

GLOBAL CLIMATE CHANGE:

A Background Paper on the Science, the Politics,

and their Implications for Electric Utilities

for the

REGULATORY ASSISTANCE PROJECT

by Beth A. Nagusky

July 1, 1997

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About the Author

Beth Nagusky was an Attorney with the Maine Public Utilities Commission from 1983 until 1987, and then with the Natural Resources Council of Maine from 1987 to 1996. She is now doing consulting work out of her home in Litchfield, Maine.

Executive Summary

In late 1995, 2,500 of the world's climate scientists who are part of the Intergovernmental Panel on Climate Change (IPCC)—an international scientific panel established in 1988 by the United Nations General Assembly—concluded that continued emissions of greenhouse gases would have a dangerous impact on worldwide climate systems, an impact that could result in environmental, economic, social, and geopolitical risks.

Sources Of Greenhouse Gases. The four principal greenhouse gases — carbon dioxide (CO₂), methane, nitrous oxide, and chloroflourocarbons (CFCs) and the substitutes hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs) — are produced from a broad range of human activities that are dominated by burning fossil fuels. Carbon dioxide represents that most abundant of the greenhouse gases. The United States emits more CO₂ — 1,371 mil tons in total and 5.26 tons per capita — than any other nation in the world. Per capita emissions in Japan and in India respectively are 2.4 tons and 0.2 tons.

Evidence Of Rising Temperature. Mean surface temperature in the 20th century is at least as warm as any other century since 1400 A.D. In the past century, global mean surface temperature has increased by between 0.3 to 0.6 degrees Centigrade (.5 to 1° F). All ten of the warmest years since record-keeping began have occurred since 1980.

Antarctica is warming rapidly. In early 1995 a 2,700 kilometer chunk of the Larsen Ice Shelf collapsed into the South Atlantic. Scientists there estimate five of nine ice shelves attached to the Antarctic Peninsula have disintegrated in the past 50 years. Marine snails and other mollusks are expanding their ranges north along the Pacific Coast. An 80 percent decline in zooplankton off the southern California coast is linked to a minor increase in local surface water temperature. In northern Finland, pine trees are moving into the tundra at a rate of 40 meters per year in apparent response to warmer temperatures. The mosquito that carries dengue fever and yellow fever has been found at over 2,000 meters above sea level, 1,000 meters higher than its previous range.

What A Warmer Temperature Could Mean. Global mean surface temperatures are projected to rise between 1 and 3.5 degree C (1.8 to 6.3° F) by 2100. If this occurs, the average rate of warming would probably be greater than any seen in the last 10,000 years. Average sea level is projected to rise on the order of between 15 cm to about 95 cm (.5 to 3 feet). More precipitation and storms are anticipated, although these will not be evenly distributed around the world. Most climate models predict lower precipitation in southern Europe in summer and increases in average precipitation in winter at high latitudes. In addition to more precipitation, the warmer world is likely to produce more intense downpours and snowfalls. This increases the potential for flooding. Precipitation has already increased over land in high latitudes of the Northern Hemisphere, especially during the cold season.

Human health, terrestrial and aquatic ecosystems, agriculture, forestry, fisheries and water resources are all sensitive to the magnitude and projected rate of climate change.

The vulnerability of human health and socioeconomic systems and, to a lesser extent, natural ecosystems, depends on economic circumstances and institutional infrastructure. This means developing countries are likely to be more vulnerable to climate change and particularly countries in arid or semi-arid lands, in low-lying coastal areas, in water-limited or flood-prone areas or on small islands.

Uncertainty Persists, But Action Makes Sense And Is Possible. The IPCC recognizes that many uncertainties limit the ability to project and detect future climate change. The IPCC warns, however, that uncertainties should not preclude action today. Climate-induced environmental changes cannot be reversed quickly, if at all, due to the long time scales associated with the climate system. Furthermore, decisions made in the near-term may limit the range of policy options available later, because higher emissions today will require deeper cuts in the future to meet a given target concentration.

The IPCC reports that significant reductions in net greenhouse gas emissions are technically possible and economically feasible through adoption of policies and use of technological measures that accelerate technology development, diffusion, and transfer in all sectors of the energy, industry, transportation, residential/commercial, and agricultural/forestry sectors.

International Problems Require International Solutions. International cooperation is needed to address global climate change.

U.N. Framework Convention. In May, 1992 the US and about 130 other countries signed the U.N. Framework Convention on Climate Change, the first binding agreement dealing directly with the issue. Signatories set a non-binding target of reducing greenhouse gas emissions to 1990 levels by the year 2000. Later that year, at the Earth Summit in Rio de Janeiro, Brazil, more countries signed onto the agreement, bringing the total to 165.

