deal with the parties in front of it; a legislature has the entire suite of U.S. emitters to address. What kind of remedy could a court fashion that would have any impact? On the other hand, if the legislature has failed to act or not fully addressed global warming, the courts may be the forum of last resort to effect a reduction in GHG emissions.

The issue of the appropriateness of this type of lawsuit came up in the first litigation of this kind, where a coalition of eight states, New York City and several conservation and public land trusts sought a court order to force the five largest U.S. electric utilities to cut their GHG emissions.[38] A federal district court held that the regulation of CO_2 was a political question not within the jurisdiction of the federal courts. (This case is on appeal.)

Automakers hope for a similar result in a case in California, where California filed suit against six major auto manufacturers alleging that emissions from their vehicles "have contributed significantly to global warming, harmed the resources, infrastructure and environmental health of California, and cost the state millions of dollars to address current and future effects."[39] California seeks monetary damages for past and ongoing contributions to global warming and a declaratory judgment that the defendants, jointly and severally, are liable for future monetary damages to California caused by the defendants' past and ongoing contributions to global warming. Automakers filed a motion to dismiss, arguing inter alia that the lawsuit raised nonjusticiable political issues and that the suit is preempted by the Clean Air Act and EPCA.[40] During oral argument, the auto companies said the courts are the wrong venue for such a complex issue and that California's action could interfere with U.S. negotiations on global warming with other countries, so the court should dismiss the case.[41]

Hurricane Katrina engendered multiple lawsuits, including one seeking to tie the severe damage of the hurricane to companies' GHG emissions. Owners of property damaged by the hurricane filed a lawsuit against their insurance companies and included three chemical companies as defendants, alleging that the damages they sustained during the hurricane were partly as a result of the companies' GHG emissions.[42] Plaintiffs filed an amended complaint on April 19, 2006, asking for class action status to sue oil, chemical and coal companies, alleging that these companies' GHG emissions have increased the frequency and severity of hurricanes.

It seems difficult to tie any particular damage, even damage to all the homes affected by Hurricane Katrina, to increased severity of storms caused by global warming, even if one could tie a percentage of the global warming experienced to date to companies' past GHG emissions. In the past "market share liability" theories have been used to resolve similar types of cases, where a product produced by several or many companies is admittedly harmful, but it is difficult to link the product of any particular company with the specific harm suffered by a particular individual. For example, in a class action case involving ten manufacturers of diethylstilbestrol (DES), the California Supreme Court agreed with apportioning liability based on the market share of companies – company Y with Y% of market share was liable for Y% of all the damages suffered by people using the company's product, and company X with X% of market share was liable for X% of the damages, etc.[43] But even if a court were to accept market share liability, the court may still require that plaintiffs to tie the increased severity of Hurricane Katrina directly to global warming, and the author is not aware of any scientific studies conclusive on this point.

Lawsuits Challenging State Government Regulations

Thus far I have discussed litigation dealing with failures of the federal government and companies to address global warming. Now I will turn to litigation challenging state regulations aimed at reducing GHG emissions.

As noted above, California adopted GHG emission standards for passenger vehicles, including SUVs, which go into effect for Model Year 2009 vehicles, and more than a dozen states are either adopting or considering adopting the California standards. Several lawsuits have been filed in different states challenging these GHG emission standards for motor vehicles.[44]

The case directly addressing the California regulations (as opposed to the adoption by another state of the California standards) is *Central Valley Chrysler-Jeep v. Witherspoon*. The judge in September 2006 made an initial ruling throwing out two of the claims[45] but finding that three other claims had a sufficient basis to go forward: that California's standards are preempted by the CAA, EPCA and U.S. foreign policy.

With respect to the CAA, because EPA has not yet granted the waiver required under section 209(b), Judge Anthony Ishii said he could not dismiss this claim.[46] With respect to EPCA, the automobile industry claimed that the California standards are preempted by EPCA because they are related to fuel economy, and by passing EPCA, Congress preempted any state from setting standards related to fuel economy. The industry also argued that EPCA provides for other objectives, such as ensuring the economic vitality of the automobile industry, that could be frustrated if states set standards that would require more fuel-efficient cars. California responded, in part, that because the CAA allows the state to set air pollution emission standards, and those standards may have an impact on fuel economy, this evidenced Congressional intent to allow California to set the GHG emission standards. Judge Ishii found that there was nothing before him that "evinces Congress' intent to permit California regulations that stand as an obstacle to EPCA's objectives," so the EPCA preemption claim could move forward.[47] The Supreme Court opinion in *Massachusetts v. EPA*, however, weakens the industry's EPCA argument.[48]

Neither of these decisions is surprising; however, Judge Ishii's decision not to throw out the foreign policy conflict claim is troubling. The automobile industry argued that California's regulation "interferes with the ability of the United States to speak with one voice upon matters of global climate change and diminishes the bargaining power of the United States in negotiating multilateral reductions" of GHGs.[49] Judge Ishii said that the "absence of a statute or executive agreement is not fatal to a foreign policy preemption claim."[50] This is disquieting, since it would prevent states from acting on a subject matter covered or addressed in any parleys between the federal government and foreign nations *even if there is no international or national agreement* (like a treaty or law) memorializing U.S. policy. Ishii concluded that, since the executive branch's preferred policy approach was to negotiate with other nations to reach agreements regarding GHG emissions reductions,[51] and the plaintiffs allege that the California regulations undercut

this strategy, there is a basis for the automobile industry's claim of foreign policy preemption.[52] Let's consider the ramifications if this proves to be a winning argument. If the U.S. federal government is discussing any environmental issue in the international arena, a state is preempted from acting on that particular issue if such action could conceivably interfere with these discussions? This could tie states' hands in all manners of environmental regulation. More specifically, does it mean that no state can regulate GHG emissions at all, as California, New Hampshire, Massachusetts, Oregon and Washington have done with respect to power plant emissions? Renewable portfolio standards (RPS) increase the amount of renewable energy generated, which decreases GHG emissions since renewable energy emits little or no GHG emissions. Does it mean a state cannot even set a RPS, as 23 states and the District Columbia have done?[53] Granted, Judge Ishii's decision was only that this claim could leap the first hurdle and go to trial, and one hopes that this is as far as it goes. Judge Ishii stayed further proceeding in this case on January 16, 2007, pending the outcome in *Massachusetts v. EPA*.[54]

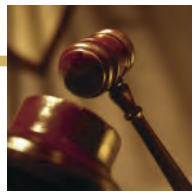
Interestingly, a judge in Vermont decided not to stay proceedings in a case where the automobile industry sued the state of Vermont for adopting California's standards. Judge William Sessions III said that the case is sure to be appealed, and the appellate court "rightfully should be able to review a 'complete' record of ... 'an extraordinary case.'"[55] Following the Supreme Court decision in *Massachusetts v. EPA*, the judge held a hearing to determine whether the case should still move forward. Those defending the Vermont standards argued that the Supreme Court case meant the California standards were valid, but the automakers said the Court decision did not settle the EPCA preemption claim. Judge Sessions decided to proceed to trial without ruling on any of the main legal issues, saying that this was such an important case he wanted to hear all the evidence before deciding the outcome.[56] The trial in *Green Mountain Chrysler Plymouth Dodge Jeep v. Crombie* began April 10, 2007.

A Peek Into the Future

The Supreme Court decision in *Massachusetts v. EPA* has provided some helpful guidance on what can be done under the Clean Air Act to regulate GHG emissions, including making it more likely that the California GHG emission standards for new motor vehicles will withstand legal challenges. And hopefully claims that state or local regulation of GHG emissions is preempted by foreign policy considerations will be rebuffed, so that states and localities may continue their leadership role on global warming.

There is another titanic legal issue around the corner, though: to what extent can states cooperate in regulating GHG emissions? In 2009 ten states[57] will launch a regional cap-and-trade program covering CO_2 emissions from power plants in the region. Watch for claims that this regional agreement interferes with interstate commerce or is otherwise unconstitutional and that it is preempted for foreign policy reasons. Other regional actions that may be the subject of lawsuits are the Western Regional Climate Action Initiative, in which Arizona, California, New Mexico, Oregon and Washington have agreed to set a regional GHG reduction target and devise a market-based program to meet that target,[58] and a multistate GHG registry launched by 30 states this spring.[59]

References



1 Any views expressed in this article are my own and do not necessarily reflect the views of NACAA or any of its members or staff.

2 Litigation is not the only global warming policy strategy being followed by environmental groups and states and localities. For example, numerous states and localities are taking action to reduce GHG emissions and are developing or have developed climate change action plans. This plethora of activity is not catalogued in this article because the focus of this article is litigation.

3 Supreme Court Case No. 05-1120. The decision, which was issued on April 2, 2007, is available at www.supremecourtus.gov/opinions/06pdf/05-1120.pdf, and hereinafter is cited as *Massachusetts v. EPA* slip opinion.

4 Section 202(a)(1) provides in part that the EPA administrator "shall by regulation prescribe . . . standards applicable to the emission of any air pollutant from any class or classes of new motor vehicles or new motor vehicle engines, which in his judgment cause, or contribute to, air pollution which may reasonably be anticipated to endanger public health or welfare."

5 68 Fed. Reg. 52922 (Sept. 8, 2003).

6 Memorandum from Jonathan Z. Cannon, EPA General Counsel, to Carol M. Browner, EPA Administrator, "EPA's Authority to Regulate Pollutants Emitted by Electric Power General Sources," (Apr. 10, 1998).

7 68 Fed. Reg. 52922, supra note 5, at 52928.

8 The CAA does provide for a cap-and-trade scheme for sulfur dioxide emissions to deal with the problem of acid rain, but the Clean Air Interstate Rule also covers nitrogen oxide emissions and was designed to address a different problem – the interstate transport of ozone and fine particulate matter.

9 In testimony before the House Energy and Commerce Committee's Subcommittee on Energy and Air Quality on March 6, 2007, Acting Assistant Administrator Bill Wehrum said that EPA "determined that the underground injection of carbon dioxide is subject to the Underground Injection Control (UIC) Program of the Safe Drinking Water Act (SDWA), which regulates injection activities to protect current and future sources of drinking water." See http://energycommerce.house.gov/cmte_mtgs/110-eaq-hrg.030607.Wehrum_Grumbles-Testimony.pdf.

10 *Massachusetts v. EPA*, 415 F.3d 50 (D.C. Cir. 2005) cert granted 126 S. Ct. 2960 (2006).

11 A transcript of the oral argument is available at http://www.supremecourtus.gov/oral_arguments/argument_transcripts/05-1120.pdf.

12 *Massachusetts v. EPA* slip opinion, supra note 3.

13 Id. at p. 30.

14 Id. at p. 17.

15 Id. at p. 10.

16 As long as one person meets the standing test, then the court need not examine whether any or all of the other petitioners meet this test.

17 *Massachusetts v. EPA* slip opinion, supra note 3, at p. 23.

18 Id. at p. 19.

19 Northwestern Environmental Defense Center, et al. v. Owens Corning, 434 F. Supp.2d 957 (D.Or. 2006). See http://law.lclark.edu/org/peac/objects/oc_order_denying_motion_to_dismiss.pdf.

20 *Massachusetts v. EPA* slip opinion, supra note 3, at p. 26.

21 Id. at p. 29.

22 *Massachusetts v. EPA* slip opinion, supra note 3, Roberts' dissent, at p.13.

23 This is strongly criticized by Justice Scalia in his dissent. He says executive agencies routinely decide not to take action based on policy reasons not expressly mentioned in a statute and that the majority failed to give due deference to this prioritization.

24 And it would seem that EPA would have to conclude that scientific uncertainty on global warming "is so profound it precludes EPA from making a reasoned judgment as to whether GHG emissions contribute to global warming" to avoid making this finding.

25 Connecticut, Maine, Maryland, Massachusetts, New Jersey, New York, Oregon, Pennsylvania, Rhode Island, Vermont and Washington.

26 Arizona, New Mexico and North Carolina.

27 *Massachusetts v. EPA* slip opinion, supra note 3, at p. 29.

28 *Coke Oven Environmental Task Force v. EPA*, 2006 U.S. App. LEXIS 23499 (D.C. Cir. 2006). The petitioners are Environmental Defense, Natural Resources Defense Council and the Sierra Club; California, Connecticut, Maine, Massachusetts, New Mexico, New York, Oregon, Rhode Island, Vermont and Wisconsin; and the District of Columbia and New York City. The case has been stayed pending a decision in *Massachusetts v. EPA*; now that a decision has been rendered by the Supreme Court, it will move forward.

29 71 Federal Register 9869 (Feb. 27, 2006) (the NSPS covered sulfur dioxide, nitrogen oxides and particulate matter).

30 *Center for Biological Diversity v. Nat'l Highway Traffic Safety Admin.*, No. 06-71891 (9th Cir. Apr. 6, 2006).

31 *Friends of the Earth v. Mosbacher*¸ Civ. No. C02-4106 (N.D. Cal. 2006), 2005 U.S. Dist. LEXIS 42335 (N.D. Cal. 2005). The petitioners claim that the National Environmental Policy Act applies to these two organizations.

32 *Center for Biological Diversity v. Kempthorne*, No. 3:07CV00894 (N.D. Cal. 2007). Incidental take regulations permit limited killing and harassing of animals protected under the Marine Mammal Protection Act.

33 Per EPA, "[s]ection 111 of the CAA requires that NSPS reflect the application of the best system of emissions reductions which (taking into consideration the cost of achieving such emissions reductions, any non-air quality health and environmental impact and energy requirements) the Administrator determines has been adequately demonstrated. This level of control is commonly referred to as best demonstrated technology (BDT)." 71 Federal Register 9868 (Feb. 27, 2006)

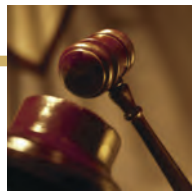
34 EPA issued a report in 2006 comparing IGCC and pulverized coal technologies. EPA, Environmental Footprints and Costs of Coal-Based Integrated Gasification Combined Cycle and Pulverized Coal Technologies (July 2006) (EPA-430/R-06/006), available at http://www.epa.gov/air/caaac/coaltech/2007_01_epaigcc.pdf.

35 *Center for Biological Diversity v. Norton*, No. 3-05-05191 (N.D. Cal. Dec. 15, 2005). This lawsuit was settled, and the U.S. Fish and Wildlife Service on December 27, 2006, proposed to list the polar bear as a threatened species. U.S. Department of Interior press release, "Interior Secretary Kempthorne Announces Proposal to List Polar Bears as Threatened Under Endangered Species Act," (Dec. 27, 2006), available at http://www.fws.gov/home/feature/2006/12-27-06polarbearnews.pdf. The groups suing hope that listing the polar bears will mean that, since the ESA requires the protection of the bears' habitat, the U.S. government will need to consider the GHG emission implications of any and all of its decisions or actions.

36 *Center for Biological Diversity v. Brennan*, No. C06-7061 (N.D. Cal. Nov. 14, 2006). The Global Change Research Act of 1990 requires that the U.S. government prepare the National Climate Change Assessment every four years; this assessment integrates, evaluates and interprets the findings of the federal government's climate change research. The federal government filed briefs February 27, 2007, seeking to dismiss the lawsuit on the basis that the plaintiffs lack standing because the law requires the reports to be submitted to Congress and the president, and not the public.

37 In 2005 the electricity sector and transportation sector were responsible for 41% and 33% of U.S. CO_2 emissions from fossil fuel combustion, respectively. EPA, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005 (April 2007), available at http://www.epa.gov/climatechange/emissions/usinventoryreport.html.

38 406 F. Supp. 2d 265 (S.D.N.Y. 2005).



39 *California v. General Motors*, No. C06-05755 (N.D. Cal. Sept. 21, 2006).

40 The motion to dismiss was filed on Dec. 15, 2006 and oral arguments were held in March 2007.

41 "Car companies ask for Calif. suit dismissal," Argus Air Daily (Mar. 7, 2007) at p. 4.

42 *Comer v. Nationwide Mutual Insurance* (filed Sept. 20, 2005) (now *Comer v. Murphy Oil*, 2006 WL 1066645 (S.D. Miss. 2006).

43 *Sindell v. Abbott Laboratories*, 607 P.2d 924 (1980). DES was prescribed for pregnant women and their daughters suffered cancerous and pre-cancerous growths as they grew up.

44 *Central Valley Chrysler-Jeep Inc. v. Witherspoon* No. CV-F-04-6663 2006 U.S. Dist. LEXIS 48892 (E.D. Cal.); Green Mountain Chrysler-Plymouth-Dodge v. Crombie No. 2:05CV00302 (D.Vt. Nov. 18, 2005); *Association of International Automobile Manufacturers v. Sullivan* No. 06-cv-69 (D. R.I. Feb. 13, 2006) consolidated with *Lincoln Dodge Inc. v. Sullivan*, No. 06-cv-70 (D. R.I. Feb. 13, 2006).

45 The judge granted the motions to dismiss the claims under the dormant Commerce Clause (saying any impact of the California regulations on interstate commerce was understood and authorized when Congress enacted section 209(a) allowing California to set separate motor vehicle emissions standards) and the claims filed under the Sherman Act. A copy of the decision is available at http://www.calcleancars.org/legal/Order_JOP_9-25-06.pdf (hereinafter "Ishii Opinion").

46 Id at 20. The CAA provides that California can set a different air pollution emission standard for new motor vehicles if EPA issues a waiver, and arguably if EPA does not issue this waiver, California's standards are preempted. EPA cannot grant the waiver if the administrator finds that "(A) the determination of the State [that its standards, in the aggregate, are at least as protective of public health and welfare as applicable federal standards] is arbitrary and capricious, (B) such State does not need such State standards to meet compelling and extraordinary conditions, or (C) such State standards and accompanying enforcement procedures are not consistent with section 202(a)(1) of this part." Section 209(b)(1)(A)-(C). Following the Supreme Court decision, EPA announced it would hold hearings and open a public comment period on the waiver request. "Under Senate scrutiny, EPA opens comment period on Calif. waiver plan," Greenwire (Apr. 24, 2007).

