

# THE CQ Researcher

PUBLISHED BY CONGRESSIONAL QUARTERLY INC.

## Global Warming Update

*Are limits on greenhouse gas emissions needed?*

This year marks the 100th anniversary of the discovery of the greenhouse effect by the Swedish chemist Svante Arrhenius. Thanks to sophisticated computers and satellites, scientists today know more about how burning fossil fuels and other industrial activities release carbon dioxide and other gases that trap solar heat in the Earth's atmosphere. Predictions about the increasing pace of global warming caused by human activity have so alarmed policy-makers that efforts are under way to draw up an international treaty — due to be signed in Kyoto, Japan, in 1997 — to curb greenhouse gas emissions. These efforts have sparked controversy in the United States, where some scientists and industry representatives dispute the accuracy of future warming predictions and oppose limits on energy consumption.



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Nov. 1, 1996 • Volume 6, No. 41 • Pages 961-984

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The CQ Researcher (ISSN 1056-2036). Formerly Editorial Research Reports. Published weekly (48 times per year, not printed March 1, May 31, Aug. 30, Nov. 29) by Congressional Quarterly Inc., 1414 22nd St., N.W., Washington, D.C. 20037. Annual subscription rate for libraries, businesses and government is \$319. Additional rates furnished upon request. Periodicals postage paid at Washington, D.C. POSTMASTER: Send address changes to The CQ Researcher, 1414 22nd St., N.W., Washington, D.C. 20037.

# Global Warming Update

BY MARY H. COOPER

## THE ISSUES

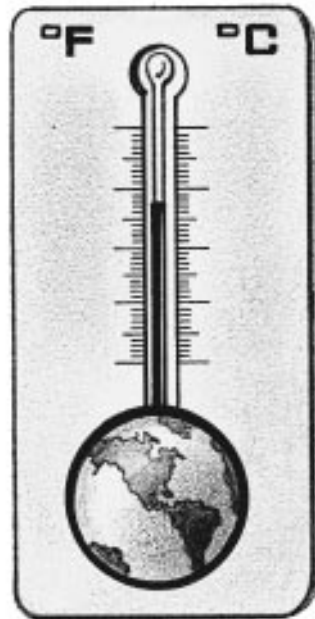
Swedish chemist Svante Arrhenius was ahead of his time. So far ahead, in fact, that for almost a century scientists couldn't confirm his far-sighted theory.

Contemplating the intense industrial development swirling around him, Arrhenius theorized in 1896 that all the coal being burned was affecting Earth's temperature. The vast amounts of carbon dioxide and other gases being released as a result, he said, were trapping solar heat in the atmosphere, much as the glass roof and walls of a greenhouse trap heat. Arrhenius predicted that escalating industrialization would add still more gases to the atmosphere, causing global temperatures to rise several degrees.

In recent years, modern technology has proved that the Earth is indeed getting warmer, launching an intense global debate. Industrialized countries and environmentalists say it is time to limit emissions of so-called greenhouse gases; developing nations and industry groups want more latitude to grow.

According to widely accepted meteorological evidence, the average global temperature has risen about 1 degree Fahrenheit since the turn of the century. Scientists are now predicting an additional 2-7 degree rise in the 21st century if current trends continue unchecked.

A temperature rise of a few degrees may seem insignificant, considering that humans have thrived for millennia in inhospitable locales from the Arctic to the tropics. But even a small rise could wreak havoc throughout the world. Some scientists predict that melting polar ice could cause a three-foot rise in sea levels. That would inundate low-lying coastal areas, threatening entire countries, such as the Netherlands and Bangladesh. Small island nations such as the Maldives, Guam and Sri Lanka



could be virtually wiped out.

Warming also is expected to cause the spread of malaria, dengue fever and other deadly tropical diseases. As tropical regions expand in size, disease-carrying mosquitoes will be able to extend their range. Human suffering could be further compounded by starvation. Rising temperatures are expected to disrupt weather patterns all over the world, possibly bringing drought to vital food-producing regions, especially in sub-Saharan Africa, South Asia and tropical Latin America. Entire species of plants and animals could become extinct.

In the 1960s and early '70s, satellites and powerful supercomputers began providing additional support for Arrhenius' theory. In 1990, concerned world leaders called on scientists to help them understand the implications of global climate change and decide what to do about it. Last December, the United Nations' Intergovernmental Panel on Climate Change (IPCC), a worldwide network of 2,500 scientists, announced that the evidence of global warming was undeniable, albeit difficult to accurately quantify. "Neverthe-

less," the panel declared in its report, "the balance of evidence suggests that there is a discernible human influence on global climate."<sup>1</sup>

As the world's leading economy and biggest consumer of fossil fuel, the United States is also the biggest producer of greenhouse gases, accounting for more than one-fifth of all the CO<sub>2</sub> — some 4.9 billion metric tons. (See graphs, p. 968.) But because the U.S. economy depends so heavily on oil, coal and natural gas, political leaders have been reluctant to ask industry to curb greenhouse gas emissions without definitive proof of Arrhenius' theory.

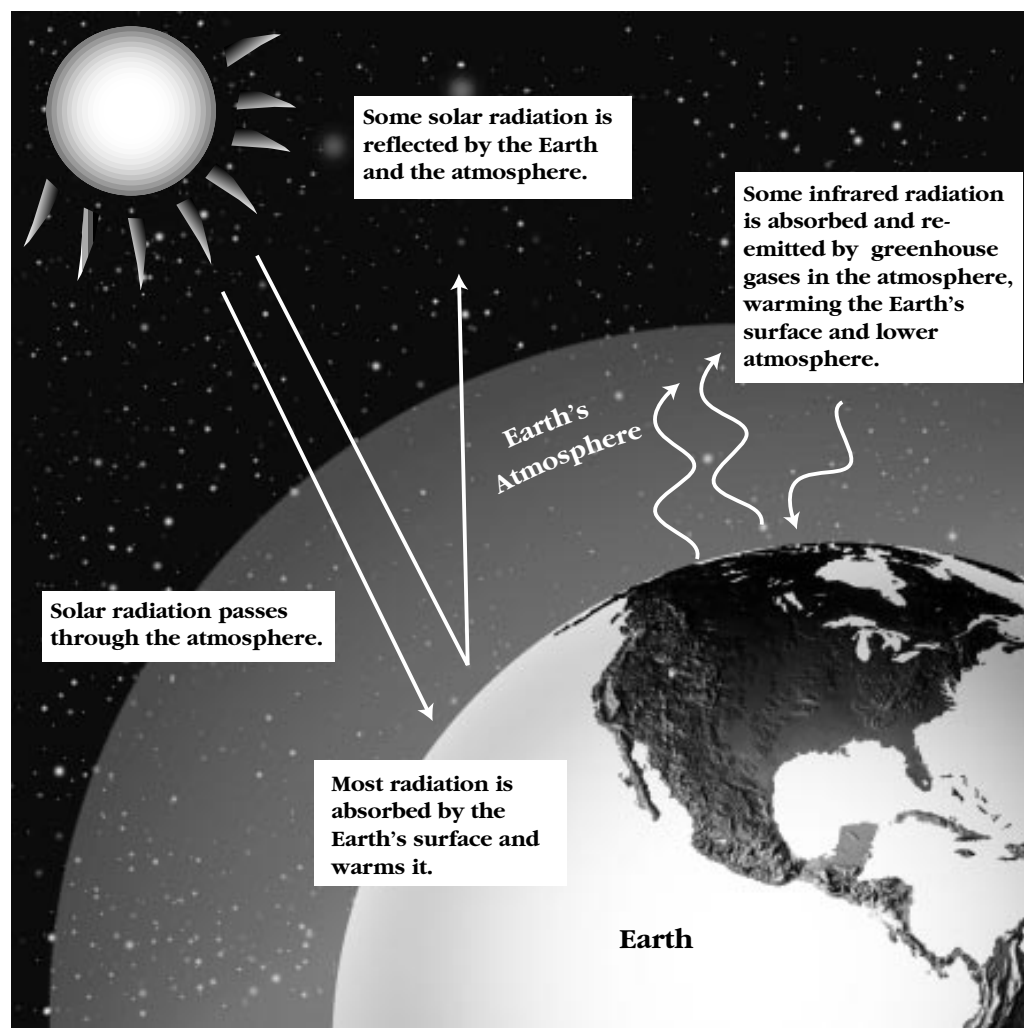
The unequivocal IPCC declaration, however, prompted the Clinton administration to toughen U.S. environmental policy. In July, former Sen. Tim Wirth, D-Colo., now under secretary of State for global affairs, announced that the United States would seek to develop yet-to-be-determined targets and timetables for reducing gas emissions. Under the sponsorship of the United Nations, the United States and other nations have been working on a global climate-change treaty and are scheduled to sign the finished document in Kyoto, Japan, in December 1997 (see p. 976).

"We think that there are lots of possible impacts from changes to the climate system, many of which are undesirable," says Eileen B. Claussen, assistant secretary of State for oceans and international environmental and scientific affairs and a lead U.S. negotiator at the treaty talks. "The fact that there is now some clear evidence of human input into those changes suggests to us that we ought to be serious about how we respond."

Although the Clinton administration refrained from stipulating either precise limits on emissions or the deadlines for achieving them, the commitment to reach such goals has roiled an already heated international

## How the Greenhouse Effect Warms Earth

*Carbon dioxide and other greenhouse gases released into the Earth's atmosphere trap solar heat, warming Earth's surface and lower atmosphere.*



Source: National Aeronautics and Space Administration

tion to mitigate climate change.”

The Global Climate Change Coalition, another industry group, is leading the charge against mandatory limits on greenhouse gas emissions, predicting that they would ruin the economy. “We’ve got to be cautious because the stakes are so high,” says Executive Director John B. Shlaes. “All the relevant economic analyses say that the United States is going to take a major hit on the economy if any of the [limits] that have been on the table are adopted.”