47 Id at 19.

48 As noted above, the majority opinion in Massachusetts dismissed a similar argument that EPA made in defending the agency's interpretation that the CAA definition of "air pollutant" does not include GHG emissions. EPA argued that if GHG emissions were air pollutants, the only way it could decrease GHG emissions from new motor vehicles would be to increase fuel efficiency standards, and this would conflict with DOT's authority under EPCA to set mileage standards. The Court said "there is no reason to think the two agencies cannot both administer their obligations and yet avoid inconsistency." *Massachusetts v. EPA*, slip opinion, supra note 3, at p. 29. The automakers may argue that there is a difference between EPA setting an emissions standard versus California so doing, since as an agency in the executive branch EPA will consult with DOT to avoid inconsistency, but California does not necessarily do so when it sets its emission standards.

49 Ishii Opinion at 23, quoting plaintiffs' brief.

50 Id. at 26.

51 However, this does not appear to be the U.S. government's current policy, given the Bush administration's renouncing of the Kyoto Protocol in February 2002 and actions to thwart agreements on future GHG reductions. For example, at an international meeting in Montreal in December 2005, the U.S. walked out of negotiations to protest the inclusion of language in a diplomatic statement calling for a dialogue on "long-term cooperative action to address climate change," and, more recently, in meetings among major industrialized countries in March 2007, the U.S. "blocked consensus for supporting a carbon trading market." "U.S. walks out as negotiators draft call for 'long-term cooperative action,'" Greenwire (Dec. 9, 2005); and "U.S. blocks consensus of G8-plus-Five on global warming issues," Greenwire, (Mar. 19, 2007).

52 Ishii Opinion at 32.

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55 Tim Johnson, "Vt. car dealers' emissions fight snares attention," Burlington Free Press (Mar. 3, 2007), available at http://www.burlingtonfreepress.com/apps/pbcs.dll/article?AID=2007703030311.

56 Candace Page, "Judge declines to drop Vermont auto emissions trial," Burlington Free Press (Apr. 5, 2007).

57 Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island and Vermont. See www.rggi.org.

58 The initiative is described at http://governor.oregon.gov/Gov/pdf/letters/022607NGA.pdf.

59 A description of this effort is available at ; scroll down to "Registry Collaboration and Linkages."

Greenhouse Gas Registries in the United States: Cutting through the Clutter

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Introduction

In recent years, multiple efforts have emerged across the U.S. to design and implement greenhouse gas (GHG) registry systems. GHG registries are being developed on several geographical levels – state, regional, and national – and are being designed to support different objectives, such as voluntary corporate reporting, state/regional-level GHG regulatory systems, and tracking progress towards a national voluntary GHG intensity target.

With all of this activity on GHG registries in the U.S., there are important questions to be addressed. What type of GHG registry system does the U.S. need to support effective U.S. action to address climate change? Is one national registry system preferred to multiple state or regional-level registries? How should such a registry be designed?

This paper aims to cut through the clutter on GHG registries in the U.S. It provides a general overview of GHG registries, evaluates the need for a U.S. registry system, and offers a brief description of existing and emerging GHG registries and reporting programs in the U.S. It then discusses, based on the World Resources Institute's (WRI) experience in GHG accounting, reporting and registry development, what a U.S. registry system would look like to support effective U.S. climate action. This paper aims to provide insights to help state and federal policy makers, businesses, environmental advocates, and other interested stakeholders better understand key building blocks of GHG registries and their function as the U.S. begins to take action on climate change.

GHG Registries: What and Why?

A GHG registry is a system or database that receives and stores GHG emissions data. GHG registries generally follow a bottom-up approach, where entities (e.g., facilities, companies, municipalities, universities, non-profit organizations, etc.) quantify their emissions from various individual sources and report this data to the registry. GHG registries can collect emissions data at various levels, including at the unit/source, the facility, or corporate or organization-wide.

Emissions data held by a registry is generally based on a series of GHG accounting and reporting standards, or a set of commonly accepted concepts and terminologies, within an agreed framework that, collectively, establish a true and fair account of GHG emissions. One widely used model is the GHG Protocol Initiative (see Box 1).

Current Status of GHG Registry and Programs in the U.S.

There is an active and widespread effort to develop GHG registry and reporting programs in the U.S (see Box 2). Most of these registries and programs have emerged within the past five years.

At the Federal level, while several emissions registries track data on CO2 emissions, only one – the DOE's 1605(b) registry – is designed to focus on GHG emissions. A second, the EPA Climate Leaders Program, focuses on providing a registry to record voluntary emissions reduction efforts by corporations that are part of the Climate Leaders Initiative.

At the state and regional level, the most established registry system is the California Climate Action Registry (CCAR), which has been in operation since 2002. All of the other regional-based registries listed in Box 2 are either still under development or in the very preliminary

BOX 1. The GHG Protocol

The Greenhouse Gas Protocol is a multi-stakeholder partnership of businesses, NGOs, governments, and others led by WRI and the World Business Council for Sustainable Development (WBCSD). The GHG Protocol provides the accounting framework for nearly every GHG standard and program in the world – from the International Organization for Standardization (ISO) to the World Economic Forum GHG Register – as well as hundreds of GHG inventories prepared by individual companies. In the U.S., key initiatives based on the GHG Protocol include the U.S. EPA Climate Leaders Program and the California Climate Action Registry. In addition, the EU Emissions Trading System uses quantification methodologies provided by the GHG Protocol and refers to the Protocol as one of the three main sources that guided the design of its Monitoring & Reporting Guidelines (MRG) published in 2006.

A GHG standard or methodology such as the GHG Protocol Corporate Standard provides a measurement and reporting framework for a GHG registry. A GHG registry and the standards on which a registry is based, together serve as the emissions accounting and reporting foundation for various types of GHG policies, programs or other initiatives. While the specific design of a registry (and its underlying measurement and reporting framework) is a function of the targeted GHG program objectives, the GHG standards themselves are usually policy and program neutral, allowing them to be integrated in these design choices.

For instance, emissions estimates from individual sources reported to a registry can be used for regulatory purposes, where individual sources or facilities face emission restrictions. For such regulatory policies, registries provide a common database for mandatory emissions reporting and can also track emission reductions and support design and operation of an emissions and allowance trading system.

Emissions estimates from individual sources can also be consolidated or "rolled-up" to the organization level to support voluntary reporting, where companies and other entities inventory their organization-wide emissions on a year-to-year basis and track progress towards emission reduction targets. Registries can support corporate GHG management efforts by providing credibility and validation to a company's emissions data, and in certain situations may be able to serve as a mechanism for an entity to protect its baseline or get "early action credit" in future regulatory schemes. Most registries also serve as a public window into the GHG emissions of reporting entities, as they make data transparently available.

stages of consideration. One very recent new regional system being developed is "The Climate Registry", a collaboration of more than 30 states seeking to create a unified GHG reporting and accounting platform in the U.S.

In addition, one private sector registry has been developed. The Chicago Climate Exchange (CCX), which in 2003 launched a voluntary emissions trading platform, set up a registry to record corporate performance within the exchange.

Key Elements and Characteristics of a U.S. GHG Registry

Given all of this activity on GHG programs (and attendant registries), it is worthwhile to examine what type of GHG registry system the U.S. needs to support effective action to address climate change.

Establish a single national registry

While the current GHG registry situation features multiple state, regional, and national-level systems, it is clear that a national "patchwork" of multiple registry systems is both overly complex and inefficient. A single (well-designed) national registry system would ensure consistency in GHG accounting and reporting and standardize best practices, and would help facilitate linkages between various types of GHG programs that may use the registry. A single system would also ease the burden on companies, which want to voluntarily report emissions by eliminating multiple reporting requirements.

Ensure the consistent reporting of absolute emissions and reductions over time

To support effective U.S. action on climate change, a national registry should track emissions and reductions based on absolute emissions, not intensity metrics. Intensity measurements can be valuable as performance indicators that are independent of company growth, and can provide helpful benchmarks for achieving emission reductions. However, in order to have a mechanism that monitors overall environmental effectiveness, a registry needs to be couched in the context of transparent and consistent reporting of absolute emissions over time. This will allow the clear and transparent monitoring of overall progress in achieving real reductions.

Follow internationally accepted GHG accounting standards and methodologies

A national U.S. registry system should not "reinvent the wheel" and should adopt credible, broadly accepted and widely used accounting and reporting standards and quantification methodologies, such as those featured in the GHG Protocol and the International Panel on Climate Change (IPCC) guidelines, and recently adopted by the International Standards Organization (ISO). Adopting best practice GHG standards and methodologies would ensure environmental credibility, enable a U.S. registry system and its associated GHG policies or programs to link with other sub-national, national, or international registries and policies; and simplify business participation for companies already following best practice methodologies.

Incorporate five key GHG Protocol accounting and reporting principles

A U.S. registry should require reporting entities to account, report, and verify their GHG emissions according to the following five principles, based on established financial accounting and reporting practices. This will ensure expectations are clearly set to promote the highest possible degree of rigor and credibility of the reported information.

Box 2. Existing and Emerging U.S. Registries and Programs

U.S. Federal Government GHG Registry Systems

U.S. DOE Voluntary Greenhouse Gas Reporting Program [1605(b)]: The federal government's GHG registry system that consists of a public reporting platform. The registry was originally established in 1994, but has undergone several rounds of revisions, with the most recent guidelines being released in April 2006. The registry tracks emission reductions made by individual entities, based on intensity metrics.

U.S. EPA Clean Air Markets Data and Maps: Designed to register data related to the Acid Rain Program and the NOx Budget Trading Program, this registry also contains CO2 emissions data for over 3,500 electricity generating units covered under the Acid Rain Program.

U.S. EPA Emissions & Generation Resource Integrated Database (eGRID): An online database for data related to electric power generated in the U.S., eGRID also contains CO2 emissions data on more than 4,700 U.S. power plants and nearly 2,000 electricity generating companies.

U.S. State and Regional GHG Registry Systems

California Climate Action Registry: A voluntary GHG registry created by California legislation, which has been in operation since 2002. Over 85 organizations including companies, cities, government agencies, and NGOs publicly report their GHG emissions through the Registry.

Eastern Climate Registry (ECR): Ten states in the eastern U.S., including Connecticut, Delaware, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, Pennsylvania, and Vermont, coordinated by NESCAUM, are in the final stages of developing a GHG registry.

Other State/Regional Registry Initiatives: Eight Midwest States, coordinated by the Lake Michigan Air Directors Consortium (LADCO), have been exploring the development of a regional GHG Registry, as have 13 Western states, coordinated by the Western Regional Air Partnership (WRAP).

The Climate Registry (TCR): An emerging collaboration of U.S. states and tribes working together to create a unified GHG reporting and accounting platform in the U.S. About 30 states are involved in development and design of the TCR, including the states from the four U.S. state and regional GHG registry efforts described above (CCAR, ECR, LADCO, & WRAP), and several states from other U.S. regions (e.g., Southeast).

Other Relevant GHG Programs and Climate Initiatives

Regional Greenhouse Gas Initiative: A partnership among nine Northeastern States (Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York and Vermont), to establish an emissions trading program within the electricity generation sector. The states have committed to stabilizing emissions at base levels by 2014, and reducing emissions by 10% by 2020. The group is still in the process of developing a registry (the Regional Greenhouse Gas registry, RGGR, sometimes referred to as the Eastern Climate Registry).

U.S. EPA Climate Leaders Program: A voluntary partnership that works with companies to develop and implement GHG management strategies. Climate Leaders partners set a corporate-wide GHG reduction goal and inventory their emissions to measure progress, and follow EPA-specified GHG accounting and reporting procedures, which are based on the WRI/WBCSD GHG Protocol. The EPA Climate Leaders program does not function as a public reporting platform for GHG emissions.

Chicago Climate Exchange (CCX): An independent, for-profit, voluntary GHG emissions and allowance trading program. CCX members make a voluntary, but legally binding commitment to reduce GHG emissions by certain levels. The CCX has specified GHG accounting and reporting procedures, which are based in-part on the WRI/WBCSD GHG Protocol. The CCX does not function as a public reporting platform for GHG emissions.

Western Regional Climate Action Initiative (WRCAI): Announced in February 2007, WRCAI brings together Arizona, California, New Mexico, Oregon and Washington in an effort to: establish a regional greenhouse gas emission reductions target by August 2007; and design a joint market-based emissions reduction mechanism, such as a cap and trade system, by August 2008.

US Climate Action Partnership (USCAP): Launched in January 2007, USCAP is a business and NGO partnership calling for "prompt enactment of national legislation in the United States to slow, stop and reverse the growth of greenhouse gas (GHG) emissions over the shortest period of time reasonably achievable." Founding USCAP members include Alcoa, BP America Inc., Caterpillar Inc., Duke Energy, DuPont, Environmental Defense, FPL Group, General Electric, Natural Resources Defense Council, Pew Center on Global Climate Change, PG&E Corporation, PNM Resources, and World Resources Institute. A primary recommendation of USCAP is the establishment of an "economy-wide, market-driven approach that includes a cap and trade program that places specified limits on GHG emissions."

Box 3: Entity vs. Project Accounting

	Entity Accounting	Project Accounting
Focus	Quantify corporate or facility-level emissions inventory	Quantify project-level emissions reductions
Primary Purpose	Manage GHG assets and liabilities	Account for offsets used to meet a voluntary or mandatory reduction target
Accounting Principles	• Relevance • Completeness • Accuracy • Transparency • Consistency	• Relevance • Completeness • Accuracy • Transparency • Consistency • Conservativeness
Boundaries	Based on ownership or control criteria	Based on extent of project's effects
Upstream and Downstream Impacts	Included (direct and indirect emissions)	Included (primary and secondary effects)
Basis of Reductions	Historical emissions reference case (base year)	Hypothetical emissions reference case (baseline)

- Relevance – Ensure the GHG inventory appropriately reflects the GHG emissions of the reporting entity and serves the decision-making needs of users – both internal and external to the reporting entity.
- Completeness – Account for and report on all GHG emission sources and activities within the chosen inventory boundary. Disclose and justify any specific exclusions.
- Consistency – Use consistent methodologies to allow for meaningful comparisons of emissions over time. Transparently document any changes to the data, inventory boundary, methods, or any other relevant factors in the time series.
- Transparency – Address all relevant issues in a factual and coherent manner, based on a clear audit trail. Disclose any relevant assumptions and make appropriate references to the accounting and calculation methodologies and data sources used.
- Accuracy – Ensure that the quantification of GHG emissions is systematically neither over nor under actual emissions, as far as can be judged, and that uncertainties are reduced as far as practicable. Achieve sufficient accuracy to enable users to make decisions with reasonable assurance as to the integrity of the reported information.

Require public reporting of entity-wide emissions data, broken down to the unit or facility-level

To design a registry that can support the requirements of a future GHG regulatory scheme (and possibly other GHG initiatives), it will be necessary for entities to report entity-wide emissions data at the greatest level of granularity – at the unit-level or at least the facility-level. Most if not all existing cap and trade programs, including the U.S. Acid Rain Program, U.S. NOx Budget Trading Program, the Northeast States regional GHG Initiative and the E.U. Emissions Trading System, regulate at the unit or facility-level. The reporting of unit or facility-level emissions data would enable a registry system to "roll-up" emissions to the company-level, which is important for corporate GHG management efforts (a significant potential value added). Emissions reported at the unit or facility-level can also be rolled-up to the state, regional, or sectoral-level, so a registry that requires unit or facility-level emissions reporting can serve as a foundation for multiple types of GHG policies and programs, including those that are either multi-sectoral or sector-specific; mandatory or voluntary; or national-level or state/regional-level.

Provide a clear and adequate distinction between entity-level and project-level GHG accounting

To be credible and ensure environmental integrity, a U.S. registry system must distinguish between the two types of GHG accounting – entity-level and project-level (often referred to as "offset") accounting. Entity-level accounting is most

commonly used to measure emissions from entities that are regulated as part of a cap and trade program and to measure organization-wide emissions of companies through a corporate GHG inventory. In entity-level accounting, a company or other entity measures its reductions in GHG emissions by comparing current year emissions against historical "base year" emissions.

Project accounting is most commonly used to measure reductions from unique GHG mitigation projects or offsets that occur outside the reporting boundary of sources covered under a cap and trade system or an entity's GHG inventory. In project accounting, GHG reductions are calculated against a hypothetical "baseline". Project offsets are commonly defined as the emissions that would have occurred had the GHG mitigation project not been implemented. It is important that any project-level or offset methodologies incorporated into a national U.S. registry ensure that reductions are environmentally additional, verifiable, permanent, and enforceable – an often difficult calculation that has led to many regimes limiting their acceptance of such projects.

Under emerging domestic and international approaches to emissions accounting, reductions against these different types of reference points are subject to very different considerations and requirements.

Conclusion

There is a clear need for a credible national GHG registry system capable of supporting effective U.S. action on climate change. The successes and failures in developing and implementing registries in the last decade by various initiatives provide a rich source of information and experience that should be used to inform the design of a national registry.

Such a system must meet a set of minimum standards to be both environmentally acceptable, and to ensure that sound business practices can be built around registry reports. Meeting this need and challenge will be possible through a registry design that:

i. tracks absolute emissions and reductions over time;

ii. requires public reporting of entity-level emissions data, broken down (at a minimum) to the facility level;

iv. ensures separation between entity and project level accounting;

v. uses widely accepted and internationally recognized GHG accounting principles; and

v. follows international standards and best practices such as GHG Protocol Corporate Standard.

References

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The Role of Glaciers and Ice Cores in Deciphering Global Climate Change

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Abstract

With the onset of a widely recognized increase in global temperature the world's glaciers and ice sheets have responded by melting and retreat. This observed recession is particularly pronounced for glaciers that survive in the tropics and mid-latitudes where, in many cases they serve as long-term and seasonal water storage repositories. In addition, archived in the stratigraphy of glacial ice is a climate record that has provided a detailed understanding of the magnitudes and timing of past climate changes. The need for continued monitoring of the world's glaciers and ice sheets and the recovery of ice cores is becoming increasingly important, for as these glaciers melt, the high resolution records they contain are being lost.

Generalities

Global climate change and its consequences for the planetary biosphere has perhaps become the most visible of contemporary environmental and social issues. While current debate is typically focused under the rubric of "global warming", it should be reiterated that this is in effect one possible state or direction of global environmental change. Having been in the forefront of discussion in scientific and political circles for some time, discourse connected to global change has increasingly moved away from the supposition that such changes are not real or inconsequential to wide agreement that indeed such changes are real and observable. Discussion is now, more than ever, focused on the possible causation of climate change, observed and potential impacts and strategies (both adaptive and mitigative) necessary to accommodate these large scale environmental shifts. Such commentaries, however, have yet to establish common and definitive ground and debate often continues to the point of acrimony and dispute (Monastersky 2003; Flannery 2005).

Regardless of the causal agents, it is certainly evident that such change is consequential from a human and environmental perspective. The recent plethora of literature related to global environmental change has now extended well beyond those publications to be found in the so-called scientific journals to a broad spectrum of readable literature now readily available to the general public. Such publications range from the multiple technical and compound details of climate change processes (Houghton *et al*, 2001; Lovejoy and Hannah, 2006) to the impact of climate change on the human, environmental and political landscape (e.g. Flannery, 2005; Nash, 2002; Beder, 1997) to those that form a more readable base to a casual and informed public (e.g. Lynas, 2004; Dressler and Parson, 2006).

It is also important to note that research related to climate change is not a new arena of academic thought nor should it be considered a recent environmental concern. Since the early 1800's glaciers in the European Alps were observed in a state of retreat, and in fact, it was through observation of these retreating glaciers that Louis Agassiz (1807-1873) postulated his theory of ice ages and so connected the dynamics of glaciers to climate. By the early to mid-1900's, a shift in thought as to the potential for a human-based (anthropogenic) influence on the Earth's climate system began to emerge as the impact of the industrial revolution was realized (e.g. Callendar 1938; 1949). In a very notable series of papers, Plass (1956; 1959) laid the foundations for understanding the relationships between changes in atmospheric composition and possible anthropogenic forcing. His studies on carbon dioxide (CO_2) variability and its role as a greenhouse gas remains as foundational research in the global warming debate. With increasing awareness of the complexities of the global climate system and its linkages to all other elements of the physical and human environment, attention was soon focused on the causation, geographical distribution, and impact of global climate change (Revelle and Suess, 1957; Broecker 1965; 1975; Mercer 1968; 1978).

The emerging picture as to the mechanics and consequences of global climate change is one that has found convergence from a diversity of independent scientific fields and a great variety of analytical techniques. The interpretation of climatic changes and events interpreted through proxy evidence such as tree rings, coral isotope records, ice cores, pollen analysis, marine sediments, to name a few, has factored into the construction of a coherent picture of the global climate and the changes that have taken place over various time scales (see for example, Bradley, 1999). In terms of areal or geographic studies such research is, of course, not solely focused on the global scale but has a fine tradition of connections at the regional level and down to the local scale (Greenland, 2001; Mountain *et al*, 2001; Offerle *et al*, 2007). Furthermore, climate variability and change as connected to other climate responsive phe-

nomena, including the timing and patterns of human occupancy, has now become a familiar focus in a constantly evolving literature base (Shimada *et al*, 1991; Thompson *et al*, 1988. Fagan 1999; Bradley *et al*, 2003; Diamond, 2005; Wei *et al*, 2007).

Where Glaciers Fit in

Of the multiple techniques developed and applied to unravel the global climate, ice cores recovered from the world's glaciers have perhaps proven the most reliable and information rich. Glaciers are global in extent surviving in the tropics, mid latitudes and the polar regions, with the great ice masses of Greenland and the Antarctic Continent the last of the Pleistocene ice sheets (see Figure 1). Perhaps one of the more utilitarian aspects of glacial analyses is that the mechanics of formation and their environmental response as we see them today are exactly the same as processes that led to their development in the past. That is, they are true modern-day analogs. While the frequency, intensity, and spatial (geographic) distribution of phenomena leading to their formation (or demise) may have altered, the physics of these processes cannot change and remain consistent with the fundamental laws accepted as governing our natural environment (i.e. the precipitation process, the transition from snow to glacial ice, the internal deformational processes that lead to glacial movement, system responses to energetic inputs, etc, are physically-based and do not change simply as a function of time).

As an integral part of the global hydrologic cycle, glaciers occupy a unique position in that they respond to shifts in the energetics of the Earth-atmosphere system at all temporal (time) and spaial scales. In addition, by the very nature of their formation, they evolve as a remarkably precise and efficient storage environment in which an archive of past climate is well preserved. As such the connections between the presence of glacial ice on the surface of the Earth, its spatial extent, and the dynamics of glacial response in continually adjusting to the variations in the climate system (both long- and short-term) has become a focal point of environmental analyses – particularly with respect to global warming (Arendt *et al*, 2002; Gerbaux, 2005).

Glaciers and ice masses can be viewed as dynamic systems that respond to a definable set of inputs and respond through a set of equally definable outputs. In the simplest of relationships, glaciers connect to the climate of the time by accumulating and expanding when the temperature lowers (or precipitation increases), or by melting or ablating when the air temperature increases (or precipitation diminishes). A third possibility exists in the event that there is, over time, a stability or permanence in the climate (with only temperature and precipitation factored in here) such that the inputs to this system are balanced with the system output. In this case the glacier will exhibit neither expansion or retreat and the resulting fixed position reflects a state of climatic equilibrium or stability.

With only a few exceptions, glaciers worldwide are today experiencing mass loss and are retreating, many very rapidly, indicating an adjustment to a climatic regime different from that responsible for their formation. For the most part this retreat or adjustment is attributed to an overall increase in atmospheric temperature, but there are cases where such retreat is a function of changes in regional precipitation patterns (Molg and Hardy, 2004). Perhaps one of the most critical issues lies in the observation that many glaciers are exhibiting a recessional response much more rapid than might have been predicted. This does open the possibility that climate shifts occur more rapidly and with magnitudes greater than previously considered. This appears to be the case even for the larger ice sheets which could well be expected to have a relatively slow response or adjustment period to swings in climate (Alley, 2000; Stieg and Alley, 2002; Turner *et al*, 2007). Furthermore, this observation of rapid climate change is supported by evidence well outside of the glacial or periglacial environment (Altmann, 2002).

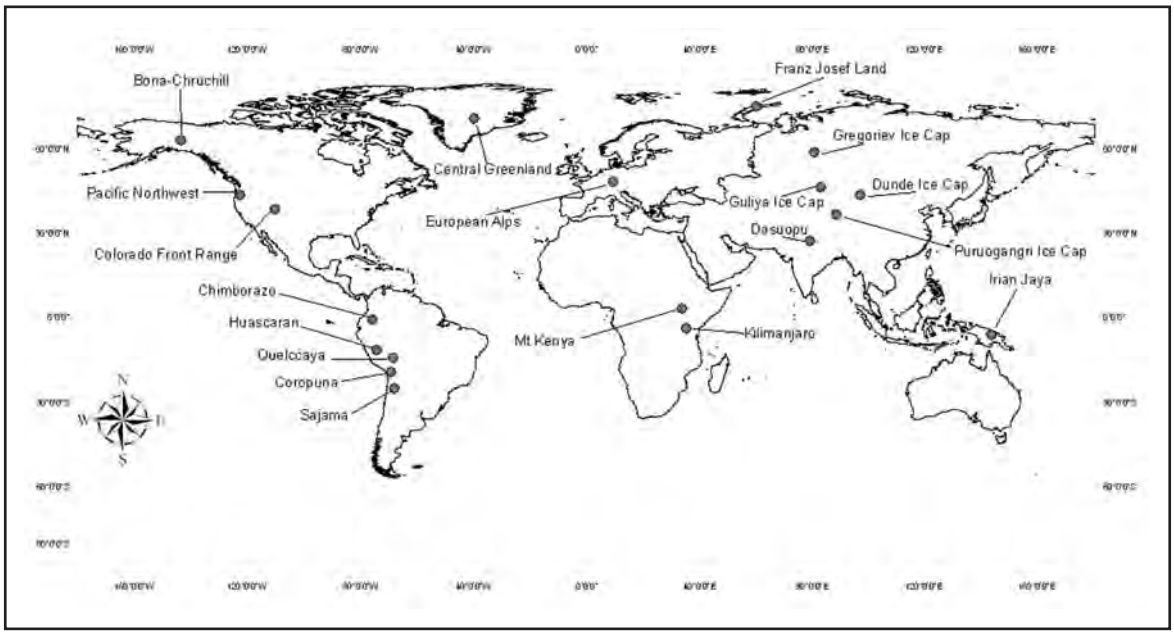

Figure 1. The distribution of mid-latitude and tropical glaciers from which ice cores have been recovered for climate reconstruction. All of these glaciers and ice sheets are characterized by melting and are in state of recession – some as many as 50 meters a year. The multiple drill sites on Greenland and in the Antarctic have not been included. Information compiled from these sites has provided a comprehensive and detailed picture of current and past global climate change.
Cartography by Alvin Rentsch

Ice Cores: How to Get Your Own!

The extraction of ice cores is anything but a straightforward process. Unlike the drilling of a standard solid geologic (bedrock) core, ice drills are required to perform and be successful in a complex and difficult environment. Consider that the temperature of the ice is often well below zero, the glacier is plastic and characterized by internal motion (flow), and at depth the ice is under extreme pressure where some of the difficulties emerge. Furthermore, the glacier environment is physically demanding, the ice core cannot be contaminated by either the drilling system or by human touch, it needs to be shielded and isolated from its new (surface) environment, has to remain frozen for transportation to the laboratory setting, often from very remote areas, and is quite fragile.

Depending upon the drilling location, ice depth and logistical support, the configuration of ice drills vary. For the deep drilling projects typical of Antarctica or Greenland, the system can be quite massive, require multiple operators and necessitates considerable logistical support (typically ski-equipped aircraft or oversnow vehicles. See Figure 2). For higher altitude, smaller glaciers typical of the middle to low latitudes, very small portable lightweight systems designed to recover cores to depths 100 to 500 meters are now commonly used (Zagorodnov *et al*, 2005). Drilling systems such as these (see front cover) are designed to be completely dismantled and reassembled in the field. Weight for individual components is kept to a minimum as is component size. These environments require that the drill be transported to the site by pack animal or through human labor (See Figure 3).

Figure 2. A large ski-equipped transport plane lands on the central Greenland ice sheet to resupply a remote drilling camp and to extract recovered ice cores.

However, for both the shallow and deep drilling environments the mechanics of ice core recovery remain essentially the same. The drill is mounted on a flexible cable through which an electric current can be passed. The drill motor is mounted on the drill barrel and the entire system is lowered into the drill hole. As the drill and the cutting head works its way downward, a hole approximately 10 centimeters in diameter is cut. As the drill rotates, the cutting teeth remove the outer centimeter of the ice leaving a "pillar"of ice over which the hollow sleeve of the drill barrel passes. The drill barrel is designed to accommodate up to a meter or so of ice and when the drill cannot travel further downward it is returned to the surface by the electrically driven winch that rewinds the cable. In the initial upward movement of the drill a set of cutting teeth inside the drill barrel effectively break the ice core at its base leaving it trapped within the drill barrel. Once at the surface, the core is removed from the drill, catalogued, packaged in sterile plastic sleeves and containerized for removal from the research site. In this way the ice core is recovered essentially meter by meter through the entire depth of the glacier.

Figure 3. Drilling equipment and field supplies are transported to the Dunde ice cap, China, by pack horses and local herdsmen. Three days of travel on horseback were required to arrive at the base of the glacier. The ice cores were also carried out by pack horses and eventually returned to the United States for analysis.
Photo: Keith Mountain

When Details Count: What do Ice Cores Tell us?

The climate and environmental information archived in ice cores has provided great insight into climate dynamics of the past as well as a detailed understanding of the contemporary global climate. Contained within recovered cores are a precipitation record for the ice cap (i.e. regional climate), a history of ambient air temperature (reconstructed through oxygen isotope analyses), non-soluble particles such as dust, volcanic ash and pollen (allowing for measures of past atmospheric turbidity, wind direction, evidence of volcanic sequences, transitions in local vegetation), and the composition of earlier atmospheres through changes in the relative abundances of trace gasses (carbon dioxide, methane, nitrous oxides). On a larger scale, transitions in atmospheric circulation phenomena such as El Niño, La Niña, the equatorial Walker Circulation and their connection to the global scale Southern Oscillation (atmospheric pressure) patterns are detectable in many of the tropical and mid-latitude ice core records (Thompson *et al*, 1984).

The length of such climate records depends upon the physical environment in which the glacier forms and the mechanics of glacier formation and motion. With the requirement that the wintertime snowfall does not melt, the total accumulation for that year is added to the glacier surface (see Figure 4). Here the simple principle of uniformity applies whereby the underlying layer or strata from the previous year's precipitation is older than the one above it. In this way the depositional record is annually sequential and, depending primarily upon the rates of accumulation and relative motion of the glacier, the full length of a recovered ice core (i.e. the depth of the ice) will represent the total archived climate history for that particular glacier or ice sheet. The longest time peri-

ods preserved in ice cores, as is to be expected, are to be found in the great depths of the Greenland and Antarctic ice cores. In 1998, a collaboration between the French and the United States, resulted in a borehole successfully drilled to the glacier base, a depth of 3,623 meters (2.5 miles) at Vostok Station on the East Antarctic Plateau. The length of the climate record, including a record of atmospheric CO_2 concentrations, has been set at 400,000 years (Bowen, 2005; Jouzel *et al*, 1987). The longest recovered climate record from the Greenland Ice Sheet is dated to approximately 120,000 years and was recovered from the central regions of the ice sheet in 1992 and 1993 at two drill sites only 17 miles apart. Each core measured just over 3,000 meters in length (Alley; 2000; Steig and Alley, 2002).

Recently attention has been focused on low latitude and tropical glaciers. Initially it was considered that tropical glaciers did not (or could not) preserve the details of the climate as effectively as their polar counterparts. The warmer tropical temperatures potentially resulted in melting at the surface and with percolation of meltwater into the interior of the glacier the essential stratigraphic signal would be destroyed. Also, as most tropical or low latitude glaciers are relatively small and often shallow, it was considered that, even if a record was preserved it would not provide a time line necessary for useful comparison to other glaciers. Logistics introduced another complication. The remote geographic locations coupled with the high elevations required for tropical glaciers to form made them unattractive for attempted ice core recovery, particularly in light of the heavy and cumbersome drilling equipment available at the time. However, the discovery and investigation of the Quelccaya ice cap Cordillera Vilcannota, Peru (13.9?S;50.83?W) provided the first indications that climate records were indeed preserved in tropical ice. In 1983, following three years of preliminary testing and along with the development and application of a solar-powered lightweight drill, a core was recovered from the 18,600 foot summit and was the first high resolution climate record containing almost 1600 years of climate history for this region of South America (Thompson *et al*,1985; 1986 and refer to Bowen, 2005;48-74). The implications of the published results settled the debate as to the utility and reliability of tropical ice core records and paved the way for continued glaciological research in Peru, Bolivia, Ecuador, Africa, China and Tibet and provided a detailed history of climate and climate change for these regions on time scales not thought possible. Table 1 provides an abbreviated listing of mid-latitude and tropical glaciers from which climate records have been recovered.

Figure 4. A sample ice core is removed from the bottom of a recently opened crevasse on the Quelccaya ice sheet, Peru. Shallow core samples such as these are often taken to ensure that a climate signal is preserved in the glacier before a deep drilling project is undertaken. The dark bands on the right wall of the ice are dirt bands that develop during the summer months (dry season). The amount of ice between the dirt bands indicates the amount of precipitation that has fallen on the glacier over one year or during the "wet" season
Photo. Keith Mountain

Conclusions and Considerations

Variation and change has and continues to characterize the Earth's climate. These changes have taken place over a wide range of space and time scales, have shaped the physical structure of the Earth's surface, and have altered the distribution and diversity of the planetary biosphere. These changes continue today and will certainly continue for time to come. There are natural forcing mechanisms behind climate change as is evident in the waxing and waning of the major ice sheets over the Pleistocene and the advent of relatively short intervals of global warming (interglacials). Today, however, there is a clear need to factor in the role of human occupancy as an influential determinant in the physical condition of the Earth's atmosphere and to come to some understanding as to the possible consequences of these additional inputs into the climate system. Given the recognized complexities of the climate system in terms of linkages, feedbacks, magnitude of changes, response times, and the geographic distribution of such change, it is essential that we develop a constructive, interpretable working knowledge base related to climate and environmental change. It is, however, unreasonable to dismiss the consequences of human population growth and the associated environmental adjustments required to sustain this growth as having no impact on the global climate. The Earth's population is increasing exponentially demanding equal growth in the availability of critical resources (energy, food, water) and necessitating physical changes be made on the surface of the earth (urbanization, expansion of agricultural land). Along with human modification to the Earth's surface and the measured changes in the composition of the atmosphere since the turn of last century, it becomes difficult to dismiss the human imprint on climate change. Such reasoning also implies that the signature of human climate change is not simply reduced to fossil fuel consumption and atmospheric CO_2 concentrations. This is merely one of the more direct indications of an anthropogenic forcing of the climate system.

The evidence as to climate change and its global impact has been greatly advanced over the past 20-30 years from ice core evidence. Glaciers, their direct connection to the global climate system and as unique, high resolution repositories of multiple climate signals, have expanded understanding of our contemporary global climate and the physical structure of past climates. Glaciers, ice cores and the many other methods for climate reconstruction that add to our knowledge base and pro-

Glacier/Ice Cap	Country	Location	Elevation (m/feet)
Mt. Kilimanjaro	Africa-Tanzania	3.06˚S ; 37.35˚E	5893m / 19,400´
Chimborazo	Equador	1.5˚S ; 78.8˚W	6,267m / 20,500´
Quelccaya	Peru	13.90˚S ; 50.83˚W	5670m / 18,600´
Huascaran	Peru	9.1˚S ; 77.61˚W	6048m / 19,850´
Coropuna	Peru	15.51˚S ; 72.78˚W	6425m / 21,074´
Sajama	Bolivia	18.0˚S ; 68.0˚W	6550m / 21,500´
Dunde	China	38.1˚N ; 96.4˚E	5325m / 17,500´
Dasuopu	China	28.0˚N ; 85˚E	6,900m / 22,600´
Guliya	China	35.3˚N ; 81.5˚E	6710m / 22,000´

Table 1. Mid and low-latitude glaciers and ice caps from which ice cores have been recovered for climatic analyses. The primary task of these analyses is to link with results obtained from more polar glaciers and ice caps to gain a coherent and detailed picture of global climate change.

vide foundational information for decision making with respect to the consequences of global climate change should be given some priority. And for many tropical and mid-latitude glaciers and ice sheets time is short. As the climate changes and moves to an increasingly warm state, these glaciers are melting and along with their disappearance, the rich climate records they contain are also being lost.