A study commissioned by the coalition predicts that adoption of some proposals would cause a 3 percent fall in U.S. gross domestic product by 2010, resulting in a 23 percent drop in the growth rate of Americans’ living standards.<sup>2</sup>

Some scientists also take issue with the need for immediate steps to cut greenhouse emissions. “There has been an intentional confusion between the concept of global warming and the

debate. Environmentalists and scientists who support immediate curbs say they are crucial to preventing future disaster. But some industry spokesmen and scientists say the evidence does not warrant policies that they say will cause irreparable harm to the U.S. economy.

“We oppose legally binding targets and timetables, as well as mandatory command-and-control policies and measures,” says John Novak, a spokes-

man for the Edison Electric Institute (EEI), which represents electric power companies and electric utility holding companies. Most of EEI’s members burn coal and would come under any caps on fossil fuel use. “We believe that those types of policies will force premature emissions reductions that will be costly and are not warranted at this time,” Novak says. “All the science shows that this is a long-term issue and that there is sufficient time to take ac-

magnitude of global warming,” says Patrick J. Michaels, a climatologist at the University of Virginia. “A lot of people can correctly state that global warming is real, that the planet warmed in this century. But the argument then stops without going into the details. You have to ask the question, not whether the planet will warm, but how much, and how. How much do we want to spend to deal with a problem that we’re not even so sure

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is a problem?”

Supporters of curbs dismiss such critics. “They are only a small handful of people,” says Michael Oppenheimer, an atmospheric physicist at the Environmental Defense Fund in New York. “The consensus view on the nature of the problem has been established by the Intergovernmental Panel on Climate Change. It’s fair to question their findings, but you have to ask what evidence the few critics are putting forward. Basically what they mostly do is pick at details without offering any new evidence. Their arguments have been considered and laid aside because they don’t deliver anything new to the equation.”

Even some U.S. industries that stand to suffer initially from caps on emissions view the stricter policy as both environmentally necessary and potentially beneficial economically, because it will encourage the development of new technology. “We believe that the science is compelling enough to urge action on the national and international level,” says Michael L. Marvin, executive director of the Business Council for Sustainable Energy, whose members include electric utilities, natural gas companies and appliance manufacturers. “It’s a two-sided coin, because the costs of inaction are of consequence as well. According to our estimate, with limited government intervention we can increase the number of jobs and decrease by about 12 percent the overall amount of carbon dioxide that goes into the atmosphere.”

As negotiations on the global climate treaty proceed, the debate in the United States and other nations will continue to center on the following questions:

***Have scientists conclusively proven that human activities cause global warming?***

For most of this century, scientists lacked the technology to prove or disprove the existence of global warming. It is only with the development of highly precise satellite measuring equipment and supercomputers able

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**“A lot of people can correctly state that global warming is real, that the planet warmed in this century. But the argument then stops without going into the details. You have to ask the question, not whether the planet will warm, but how much, and how. How much do we want to spend to deal with a problem that we’re not even so sure is a problem?”**

— *Patrick J. Michaels*  
*climatologist, University of Virginia*

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to process vast quantities of weather data that scientists in recent years have established firm grounds for their climate assessments.

As a result, certain findings are supported by virtually all climate scientists. “We know that greenhouse gases warm Earth because they are there naturally,” Oppenheimer says. “We know that they trap heat — otherwise we wouldn’t be here because the Earth would be 60 degrees

colder. Nobody argues about all that. We also know that greenhouse gases are building up and that the buildup of gases will warm Earth further. Nobody argues with that either. The question is how much, how fast.”

The consensus view expressed by the IPCC is that current rates of emissions will leave twice as much carbon dioxide in the atmosphere in the next several decades as there was before the Industrial Revolution. Such an increase, the panel predicts, would result in global temperatures up to 7 degrees Fahrenheit higher than today — and the fastest warming trend of the past 10,000 years.

But while climatologists agree that Earth’s temperature is rising, some dispute the level of man’s contribution to the rise. The main flaw in the science, they say, lies in the computer representations of global climate known as “general circulation models.” (See “*At Issue*,” p. 977.)

Sallie Baliunas, an astrophysicist at Harvard University, said that “only a small part of the 0.5 degree Celsius [about 1 degree F] rise in the past 100 years — no more than a few tenths of a degree — could have been caused by human-made greenhouse gases.” That’s because most of the warming occurred before 1940, while most of the 50 percent increase in gas emissions by industrial development and transportation came after 1940, she said. For this reason, Baliunas said, “the 0.5-1.5 degree C warming predicted by the computer simulations exaggerates the greenhouse effect produced by the equivalent 50 percent buildup of carbon dioxide.”<sup>3</sup>

As the debate intensifies over what to do about global warming, questions about the reliability of scientific

## Cars That ‘Burn’ Hydrogen . . .

The United States is currently the world’s biggest emitter of carbon dioxide, the main greenhouse gas, and gasoline-powered vehicles account for nearly a third of the U.S. total.<sup>1</sup> If the United States is going to get serious about reducing greenhouse gas emissions, clearly something must be done about the kinds of cars Americans make and use.

Automakers are working on developing cleaner cars by searching for alternatives to the gasoline-powered internal-combustion engine. But their goal primarily has been to reduce smog-causing pollutants, rather than CO<sub>2</sub> and other greenhouse emissions.

Toward that end, the California Legislature in 1990 passed a law requiring automakers to include a “zero-emissions” vehicle among the models they sell in the state by model year 1998. Early this year, however, the state bowed to industry pressure and dropped the 1998 deadline. But by then automakers had already dusted off an old idea — a battery-powered electric car — which made its market debut this fall.<sup>2</sup>

General Motors’ Saturn division has introduced the first commercially available electric passenger car — the EV1 (for Electric Vehicle 1) — in Southern California and Arizona,

the only states where GM has set up service centers for the new model.

The car offers few real improvements over earlier electric prototypes, which were plagued by sluggish performance and

the need for frequent and time-consuming battery recharging. The EV1 can go just 90 miles between recharging its lead-acid battery, which can take more than two hours. In any case, American consumers in recent years have been drawn more to high-performance, gas-guzzling sport utility vehicles and luxury cars than energy-efficient models. With its technical drawbacks and \$35,000 sticker price, the EV1 is not likely to break any sales records.

Experts say that smog in Los Angeles and other cities would lift significantly if electric cars took hold. But

while they can greatly reduce ground pollution by eliminating tailpipe emissions, electric cars are not entirely pollution-free. Many utility plants supplying the electricity they run on still burn coal, the dirtiest fossil fuel of all. And coal-fired utilities would still generate particulate matter and sulfates in an electric-car era.

For the same reason, electric cars would be of limited



*Toyota says its new non-polluting car runs on electricity generated by a reaction between hydrogen and oxygen.*

Reuters

data have at times led to charges impugning the integrity of the scientists themselves. Each side accuses the other of bending its findings to suit political and business interests.

Critics say the way the IPCC found “a discernible human influence on global climate” throws the finding itself into doubt. After the report was submitted to scientists for review and the peer-review process was completed, wording expressing uncertainties about the report’s findings reportedly was altered.<sup>4</sup> The revised text was then published without again undergoing the full peer-review process.<sup>5</sup>

The University of Virginia’s

Michaels concedes that panel members did nothing technically wrong in changing the wording after the peer-review process was completed because their own rules permitted the change. “But the real question is, Was it the right thing to do?” he asks. “Was it right to insert a few sentences [about the human role in climate change] that the authors knew were political dynamite and then to disingenuously turn the other way and pretend they didn’t realize that they would be used like this? That is hokum.”

Supporters of the IPCC dismiss the criticism. “It’s nonsense,” Oppenheimer says. Claussen suggests that the issue

has been blown out of proportion by people with an interest in subverting the treaty negotiations. “I think there are people — some, but not all, of the industry groups — who have tried to create a controversy,” she says. “But I don’t actually think there is much of a controversy.”

Michaels himself has been charged with bias because the coal industry funds some of his research. “Where in the Constitution is it written that industry cannot ask a scientific research question, and that in asking the question it tarnishes the reputation of the person they asked it of?” he responds indignantly. Michaels also says that

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## ... Would Reduce Greenhouse Emissions

use in reducing global warming unless non-fossil energy sources are used to produce the electricity needed to recharge their batteries. Carbon dioxide, the main greenhouse gas implicated in warming, is emitted by all fossil fuels, including the main current alternative to coal in U.S. power plants, natural gas. According to Mark Delucchi, a researcher at the Institute of Transportation Studies at the University of California, Davis, the reduction in greenhouse gases emitted from using an electric car vs. a gasoline-powered car amounts to less than 20 percent.

Other technologies may offer greater hope for reducing greenhouse gas emissions from cars. The most frequently cited alternative to conventional lead-acid batteries is the "hydrogen fuel cell," which produces electricity by "burning" hydrogen. Because the process takes place on board the vehicle, the fuel cell would eliminate one of the main drawbacks of the EV1, plugging it into a wall outlet for hours when its battery runs down.<sup>3</sup>

Fuel cells are the main focus of research supported by the Clinton administration's Partnership for a New Generation of Vehicles, a cooperative venture with the Big Three U.S. automakers. The program's goal is to triple fuel economy in passenger cars without sacrificing the performance, comfort and affordability available in today's gasoline-driven models, all by 2003.

The main drawback of fuel cells involves hydrogen storage. "Hydrogen in its natural state is a very diffuse gas, so to get it in a compact form that you can carry around with you on a vehicle requires compressing it or reacting it with something else," Delucchi says. "Systems exist to do this, but so far they are expensive, heavy and bulky."

Ultimately, the electric car's ability to reduce greenhouse gas emissions, whether it is run by a conventional battery or

a fuel cell, depends on where the fuel comes from. "Even if you just limit the electric vehicle to California, you'll still have a fairly large reduction in greenhouse gases," Delucchi says, "because California's fuel mix includes a lot of natural gas and imported hydropower, a little nuclear power and not too much coal." But in places like the Midwest, where utilities depend heavily on burning coal to produce electricity, switching to battery-powered electric cars would have much less of an effect on greenhouse gas emissions.