As the inevitable policies and strategies that will be required to accommodate continuing climate change are considered and implemented, the outcome and the long-term consequences of these decisions will become the hallmark of our planetary stewardship. Therefore, the efforts, costs, time and resources necessary to understand the mechanics of global climate and environmental change can only be seen as a wise investment in our collective futures.

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The Response of Glaciers to Climate Change: The Example of Mt. Kilimanjaro, East Africa

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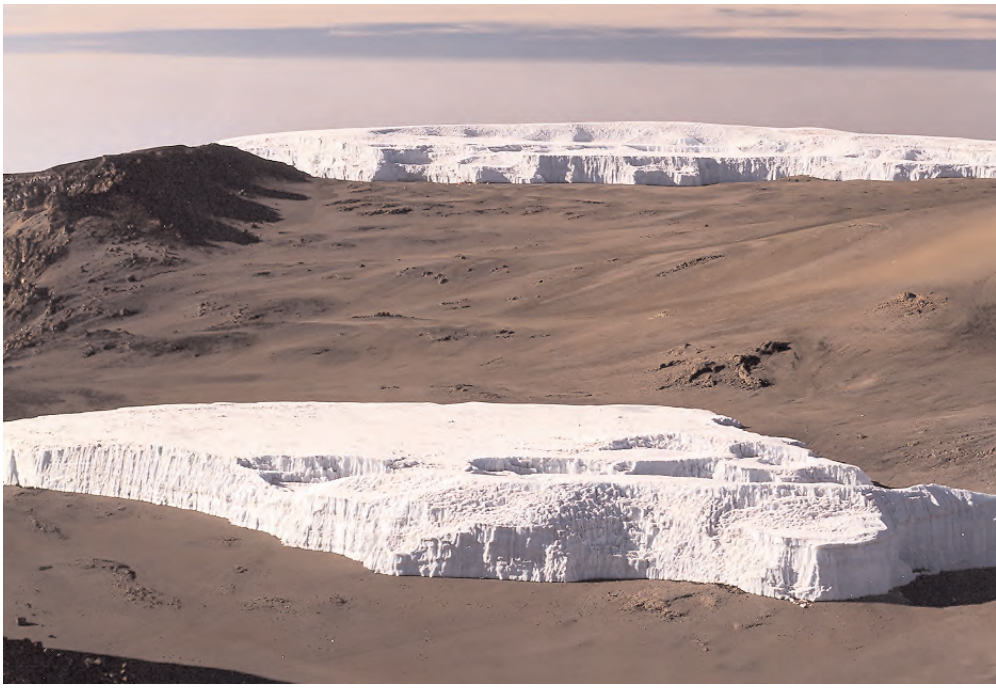

Figure 1. View across the summit of Mt. Kilimanjaro towards the distant Northern Ice Field indicating the typical structure of the existing glaciers and the exposed volcanic surface. Energy balance measurements over the ice surface were taken from a meteorological station established on the summit of the Northern Ice Field. Measurements for the ground surface were recorded at a study site approximately one half a kilometer south of the North Dome. Distance from the observation point to the summit of the Northern Ice Field is approximately 3 kilometers (Photo: Keith Mountain).

Abstract

Existing glaciers in the tropics and mid-latitudes are in a state of recession, widely regarded as a response to global warming since the beginning of the 20th Century. Glaciers on the summit of Kilimanjaro have reduced in size as much as 80% since 1912 largely in response to a reduction of available moisture rather than an overall increase in air temperature. Comparative surface energy balance investigations on the summit of Kilimanjaro indicate that the current retreat of ice will continue. As the remaining ice retreats, a surface type typical of a high altitude desert remains which has an energy balance structure that cannot support the presence of glacial ice.

Introduction

Glaciers and ice masses form and respond to the physical state of the overlying atmosphere and, as an integral part of the hydrologic cycle, are considered to be one of many obvious indicators of shifts and transition in global climate. Glaciers are dynamically responsive to changes in the most basic of meteorological quantities (notably temperature and precipitation) but have a decided advantage in that they effectively "filter" short-lived variations and respond to the more long-term, sustained shifts in the global climate. In the simplest of relationships, the physical state of a glacier system (as with any system) can be expressed in terms of basic energetic inputs and outputs. In the case of a glacial system, the inputs (usually snowfall) are required to be balanced against the system output or mass loss (dominantly melting or sublimation). Here three possibilities exist. First, with the input exceeding the output, the glacier moves toward a state of growth. Second, with outputs exceeding inputs, melting or mass loss predominates and the glacier will diminish both in volume and areal (spatial) extent. The third (and least likely of the possibilities) is that input is matched by the melting or the rate of mass loss. In this latter case the glacier will arrive at a condition of steady state and be in balance with its climatic environment.

From observation, it is clear that glaciers worldwide are in a general state of retreat, and certainly this is true of all mid-latitude and tropical glaciers. Of the many intriguing questions related to glaciers and the global climate is, if the climate were to either reverse direction from its current state of warming or stabilize at current levels, would the observed rate of glacial retreat continue? This fundamental question connects the permanence of ice masses and their phase relationships to shifts in climate both at the regional and global scales. Since the early 20th Century, almost all of the world's glaciers have been characterized by retreat, a response largely attributed to the simultaneous increases in observed global atmospheric temperatures (Houghton *et al*, 2001). With many of the world's glaciers serving as long-term and seasonal water storage, their disappearance is consequential and in many cases has already become a significant environmental concern (Cao, 1998; Mark and Seltzer, 2003; Bryan *et al*, 2005; Bradley *et al*, 2006).

Kilimanjaro: The Setting

In February of 2000, an expedition was undertaken to recover ice cores from the remaining glaciers on the summit of Mt. Kilimanjaro, East Africa (3.06˚S; 37.35˚E; elevation 5893m.). These glaciers are the last of the glaciers in Africa (other than remnant and stagnant ice masses of Mt. Kenya and the Ruwenzori Mountains, Uganda) and the only ice masses on the African continent preserving a climate record for the region. In the late 1880's, the glaciers on Kilimanjaro were expansive, but since this time have been in a state of continual recession (Hastenrath, 1984). This retreat has accelerated over the last part of the twentieth Century such that by 2000 Kilimanjaro's

glaciers had reduced in size by 80% since 1912 (Thompson, *et al*, 2002, 590). This retreat continues today and recession based on cartographic and climatological analyses suggest that by 2015 no ice will remain on the summit of Kilimanjaro (Thompson, *et al*; 2002; Molg *et al*, 2003).

Energy Balance Studies

The intent of surface energy balance investigations is to resolve the details of how the glacial ice (or any surface type) interacts with the atmosphere directly above it. These are high resolution analyses and factor in all components and processes known to influence the character or response of surface to a set of climatological inputs. In the case of glacial ice, the fluxes of energy, how they are partitioned and their relative magnitudes become a direct measure of energy available for melting.

The initial input of energy to the surface of the Earth is simply that of solar radiation. Energy that arrives at the edge of the atmosphere above a point on the Earth's surface depends upon the site latitude, time of the year, and time of day, and this extraterrestrial receipt of radiation can be calculated through standard earth/sun orbital relationships (see, Oke, 1978). It is this supply of energy that passes down through the atmosphere which, after some absorption and scattering, arrives at the surface to serve as the primary driver for the resultant energy balance. At the surface, the general form of the energy balance equation can be given as:

$$0 = Q^* \pm Qe \pm Qh \pm Qg + Qp \qquad \text{Eqn.1}$$

where Q^* is the surface net radiation, Qh and Qe the latent and sensible heat fluxes respectively, Qg is the system heat storage, and Qp the heat supplied through precipitation. Convention dictates that fluxes directed toward the surface are positive; fluxes directed away from the surface are negative. Essentially, this is a statement of the conservation of energy in that equilibrium is reached when all the contributing fluxes are zero (i.e. no net gain or net loss of energy). Typically the radiative fluxes provide the greatest energy input to high elevation environments and the net radiation can be partitioned as:

$$Q^* = (K\downarrow - K\uparrow) + (L\downarrow - L\uparrow) \qquad \text{Eqn 2.}$$

where $K\downarrow$ is the incoming solar (shortwave) radiation; $K\uparrow$ the reflected shortwave radiation, $L\downarrow$ the incoming (atmospheric) longwave radiation and $L\uparrow$ the emitted surface longwave radiation. The sensible and latent heat fluxes can be expressed:

$$Qh = \rho\, Cp\, Kh \frac{\partial T}{\partial z} \qquad \text{Eqn.3.}$$

$$Qe = \rho\, Lv\, Kw \frac{\partial q}{\partial z} \qquad \text{Eqn.4.}$$

where ρ is the density of air, Cp specific heat of air at constant pressure, Lv the latent heat of vaporization, Kh the coefficient of eddy conductivity and, Kw , the coefficient of eddy diffusivity for water vapor. The gradients of both temperature, T, and vapor pressure, q, (moisture) are given with respect to height, z, above the surface. With respect to the surface types for which energy balance assessments were carried out over Kilimanjaro, energy entering or leaving the system through storage was negligible as was input from precipitation.

Figure 2. The vertical ice walls typical of the remaining ice masses on Kilimanjaro and the volcanic surface that is continually exposed as the ice retreats.
Photo: Keith Mountain

While the radiative fluxes (Q^* and its components) can be measured, the latent and sensible heat fluxes cannot. Furthermore, as there is no utilitarian analytical solution to the governing equations (Eqns. 3 qnd 4), many empirically-based procedures have been proposed and find widespread application in energy balance computations (e.g. Hay and Fitzharris, 1988; Brock, *et al*, 2000; Molg and Hardy, 2004) .

The Measurement Program

The goal of the Kilimanjaro study was to simultaneously measure the climatological components to complete a full surface energy balance for two sites on the summit. For the ice or glacier surface, the summit of the Northern Ice Field was selected. For the ground surface, a site approximately one kilometer south from the glacier station was established. In this manner the two observation sites were close enough to be unaffected by distance, but independently represent the surface types characteristic of the summit (see Figure 1). Perhaps the most notable characteristic of the surface types to be found on Kilimanjaro is the immediate transition from the ice boundaries to the underlying ground and the extraordinary vertical ice walls, many as high as 50m. (Figure 2).

Each observation site was comprised of identical measurement systems with data collection at exactly the same times and integrated over the same time periods. Table 1 presents those quantities measured and derived to complete the surface energy balance. Measurements were made over a 20 day period beginning February 5th (Julian Day 36) to February 25th (Julian Day 56) in 2000. For this analysis, only those days for

MEASURED QUANTITIES	*DERIVED QUANTITIES*
Incoming shortwave radiation ($K\downarrow$)	Extraterrestrial radiation
Reflected shortwave radiation ($K\uparrow$)	Emitted longwave radiation ($L\uparrow$)
Net radiation (Q^*)	Incoming longwave radiation ($L\downarrow$)
Air temperature (1.5 and 0.5 meter levels)	Albedo ($\alpha = (K\uparrow / K\downarrow)$)
Surface temperature (**To**)	Saturation vapor pressure
Relative humidity (1.5 and 0.5 meter levels)	Actual vapor pressure
Wind Speed (1.5 and 0.5 meter levels)	

Table 1. Measured and derived quantities required to complete the surface energy balance for the two observation sites on the summit of Kilimanjaro.

which the skies were cloud free are considered, as they effectively represent those times when the greatest amounts of energy are available for surface melting.

Results

A principal characteristic of tropical locations such as the summit of Kilimanjaro is the receipt of high levels of solar radiation. At the 6000 meter level (19,500´), the atmospheric pressure is approximately 480 millibars resulting in more than one half of the Earth's atmosphere below the glaciers of Kilimanjaro. As such, the path length for a stream of solar radiation through the atmosphere to the summit is short, resulting in only a minor loss of radiation due to absorption and scattering by the mass of the atmosphere. The net effect is that, under the condition of clear skies, approximately 90% of the solar radiation incident at the edge of the atmosphere above Kilimanjaro (3.06˚S latitude) can be expected to arrive at the summit. In addition, for equatorial latitudes, the annual receipt of solar radiation is unaffected by seasonality. Averaged results for the shortwave radiative fluxes as measured and estimated on the summit of Kilimanjaro are presented in Table 2.

The incident shortwave radiation over a given surface is modified by the reflectivity of that surface and highly reflective surfaces such as snow and ice can reflect upwards of 70% of the incident shortwave radiation. The resultant net shortwave radiation, K^*, represents the available shortwave radiation for surface processes and is related to the surface reflectivity or albedo (α) as:

$$K^* = K\downarrow - K\uparrow \quad \text{and} \quad \alpha = (K\uparrow / K\downarrow)$$

Eqn.5.

For Kilimanjaro the effect of the two basic surface types upon the net shortwave radiation balance is evident from the computed albedos as presented in Table 2. Over the observation period the average albedo for the glacier surface was 0.65, reducing the net input of solar radiation to just under 13 megajoules per day. In contrast, the very low reflectivity of the ground ensures large values of K^*. For this observation period a difference of approximately 57% in the net shortwave radiation was measured even though each surface received similar amounts of incoming shortwave radiation ($K\downarrow$).

The net radiation, Q^*, represents the total amount of radiative energy available at the surface. For snow or ice surfaces, if this flux is positive, energy can be used to increase the surface temperature or, if the surface is at 0˚C, produce melting. If the net radiation is negative (standard nighttime conditions) the surface will respond by lowering in temperature or storing energy through conduction into the substrate. Table 3 presents a summary of the integrated daily totals of the primary radiative fluxes for selected days of the observation period for the two surface types.

Typical of the two surfaces on Kilimanjaro under clear sky conditions are the stability in the net radiation for the ground surface and the systematic increase in the net radiation over the glacier with time. With constant exposure to positive inputs of energy, the ice surfaces typically transition from a smooth, often snow covered surface to one of exposed glacial ice. As a consequence, a positive feedback is set in motion whereby the net radiation increases proportionately providing increasing amounts of available energy for continued surface transformation.

On a daily basis, the surface net radiation can be both positive and negative (Eqn. 2). However, determining Q^* as a simple arithmetic outcome of flux direction can misrepresent the effectiveness of the net radiation as a primary driver of the overall surface energy balance. Figure 3 presents the trends in the surface net radiation for both the glacier and ground surface as measured on Julian Day 47 (Feb. 16th). Data are plotted with respect to the extraterrestrial flux of energy, *Kex*. By day over the ground surface, Q^* is strongly positive approaching 600 wm^{-2}. In contrast, the glacier surface records a maximum positive Q^* of approximately 220 wm^{-2}. During the evening hours, driven by the longwave fluxes, the net radiation is negative at approximately 90 wm^{-2} for both surface types. This relationship indicates uniformity in evening surface and air temperature (and emissivities) over the summit of Kilimanjaro. The

Surface Types	*Kex*	*K↓*	*K↑*	*K**	*Albedo (α)*	*T*
Glacier	37.54	33.43	19.98	12.91	0.65	0.91
Ground	37.54	32.80	3.42	30.01	0.11	0.89
Mean	**37.54**	**33.12**	NA	NA	NA	**0.90**

Table 2. Integrated daily totals of shortwave radiation, averaged albedo and atmospheric transmissivity (T) for both surface types on the summit Kilimanjaro. Values are averaged for all days over the 20 day observation period. All radiation estimates in megajoules per square meter.

area under the curves of Q^* for values greater than zero (see Figure 3), represent a true measure of the total radiative energy available at each surface. For the most part, this energy is used for either daytime melting of the ice surface or heating of the ground. It is also important to note that both substrates have little capacity to store energy. The thermal conductivity of the ice is very low as is that of the ground surface, and each surface responds by attaining a nighttime radiative temperature that represents a balance in the longwave fluxes. This relationship is presented for representative days over the study period from which it is critical to note that for the ice surface in particular, the daytime estimates of Q^* are considerably greater than those estimated as the overall net flux as derived from Eqn.2.

Date	*K↓*		*K**		*Albedo (α)*		*Q**	
J-Day	**Ice**	**Ground**	**Ice**	**Ground**	**Ice**	**Ground**	**Ice**	**Ground**
44	34.47	33.30	9.90	29.74	0.71	0.11	1.46	5.31
47	34.38	33.75	9.18	30.28	0.74	0.10	-0.58	8.86
48	34.32	33.66	11.86	30.23	0.65	0.10	0.55	8.69
51	34.29	32.31	16.95	28.89	0.51	0.11	2.57	7.70
53	33.84	34.29	16.87	30.82	0.50	0.10	4.37	6.97

Table 3. Integrated daily totals of shortwave and net radiative fluxes and averaged daily albedos for selected days over the observation period (Julian Day 44= Feb. 14th; Day 53 = Feb.22nd). All radiation estimates are in megajoules per square meter.

	Q Ice/Glacier*			*Q* Ground*		
J-Day	**>0.0 (+)**	**<0.0 (-)**	**Net**	**>0.0 (+)**	**<0.0 (-)**	**Net**
44	6.90	5.45	1.46	9.45	4.14	5.31
47	4.59	5.18	-0.58	12.87	4.01	8.86
48	6.17	5.62	0.55	12.91	4.23	8.69
51	8.19	5.61	2.57	11.61	3.92	7.70
53	9.72	6.36	4.37	11.02	4.05	6.97

Table 4. Daily totals of surface net radiation (Q*) for the glacier and ground surface partitioned into energy gains (+) and losses (-) for each day. All values are in megajoules per square meter.