The same caveat holds for fuel-cell electric vehicles. "Eventually we could obtain the hydrogen from electrolysis, or water-splitting," Delucchi explains. "But the question remains, Where do you get the electricity to split the water? It would be a pollution-free system only if the electricity comes from solar energy."

Ultimately, the usefulness of the next generation of electric cars in combating global warming — whether they run on batteries or hydrogen fuel cells — depends on the future development of alternative energy sources.

"If you charge the electric vehicle from places that use pretty much exclusively solar power," Delucchi says, "then you can pretty much eliminate emissions of greenhouse gases. The real attraction of electric vehicles is not so much what they can do now, but what they can do in the long run."

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<sup>1</sup> Alliance to Save Energy, American Gas Association and Solar Energy Industries Association, *An Alternative Energy Future* (1992), p. B1.

<sup>2</sup> For background, see "Electric Cars, *The CQ Researcher*, July 9, 1993, pp. 577-600.

<sup>3</sup> See Daniel Sperling, "The Case for Electric Vehicles," *Scientific American*, November 1996, pp. 54-59.

industry accounts for only about 16 percent of his research funds, with the rest coming from government grants. "Does this make me 16 percent biased and 84 percent unbiased?" he asks.

Michaels says he received at most \$210,000 from the coal industry last year for climate research, compared with the federal government's \$2.1 billion budget for climate research over the same period. "If you are telling me that \$2.1 billion is being derailed by \$210,000, I think you might have an inaccurate perception of conspiracy," he says. "Someday that funding disparity is going to get out in public, and people are going to

wonder where in the heck the \$2.1 billion is going and what it's buying."

### ***Would global warming cause irreparable harm to the environment or human health?***

The IPCC report summarized the findings of recent scientific studies, listing several likely negative outcomes of global warming, including:

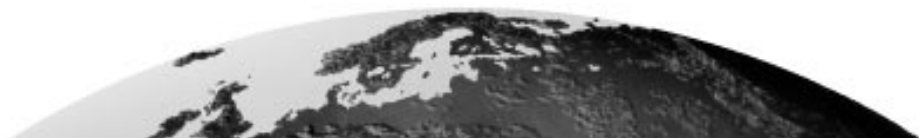
- Sea levels would rise on average 15-90 centimeters, or 6 inches to 3 feet, by 2100, because rising temperatures would cause some melting of glaciers and polar ice sheets, and water expands as it gets warmer. Seas would continue to rise at the same rate thereafter.

- The number of extremely hot days would increase, while extremely cold days would decrease.

- Weather patterns would change, bringing more floods or droughts to some areas.

- Rainfall would be more intense, though scientists could not say if tropical cyclones and other severe storms would change in location and intensity.<sup>6</sup>

Since the report came out, other media and scientific reports have predicted dire consequences from climate change in the absence of measures to curtail emissions of greenhouse gases. In January, for example, newspaper and magazine stories blamed climate



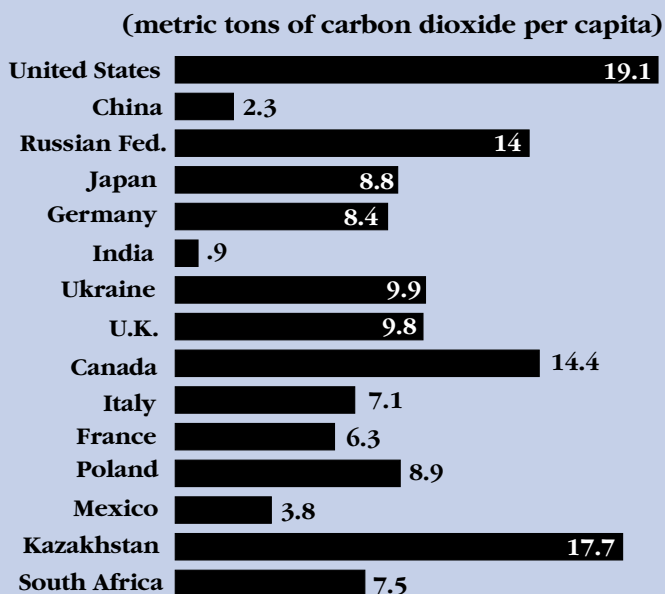
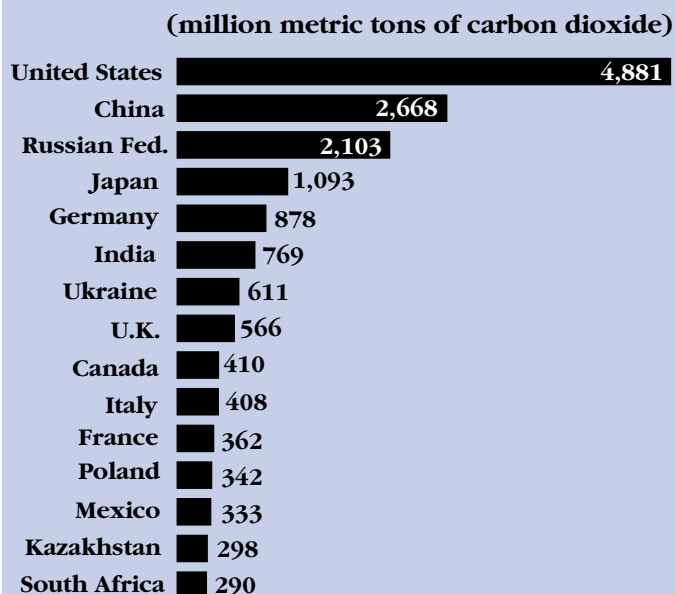
## The 15 Countries With the Highest CO<sub>2</sub> Emissions

### Highest Total CO<sub>2</sub> Emissions, 1992

Heavily industrialized countries, led by the U.S., are among the world's biggest emitters of industrial carbon dioxide.\* Rapidly industrializing China and India could account for more than half the developing world's CO<sub>2</sub> by 2010.

### Highest Per Capita CO<sub>2</sub> Emissions, 1992

Wealthy, industrialized countries tend to release more industrial carbon dioxide per person than other countries. In largely undeveloped Kazakhstan, however, the high per capita rate is largely due to oil production.



Note: A metric ton equals 1,000 kilograms or 2,204.6 pounds.

\* Industrial carbon dioxide refers to any CO<sub>2</sub> produced by burning fossil fuel, including automobiles.

Sources: World Resources 1996-97, *The World Resources Institute*, 1996; based on data from *Carbon Dioxide Information Analysis Center*, Oak Ridge National Laboratory, September 1995; *Population Action International*.

instability brought on by global warming for the blizzard that paralyzed the East Coast.<sup>7</sup>

Of all the predicted results of climate change, none is more certain to many scientists than rising sea levels. "I would consider it firm that the sea level will rise by a global average of a half-foot to three feet in the next century," Oppenheimer says. "To understand whether that's important

or not, over the last 100 years sea level has risen about five inches, and we're already experiencing difficulties in managing that level of sea-level rise."

In the United States, he says, a three-foot rise "would extensively flood areas where a lot of people live, like southern Louisiana and parts of South Florida, and would require expensive infrastructure changes in places like Dallas, Texas, Charleston, S.C., and to

some extent New York City."

While wealthy countries like the United States or even the low-lying Netherlands could probably manage such a threat, the same is not true for many threatened regions, such as the Maldives, the Ganges delta in Bangladesh and Egypt's Nile delta. "For many countries, managing three feet of sea level rise is not going to be possible," Oppenheimer says.

Even if warming does occur, critics respond, the sea-level predictions are exaggerated because temperatures in the polar regions would still remain below freezing. They also suggest that a slight warming would likely cause an increase in snowfall, binding up some of the projected melt in snowpack.<sup>8</sup> According to another report, however, a regional warming trend over the past 50 years already has caused ice shelves along the coast of Antarctica to collapse.<sup>9</sup>

Another widely cited threat to human life resulting from climate change is the spread of mosquito-borne infectious diseases, such as malaria and dengue fever, as the insects' tropical habitat expands northward. Concern mounted in the United States last year when a dengue outbreak spread to northern Mexico.<sup>10</sup>

But skeptics say that faulty climate models were used to predict an increase in the mosquitoes' habitat, and that technological advances such as air-conditioning and improved living conditions eradicated malaria from the United States in the past and can protect humans from these diseases in the future.<sup>11</sup> Similarly, a report predicting that algal blooms enhanced by warming waters would spread cholera was criticized as unfounded by the evidence.<sup>12</sup>

Other studies indicating irreversible damage to the environment as a result of climate change have emerged in recent months. One study, hailed as the first direct observation of global warming's biological impact, found that the range of Edith's checkerspot butterfly had shifted northward along the West Coast as the small insect died out in Mexico and spread into south-

ern Canada at the same time that temperatures rose throughout the region.<sup>13</sup> Michaels refutes the finding, saying there has been no measurable warming in the region.<sup>14</sup>

Some critics of the global warming theory suggest that even if they are proved wrong over time and temperatures do rise, people will benefit from change. *World Climate Report* argues that warmer temperatures will open



*Scientists consider this iceberg, which recently broke away from Antarctica, as an important clue to the rate of global warming. Some experts predict that increasing global warming could melt polar ice and cause a three-foot rise in seas levels, flooding low-lying areas around the world.*

Siberia and northern Canada to agricultural production, increase global rainfall and reduce the hazards of winter driving. "If global warming occurs," the magazine says, "the many benefits will offset [the] drawbacks. People like warm climates. Heating bills are lower. Clothing costs are reduced. Transportation is less troubled. And death rates are lower."<sup>15</sup>

### ***Can an international treaty succeed in reducing global greenhouse emissions?***

The major challenge to policymakers intent on thwarting global warming is the pervasive nature of greenhouse gases. Some of the gases, such as chlorofluorocarbons (CFCs), are man-made. They can be removed

from the equation if people agree to stop producing them.