	Temperature (°C)		*Wind Speed (ms^{-1})*		*Humidity (%).*	
J-Day	**Glacier**	**Ground**	**Glacier**	**Ground**	**Glacier**	**Ground**
44	-8.02	-6.77	13.59	10.54	37.43	30.16
47	-8.01	-7.01	6.27	6.19	27.19	30.32
48	-7.11	-5.67	7.64	6.96	17.03	6.88
51	-7.40	-6.26	5.81	4.89	16.74	10.25
53	-4.59	-5.01	2.72	2.71	23.44	19.92

Table 5. Averaged daily values of air temperature, wind speed and relative humidity for selected days at the 1.5 meter level above the surface.

	Glacier RH (%)		**Ground RH (%)**	
J-Day	**1.5m.**	**0.5m.**	**1.5m.**	**0.5m.**
44	37.43	46.22	30.16	27.42
47	27.19	35.31	20.32	19.03
48	17.03	24.65	6.88	6.09
51	16.74	25.99	10.25	9.28
53	23.44	31.54	19.92	18.03

Table 6. Relative humidity profiles for the glacier and the ground surface for selected days. All values in %.

Solutions to the sensible and latent heat flux calculations (Eqns. 3 and 4) require input of the gradients of wind, temperature and moisture with height above the surface. Although empirically-based estimation procedures using measurements of these quantities taken at only one height above the surface have found widespread application, more accurate estimates require reconstruction of the non-linear profiles with height above the surface. At both observation stations on Kilimanjaro, measurements of wind speed, temperature and moisture were made at the 0.5 and 1.5 meter levels above the surface. Surface temperatures, *To*, were also recorded. Table 4 presents daily averaged temperature, wind speed and humidity as measured at the 1.5 meter level for both surface types.

Averaged daily air temperatures over the summit of Kilimanjaro are constantly negative with only slightly higher temperatures recorded above the ground surface. Results are summarized in Table 5. At no time over the observation period did the air temperature over both sites rise above zero at either the 0.5 or 1.5 meter levels. Wind is a constant feature with no periods of calm conditions recorded. Highest wind speeds approached 20 ms-1 and in general were slightly higher over the more exposed summit of the Northern Ice Field. Humidity levels as recorded at both sites are notable for their very low values (and hence very low vapor pressures) and far more typical of a very dry, arid environment than that of a low latitude glacial environment characterized by high energy inputs and surface melting.

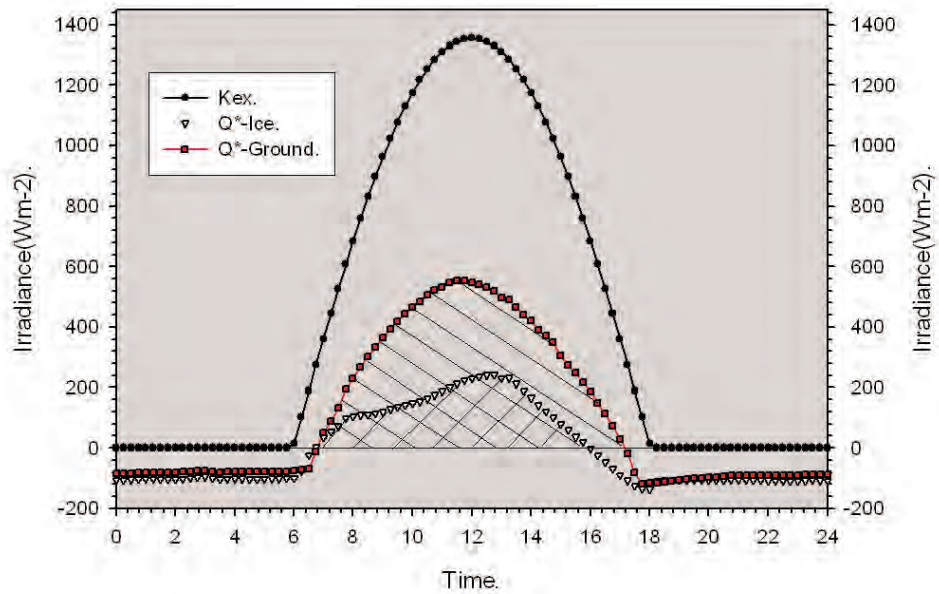

Figure 3. Surface net radiation (Q*) for the glacier and ground surface as measured on Julian Day 47 (Feb.16th). Areas under the curves as indicated by the diagonal lines represent the total amount of radiation available for either surface melting or heating. Estimates of Q* are given with respect to the total available radiation at the edge of the atmosphere for this day.

Analyses of the surface energy balance over the summit of Kilimanjaro reveal significant distinctions relative to most other high elevation, low latitude glacial systems. Here the persistently low air temperatures in association with the extremely dry air exert significant control over both the magnitudes and directions of the latent and sensible heat fluxes. The vertical profiles of humidity as measured over the two surfaces are presented in Table 6. For each site the moisture characteristics of the overlying air are reasonably similar at the 1.5 meter level indicating a uniformly dry air mass over the summit of the mountain. However, at each site the gradient of moisture is reversed towards the surface. For the glacier, assuming that the air in contact with the surface is at saturation (relative humidity of 100% and a vapor pressure of 6.11 millibars at 0˚C), the overlying air increases in moisture content toward the surface. In terms of actual vapor pressure, this translates into a vapor pressure gradient such that within the first 1.5 meters above the surface an upward transition from approximately 6.11 millibars to approximately one (1) millibar can be expected. Thus, for this surface, by virtue of this pressure differential, moisture is efficiently directed upward and away from the surface (i.e. from high to low pressure). For the ground site, while the daily air temperatures do not rise above freezing, as a response to high values of the net radiation, the average daily surface temperature is typically 5˚C. Thus the moisture content of the air near the surface is less than that of the air above it, which at these moisture levels, essentially removes any influence of latent heat transfer on the total energy balance for the ground surface.

Diurnal Trends in Components of the Surface Energy Balance

While the average daily conditions may be useful in identifying the longer-term energy balance structure over Kilimanjaro (e.g. Molg and Hardy, 2004), such averaging can mask many of the critical energetic processes that take place on an instantaneous basis. Figures 4 and 5 present the diurnal trends in air temperature and wind speeds at the 1.5 meter level recorded at both sites on Julian Day 47. Results for this day are representative for all clear sky days included in this study. The air temperatures indicate the degree of thermal uniformity over the summit at night with a divergence of several degrees during the morning and afternoon hours such that air temperature above the non-glaciated surface is warmer than that over the glacier. This is largely in response to the extreme heating of the ground surface during the daytime hours. The wind speeds as recorded at the two stations are essentially identical with speeds at both sites similar in instantaneous magnitudes and phase relationships. The most critical divergence in the climatological structure of these two surfaces is to be found in the measured surface temperatures (Figure 6). For the nighttime hours, both surfaces stabilize at around -10˚C. At the onset of sunrise, the ground surface temperature rapidly moves towards positive values in response to a low albedo and the poor heat storage capacity typical of this surface material. The glacier surface temperature indicates a slight thermal lag following sunrise. This forms largely in response to an increase in surface reflectivity typical of snow and ice surfaces at low sun angles and the time required to raise the temperature of the upper few centimeters of the glacier surface to its maximum possible of 0˚C.

The transfers of latent and sensible heat over the surface of the glaciers on Kilimanjaro result in a set of unique characteristics relative to other melting glaciers. The most notable is the absence of any surface meltwater. Given the availability of a positive net radiative balance during most of the day (Figure 3) and a corresponding surface temperature at the melting point (Figure 6), the presence of surface meltwater is to be expected. The nature of the surface temperature with height above the glacier surface is also atypical of melting glaciers. During summertime melting conditions, the air overlying mid-latitde and equatorial glaciers can be expected to be greater than zero degrees. In this case, as the surface temperature of a melting glacier cannot exceed 0˚C, the standard temperature profile would be that of an inversion in which case the sensible heat flux is directed toward the surface adding to the total amount of energy available for melting. The primary forcing mechanism governing the latent and sensible heat fluxes over the ice on Kilimanjaro can be derived from inspection of Figure 7 and Figure 8 that detail the thermal structure of the atmosphere between the surface and the 1.5 meter levels for both surface types. For the ice surface, it is important to note that throughout the day conditions of lapse temperature profile dominate which, with a temperature differential of 6˚C within the first 1.5 meters above the surface, is supportive of a general condition

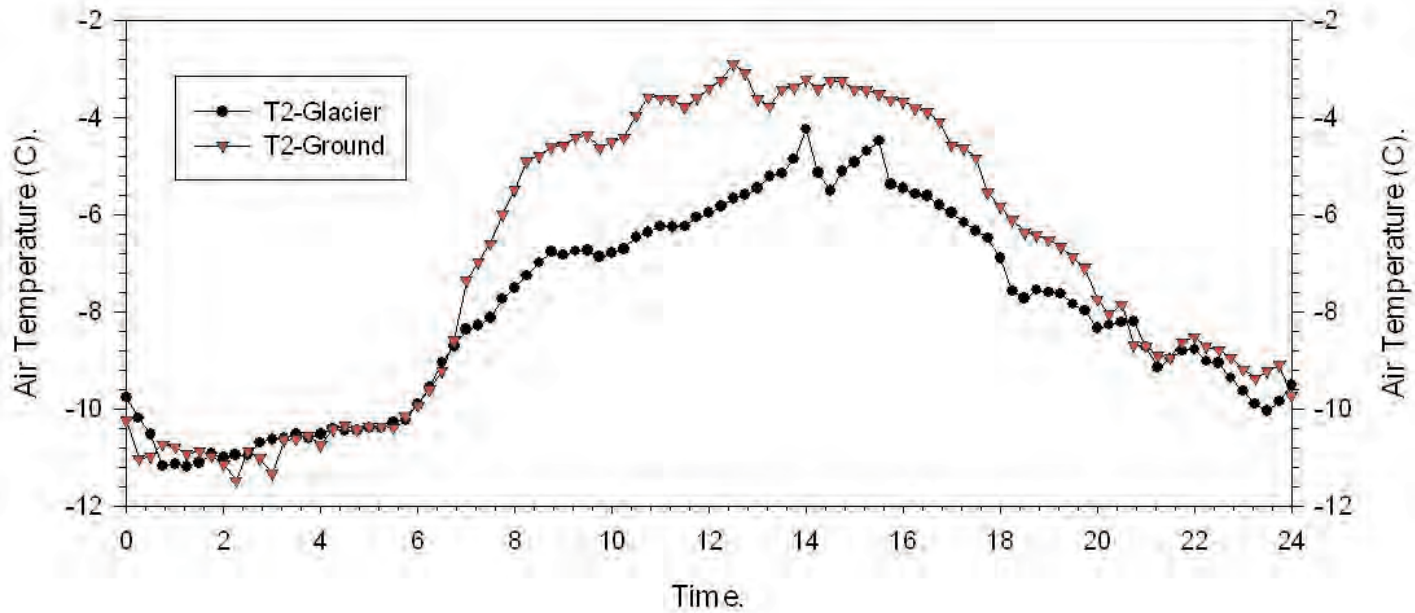

Figure 4. Diurnal trends in air temperature at the 1.5 meter level above the glacier and ground surfaces for Julian Day 47 (Feb.16th).

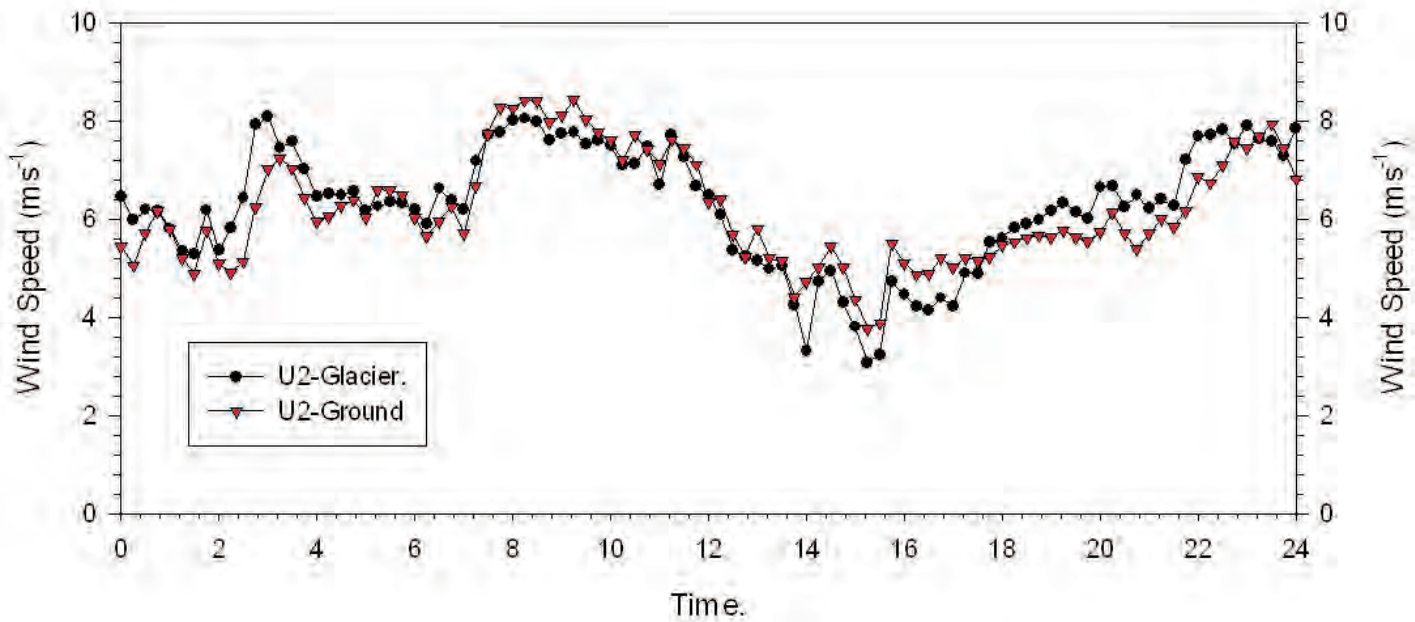

Figure 5. Diurnal trends in winds speeds at the 1.5 meter level above the glacier and the ground surfaces for Julian Day 47 (Feb. 16th).

of free convection. This is conducive to a transfer of sensible heat away from the surface (negative flux) and is enhanced by turbulent transfer due to the continual winds over the surface (forced convection). With the upward directed vapor pressure gradient between the surface and the 1.5 meter level aided by both free and forced convection, any moisture (water) that develops on the glacier surface is immediately moved upwards into the overlying air as vapor. Even during the nighttime hours, with low atmospheric moisture and persistent winds, forced convention supports surface sublimation. For the glaciated surface on the summit of Kilimanjaro, results indicate that the contribution of sensible heat transfer to the total energy balance is negligible (less than one (1) megajoule per day), while the latent heat transfer is as much as three to four (3-4) megajoules per day. This represents a significant impact on the total surface energy balance and is a notable departure from the typical energy balance of most melting glaciers (see for example Wagnon *et al*, 1999; Hay and Fitzharris, 1988).

The surface energy budget of the ground surface presents an equally extreme set of climatic conditions. The two primary climatic controls for this surface are the low albedo and surface heating due to high levels of both net shortwave (K^*) and net radiation (Q^*). With

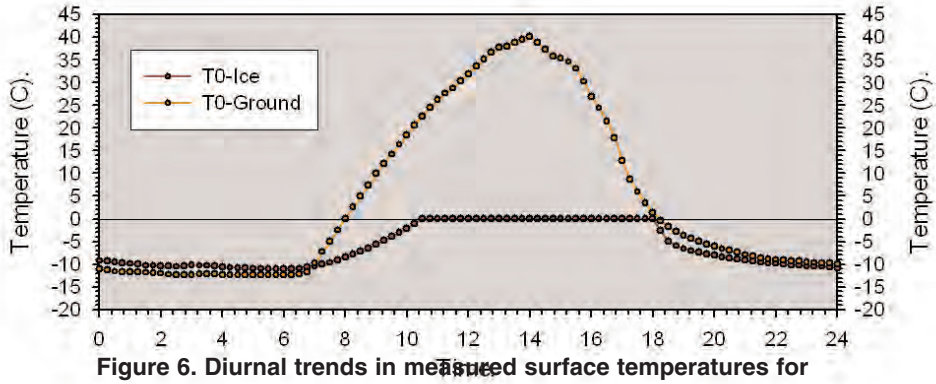

Figure 6. Diurnal trends in measured surface temperatures for the glacier and ground surfaces on Julian Day 47 (Feb.16th).

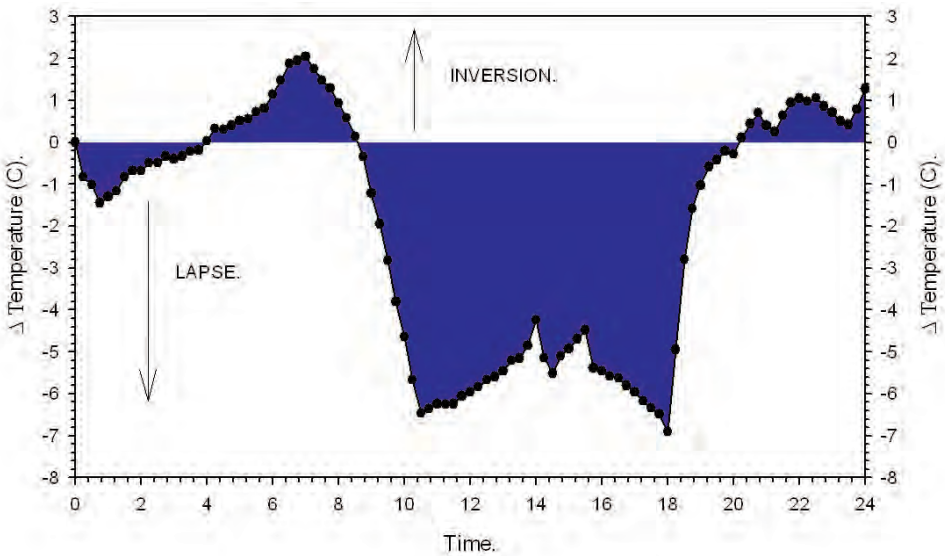

Figure 7. Temperature differences between the surface and the 1.5 meter level above the glacier surface for Julian Day 46 (Feb.16th). Negative values indicate a lapse temperature profile (To>T1.5) . Positive values indicate conditions of temperature inversion (To< T1.5).

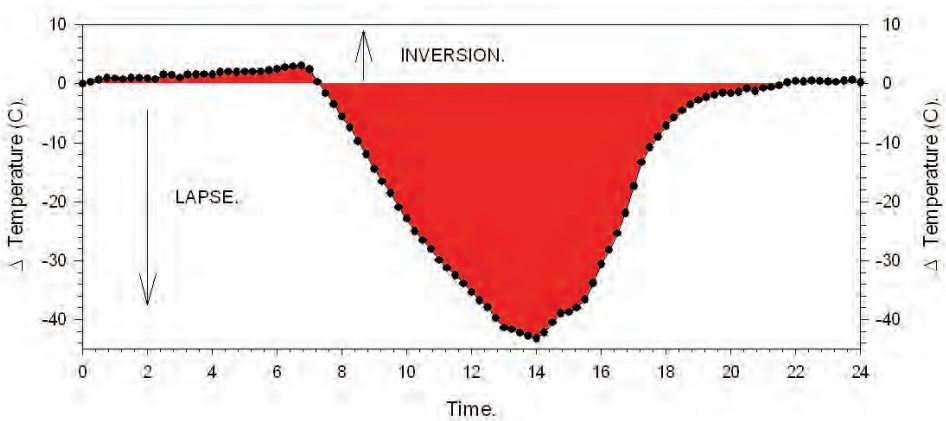

Figure 8. Temperature differences between the surface and the 1.5 meter level above the ground surface for Julian Day 46 (Feb.16th). Negative values indicate a lapse temperature profile (To>T1.5) . Positive values indicate conditions of temperature inversion (To< T1.5).

the air temperature at the 1.5 meter level below zero and a surface temperature approaching 40˚C, a condition of extreme free convection is supported. In this instance, sensible heat is efficiently moved upwards and away from the surface, and assisted by the turbulent wind flow, increases the overall air temperature (as measured at the 1.5 meter level) relative to that of the ice surface (Figure 4). The other critical issue here is that with the extremely dry air, persistent winds, and the capacity to reach high surface temperatures, any snowfall that takes place over the ground surface is rapidly evaporated leaving little opportunity for the development of a permanent snow pack on the summit.

Conclusions

As of the turn of the 20th Century, the glaciers of Mt. Kilimanjaro, East Africa, have been in a constant state of recession. Measurements of the extent of ice cover over the summit of Kilimanjaro in 1912 relative to those of the year 2000 indicate that as much as 80% of the ice has disappeared. Results from long-term meteorological studies undertaken on the summit indicate that the primary cause of this recession is attributable more to a large scale change in the supply of atmospheric moisture over this region of East Africa rather than directly related to the recognized increase in average global temperatures over this time (Nicholson and Yin, 2001). Surface energy balance analysis supports this assessment. Results from this study indicate that the rapid loss of ice from the summit is attributable to the high levels of available (net) radiation and the loss of ice due to evaporation and sublimation. This is consistent with the unusual physical appearance of the remaining ice masses. The extensive vertical walls, the immediate transition from the volcanic surface to the ice boundary, and the absence of surface or running water typical of melting glaciers make these residual ice masses unusual. Perhaps one of the most unusual patterns of this retreat is that the remaining ice masses become fragmented creating residual lobes of ice as seen in Figure 9. With this pattern of retreat and the continual exposure of more ground surface between these ice masses, the rate of retreat and mass loss can be expected to accelerate. Above all, it is clear that there is little chance of a reversal of this current state of retreat or even a decline in rate of mass loss for these glaciers under the current climatic conditions over the summit of Kilimanjaro. This observed recession and ongoing climatological analysis support the proposal of Thompson (2002) that within the next decade (2015) no ice will remain on the summit of Kilimanjaro.

Figure 9. A typical pattern of retreat for the remaining glaciers on Kilimanjaro is the separation of large ice masses into smaller, disconnected fragments. The continual exposure of the volcanic surface and its associated energy balance will accelerate the rate of melting supporting the prediction that all glaciers on the mountain will disappear within the next decade (Photo: Keith Mountain).

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Agreement Reached by Seven Northeastern States to Address Global Warming: The Regional Greenhouse Gas Inititiative

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On December 20, 2005, seven Northeastern states reached an agreement to limit greenhouse gas emissions produced by the region's power plants. This historic effort, the first of its kind in the United States, completes an effort initiated more than two years earlier by New York Governor Pataki, who had invited Governors in New England and the Middle Atlantic States to participate in the development of a market-based cap-and-trade system for carbon dioxide emissions. The government caps the maximum amount of a pollutant a state can emit. A state can trade its credits on the market based on the value of the cap establishes.

The effort, known as RGGI [Regional Greenhouse Gas Initiative], began in the fall of 2003 with the six New England states, New York, New Jersey and Delaware as participants and Maryland and Pennsylvania as observers. This region has a long history of co-operation on environmental issues and particularly with emissions trading schemes. RGGI was therefore a natural outgrowth of the region's experience and success with previous initiatives, such as the NOx budget program, limits to gasoline vapor pressure and various measures to reduce precursors to ground-level ozone. The states were informed by the clear, strong and compelling science that global warming is already happening and that action is needed now to address it. Further, the region recognizes that at its heart, global warming is an economic development as well as an energy issue.

The electric generating sector was selected first due to our previous experience developing the NOx budget program (NBP) and the relative precision of emissions data collected for this sector. However, unlike the NBP, the signatory states anticipate that the bulk of the reductions will not be achieved through direct in-stack controls. Energy efficiency, clean energy resource development, distributed generation and combined heat and power, limited fuel switching and replacement of older sources with newer ones are among the options encouraged to meet the RGGI emissions targets.

The December 20th agreement represents a commitment of seven states: Connecticut, Delaware, Maine, New Hampshire, New Jersey, New York and Vermont. Massachusetts and Rhode Island have rejoined RGGI as of January 2007, and Maryland is expected to fulfill its legislatively authorized commitment to join RGGI by June 2007. The nine state agreement (not including Maryland) covers over 600 net electric generating units, each with a size greater than 25 MW. (Electricity generating turbines are rated by the number of megawatts they produce. A megawatt is a million watts of electricity). The RGGI cap was set at a level of about 150 million tons of CO2, which is larger than that of Germany. The cap will be fixed at this level for the period from 2009-2014, then decline 10% by December 31, 2018. The cap is therefore deliberately modest in keeping with the recommendations to "slow, stop and then decrease" greenhouse gas emissions. Several recent technical and scientific publications, including that by the National Commission on Energy Policy, emphasized the certainty of the science, the long-term nature of global warming, the importance of taking actions now, the need for a decades long commitment and the nature of generating assets and the long useful life periods of power plants(40 to 60 years is the normal life span of a power plant).

During the MOU development period, eleven regional meetings were held, often with over 125 attendees. These were augmented by numerous conference calls and outreach and discussions at the individual state level. Participating groups included individual generating companies, distribution companies, environmental groups and state environmental and utility regulatory agencies. States had use of a broad and deep resource panel that included representatives from the region's ISOs(Industrial Service Organization), consultants to the utility industry, groups with previous emissions trading experience, brokerages and environmental and energy policy experts.

The Memorandum of Understanding (MOU) provides the RGGI description and implementation building blocks. Following are descriptions of the main components:

- Model rule to provide guidance and consistency among the states. It was released in March 2006 for a 60-day comment period; two stakeholder meetings were held to provide for public input and comment. The rule was revised to reflect comments received and was released in mid-summer.
- Allowance auction. States have agreed to auction at least 25% of their allowed caps for consumer benefit or strategic energy purposes. These can include: investments in energy efficiency and clean energy, or to directly mitigate any potential ratepayer impacts.
- Offsets and their protocols. The MOU currently provides for companies to achieve thier required reduction through other strategies such as afforestation, landfill gas, end-use efficiency for natural gas, propane and heating oil and methane capture from farming operations to be used to sat-

isfy compliance obligations. Additional offset mechanisms and protocols will be considered and developed in the future. Initial offsets generated within a RGGI signatory state will be valued at 1:1. i.e., the value of the offset is equal to the credit awarded; those generated outside a RGGI state, but still within the United States will be valued at 1:2 (50% discount).

- Price discovery and safety valves. The states realize that carbon emissions trading is a nascent market. To provide certainty and to reduce initial market volatility, two mechanisms have been agreed to:
  - Offsets trigger: if the carbon market price reaches $7 per ton for twelve months, three events occur: offsets can be used for any qualifying project in North America; their value will be 1:1 and the amount of offsets that can be used for compliance increases.
  - Safety valve trigger: if the carbon market price reaches $10 per ton for twelve months, the compliance period may be extended for one year. It also permits international offsets to be used. This process can be repeated for up to three one-year extensions if the market price remains at or above $10 per ton. This has the effect of freezing the cap or the rate of its decline for that period.
- Modeling that was conducted for RGGI and in some previous state level actions identified electricity imports and emissions leakage as a potential issue of concern. The price differential between various power pools may encourage wheeling of electricity from the pool with the lower price to that with higher prices. Leakage has also been raised in the context of the NOx budget program. The MOU charges a workgroup to investigate the issue and to develop potential recommendations by December 31, 2007, for future action. The workgroup will be weighted towards utility and energy stakeholders, along with a resource panel.
- A regional organization is envisioned to serve as the RGGI program administrator. Its role will be advisory and administrative, and is expected to focus on development of additional offset protocols, emissions and allowance tracking of carbon emissions, and helping to assure regional consistency.
- Additional RGGI states. Additional states are welcomed. The RGGI signatory states would discuss the entry terms and conditions with any other state that was interested in joining.
- Program review. Since this is the first such program of its type in the US, and there is no Federal driver at this time, states have agreed to formally conduct a thorough review of the program's success and impacts during 2012, prior to the period when emissions will decline. This will enable us to complete any revisions recommended by the review prior to 2015 and to recommend and adopt longer-term reductions for the period after 2018. Also, should there be a Federal program by then, the effect and impacts of this would also be reviewed.

RGGI represents continued regional leadership and cooperation on environmental, economic and energy issues. Its implementation complements the economy-wide measures being considered and adopted in many US states, including several outside the RGGI region. Increased energy efficiency, development of clean energy and combined heat and power projects will improve our energy security, reduce our addiction to fossil fuel, stabilize electricity rates and help us to achieve ancillary environmental benefits, such as decreased fine particulate and NOx emissions. For more information about RGGI and to remain informed on future progress, please go to www.rggi.org

State Climate Policy Planning: Once Again, Leading by Example

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U.S. states are often referred to as "laboratories of democracy" for the innovative policy experiments they regularly attempt in the service of delivering greater benefit to their citizens at less cost. Successful experiments then replicate serially in other states, until ultimately, new federal policy may be implemented as a result. In this sense, states are certainly "laboratories for what works in government." A notable subset of this dynamic, states are certainly "laboratories of environmental progress," where the states have a long history of protecting public health and the environment ahead of corresponding federal policies. In some cases, this relates to process characteristics, like generating new ways to streamline environmental permitting processes. But often, it reflects states' recognition of, and willingness to act upon, profound environmental problems. In air quality alone, for instance, state actions to reduce acid rain pollution, toxic emissions, mercury contamination, vehicle emissions, and smog-forming nitrogen oxides all occurred years before similar federal regulations.

Global climate change represents the next chapter in this book. The breadth and scale of global warming impacts – including air quality, water quantity and quality, sea level rise, habitat migration, heat waves, precipitation changes, health vectors, biodiversity, etc. – makes it the "mother of all" environmental concerns. And these concerns, if manifested in reality, will impact state services and budgets significantly.

There is now overwhelming consensus within the scientific community that anthropogenic emissions are the root cause of increasing atmospheric concentrations of greenhouse gas (GHG), and that GHG concentrations are rapidly approaching the level of dangerous interference to Earth's natural climate systems. GHG emissions are primarily due to the combustion of fossil fuels to produce energy, which in the U.S. is done so inefficiently that we waste more energy annually than Japan uses.

Accordingly, states divine not only environmental risk from climate change, but economic opportunity as well – through more efficient, less carbon-intensive production and use of energy. Less waste, after all, ultimately means less cost – particularly when appropriate "externalities" are taken into account.

States also understand the benefit of getting ahead of the curve – not least the learning curve – when it comes to adjusting their economies to new economic trends and realities. If a carbon-constrained world is in our future, as now appears likely, progressive states will seek to position their economies for competitive advantage in that future. They recognize that denying reality is rarely a formula for long-term economic success.

State Climate Action Plans

Against this framework, several U.S. states have undertaken (or are currently undertaking) comprehensive climate policy planning efforts. Early documents called state climate plans originally came on the scene in the mid-1990's, typically after the United Nations Framework Convention on Climate Change (UNFCCC) was adopted at the Rio Earth Summit in 1992, and before or soon after the Kyoto Protocol adopted in 1997. These "plans" however, were often simply lists of measures that could be taken. They were rarely buttressed by state-specific technical analysis, evaluation of costs (or cost savings) and anticipated GHG reductions, or well defined implementation schemes.

Although drawing a specific chronological "bright line" is necessarily arbitrary, around the year 2000 things started to change. Approximately nine states developed climate action plans after that date which included substantive analytical, cost, benefit, and implementation elements. Not surprisingly, these were the "usual suspects," Northeast and Pacific coast states with long traditions of environmental leadership.

Soon after, however, several states that haven't been traditionally regarded as environmental leaders joined the club. The Governors of Arizona and New Mexico launched comprehensive, multi-sector, stakeholder-based climate action planning processes in 2005, both of which were completed in 2006. Similar efforts were launched in 2006 in Colorado, Montana, North Carolina, and Vermont. These states were joined in 2007 by Illinois, Minnesota, and South Carolina, along with new efforts in New Jersey and Washington. Most of these state efforts have been assisted by the Center for Climate Strategies (CCS), a non-profit consulting organization whose practice is specifically tailored to bringing structure, facilitation, and technical analysis to state climate action planning efforts.[1]

Given states' twin interests in economic well-being and environmental quality, the early results are quite encouraging. The GHG reduction policies selected by stakeholders, analyzed by CCS, and ultimately recommended to the Governor as Arizona's Climate Change Action Plan indicate that concerted climate action could reduce GHG emissions markedly while simultaneously producing substantial economic benefit over "business-as-usual" (BAU). Specifically, Arizona stakeholders made 49 recommendations to the Governor – 45 of them with unanimous stakeholder consent – covering energy supply; residential, commercial, and industrial energy demand; transportation and land use; agriculture, forestry, and waste management; and certain "cross-cutting" issues (e.g., public education and outreach). Policy recommendations included enhanced appliance efficiency standards and building codes, an escalating environmental portfolio standard, electricity pricing changes, increased efficiency and demand-side management, cleaner cars, an alternative fuel standard, transit-oriented development, increased reforestation, and reduced land conversion, and increased water use efficiency, among others.[2]

Arizona is the fastest-growing state in the union, and its GHG emissions are forecast to increase 149% by 2020 compared to 1990. By implementing the full suite of stakeholders' recommendations, however, it could cut statewide GHG emissions back to 2000 levels by 2020 instead. As penetration increased with time, the same policies could reduce GHG emissions an additional 50% by 2040.

Conventional wisdom in the U.S. has held that implementing climate actions such as the Arizona plan's recommendations would impose large additional costs on its economy, and indeed, analysis of several of the recommendations showed positive net present value (NPV) costs. Many other recommendations carried such large negative NPV costs (i.e., savings) that, implemented as a package, Arizona's Climate Change Action Plan would produce $5.5 billion in NPV savings from 2007-2020 over "business as usual." Further economic analysis indicated that approximately 285,000 new jobs would be created in Arizona as well. Cumulative GHG emission reductions – in million metric tons of carbon dioxide equivalents (MMTCO2e) – would approach one-half billion.

Aside from these quantitative outcomes of the year-long Arizona Climate Change Action Plan process, there were notable less-quantitative results as well. In particular, the 35 members of the stakeholder group developed not only policy consensus, but also relationships with each other and better understanding of each others' concerns. This enhances the likelihood of successful policy implementation. Where opposing advocates typically fight for win-lose-draw outcomes in legislative or regulatory venues, Arizona's climate plan stakeholders already hammered out their serious differences and reached documented consensus on the Plan's specific, implementable policy recommendations.

While some plan recommendations will require additional legislative authorization, many can be adopted under existing statutory authority, and Arizona has already commenced doing so. Following her review of the Arizona Climate Change Action Plan, on September 7, 2006 Governor Janet Napolitano issued Executive Order 2006-13 ordering adoption of the recommended clean car program, biodiesel and fuel ethanol standards, new state vehicle purchasing requirements, hybrid vehicle incentives, and GHG reporting and registry programs. The Governor's Executive Order also established statewide GHG reduction goals for Arizona consistent with what the Plan demonstrated could be cost-effectively achieved.

Arizona's stakeholder-based climate change policy planning experience, while extraordinary, does not appear to be unique. A similar CCS process in New Mexico concluded in December 2006, with stakeholders making 69 GHG-reducing policy recommendations (67 of them unanimous) to Governor Bill Richardson. A smaller state in terms of population and economy, New Mexico's plan would "only" save approximately $2.1 billion NPV from 2007-2020, while reducing GHG emissions almost one-third again below the target originally set by the Governor.[3] Preliminary results from North Carolina suggest that its GHG emissions in 2020 could be nearly halved over "business-as-usual" with 53 GHG mitigation options that the state's Climate Action Plan Advisory Group (CAPAG) is considering.