This is already happening in the case of CFCs, once widely used as propellants in aerosol containers, as refrigerants and as solvents in computer chip production. After it was found that CFCs were destroying the stratospheric ozone layer, allowing more of the sun's harmful ultraviolet radiation to reach the Earth, the world's CFC producers agreed, by signing the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer, to phase out their production for most uses by January 1996.<sup>16</sup>

But man-made gases contribute only slightly to the greenhouse effect, so removing CFCs will do little to mitigate global warming. By far the biggest contributor is carbon dioxide, which people the world over release, chiefly by burning fossil fuels and cutting

down the forests that remove the gas from the atmosphere. That makes carbon dioxide much harder to curtail than CFCs. "The economics underlying the Montreal Protocol are different than what underlies global warming," Oppenheimer says, "just because carbon is so pervasive."

Industry critics adamantly oppose any treaty with binding targets and timetables. "All economic analysis that's been done so far says this will cost the United States up to 4 percent in lost gross domestic product (GDP) at the same time that lots of countries that will not be part of the treaty will be able to develop their fossil fuel sources unfettered," says John B. Shlaes, executive director of the Global Climate Coalition, the chief indus-

try group opposed to the IPCC findings and the treaty process. “We’ve probably never been confronted by a treaty of this scope in United States history, perhaps outside of a major trade negotiation. There’s also never been a treaty where governments are negotiating on behalf of firms and households. We’re looking for a more rational, sensible and balanced approach to this issue.”

Despite the challenge, supporters of curbs on greenhouse gases see the Montreal Protocol — the first global treaty dealing with climate — as reason for optimism. “We learned something from the Montreal Protocol process,” says Claussen, who helped negotiate the treaty and directed the Environmental Protection Agency (EPA) program implementing it in the United States. “For one thing, the treaty is legally binding, and countries that agreed to phase out CFCs have done so. It also has in it a rational system for reconsideration of the targets, which was very helpful, both scientifically and in terms of the technology.”

Supporters also embrace the Montreal Protocol as a model for its differentiation between developed and developing countries. Because industrial countries benefited from CFCs long before the rest of the world, developing countries argued that they should receive concessions for agreeing to forgo the chemical. They signed on to the treaty after they were given additional time to live up to its provisions. “I’m not sure if a time lag is the perfect example in this case,” Claussen says. “But the developing countries have moved forward [in phasing out CFCs], so it’s not as if they decided not to do anything just because they aren’t required to until later.”

Some critics say a treaty to curb greenhouse gases would be impossible to enforce. “Who’s going to verify and monitor every power plant every minute, or every factory every minute?” Shlaes asks. “And yet that’s what you’ve got to do to if you want

to go to that kind of process.”

But the kind of enforcement needed to monitor, say, an arms control agreement may not be necessary for a climate treaty. “There is no enforcement mechanism in the Montreal Protocol,” says Claussen. “There is reporting and an implementation committee, which helps countries comply rather than punishing them for not complying.”

Industry response to U.S. acid rain legislation provides another model treaty supporters say could be included to help countries comply with caps on greenhouse gas emissions.<sup>17</sup> After Title IV of the 1992 Clean Air Act required utilities and other industries to reduce their emissions of sulfur dioxide released by burning coal, many companies that exceeded their clean-air quotas sold their excess allowances to companies that failed to comply. A market in sulfur dioxide allowances emerged, which today is conducted on the Chicago Board of Trade along with markets for pork belly futures and other agricultural commodities.

“I think that, too, is a model because in the end that system gave us greater reductions in sulfur dioxide emissions than we expected, and at a much cheaper price,” says Claussen, who also ran the acid rain compliance program at EPA. She concedes, however, that setting up an international market in carbon emissions poses a far more daunting challenge. “It wasn’t easy to set up the system domestically, and it will be far harder to do it internationally,” she says. “To make that kind of system work, you have to have something in place that assures you that the emissions that are being traded are real, which is much harder to do internationally.”

Some industry representatives are more pessimistic. “The only way something like the sulfur dioxide market can work is if you have a cap on emissions,” says Novak of the Edison Electric Institute, who opposes any mandatory limits or timetables on carbon emissions. “We can provide the emis-

sions reductions to help mitigate climate change on a voluntary basis. We don’t need mandatory targets and timetables that will force us to reduce in ways that would be more costly.” ■

## BACKGROUND

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### Proof at Last

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Carbon dioxide, the predominant greenhouse gas, occurs naturally, as do other greenhouse gases such as methane, nitrous oxide and water vapor. Indeed, without them, Earth would be too cold to sustain life as we know it.

Over the millennia, greenhouse gases have become part of the complex exchange of elements that allows life to thrive. In one of these vital cycles, plants take up carbon dioxide through their leaves, use it in photosynthesis and then release oxygen, which animals require to live. Completing the cycle, the same carbon dioxide that animals exhale returns to the atmosphere to be taken up once again by plants, as well as by the oceans that cover most of the Earth’s surface.

Until human populations soared and began burning fossil fuels, greenhouse gases remained in relative balance. The huge climate changes that produced periodic ice ages and heat waves were the result of natural variations caused by sudden fluctuations in the sun’s emission of radiation, volcanic eruptions on Earth and other phenomena beyond man’s control.

But the Industrial Revolution, which began in 19th-century Britain, ushered in a new age of rapid industrialization that greatly increased man’s impact on the natural environment. By 1896, when Arrhenius postulated what became known as the green-

*Continued on p. 972*

# Chronology

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**1800s** *Svante Arrhenius, a Swedish chemist, postulates in 1896 that increasing amounts of carbon dioxide released into the atmosphere by coal-fired industries will cause global temperatures to rise.*

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**1950s-1960s** *Scientists begin monitoring the atmosphere for carbon dioxide and temperature variations.*

**1958**  
Charles Keeling and other scientists from the Scripps Institute of Oceanography in La Jolla, Calif., begin monitoring carbon dioxide levels in Hawaii and other sites. Their work later shows a steady buildup of the gas.

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**1970s-1980s** *Computer and satellite technologies permit more precise detection of greenhouse gas trends.*

**1974**  
Chemists Sherwood Roland and Mario Molina warn that emissions of chlorofluorocarbons (CFCs) and other man-made chemicals are destroying the layer of stratospheric ozone protecting Earth from the sun's harmful ultraviolet B radiation.

**1985**  
A large ozone hole is discovered over Antarctica, confirming the ozone hole theory. Roland and Molina later receive the Nobel Prize in chemistry (1995).

**1987**  
Some 150 countries, including the United States, sign the Montreal Protocol on Substances that Deplete the Ozone Layer, which restricts industrial use of CFCs.

**June 23, 1988**  
James E. Hansen, a climate specialist at the Goddard Institute for Space Studies in New York City, tells a Senate committee that global warming is occurring. The U.N. General Assembly sets up the Intergovernmental Panel on Climate Change (IPCC), a global network of scientists to advise world leaders.

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**1990s** *The climate-change debate intensifies as world leaders narrow their differences over a global treaty to curb greenhouse gas emissions.*

**1990**  
In its first report, the IPCC announces that greenhouse gases are building up at an unprecedented pace but refrains from recommending emission cuts under political pressure from the United States and other industrial countries dependent on fossil fuels.

**May 9, 1992**  
The United States and about 130 other countries sign the U.N. Framework Convention on Climate Change, the first binding agreement dealing directly with climate change. Signatories agree to try to reduce their greenhouse gas emissions to 1990 levels by the year 2000.

**June 1992**  
At the Earth Summit in Rio de Janeiro, Brazil, more countries sign the climate change convention, bringing the total to 165.

**April 1993**  
President Clinton announces his Climate Change Action Plan, a set of voluntary programs aimed at meeting the framework target by enabling companies to join in partnerships with federal government agencies to improve energy use and cut greenhouse gas emissions.

**March 1995**  
Framework signatories issue the Berlin Mandate calling for concrete plans to toughen the agreement by the end of 1997.

**December 1995**  
The IPCC announces for the first time that the scientific evidence shows a "discernible human influence on global climate."

**July 17, 1996**  
Under Secretary of State Tim Wirth announces that the United States has abandoned its call for voluntary steps to reduce greenhouse gas emissions and will press instead for legally binding targets and timetables in treaty negotiations in Kyoto, Japan.

**December 1997**  
Negotiators from the United States and other nations are scheduled to produce a U.N.-sponsored climate-change treaty in Kyoto.

*Continued from p. 970*

house effect, the Industrial Revolution was at full throttle and much of Europe and the United States had switched from wood to coal to drive their economies. With the invention and mass production of automobiles, demand for gasoline and other petroleum derivatives to fuel an ever-growing technological revolution mushroomed, pouring more excess carbon dioxide into the atmosphere.

Arrhenius predicted that a doubling of carbon dioxide in the atmosphere would cause a rise in the Earth's surface temperature of four to six degrees Celsius (7.2 to 10.8 degrees Fahrenheit). But it would take almost a century to prove him right.

The first major effort to confirm the theory came in 1958, when Charles Keeling and other scientists at the Scripps Institute of Oceanography in La Jolla, Calif., began monitoring carbon dioxide levels in Hawaii's famed Mauna Loa volcano.

Using actual measurements of the increase in carbon dioxide levels to date, scientists began developing ways to predict how much greenhouse warming might occur in the future. Their efforts laid the groundwork for the so-called general circulation models in use today to predict future climate conditions. The first credible projections came in the mid-1960s, when Syukuro Manabe of Princeton University estimated that average global temperatures would rise by 2 degrees C in the 21st century if carbon dioxide levels doubled. In the 1970s, scientists were able to better establish the role of other greenhouse gases, including man-made chemicals such as CFCs.

### ***Doubts Emerge, and Then New Evidence***

The development of advanced computers and satellite technology enabled scientists to take ever more detailed measurements of greenhouse gas emissions. But their work also uncovered what critics said was a major discrep-

ancy in the greenhouse theory. While the global temperature was found to have risen from around 1880 and 1940, it leveled off between 1940 and 1970. Scientists discovered that particulate matter cast aloft by volcanic eruptions and by coal burning itself could deflect sunlight back into space, perhaps countering the greenhouse effect. Some scientists began to predict instead a coming ice age.

By the late 1980s, however, the warming trend had reappeared, and there was a growing consensus within the scientific community that Arrhenius' prediction was indeed coming to pass. New evidence brought up in ice core samples from Antarctica and Greenland bolstered that view. By analyzing the gases trapped in ice for up to 20,000 years, scientists found that carbon dioxide levels had held relatively steady until the beginning of industrialization in about 1800, when they began to rise. Further evidence of global warming emerged as the carbon dioxide measurements from Mauna Loa and other stations confirmed a continuing buildup of the gas since 1958.

In 1988, concern over the threat of global warming was brought to the world's attention. On June 23, James E. Hansen of the Goddard Institute for Space Studies in New York testified before a Senate committee that the evidence was growing daily that global warming already was under way. The same month, participants at an international conference in Toronto, "The Changing Atmosphere: Implications for Global Security," warned that global warming posed a threat second only to nuclear war.

### ***Action by U.S., U.N.***

**I**n 1988, the same year as Hansen's call to action to curb global warming, the U.N. General Assembly set up a special body—the Intergovernmental Panel on Climate Change—to

advise world leaders on the nature of the problem. The panel, established as a partnership of the World Meteorological Organization and the U.N. Environment Programme, eventually would involve more than 2,500 scientists from more than 100 countries.

Reflecting the unprecedented complexity of climate change, the IPCC called on three working groups to address major areas involved in the issue: one to assess the scientific measurements and predictions; another to analyze the probable impacts of climate change on the environment, human health, society and the economy; and a final group to recommend policies to address the problem.

Most government leaders were reluctant to act on the early warnings. Reducing emissions of carbon dioxide and other greenhouse gases not only would mean burning less fossil fuel for industry and transportation but also curbing deforestation, a process that adds to the excess carbon dioxide by destroying trees, which absorb it. Carbon dioxide also is released when wood is burned. But such steps threatened to undermine economic growth and even destroy entire industries if undertaken too quickly. The world's oil, coal and natural gas industries alone are worth more than a trillion dollars, while many developing countries are undergoing rapid deforestation as a result of population growth, a trend that may take many decades to reverse.<sup>18</sup>

Although they were loath to take action, political leaders were coming under pressure from both sides either to curb emissions or resist such efforts, even before the IPCC released its first reports on climate change. In 1989, a Dutch government official, for example, warned the president of Brazil that if his government failed to curb deforestation of the Amazon basin, the Netherlands would cease to exist, as rising temperatures would melt polar ice caps and raise sea levels. At the same time, industry representatives in the United States called

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on the Bush administration to “hang tough on this one” and reject calls to curb emissions.<sup>19</sup>

For his part, President George Bush was quick to acknowledge the threat of climate change. He clearly stated at a February 1990 IPCC meeting in Washington that, “We all recognize that the atmosphere is changing in unexpected and unprecedented ways,” and that “the future of the Earth must not be compromised.”<sup>20</sup>

But Bush was reluctant to make policy changes without further evidence that global warming was occurring. When he called on other industrial countries to adopt a wait-and-see approach, he was met with strong criticism from many European allies who accused him of risking the global environment to protect U.S. industries — collectively the biggest emitters of greenhouse gases in the world. (*See graphs, p. 968.*)

The new U.N. panel’s scientific working group concluded in its first report in 1990 that emissions of greenhouse gases were already heating up the planet at an unprecedented pace. They predicted that if current trends continued the average global temperature would rise one degree C — nearly two degrees Fahrenheit — within the next 30 years.

But the overall IPCC report issued that August containing the findings of all three working groups struck a more cautious note, clearly reflecting the controversial nature of the debate between scientists and industry interests. In contrast to the scientists’ warning of global warming, the report referred only to “potential climate change” and refrained from calling for cuts or even a freeze in greenhouse emissions, steps the IPCC scientists had said were necessary to slow the warming trend.<sup>21</sup>

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## Climate Treaty Signed

On May 9, 1992, the United States and about 130 other countries signed the first binding agreements dealing directly with climate change — the United Nations Framework Convention on Climate Change. The pact, which was presented at the Earth



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**“Continued use of non-binding targets that are not met makes a mockery of the treaty process. It leaves the impression that rhetoric is what counts rather than real emission reductions — an outcome that is both unacceptable and counterproductive.”**

— *Tim Wirth, Under Secretary of State*

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Summit held the next month in Rio de Janeiro, Brazil, eventually was signed by 165 countries and the European Union.\* The pact called for “stabilization of greenhouse gas concentrations at a level that would prevent dangerous anthropogenic [human] interference with the climate system.”

Most industrial countries agreed to

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\*The 15 members of the European Union also signed the treaty individually.

try to reduce their greenhouse gas emissions to 1990 levels by the year 2000. Developing countries were given extra time to meet the target and were asked to report on their energy use and emission levels and the steps they intended to take to reduce them. Because developing countries are expected to account for a growing portion of gas emissions as they industrialize, industrial countries promised to provide financing and technology to help them meet their targets.

As it became increasingly clear that few countries would meet their emissions targets, the framework signatories met in March 1995 in Berlin, Germany, to discuss ways to strengthen their commitment. In a decision called the Berlin Mandate, the parties agreed to come up with concrete plans to toughen the treaty by the end of 1997. Developing countries such as China, India and Brazil would be exempted from any new commitments, however.

The meeting revealed significant disagreements in how to make the treaty tougher. The European Union called for the adoption of a carbon tax, an energy tax based on the amount of carbon dioxide released by a given energy source. A group of 37 countries with the most to lose from rising sea levels — the Alliance of Small Island States (AOSIS) — urged the industrial countries to cut their emissions 20 percent below 1990 levels by 2005. The United States and other industrial countries rejected this goal as potentially ruinous to their fossil-fuel-driven economies.

One innovative scheme that emerged from the Berlin summit was an agreement to start a pilot program to encourage firms in industrial countries to set up renewable energy or reforestation projects in developing

## How YOU Can Fight Global Warming

While the United States and other nations continue to negotiate a U.N. treaty to reduce emissions of greenhouse gases, there are many things that consumers can do on their own:

**1. Drive less.** Cars account for about one-third of all U.S. carbon dioxide emissions. Take public transportation, walk or bike when possible. If you have to use your car, consolidate errands into a single trip.

**2. Buy a fuel-efficient model.** Geo Prizm, Acura Integra, Ford Contour 4, Chrysler Concorde and Honda Odyssey/Isuzu Oasis are among the most efficient vehicles in their classes, according to *Consumer Reports*. Popular sport-utility vehicles and pickup trucks generally consume more fuel than cars and minivans.

**3. Buy energy-efficient appliances.** Federal law requires manufacturers to place an Energy Guide label on most major appliances. Refrigerators, the biggest electricity consumers in most households, are now about 75 percent more efficient than those made in the 1970s.

**4. Weatherize your home.** Caulking, weatherstripping, insulation and replacement windows can stop leaks of heated or cooled air. Use heating and air-conditioning wisely to reduce fuel consumption.

**5. Lighten up your roof.** Air-conditioning use can be cut by one-fifth in hot climates by replacing a dark roof with a light-colored roof that reflects sunlight.

**6. Plant trees.** By absorbing carbon dioxide, trees reduce greenhouse gas emissions. Strategically planted deciduous trees can be used to shade houses in the summer while allowing sunlight to penetrate in the winter, reducing demand for both air-conditioning and heating. Evergreens also can be used as wind breaks, further reducing heating needs.

**7. Replace conventional incandescent light bulbs.** Compact fluorescents and Tungsten-halogen lamps cost more to buy, but save money over time in reduced electricity consumption.

**8. Buy fewer things.** About half the energy we consume goes into the myriad products and services we buy.

**9. Speak up.** Urge your political representatives to enact laws that save energy and combat greenhouse gas emissions.

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Sources: Natural Resources Defense Council; "Turning up the Heat," *Consumer Reports*, September 1996, p. 43.

countries. This "joint implementation" plan came immediately under attack by developing countries and some industry representatives alike. Developing countries worried that industrial countries would try to get credit for such projects as a way to get out of their commitments to cut carbon emissions at home. Energy industries insisted that they would only go along with a stronger treaty if they were allowed to get credit for helping reduce emissions abroad.<sup>22</sup>

Meeting again in Rome last December, signatories to the framework convention endorsed the IPCC's finding of a "discernible human influence" on global climate change. Participants at both the Berlin and Rome conferences failed, however, to agree to legally binding targets and timetables for greenhouse gas emissions. ■

## CURRENT SITUATION

### Voluntary Programs

President Clinton has placed environmental protection near the top of his policy agenda from the start of his administration. Shortly after entering the White House in 1993, Clinton signaled his support for international environmental efforts by creating the position of under secretary for global affairs and naming Wirth, a longtime environmental advocate, to the post. He also named Claussen, a

longtime environmental regulator, to assume the top State Department post dealing directly with climate change negotiations.

Until this year, the Clinton administration's stance focused on encouraging U.S. industry to voluntarily reduce their emissions of greenhouse gases. On Earth Day 1993, the president introduced the Climate Change Action Plan, a set of voluntary programs enabling companies to join partnerships with the Department of Energy, the Environmental Protection Agency and other federal agencies to help improve energy use and cut emissions at the same time. The plan's goal was to enable the United States to meet its commitment to reduce carbon emissions to 1990 levels by 2000 through voluntary incentives rather than mandatory regulations.

The EPA's Green Lights program, for example, encourages businesses to install energy-efficient lighting in stores and plants, saving 800,000 tons of greenhouse gases a year. Stated another way, energy saved through the program would light 3 million homes for a year. The Energy Department's Climate Wise program to publicly recognize companies' voluntary efforts to cut emissions and Motor Challenge program to improve industrial motors systems are expected to reduce carbon emissions by a total of nearly 10 million metric tons of carbon equivalent (MMTCE) by 2000. The EPA's Voluntary Aluminum Industry Partnership is expected to reduce emissions of purofluorocarbons, another greenhouse gas, by nearly 2 MMTCE by 2000.