Recent Climate Developments

About 18 states have concluded or have underway comprehensive, stakeholder-based climate action planning initiatives. The wisdom of these states in commencing timely climate efforts has certainly been validated by recent events – if it was ever in doubt. First, one of the quickest and clearest results of the 2006 election was the elevation of climate change to a national priority. Almost as though Members of Congress recognized overnight that the prior federal position was an emperor without clothes, Members from both parties clamored to be named to committees of jurisdiction (both standing and ad hoc) over the issue. Given the array of profound economic and quality of life benefits that concerted climate action will bring to the nation – far greater security (both national security and energy security), an unleashing of technology innovation and development (especially concerning energy efficiency technologies and practices), new jobs, greater global competitiveness, better air quality, improved public health, and oh yes, a better, safer environment – it is not surprising that politicians of all stripes are now tussling to get a seat on the climate bandwagon.

Second, a regular review of global climate change conducted by thousands of the world's leading climate scientists under the auspices of the UNFCCC's Intergovernmental Panel on Climate Change (IPCC) occurs roughly every five years, and the IPCC's Fourth Assessment Report (AR4) "Climate Change 2007" is being released in stages in 2007. The AR4 has prepared and drafted in three sections (reflecting three "Working Groups"): "The Physical Science Basis;" "Climate Impacts, Adaptation and Vulnerability;" and "Mitigation of Climate Change." A fourth offering – "The Synthesis Report" – will follow. The first two Working Group reports were available as this article was being prepared, and they show conclusively that (1) climate change has already begun to profoundly affect natural ecosystems and biological processes; and (2) the impacts of climate change will

have overwhelmingly (though not universally) negative consequences to humanity, especially the world's poorest populations. Adding to these concerns, the AR4 comprises only scientific findings available through 2005; more recent scientific literature shows cause for even greater concern in terms of exacerbated and accelerating climate impacts. By the time the AR4 synthesis report is released, it may be difficult to conclude that tardy jurisdictions have been acting adequately in the public interest.

Third, recent political and scientific developments on climate change are buttressed by parallel developments in business and the law. On April 2, 2007, the U.S. Supreme Court not only denied but effectively chastised the positions taken by the U.S. Environmental Protection Agency (USEPA) and the Administration with respect to the regulation of greenhouse gases, as well as states' standing with respect to climate-induced damage. The Court's decision in *Massachusetts v. USEPA* suggests that USEPA can – and should – treat greenhouse gases as pollutants for all practical (i.e., regulatory) purposes. At the same time, under the banner of the U.S. Climate Action Partnership (USCAP), an array of large, U.S. multinational corporations (including two global oil companies) recently called on the Federal government to adopt substantial, mandatory limits on greenhouse gas emissions – specifically, a 60-80% cut by 2050 in order to keep atmospheric GHG concentrations in the 450-550 parts per million CO2e range. This illustrates that debate within the nation's business community has moved from *whether* any mandatory emission reduction requirements should be adopted to specifically *how* such requirements should be designed to maximize individual firms' competitive advantage. This is hardly surprising in light of the fact that early participants in the first phase of the European Union's Emission Trading Scheme (EU ETS) generally profited from their pro-active involvement in designing this GHG emission reduction program. Although EU ETS allowance prices have experienced ups and downs as an unsurprising function of supply and demand, overall the market for carbon dioxide credits under the EU ETS has grown exponentially – to ~$20 billion, and we're still in the first, pilot phase of the program. A reasonably robust U.S. carbon market could easily double in size.

States' Motives

The leadership states' interest in climate action, of course, mirrors that of the USCAP businesses; it reflects both "offensive" and "defensive" motivations. Defensively, leadership states are increasingly aware that the likely effects of global climate change – including water supply disruption; agricultural crop yield changes and forest productivity shifts; water and air quality degradation; tourism and infrastructure impacts; and weather-related stresses to human health, among others – could significantly impact their economy, level of public expenditures, and quality of life. Leadership states are also aware, of course, that a number of climate proposals have been introduced in Congress – and more are likely to follow – which may or may not adequately reflect their best interests, credit their best opportunities for mitigating greenhouse gases, or provide appropriate aid for market transitions or climate adaptation. Leadership states know that engaging early and concretely in climate actions may give them a leg up in guiding future federal climate policy outcomes.

It is evident that advocates of continued climate inaction or delay now lie well outside the mainstream of American political, business, legal, or economic consensus. But exactly where the American climate consensus will go from here – or how it may become manifest in statute and/or regulation – is not yet clear.

Offensively, leadership states recognize that actions which reduce emissions of greenhouse gases – including boosting energy efficiency, developing renewable and low-emission energy sources, capturing and using currently wasted energy (i.e., "recycling waste energy"), conserving natural resources, improving industrial processes, sequestering carbon through agriculture and forestry practices, and improving transportation and land use policies – can enhance energy security, keep more of citizens' energy dollars at home, spur greater resource productivity, provide direct cost savings, improve air quality and public health, and enhance economic development, job creation, and quality of life. Leadership states similarly recognize that many such actions can be implemented through market-based policies and other economically sound means, and can advance their position in the development and application of new efficient technologies, boost their participation in global markets, and enhance their competitive advantage.

By ramping up the learning curve, gaining familiarity with climate change issues and what options are available to address them, leadership states put themselves in a better position to influence future federal climate policies to their advantage. Bob Gough of Native Energy captured states' fears of these outcomes quite succinctly in a 2005 presentation, "If you're not at the table, you're on the menu." Jurisdictions that have been recalcitrant to date on climate action may be increasingly aware that they're "on the menu." Against this risk, it is little wonder that numerous states – and groups of states – across the country have adopted emission reduction goals for GHGs. Several state and regional goals are shown in Table 1.

A Model for National Action

It is evident that advocates of continued climate inaction or delay now lie well outside the mainstream of American political, business, legal, or economic consensus. But exactly where the American climate consensus will go from here – or how it may become manifest in statute and/or regulation – is not yet clear.

Consistent with the states' history of breaking new environmental ground in other arenas, the climate action plans developed by the leadership states are up to the task at hand. Leading climate scientists indicate that GHG reductions on the

Table 1. State and Regional GHG Emissions Growth Forecast, Goals, and Coverage of Goals by Climate Action Plans, April 2007

State	1990-2020 GHG Forecast	State Goals	Climate Plan Coverage
Arizona	149%	2000 levels by 2020; 50% below by 2040	106%
California	41%	- Executive Order: 2000 level by 2010; 10% below by 2020; 80% by 2050 - AB-32: 1990 levels by 2020	100%
Connecticut	32%	1990 level by 2010; 10% below by 2020; 75% by 2050	100%
Massachusetts	Not available	1990 level by 2010; 10% below by 2020; 75% by 2050	Not available
Maine	34%	1990 level by 2010; 10% below by 2020; 75% by 2050	100%
North Carolina	113%	Not available	TBD
NEG/ECP	Not available	1990 level by 2010; 10% below by 2020; 75-85% ultimately	TBD
New Jersey	Not available	- E.O.: 1990 level by 2020; 80% below 2006 levels by 2050	Not available
New Mexico	48-64%	2000 level by 2012; 10% below by 2020; 75% by 2050	133%
New York	24%	5% below 1990 by 2010	Not available
Oregon	38%	1990 level by 2010; 10% below by 2020; 75% by 2100	85%
Puget Sound	37%	1990 level by 2010; 10% below by 2020; 75% by 2100	100%
Rhode Island	35%	1990 level by 2010; 10% below by 2020; 75% by 2050	100%
Vermont	Not available	25% below 1990 levels by 2012; 50% below 1990 by 2028; 75% by 2050	Not available
Washington	Not available	- E.O.: 1990 levels by 2020; 25% below 1990 by 2035; 50% below 1990 by 2050	Not available
Western Regional Climate Action Initiative	Not available	- Specific goals are to be identified; now under development	Not available

magnitude of 75-80% are necessary by 2050 in order to limit global surface temperature rise to 2 degrees Centigrade – our current best understanding of the threshold to avoid dangerous anthropogenic interference in the Earth's climate system. A few bills have been introduced in Congress which reflect this scientific necessity, but most are significantly weaker. Typically, the more aggressive bills have been viewed as impossible, impractical, or simply an "opening position" subject to political compromise.

Early climate action plans from the leadership states, however, demonstrate that on a proportional basis, aggressive greenhouse gas emission reductions of the magnitude called for by the scientific community are actually attainable – *at a net economic savings*. Further, these plans are grounded in effective implementation of *existing* technologies and policies; their success does not hinge on prospective technological breakthroughs or unidentified silver bullets. Instead, they reflect the "silver buckshot" of many proven, but underutilized, opportunities already available to us, like those identified in the Arizona plan (e.g., low-emission vehicles, appliance efficiency standards, building codes, electricity pricing and demand-side management policies, distributed generation, combined heat and power and waste energy recovery, renewable portfolio standards, reduced land conversion and increased reforestation, etc.). Figure 1 illustrates the magnitude of early leadership states' climate action plans, scaled up to the national level for comparison to measures that have been proposed in Congress.

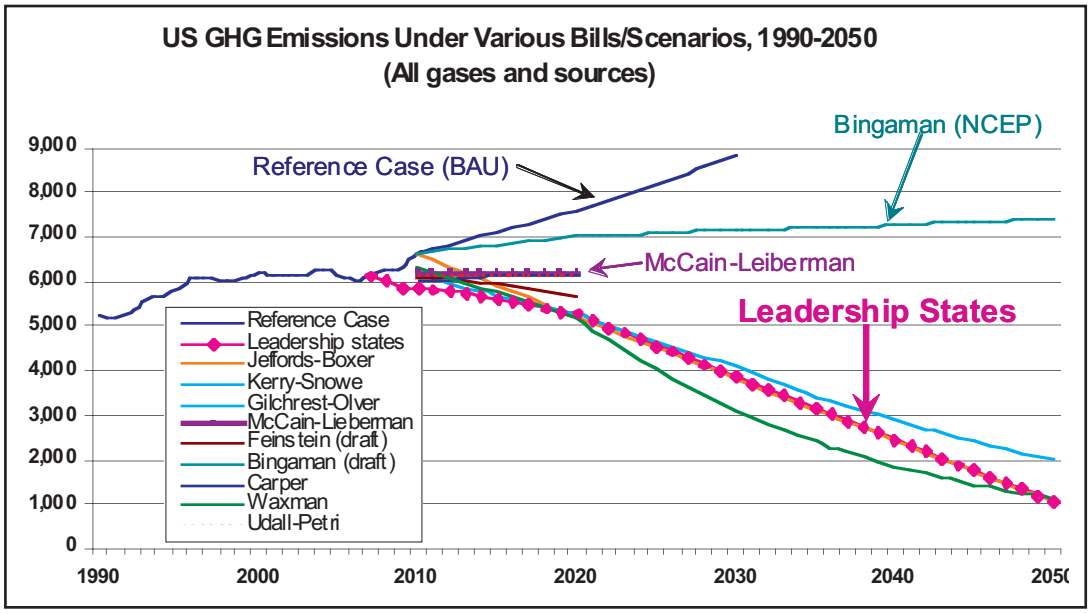

Figure 1. Approximation of Leadership States' Planned Reductions Compared to Proposed National Legislation

Preliminary, "back of the envelope" extrapolation of the economic outcomes of early leadership states' climate action plans is also encouraging. Although far more data must be assembled, and greater analytical rigor applied, there is little reason at this point to suspect that the categories of climate policy options identified by leadership state stakeholders and recommended to their Governors are not generally scalable to the national level. Based on the limited sample of early leadership states' climate action plans completed to date, Table 2 identifies these categories of options, their approximate contribution in reducing GHG emissions from 2020 BAU levels down to approximately 1990 levels, and approximate costs or savings per MTCO2e reduced.

If these results are similarly extrapolated to the national scale, U.S. GHG emissions could plausibly be reduced by more than one-quarter by 2020, at a net present value savings of over $100 billion. As noted, these figures are very preliminary, and based on a very limited data set of leadership states' results. It is possible that a properly rigorous assessment would show this savings figure to be off by an order of magnitude. However, in the past, initial estimates of costs have typically proven to be far too conservative, compared to reality as it actually evolved (e.g., even USEPA's cost estimates for Phase 1 sulfur dioxide reductions under the federal Acid Rain Program were high by a factor of approximately eight). Accordingly, the 2007-2020 NPV of aggressive climate action at the national scale may be more likely to approach savings of several hundred billion dollars than to be as low as savings in the realm of "only" ten billion dollars.

Conclusion

As the above discussion shows, states are more than just "laboratories;" they are full-fledged policy proving grounds. The policy innovations emanating from their "laboratories" are piloted, yes, but then they are forged into successful policies through the heat of conflict resolution, political negotiation, compromise, consensus, adoption, implementation, and in some cases, enforcement.

Effectively, policy adoption at the federal level echoes – albeit in macrocosm form – all of the trials and tribulations that policy adoption at the state level requires. Federal policymaking may be encumbered by the sheer magnitude of national applicability and an even greater plethora of competing interests than the states typically face, but federal policymaking enjoys one significant advantage – the path forward has been broken by one or more states. In short, state environmental efforts are often unprecedented in the U.S., whereas federal environmental efforts rarely are. Table 3 illustrates states' pathbreaking activities with respect to air quality concerns, an arena that has substantial overlap with climate action in terms of sources, emissions, and solutions. It shows that many, if not most, major air quality initiatives over the last

Table 2. Preliminary GHG Reduction Potentials and Costs by Sector Based on Early Leadership States' Climate Action Plans.
Source: Center for Climate Strategies

Category of Action	Preliminary Contribution to Reducing GHG Emissions from 2020 BAU to 1990 Level	Preliminary Cost or Savings per MTCO2e
Energy Efficiency and Conservation	~24%	-$10 to -$30
Clean and Renewable Energy	~24-30%	$7 to $21
Transportation and Land Use Efficiency	~20-36%	-$32 to -$36
Agriculture and Forestry Conservation	~6-9%	-$1 to -$5
Waste Management, Industrial Process Improvement, etc.	~11-18%	Not Available

Table 3. Examples of State-to-Federal Environmental Pathbreaking – Air Quality

State Policy	State Adoption	Federal Adoption
Acid Rain Laws (SO2)	1985	1990 (Federal Acid Rain Program)
Air Toxics Laws	1987	1990
NOx Trading (OTC)	1995	2004 (NOx SIP Call)
Mercury Emission Reductions from Power Plants	1998-2002	2005 (Federal CAMR Rule)
Renewable Portfolio Standard	1997-2007	Introduced
"Four-Pollutant" Laws for Power Plants	1997-2002	Introduced
Multi-Sector GHG Reduction Laws	2003-2006	Introduced (McCain-Lieberman, Carper)
Vehicle GHG Emission Standards	2002	?

20-25 years have been pioneered by states well in advance of federal adoption. In several cases, such as renewable portfolio standards, GHG emissions standards from motor vehicles, and broader GHG emissions reduction requirements, the states are still waiting for parallel policy action from the federal government.

Although states have worked together to some degree in the past to engineer regional agreements and commitments, climate change concerns have accelerated multi-state collaboration markedly. No doubt this is in large part due to the states' recognition that climate change is a global problem; climate actions by any individual state are likely to matter little in terms of absolute global emissions changes. Regionally, however, multi-state collaborations readily equate to the highest-emitting nations in the world. Regional efforts also pool states' expertise, which is particularly crucial from a resource standpoint in the absence of technical assistance normally available from the federal government. Leadership states' successes belie opponents' predictions of economic disaster, contradict suggestions of public political retribution, provide model policies for adoption by other states, and build collective critical mass toward comprehensive federal action.

In short, given states' history of successfully paving the way for federal environmental progress, it seems prudent to anticipate that climate action will be no exception. The fact that states are engaging with each other to an unprecedented degree to achieve – and demand – progress on climate change reinforces this expectation. So does the political reward enjoyed by many pro-active governors for their insistence on tackling climate change. Faced with the twin challenges of the most daunting, all-encompassing environmental problem of all time coupled with a virtual absence of constructive federal involvement or assistance, it might seem reasonable for states to wait this one out. Instead, leadership states are epitomizing responsibility in their efforts to avert a global "tragedy of the commons," and in doing so, are finding savings, innovation, competitiveness, public appreciation, and corresponding economic and quality of life gains. History may remember leadership on climate change action as the states' finest hour.

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1 See www.climatestrategies.us

2 For the full Arizona Climate Change Action Plan, see www.azclimate-change.us

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A Climate of Hope: How American Cities are Changing the Debate on Climate Change

By Greg Nickels
Mayor of Seattle

It has been two years since the community of nations took the first, important step to address the biggest threat facing our planet -- global warming. I remember very well the day the Kyoto Protocol took affect in 141 countries around the world, but not ours.

In Seattle that winter, the warnings about the distant threat of climate change became all too real. The mountain snowfall that we rely on for clean drinking water and hydroelectric power literally didn't fall. We faced an uncertain year of water supply. I was concerned for my city. I was worried about the future. And I was mad that my nation's government was sitting on its hands.

As Americans, we view ourselves as part of a great nation, a principled people with a history of rising to the challenge of the most serious international threats. Yet here we were, responsible for fully 25 percent of the greenhouse gases causing a global meltdown, but somehow incapable of doing anything about it.

I was determined to show the world that intelligent life had not been snuffed out in America

So, I asked nine fellow mayors to join with me in pledging to cut greenhouse gas emissions in our cities and meet the goals of the Kyoto Protocol. We also agreed to challenge other mayors from around the country to do the same. We called it the U.S. Mayor's Climate Protection Agreement.

Our initial goal was to get a symbolic 141 cities to join. Today, I am proud to say that 432 mayors have signed our climate commitment. They represent more than 61 million people in cities from every state in the nation. They are Republicans, Democrats and Independents. They are leaders of some of our biggest cities and some of our smallest towns.

And they are united in the knowledge that cities are the frontlines of the war on climate change, where the risks are most keenly felt and where the opportunities springing from the clean-energy revolution will be seized.

Population centers on rivers and in coastal areas—from New York City and New Orleans to St. Louis and Seattle—will bear the brunt of increasingly severe weather, flooding and rising sea levels associated with climate disruption.

America's hottest and driest cities—places like Phoenix, Las Vegas, Los Angeles and Houston—are becoming more vulnerable to drought, water shortages and wildfires.