"The beauty of the voluntary programs is that there is a presumption that the actions they encourage will actually be profitable," says Paul Stolpman, director of the EPA's Office of Atmospheric Programs, which runs the administration's voluntary emissions programs. "When people sign up for these programs they actually make money because they're saving so much energy. We're hopeful that voluntary efforts to reduce greenhouse gases in ways that are economically efficient will actually improve the state of the U.S. economy and lead to increased employment and output because our economy will be more efficient."

Perhaps more than any other sector, the electric utility industry has taken advantage of voluntary programs to reduce greenhouse emissions. Utilizing a provision of the 1992 Energy Policy Act, the industry has since 1993 worked with the Energy Department to cut emissions by encouraging consumers to cut their electricity use by purchasing more efficient lighting, appliances and building materials. Utilities have also switched from coal to less-polluting natural gas and improved the efficiency of coal-fired plants.



*A section of Amazon forest in Brazil is cleared by slash and burn. Many developing countries are undergoing rapid deforestation, increasing emissions of carbon dioxide and other greenhouse gases. Trees remove CO<sub>2</sub> from the air during photosynthesis; burning of brush and tree limbs releases large amounts of CO<sub>2</sub> into the atmosphere.*

According to EEI's Novak, more than 600 electric utilities, accounting for 60 percent of the industry, are participating in the voluntary program, which he estimates will reduce emissions by 44 million metric tons of carbon by 2000. "We're encouraging our members to continue their efforts," Novak says. "And we're working with the administration to make sure that if there are targets or time-tables after 2000, we will get credit" for the cuts already made. "If we're not going to get allowances, we may consider not doing them."

The administration's voluntary programs have been far less successful in reducing carbon dioxide emissions from cars, trucks and airplanes, the leading sources of greenhouse gas emissions in the United States. One voluntary program, the Partnership for a New Generation of Vehicles, is designed to encourage the auto industry to go beyond current research into electric battery-driven cars to develop an emission-free, efficient vehicle.<sup>23</sup> (See story, p. 966.) But results from this initiative will not come soon enough to meet the 2000 target.

Last year, the administration also called a meeting in Detroit — dubbed the "Car Talks" — aimed at improving fuel economy standards beyond existing corporate average fuel economy (CAFE) standards mandated by Congress in 1975. By 1985, domestic automakers had reached the fleetwide CAFE target of 27.5 miles per gallon, but lower gasoline prices and rising consumer demand for more powerful vehicles have stymied further improvements. After energy and auto industry representatives failed to resolve their differences over whether to tighten CAFE standards to raise the gasoline tax, the talks broke up without reaching a final agreement.

## Clinton Gets Tougher

As it became clear that the voluntary programs would not enable the United States to meet its emissions goal by 2000, the administration toughened its policy. At the most recent meeting of the parties to the U.N.

climate change agreement, Under Secretary of State Wirth announced that the United States was abandoning its insistence on non-binding goals for emission cuts.

“Continued use of non-binding targets that are not met makes a mockery of the treaty process,” Wirth said. “It leaves the impression that rhetoric is what counts rather than real emission reductions — an outcome that is both unacceptable and counterproductive.”<sup>24</sup>

The administration emphasizes that it supports making the target and the timetable for emission reductions binding — not the measures used to meet them. This puts the United States at odds with the European Union and some developing countries that have proposed introducing a worldwide carbon tax to force compliance with the treaty’s eventual targets.

“The Europeans’ position going into the Geneva meeting was that they wanted binding policies and measures, like refrigerator efficiency standards and uniform taxes, and a non-binding target,” Claussen says. “That gives you the ability to say you’re doing great things, even though the target isn’t real. We essentially reversed that by saying you have to achieve a certain level of emissions by a certain date.” This more flexible approach would leave the matter of how to reach the goal up to the countries themselves.

The Clinton policy also rejects the island nations’ timetable for a 20 percent cut in greenhouse gas emissions by 2005. “This is too much too fast,” Claussen says. “In the United States, where we would have to have any treaty we negotiate ratified by the Senate and would probably need implementing legislation to do that, we couldn’t even get off the ground

for a couple of years.”

With no treaty feasible before the December 1997 meeting in Kyoto, Claussen says, “We couldn’t possibly do anything like that by 2005.” ■



*Heavy smog virtually obscures high-rise buildings in downtown Los Angeles, Calif. Auto exhausts are a major source of carbon dioxide, the predominant greenhouse gas.*

Tom Carroll/Phototake/Picture Network International

adopt binding targets and timetables — chiefly the 11 members of the Organization of Petroleum-Exporting Countries (OPEC) and Russia, which see a binding treaty as a threat to oil-dependent economies.

But opposition remains strong in the United States, where many industries that have supported the Clinton administration’s voluntary programs to cut greenhouse gas emissions oppose binding targets and timetables. “This is a competitiveness issue,” says Shlaes of the Global Climate Coalition. “The United States is 85 percent dependent on fossil fuel, so it is [vital] for our manufacturing. Meanwhile China, which is going to equal all the world’s emissions today in the next 25 years, has no meaningful obligation to cut emissions.”

Shlaes and other critics continue to downplay the urgency of taking steps to mitigate carbon emissions and call for more research before committing the United States to any binding treaty obligations. “There’s time to get it right, both in terms of understanding how the science is working and also understanding what our economic options are,” Shlaes says.

“Rather than give us a balanced worldwide approach, this could end up hurting the United States because we haven’t really done our homework.”

Aside from declared opponents to a binding treaty, such as Shlaes’ coalition, American businesses are by no means united in their views of U.S. policy on climate change. “This whole concept of the economy vs. the environment is a non-starter,” says Marvin of the Business Council for Sustainable Energy. “We need to figure out how we can preserve our quality of

*Continued on p. 978*

## OUTLOOK

### Opposition to Treaty?

Most participants at the Framework Convention on Climate Change in Geneva agreed with the Clinton administration’s new strategy. By the end of the meeting, all but 14 countries had endorsed the proposal to

# At Issue:

## *Are computer models reliable tools for predicting climate trends?*

**MICHAEL C. MACCRACKEN**

*Director, Office of the U.S. Global Change Research Program*

*FROM TESTIMONY BEFORE HOUSE SCIENCE COMMITTEE,  
MARCH 6, 1996.*

**f**or simple systems or single processes, conceptual models can be particularly useful. For systems as complex as the full Earth system, arguably the most complex of all research endeavors, a systematic means must be found for incorporating our understanding into a quantitative framework.

The approach that is used is to construct mathematical models that to the greatest extent possible rely on fundamental and immutable laws of nature. Reliance must be placed on various approximations because understanding will never be fully complete and computer size and resources are limited. Uncertainties will always exist — and there will always be questions — for not everything can be explained; but uncertainties are also the reason for an aggressive associated program of observations, analysis and process studies.

The mathematical climate models (variously called climate models, general circulation models or Earth system models, depending somewhat on their implementation) strive to include all that is understood about the climate system. Because there is no means to prove them right — only to see where they break down — the models are constantly being put through an increasingly grueling series of tests to see how well or poorly they match observations.

Models reproduce many aspects of the observed climate. That there are shortcomings, however, is to be expected — all modelers acknowledge them (just as all good observationalists acknowledge the shortcomings in their observations). The challenge is to identify why they are not precisely reproducing nature and how to make them better.

But at any given time, models are at the cutting edge of what we understand. They treat dozens of processes spread out over the globe and up through to atmosphere and down through the oceans, all the time requiring that everything be done consistently — no leaving out a process here and including it there, no assuming that changing one thing will not change something else and so on. While experiences from past climatic conditions can be a rich source of tests of models (hence we study paleoclimates), only models can provide quantitative projections of future conditions. . . .

While it might be tempting to wait until each process is understood before model calculations are attempted, making and analyzing such calculations is as much part of the research and learning process as are observational and process studies. All of these efforts must proceed in parallel.

**ROBERT E. DAVIS**

*Associate professor, Department of Environmental Sciences,  
University of Virginia*

*FROM TESTIMONY BEFORE HOUSE SCIENCE COMMITTEE,  
MARCH 6, 1996.*

**m**easurements of atmospheric circulation (a term that encompasses wind flow at and above the surface) have been taken over much of the Earth for 50 to 100 years or more. Circulation is a critical climate variable since it is closely linked to temperature, rainfall and other weather events. Models that generate daily weather forecasts are founded upon principles that describe changes in the atmosphere's circulation. Similarly, general circulation models (GCMs), like the ones used as the motivation for the Rio climate treaty, are based on fundamental circulation principles. . . .

The developers of GCMs frequently state that, although their forecasts are not suitable for analysis on smaller spatial scales (regions or sub-regions), the models properly describe the large-scale features of the atmosphere accurately. Thus, the model predictions for an atmosphere with double the preindustrial concentrations of greenhouse gases should be basically correct over large areas.

Although individual GCMs differ substantially in their regional forecasts, most are in agreement with respect to some larger-scale features that should be expected in an enhanced greenhouse atmosphere. Tropical temperatures are expected to increase only slightly relative to polar temperatures. Furthermore, this polar temperature increase is predicted to be concentrated largely in the winter. Thus the models predict a decrease (in comparison to current values) in the equator-to-pole temperature gradient. In response, the winter atmospheric circulation should become more summer-like, as represented by a weakening of the jet stream and a contraction of the circumpolar vortex.

Based on observations of the upper atmosphere taken since the late 1940s, the winter circumpolar vortex has actually exhibited a statistically significant expansion. . . . This response is the opposite of what would be expected from a greenhouse warming influence. Furthermore, these observed, large-scale changes are not depicted by GCMs. . . .

Models can serve a very useful scientific purpose, such as the proposition and testing of hypotheses. The use of GCMs to examine changes in greenhouse gas concentrations in the atmosphere is an appropriate and important scientific question. However, when the results of these experiments are used to influence public policy (both nationally and globally), then concerns about the various models' accuracy must be raised. The simple fact is that the current generation of GCMs are incapable of reproducing the historic climate of the Earth sufficiently at anything but the broadest time and space scales.

## FOR MORE INFORMATION

**Global Climate Coalition**, 1331 Pennsylvania Ave. N.W., Suite 1500, North Tower, Washington, D.C. 20004; (202) 637-3158. The coalition is the main energy industry lobbying and public relations arm that opposes binding restrictions on greenhouse gas emissions.

**Global Greenhouse Network**, 1660 L St. N.W., Suite 216, Washington, D.C. 20036; (202) 466-2823. This coalition of legislators and public interest groups concerned with global warming promotes cuts in fossil fuel use.

**Environmental Defense Fund**, 257 Park Ave. South, New York, N.Y. 10010; (212) 505-2100. The EDF is a citizens' interest group that conducts research and provides information on global warming and other environmental issues.

**Environmental Protection Agency**, Atmospheric Programs, 401 M St. S.W., Washington, D.C. 20460; (202) 233-9140. This office of the EPA examines strategies to mitigate climate change.

*Continued from p. 976*

life and continue our economic growth in the most sustainable way possible. It's a simple question, and it deserves to be approached with the seriousness of the issue and not the hyperbolic response that we're seeing from all sides, frankly."

The tone of the debate will depend on the details that will emerge from negotiations leading up to the Kyoto meeting next December, when a treaty is scheduled to be finalized. The Clinton administration has carefully avoided all reference to specific targets and timetables, except to reject the island nations' proposal of a 20 percent reduction in emissions by 2005.

Claussen suggests that a "midterm" timetable for achieving emission targets might be between 2010 and 2020. "But we can't say exactly what the date will be and exactly what the target will be and how you define that target," she says. "All those things we are still looking at, and we think others are as well."

For supporters of a strong treaty to curb global warming, the main challenge will be to maintain the U.S. commitment to binding targets and timetables over the year remaining

before the meeting in Kyoto next December. "The negotiations should produce something by the end of 1997," Oppenheimer says. "If they don't, I think credibility in the whole treaty process will disintegrate." ■

## Notes

<sup>1</sup> Intergovernmental Panel on Climate Change, *Climate Change 1995: The Science of Climate Change* (1996), p. 5.

<sup>2</sup> See Peter B. Jaquette and Mary H. Novak, "Review of Recent Estimates of the Economic Impacts of Proposed Carbon Abatement Policies," WEFA Group, an economic forecasting company in Eddystone, Pa., October 1996, p. 3.

<sup>3</sup> Testimony before the Senate Energy and Natural Resources Committee, Sept. 17, 1996.

<sup>4</sup> IPCC, *op. cit.*, p. 439.

<sup>5</sup> For a critical view of the panel's procedures, see Frederick Seitz, "A Major Deception on 'Global Warming,'" *The Wall Street Journal*, June 12, 1996, p. A16.

<sup>6</sup> IPCC, *op. cit.*, pp. 6-7.

<sup>7</sup> See, for example, "The Hot Zone," *Newsweek*, Jan. 22, 1996.

<sup>8</sup> See Global Climate Coalition, "Science and Global Climate Change: What Do We Know? What Are the Uncertainties?" Background,

undated.

<sup>9</sup> See D.G. Vaughan and C.S.M. Doake, "Recent Atmospheric Warming and Retreat of Ice Shelves on the Antarctic Peninsula," *Nature*, Jan. 25, 1996, pp. 328-330.

<sup>10</sup> For background, see "Combating Infectious Diseases," *The CQ Researcher*, June 9, 1995, pp. 489-512.

<sup>11</sup> See "Global Warming Pests and Pestilence," *World Climate Report*, Sept. 30, 1996, p. 3, a biweekly newsletter edited by the University of Virginia's Patrick J. Michaels and funded by the Western Fuels Association, which supplies fuel to electric utilities.

<sup>12</sup> See Jonathan A. Patz, Paul R. Epstein, Thomas A. Burke and John M. Balbus, "Global Climate Change and Emerging Infectious Diseases," *Journal of the American Medical Association (JAMA)*, Jan. 17, 1996, pp. 217-223. See also letter to the editor by John S. Gray, Michael Depledge and Anthony Knap, "Global Climate Controversy," *JAMA*, Aug. 7, 1996, pp. 372-373.

<sup>13</sup> Camille Parmesan, "Climate and Species' Range," *Nature*, Aug. 29, 1996, pp. 765-766.

<sup>14</sup> "Chasing Butterflies," *World Climate Report*, Sept. 16, 1996, p. 2.

<sup>15</sup> Thomas Gale Moore, "Global Warming: Costs and Benefits," *World Climate Report*, Aug. 19, 1996, p. 2. Moore is an editor of the newsletter.

<sup>16</sup> See "Ozone Depletion," *The CQ Researcher*, April 3, 1992, pp. 289-312.

<sup>17</sup> For background, see "Environmental Movement at 25," *The CQ Researcher*, March 31, 1995, pp. 273-296.

<sup>18</sup> See Jeremy Leggett, ed., *Global Warming: The Greenpeace Report* (1990), p. 4. For background, see "Saving the Forests," *The CQ Researcher*, Sept. 20, 1991, pp. 681-704.

<sup>19</sup> Intergovernmental Panel on Climate Change, Report to IPCC from Working Group 1: Policymakers' Summary of the Scientific Assessment of Climate Change, June 1990, p. 4.

<sup>20</sup> *Ibid.*, pp. 4-5.

<sup>21</sup> *Ibid.*, p. 5.

<sup>22</sup> See "The Berlin Climate Summit," in *World Resources 1996-97* (1996), pp. 322-323.

<sup>23</sup> For background, see "Electric Cars," *The CQ Researcher*, July 9, 1993, pp. 577-600.

<sup>24</sup> Wirth spoke July 17, 1996, at the second conference of the parties to the Framework Convention on Climate Change, held in Geneva, Switzerland.

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**Singer, S. Fred, ed., *Global Climate Change: Human and Natural Influences*, Paragon House, 1989.**

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### **Articles**

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Negotiators for a climate change treaty look for guidance to the 1987 Montreal Protocol, which phased out the production of chlorofluorocarbons (CFCs), man-made gases that destroy the stratospheric ozone layer. New evidence suggests the treaty may have been less effective in closing the ozone hole than was once believed.

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Recent scientific studies are raising concern that global warming may spread deadly infectious diseases such as cholera, dengue fever and hantavirus by extending the tropical conditions in which they thrive.

**"Reading the Patterns," *The Economist*, April 1, 1995, pp. 65-67.**

While evidence is mounting that greenhouse gases are affecting global climate, its implications are uncertain. Fossil fuel burning releases both carbon dioxide, which heats the atmosphere, and sulfates, which appear to cool it.

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This review of the debate over global warming takes up the implications of climate change projected by the U.N. Intergovernmental Panel on Climate Change and steps that can be taken to curb greenhouse gas emissions.

### **Reports and Studies**

**Alliance to Save Energy, American Gas Association and Solar Energy Industries Association, *An Alternative Energy Future*, April 1992.**

By replacing mandatory regulations with incentives to develop new technologies, the authors report, governments can help industry curb carbon dioxide emissions associated with fossil fuel use.

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A research group that questions the consensus view of global warming claims that recent weather patterns show no sign of adverse effects and that policy-makers have up to 30 years to further their research before the greenhouse gas buildup will have a significant influence on climate.

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# The Next Step

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### ***Global Climate Change***

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**Cowen, Robert C.**, "Global warming is real many scientists agree," *The Christian Science Monitor*, Oct. 10, 1995, p. 14.

Scientists are increasingly convinced that global warming is a reality in late 1995. Subtle changes in weather patterns which conform to predictions of improved computer climate simulations suggest that man-made climate changes are upon us.

**Dawson, Bill**, "Experts debate global warming's effect on tropical storm climate," *Houston Chronicle*, Oct. 22, 1995, p. A21.

The possible connection between global warming and the formation of hurricanes is examined. As of Oct. 1995, 18 tropical storms have been formed, with 10 reaching hurricane force.

**Gray, Gerry**, "A second look at global climate change," *American Forests*, summer 1996, pp. 22-23.

Findings of a recent study on the adverse effects of global warming on the world's ecosystems are discussed. The potential impact of climate change is being taken more seriously by policymakers and citizens alike.

**McMichael, A. J.**, "Global climate change and health," *Lancet*, Sept. 23, 1995, p. 835.

Participants at the conference on the potential health impacts of global climate change, held in Washington, D.C., September 11-12, 1995, directed a considerable amount of their attention to the two most predictable indirect health impacts — changes in vector organism habitat and parasite transmissibility and in regional productivity of agriculture and fisheries.

**Rubin, Barry M., and Mark D. Hilton**, "Identifying the local economic development impacts of global climate change," *Economic Development Quarterly*, August 1996, pp. 262-279.

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Sea levels will rise and average global temperature will increase over the next century, but not as fast and not as high as was feared earlier, according to new estimates from two scientific organizations that have led the way in warning about the effect of future climate change.

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While it seems a paradox, some experts cite evidence suggesting that climatic changes associated with global warming are actually creating more severe snowstorms.

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The apparent flight from global warming of the small Edith's checkerspot butterfly is giving West Coast scientists their first look at the kind of biological havoc that climate change may one day create in the world's ecosystems.

### ***Global Warming***

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A handful of scientists with connections to the oil and coal industry are giving the public the false impression that global warming is not a serious threat, environmentalists asserted, as three such skeptics testified on the issue before Congress.

**Anderson, John**, "Why global warming matters to the Texas Gulf Coast," *Houston Chronicle*, Aug. 18, 1996, p. C4.

Anderson discusses the consequences for future generations and the quality of life on Earth of global warming, as well as the effects that rising sea levels will have on the Gulf Coast of Texas.

**Brown, Paul**, "Global warming divide deepens," *Guardian*, July 17, 1996, p. 11.

A speaker at the climate convention in Geneva, Switzerland, urged journalists not to listen to individual scientists whose theories had not been tested and whose motives appeared dubious concerning global warming. Man is dangerously altering the Earth's climate, the journalists were warned.