Some communities have even had to move in Alaska, where rising winter temperatures have caused erosion, landslides and a rapid melting of the permafrost.

Winter snow pack in Seattle's nearby Cascade Mountains is in some places half what it was 50 years ago. It will suffer further dramatic decline in the next 30 years if we don't act aggressively to cut emissions now.

The good news is that cities have long been the incubators of great ideas. That remains true today. In Seattle, we are already seeing a growing green economy create jobs and economic opportunities in fields such as energy, construction and transportation.

Across the country, cities are trying new approaches to reducing emissions. They have focused on cleaner electricity production, reducing energy consumption in buildings and encouraging clean-burning cars and transportation. If an idea works well, it can be quickly adopted by other cities. If it fails, others can avoid the mistake.

We've had success in Seattle

Our publicly-owned electric utility, City Light, is the first in the nation to achieve net-zero greenhouse gas emissions, through a combination of renewable energy sources and carbon offsets—essentially paying others to reduce their pollution. It's a source of great pride: we're powering our city without toasting the planet!

Most of our garbage trucks run on cleaner biodiesel. Cruise ships based in Seattle now plug into shore power rather than run their massive engines when in port. And we are investing heavily in mass transit systems. More and more people are choosing to live in the city and close to their jobs. And we are making it easier to bike and walk in Seattle.

We are now building a broad, action-oriented public campaign to encourage energy conservation in transportation, heating and lighting. And the private sector is also joining the effort by working to reduce their emissions through the Seattle Climate Partnership.

If Seattle were doing this work alone, it would be a symbolic gesture. But the fact that more than 400 other cities are working together to reduce emissions means that we are making a real difference for the future of our planet.

In January, more than 100 mayors joined me in Washington, D.C., to make our voices heard on the need for federal action. We asked Congress to take meaningful steps to protect the climate, and they have responded with a series of strong proposals.

It was clear to me that the climate has indeed changed in the nation's capitol. As mayors, we have accomplished much over the past two years. And while we have a great deal of work ahead, my mood has improved. The frustration has turned into a sense of hope that we have helped build a movement that will result in this great nation joining—even leading—the global battle for a stable climate.

Local Momentum Brings a Wave of Change – Meeting the Threat of Global Climate Change Head-on

By Dennis J. McLerran
Executive Director
Puget Sound Clean Air Agency

In the absence of significant federal action on climate change, local communities and states are stepping up to the plate. Local leaders in the Pacific Northwest have embraced aggressive emission reduction goals, developed action plans and adopted legislation.

While climate change is a global problem, it will have profound impacts on the state of Washington. Regional impacts include loss of snow pack, rising sea levels, increased drought and risk of forest fire.[1,2] Less snow in the mountains means reduced water supply for hydroelectric dams, irrigation and habitat for fish like threatened and endangered species of salmon. Sea level rise threatens coastal communities with shore erosion, property loss and low-land flooding. Drier, warmer summer weather accompanied by reduced runoff in spring and summer will likely increase drought, crop threat and risk of forest fire. Hotter climate could also lead to more noxious pest infestations of the region's timberlands, as trees are often more susceptible to pests and disease when stressed by heat and lack of water.

These predicted consequences combined with a sense of responsibility have motivated state and local leaders to take actions that will mitigate these impacts. The Puget Sound Clean Air Agency was an early leader in organizing efforts at the local and regional levels. This article describes some of the major actions and leadership initiatives taking place in the state of Washington for what will certainly be the predominant environmental issue of this century.

Washington has much to lose from climate change and therefore has been involved earlier than many other regions of the country. For many decades the state has relied on cheap, abundant and reliable hydro electricity that is inherently climate friendly as it takes little carbon to generate. Historically, the Pacific Northwest has had abundant mountain snowfall that acts as a reservoir for the rivers where dams and hydroelectric generators have been built to produce electricity. Peak demand for electricity in the northwest is in winter when rain and snow historically have kept stream flows up and reservoirs adequately supplied. The snow accumulates above 3,000 feet in elevation and melts gradually through the spring and into the summer, storing the water and releasing it over many months. In recent years, however, the growth in Washington's urban areas has caught up with hydro power supplies which, even with normal snowfalls, are a finite resource. Without significant additional conservation, new non-hydro sources of energy will become necessary. The state and the Pacific Northwest are at a choice point, where either new natural gas and coal power plants will be needed, or the region can choose enhanced conservation and renewable energy resources like wind, solar or thermal power.

The critical nature of making new choices regarding energy supply became starkly evident in the winter of 2004-2005. Climate change had reduced peak snow pack in the Cascade Mountains by as much as 50 percent from 1950s levels by the mid-2000s. But in the winter of 2004-2005, the snow was not falling even at the diminished levels already resulting from climate change. The reservoirs were nearly empty and crucial snow pack was not building. At the same moment, California was experiencing unprecedented energy shortages from a combination of manipulation of energy supplies due to deregulation and power plants being down for maintenance or other reasons. In a normal winter, the northwest would be able to receive relatively inexpensive power from California, as peak power demand in California comes from air conditioning use in the summer. But after the 2000-2001 brownouts, California was

experiencing record energy prices as a result of the market crisis that had been created there. This resulted in peak power costing more than 50 times what it normally would have. A power crisis in the public and private utilities erupted quickly in Washington state with large surcharges being imposed on ratepayers coupled with major concerns about brownouts or blackouts. Utilities scrambled to obtain emergency diesel generators and sought permission to use peaking power plants beyond permit limits. Some utilities began unprecedented borrowing which resulted in rate increases that would last for years into the future. The governor of Washington issued emergency orders addressing the crisis. The bottom line was that this crisis made it crystal clear to many local and regional leaders that the changing climate could have profound local impacts which needed to be addressed.

For Mayor Greg Nickels of Seattle, who is now leading mayors from across the United States with over 435[3] cities (including at least 15 from the Puget Sound area) joining in a pact to meet Kyoto targets with local emission reduction plans, this was, as he describes it, an "aha" moment. Local leaders like Mayor Nickels and King County Executive Ron Sims, directed the Puget Sound Clean Air Agency to develop a regional climate change program to help identify what steps could be taken at the regional and local level to address changing climate. In 2004, the Puget Sound Clean Air Agency formed a Climate Protection Advisory Committee to begin to identify what steps should be taken[4]. The charge given to the group was to identify key local and state options to address climate change which might also have collateral air quality and economic benefits. The group began by looking to other state and regional plans and strategies that had been developed in New England, such as the Rhode Island plan. Its priority recommendations, released in December 2004[5], were to:

- Maximize energy efficiency and increase renewable energy in the region's power mix
- Reduce the greenhouse gas emissions of new vehicles sold
- Reduce motor vehicle miles traveled
- Protect natural landscapes and forest biomass
- Increase recycling and composting rates; reduce waste
- Develop and adopt a climate change policy framework
- Promote public education and citizen/corporate/government action
- Encourage local government to act

At the request of former Gov. Gary Locke, the committee also offered recommendations for statewide action to inform the State of Washington's participation in the West Coast Governor's Global Warming Initiative, launched by the governors in September 2003.

The Puget Sound Clean Air Agency's Climate Protection Advisory Committee process was a major stimulus for legislative action in Washington State. In the 2005 legislative session a number of major climate change bills were successfully passed. Most significant was the passage of the Washington Clean Car Act which adopted California emissions standards for cars in Washington, including the greenhouse gas standards which would reduce greenhouse gas emissions from automobiles by up to 30 percent by 2017. This is particularly important in Washington State where more than 50 percent of greenhouse gas emissions come from transportation. This is in stark contrast to most areas of the nation where power generation from fossil fuels is the major source of emissions. The 2005 Washington legislative session also resulted in successful legislation requiring future public buildings (including schools) to meet green building efficiency requirements; commercial appliances not regulated by federal standards to meet energy efficiency requirements; and adoption of significant solar energy incentives. The 2006 legislative session resulted in clean fuel mandates requiring 10 percent of gasoline and diesel supplies to be from renewable sources.

Since that time, local, regional and national momentum around global climate protection has moved into high gear. As mentioned earlier, Seattle Mayor Nickels launched the U.S. Mayors Climate Protection Agreement[6] on February 16, 2005, the day the Kyoto Protocol took effect in the 141 countries that ratified it. To meet the Kyoto goal locally and to provide a "green-print" for others to use elsewhere, the mayor appointed the Green Ribbon Commission on Climate Protection. The commission – which includes 18 leaders from Seattle's business, labor, non-profit, academic communities and government, including the Puget Sound Clean Air Agency – was specifically charged with developing local solutions to global climate disruption. The commission issued its report and recommendations to Mayor Nickels in March 2006[7], followed by the release of Seattle's Climate Action Plan in September 2006[8]. The plan offers a template for other local governments in the country to meet the commitments of the U.S. Mayors Climate Protection Agreement.

In October 2005, King County, Washington hosted a Climate Change Conference where over 650 partners engaged a broad cross-section of Washington State governments, business-

es, tribes, farmers, non-profits, and the community-at-large in a dialogue about climate change impacts and potential adaptation[9]. The conference was significant as it was one of the first in the nation to focus on the need for adaptation to climate change.

King County Executive Sims, representing the most populous county in the state, then announced the King County Climate Plan on February 7, 2007[10]. He joined Washington Gov. Christine Gregoire at the state capital later that day as she announced the Washington Climate Change Challenge. The governor's executive order established greenhouse gas emissions reduction and clean energy economy goals which, among other things, strive by 2035 to reduce greenhouse gas emissions in the state of Washington to 25 percent below 1990 levels, a reduction of 30 million metric tons below 2004; by 2020 increase the number of clean energy sector jobs to 25,000 from the 8,400 jobs we had in 2004; and by 2020 reduce expenditures by 20 percent on fuel imported into the state by developing Washington resources and supporting efficient energy use[11].

Work is already underway in the state's legislature with the 2007 Clean Air/Clean Fuels bill which will, in part:

- Protect our children's health by replacing dirty diesel school buses with clean diesel buses to reduce our kids' exposure to toxic air pollution.
- Require a 25-percent reduction in petroleum use by state fleets by 2020, growing the market for cleaner fuels and vehicles.
- Reduce greenhouse gas emissions and clean up our air by creating the infrastructure and incentives for Washington State to produce and use biodiesel and cellulosic ethanol.

In late February, 2007 came the agreement between the five western governors from Washington, Oregon, California, New Mexico and Arizona to develop a joint strategy to reduce emissions and create a market-based trading system for climate change emissions. The Western Regional Climate Initiative[12] builds on the earlier efforts of the West Coast Governor's Global Warming Initiative and coincides with similar Northeastern and Mid-Atlantic state agreements.

Such momentum brings hope that both our region and our nation are beginning to make headway against the global crisis of climate change. In the Puget Sound region and in Washington State, we are committed in the near-term to crest the hill and begin reducing greenhouse gas emissions rather than continuing to increase them. And by 2050 we know we must reduce emissions by 70 percent or more to do our proportionate share to stabilize the climate. As our agency's Climate Protection advisors pointed out just over two years ago, acting now makes that journey easier and more effective and should create opportunities for our communities to prosper by developing the technologies needed in a world transitioning to a low-carbon economy.

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Louisville Metro:

Addressing Local Opportunities and Obligations to Address Global Climate Change

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Since shortly after we were able to observe our planet from out in space in the late 1960's, there has been a growing awareness and concern about our affects on our global systems.

From the nascent focus on these concerns in the 1970's and 1980's, by the early 1990's national and international scientific and governmental organizations were deep into research and analysis on causes, effects and appropriate policy responses.

Louisville's evolution on the issue of climate change has tracked these national and international developments.

In 1992, the United Nations convened what is sometimes referred to as the Earth Summit in Rio de Janeiro. This Summit produced an International Convention on Climate Change which the first President Bush signed on behalf of the United States. This convention acknowledged the significance of global warming as an issue and pledged national actions to begin to address it.

In attendance at the Rio Summit was a noted University of Louisville Professor of Sociology, Dr. Lilyalyce Akers. Upon returning to Kentucky she persuaded Kentucky Governor Brereton Jones to convene the first North American follow-up conference to the Rio Summit. This groundbreaking conference, called "From Rio to the Capitols," brought together about 1500 participants from state and local governments and nongovernmental organizations from across the United States in May 1993.

The conference sought to identify opportunities, strategies and policies to begin to address climate change and related issues. The conference created enormous energy and momentum in Louisville to address an issue that was clearly of increasing significance.

Building on that momentum, Dr. Akers persuaded University of Louisville President Donald Swain to use the 1993 Louisville conference as an organizing principle around which to focus many of the University's programs and resources. To this end, the University created the Kentucky Institute for the Environment and Sustainable Development. Over the last decade, the Institute has played a key role in researching environmental issues and developing and implementing strategies to address those issues, including climate change.

The 1997 United Nation's Climate Change Convention in Kyoto, Japan brought a heightened level of attention to climate change. While the United States was an active participant in the United Nation's process, it has yet to ratify the Kyoto Protocol. However, enough countries have signed on to the agreement so that in effect it obligates the signatory countries to undertake significant greenhouse gas emission reductions.

Even though the United States has not acted to adopt the Kyoto Protocol, there has been increasing activity in the United States at the state and local level to begin to address climate change.

In 1996 the National Association for State and Local Government Air Pollution Officials created a global warming committee to begin to better understand the issue and to evaluate appropriate roles and responses for air pollution agencies. In January 1997, I was elected co-chair of that committee. In that capacity I have had the good fortune to attend several of the United Nations Climate Change Conventions (1997-Kyoto; 1998-Buenos Aires; 1999-Bonn; 2000-The Hague; 2001-Bonn).

Additionally, the national group (now called the National association of Clean Air Agencies[NACAA]), in 1998, became one of the first organizations in the United States to publish a guide for local and state

Art Williams presenting at Sixth UN Conference in the Hague.

governments which identified strategies to reduce greenhouse gas emissions from all sectors of the economy. ("Reducing Greenhouse Gases and Air Pollution: A Menu of Harmonized Options").

This publication was followed in 2000 by the publication of a software tool, still in wide use, that identifies strategies at the city or state level and assists in quantifying the greenhouse gas emission reduction benefits from a particular strategy.

Against the backdrop of this international and emerging national discussion, the City of Louisville Board of Aldermen, in September 1997, adopted Resolution 178, Series 1997 authorizing the City's participation in the Cities for Climate Protection Campaign, part of the not-for-profit organization the International Council for Local Environmental Initiatives(ICLEI). ICLEI provided a $40,000 grant to the City of Louisville. The City, through its participation in the campaign, agreed to implement a local internal energy efficiency project. The project is designed to promote energy efficiency in the private sector by attempting to recruit twelve local industrial and manufacturing companies to participate in a climate change campaign for businesses and to develop a local action plan to reduce greenhouse emissions.

While progress was being made by the City on this initiative, by 2000 it was clear that a broader effort in the community was necessary and appropriate. To accomplish this, the Louisville chapter of the Sierra Club undertook an effort to seek the participation of Jefferson County Government in the ICLEI campaign. The Sierra Club requested that the Jefferson County Air Pollution Control District take the government lead in this and with close collaboration with the Sierra Club and a number of other interested individuals and organizations, especially including several faith-based groups, the Jefferson County Fiscal Court, in 2002, authorized County participation in the ICLEI campaign.

Coincidentally, at this time, the merger of City and County government became a predominant governmental pursuit (local voters having approved merger in the November 2000 election to be effective January 2003).

While the ICLEI campaign helped get the local City and County governments energized and focused on beginning to grapple with the issue of reducing greenhouse gas emissions, the effort has kicked into a much higher gear the last two years.

In 2004, Mayor Greg Nickles of Seattle, Washington initiated what has become one of the most important local government initiatives to address climate change. Within the framework of the US Conference of Mayors(USCM), Mayor Nickles launched the Climate Protection Agreement to focus and commit local government efforts to reduce greenhouse gas emissions.

In April 2005, Louisville Metro Mayor Jerry Abramson signed the City of Louisville on to the Climate Protection Agreement. As detailed elsewhere in this issue of Sustain, the agreement seeks to have participants pursue a wide range of activities and strategies including establishing a baseline greenhouse gas emissions inventory and to reduce such emissions to levels suggested for the United States by the Kyoto Protocol—that is, 7% below 1990 levels by 2012.

One of the important features of the US Conference of Mayor's initiative, which now has over 400 signatories, is that the authorizing resolution recognizes and promotes close cooperation with ICLEI. Thus, Louisville Metro's efforts, begun within the context of the ICLEI campaign has now evolved and merged with the Climate Protection Agree-ment of the USCM.

To further the City's pursuit and implementation of the agreement, the City has now created a new climate change committee of the Partnership for a Green City. This partnership is a unique collaboration between Louisville Metro government, the University of Louisville and the Jefferson County Public School system to identify and implement progressive environmental strategies across all three entities. (You can find more information about the partnership at: http://www.jefferson.k12.ky.us/Departments/EnvironmentalEd/GreenCity/).

This new climate change committee, which began meeting in December 2006, has a diverse representation from across the three organizations, and appropriately includes key staff with responsibility for many energy use activities such as buildings and motor vehicle fleets. Also, the group reflects expertise in numerous policy areas such as land use, transportation and reforestation.

The committee is now in the process of establishing subcommittees to accomplish its work. Among the subcommittees under consideration are ones to address education and outreach; energy efficiency across all sectors, promoting renewable energy; studying, adapting to and mitigating local climate change impacts; and evaluating opportunities for offsets, trading and participating in greenhouse gas emission registries or exchanges.

While the committee's efforts are initially focused on the greenhouse gas emissions of the three partners, in order to achieve the broader goals of the agreement it will be necessary and appropriate to link to the broader community.

With the increasing momentum on climate change, reflected by the landmark US Supreme Court decision on April 3, 2007, the creation of the groundbreaking Climate Registry, the numerous bipartisan bills pending in Congress, and the updated science reports out of the Intergovernmental Panel on Climate Change which lend increased concern to the probable dramatic, if not catastrophic, effects of climate change, Louisville is well-positioned to take decisive action to reduce greenhouse gas emissions.

Global Warming "Lifeboat" by Friends of the Earth at COP 5 in Bonn, Germany (1999).