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**Davis, Robert E., "Don't worry about global warming — end is not near," *Houston Chronicle*, Sept. 22, 1996, p. C4.**

Davis asserts that because the belief in apocalyptic greenhouse-related warming persists — despite what he called an almost total lack of hard evidence — some politicians and international policy-makers are determined to legislate.

**"Getting serious about global warming," *St. Louis Post-Dispatch*, Aug. 4, 1996, p. B2.**

An editorial notes the Clinton administration's announcement that it will seek binding targets for curbing fossil fuel burning in an effort to retard global warming and suggests that targets need to be set and plans made for how the targets are to be enforced among nations.

**Goering, Laurie, "Global warming may bring more epidemics," *Chicago Tribune*, Feb. 13, 1996, p. 4.**

Public health officials warn that subtle warming of the Earth's climate during the next 50 years may nearly double the number of malaria deaths worldwide, prompt more frequent outbreaks of cholera and put the U.S. at risk of epidemics of encephalitis and other infectious diseases.

**Hertsgaard, Mark, "Who's afraid of global warming? Surprise! It's big business that's worried now," *The Washington Post*, Jan. 21, 1996, p. C1.**

Hertsgaard comments that while global warming does not exist according to the oil and coal lobbies, the global insurance and banking industries are now coming to believe that their self-interest is incompatible with humanity continuing to pump 6 billion tons of heat-trapping greenhouse gases into the atmosphere every year.

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An editorial criticizes the U.S. for not naming the air

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New evidence linking the recent warming of the Pacific Ocean's surface waters with records of melting glaciers high in the Andes shows that temperatures in the tropics are higher now than they have been for thousands of years. Scientists say the study adds fresh confirmation that global warming is real.

**Perlman, Michael, "Face up to global warming troubles," *Houston Chronicle*, Jan. 7, 1996, p. C5.**

Perlman comments that the world community is in denial about the threat of global warming, and must turn to face the problem.

**Sinisi, J. Sebastian, "Global warming solutions simple, many experts say," *Denver Post*, March 24, 1996, p. A31.**

The world doesn't need expensive, grandiose projects to combat global warming, but it does need simple measures to slow the encroaching environmental problems, scientists agree. Some plans to combat global warming are discussed.

**Snow, Tony, "Global warming plague looming? Wrong," *USA Today*, Feb. 19, 1996, p. A11.**

Snow takes issue with Vice President Al Gore's warning that global warming will set off a plague of infectious disease, arguing that he generated a false sense of urgency about a dubious public-health problem and proposed to solve things by increasing the government's power to micromanage the economy.

**Spotts, Peter N., "New global warming report: Don't panic, but let's take action," *The Christian Science Monitor*, Dec. 18, 1995, p. 3.**

Global warming is discussed, including conclusions from a U.N.-sponsored report which will guide policymakers who are setting targets for gas emissions in the next century.

**Tyson, Ann Scott, "A Kansas detective is hot on the trail of global warming," *The Christian Science Monitor*, Sept. 25, 1996, p. 1.**

The Atmospheric Radiation Measurement Program, aimed at providing the missing link in scientists' knowledge of global warming, employs a wide variety of people in

Hillsboro, Kan., to monitor conditions and launch weather balloons.

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**“Atlanta, Georgia: Recycling reduces greenhouse effect,”** *Biocycle: Journal of Waste Recycling*, March 1996, p. 22.

A study by the Institute for Local Self-Reliance for the Environmental Protection Agency’s Region IV in Atlanta indicates that recycling of construction and demolition debris significantly reduces the emissions of carbon dioxide by saving energy.

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While life on Earth depends on it, the greenhouse effect has also boosted global temperatures alarmingly, and vast climatic changes are predicted. The greenhouse effect is discussed.

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A group of 58 international insurance companies on July 9, 1996, called on governments of industrialized nations to achieve “early substantial reductions” in greenhouse gas emissions.

**Miles, Henry, “Greenhouse effect,”** *Architectural Review*, May 1995, pp. 50-56.

An office and workshop complex in the small town of Ettlingen, Germany, perfectly illustrates the country’s concern with the imaginative, beneficial use of ambient energy to improve the well-being of building inhabitants. The design of the structure is described.

**Morgan, Dan, “Strengthened U.S. commitment lights a fire under global warming debate,”** *The Washington Post*, Sept. 13, 1996, p. A4.

A U.S. pledge to seek binding limits on releases of “greenhouse gases” after the year 2000 has produced an angry response from the domestic coal, oil and utility industries.

**Nissani, Moti, “The greenhouse effect: An interdisciplinary perspective,”** *Population & Environment*, July 1996, pp. 459-489.

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resolved by disinterested analysis, are tragically mistaken, Nissani writes. Given the stakes of the greenhouse debate, concerned scholars and citizens ought to understand this issue.

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The security of the world’s food supply is one of the key goals of reducing greenhouse gas emissions, but this is fraught with difficulties. Documents pertinent to this issue are reviewed and discussed.

**Reiss, Bob, “Fran’s early warning — The curfew life: A hint of what global warming has in store,”** *The Washington Post*, Sept. 22, 1996, p. C2.

Reiss describes life under curfew in Wrightsville Beach, N.C., following the disaster of Hurricane Fran and comments on the conclusion of a panel of prominent climatologists that the greenhouse effect is changing how people live.

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The U.S. is getting more rain in heavy downpours now than early in the century, a possible sign of global warming from greenhouse gases.

**Stevens, William K., “Science Times: In rain and temperature data, new signs of global warming,”** *The New York Times*, Sept. 26, 1995, p. C4.

In a new study of weather trends in the U.S., China, Australia and the former USSR, scientists have turned up further evidence that some of the predicted effects of greenhouse gases on the world’s climate are being felt.

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Stocker comments on Saugus, Mass., resident Nancy Potter’s greenhouse, which was a sunroom in her home that she converted and she and her husband now call their retirement room.

**Toner, Mike, “Past rapid shifts in climate cast new light on greenhouse effect,”** *Atlanta Journal Constitution*, Feb. 18, 1995, p. A6.

Dramatic swings in the world’s climate can come and go with surprising swiftness, sometimes within the course of a single lifetime, according to evidence from the Greenland icecap and from the floor of the North Atlantic Ocean presented by researchers at the American Association for the Advancement of Science meeting in Atlanta.

**Victor, David G., and Julian E. Salt, “From Rio to Berlin: Managing climate change,”** *Environment*, December 1994, pp. 6-15.

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FCCC is focusing on the targets and timetables for controlling emissions of greenhouse gases and technological and financial transfers. The preparations for the Berlin meeting are discussed.

**Weiss, Rick, "The sun also braises: Renewable energy advocates offer invention that can harness and ease global warming," *The Washington Post*, Oct. 7, 1996, p. A3.**

As advocates of solar cooking know, the greenhouse effect can be harnessed in a way that benefits the environment. All it takes is some cardboard, aluminum foil and a plastic bag.

### ***Montreal Protocol***

**Smith, Gar, "Blowing holes in the Montreal Protocol," *Earth Island Journal*, fall 1995, p. 13.**

According to an Ozone Action report entitled "Deadly Complacency," the Montreal Protocol has been rendered ineffective by waivers that extend the CFC-production rights of DuPont, LaRoche, Allied Signal and Elf Atochem.

**Solomon, Susan, and John S. Daniel, "Impact of the Montreal protocol and its amendments on the rate of change of global radiative forcing," *Climatic Change*, January 1996, pp. 7-17.**

Increases in chlorinated and brominated halocarbons are believed to be responsible for the depletion of stratospheric ozone. A study found that the increasing atmospheric concentrations of ozone-depleting halocarbons has led to a negative forcing of the climate system.

### ***U.N. Intergovernmental Panel on Climate Change***

**Abbott, Alison, "Climate change panel to remain main source of advice," *Nature*, April 13, 1995, pp. 584-585.**

The Intergovernmental Panel on Climate Change is to continue as the major scientific advisory body to governments that have signed the United Nations Climate Change Convention.

**Cushman, John H. Jr., "Report Says Global Warming Poses Threat to Public Health," *The New York Times*, July 8, 1996, p. A2.**

As international negotiations on global warming resume in July 1996, U.N. health and environmental agencies are warning of serious threats to public health if actions to

reduce climate change come too slowly. In a report to be issued during the talks that resume on July 8, scientists from U.N. agencies warn that warming due to air pollution "could have a wide range of impacts on human health, most of which would be adverse."

**"Heating up the climate change debate," *Environment*, January 1996, pp. 22-23.**

The economic and social implications of climate change that were addressed at the U.N.'s Intergovernmental Panel on Climate Change's plenary session are discussed. Delegates' conclusion that the costs required to fight greenhouse gas emissions may exceed estimates of damage due to climate change was, in effect, canceled.

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**Mathews, Jessica, "Global warming: No longer in doubt," *The Washington Post*, Dec. 26, 1995, p. A23.**

Mathews notes the Intergovernmental Panel on Climate Change's declaration that global warming was, indeed, underway.

**"Report on global warming makes dire predictions," *The Wall Street Journal*, Oct. 25, 1995, p. B4.**

A report issued on Oct. 24, 1995, from the Intragovernmental Panel on Climate Change foresees global warming bringing an increase in diseases, dramatic shifts in forests and consequences for industries from insurance to tourism.

**Santer, Benjamin D., "Global warming critics, chill out," *The Wall Street Journal*, July 23, 1996, p. A23.**

Santer responds to the July 11, 1996, Letters to the Editor "Coverup in the Greenhouse." Santer defends his role as lead author of a key chapter in a recent report by the Intergovernmental Panel on Climate Change.

**"The long view on global warming," *Boston Globe*, July 30, 1996, p. A12.**

An editorial comments on the early world health warning that scientists, environmentalists and some government officials sought to convey at the U.N. Intergovernmental Panel on Climate Change.

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