Since the Framework Convention, most industrial countries have moved in the opposite direction from the stabilization goal. In 1993, the US announced its Climate Change Action Plan, a set of voluntary programs aimed at meeting the Framework Convention's target. The plan included fifty new and expanded initiatives in all sectors of the economy to reduce all greenhouse gases. Yet, US carbon emissions in 2000 are predicted to exceed 1990 levels by 11 percent. The expectation in other countries is mixed. Developing countries' emissions are rising rapidly as well. China's CO₂ emissions rose 13 percent between 1990-94, Brazil's 16 percent, India's 24 percent and South Korea's 44 percent. Western Europe's CO₂ emissions in 2000 are likely to exceed 1990 levels by 5 percent. But there have been some notable successes there as well. By 1995, German CO₂ emissions were already more than 10 percent below the 1990 level. Denmark and the Netherlands have adopted the world's strongest climate policies.

Berlin Mandate. In the spring of 1995 signatories to the Framework Convention issued the "Berlin Mandate", which charged treaty members to adopt a protocol to set quantified limitation and reduction objectives [for industrial countries] within specified time frames,

such as 2005, 2010 and 2020. Signatories were not able to agree on how to make the treaty tougher.

US Seeks Flexibility. In July, 1996 the US abandoned its call for voluntary steps to reduce greenhouse gas emissions and announced it would press for legally binding greenhouse gas emissions targets and timetables that cover a multi-year period, as opposed to single year targets, to smooth year-to-year variability in emissions.

Kyoto Potential. A third session of the Parties of the Framework Convention is scheduled for December, 1997 in Kyoto, Japan. There is no way to predict whether what emerges from Kyoto will look more like the flexible US proposal or the more specific European Union proposal, what the starting date will be, or what percent reduction below 1990 levels will be required.

The Electric Utility Industry And Climate Change. The electric utility industry is particularly vulnerable to carbon emission reductions because of the industry's significant contribution to these emissions. In the US, electricity use is a major source of carbon emissions and accounted for 36 percent of total US carbon emissions in 1995. This figure is projected to rise to 38 percent in 2015. Coal is a major contributor, especially older coal-fired power plants that account for more than one-half of US electricity generation. Coal is projected to continue to account for 50 percent of electricity generated in the year 2015, and 80 percent of electricity-related carbon emissions. Gas-fired generation, on the other hand, will account for 29 percent of total electricity but only 18 percent of electricity-related carbon emissions. The difference is attributable to the fact that conventional coal-fired generation averages more than 2 pounds of CO₂/kWh (or 1.6 million tons per year from a medium-sized 250 MW plant), while natural gas produces 44 percent less CO₂/kWh, and oil produces 16 percent less. Renewable resources and nuclear facilities do not emit carbon.

Overview

When the notion that humans could alter temperatures and the weather was first advanced by a Swedish chemist named Svante Arrhenius one hundred years ago, it probably seemed ridiculous to most people. Today, many people are aware that this is the warmest decade on record and that the number of extreme and highly disruptive weather events seems to be increasing. Recent flooding in North Dakota that has forced the evacuation of an entire community follows on the heels of earlier spring floods in the southeastern United States and flooding last fall in the northeast and northwest. While no one can say for sure that any one of these events is a result of the build-up of greenhouse gases in the earth's atmosphere or global warming,¹ many are worried that this is the case.

By late 1995 a consensus had developed among 2,500 of the world's climate scientists that "[T]he balance of evidence, from changes in global mean surface air temperature and from changes in geographical, seasonal and vertical patterns of atmospheric temperature, suggests a discernible human influence on global climate." Moreover, these same scientists agree that if current trends of increasing emissions of greenhouse gases continue, "interference with the climate system will grow in magnitude, and the likelihood of adverse impacts from climate change that could be judged dangerous will become greater." Earlier this year, more than 2,000 United States economists, including six Nobel Laureates, signed a statement declaring that global climate change "carries with it significant environmental, economic, social, and geopolitical risks, and that preventive steps are justified."

The 2,500 world climate scientists that reached agreement on the reality and seriousness of global climate change make up the Intergovernmental Panel on Climate Change, or "IPCC." The IPCC is an international scientific panel established in 1988 by the United Nations General Assembly to assess the peer-reviewed scientific literature and advise the world's governments on global climate change. The IPCC is comprised of three Working Groups. Working Group I analyzed the scientific basis of human-induced climate change and developed a range of likely climatic futures. Working Group II reviewed the likely impacts of climate changes on natural and human systems, as well as adaptation and mitigation options. Finally, Working Group III assessed existing literature on the socio-economics of climate change, including the economic, social and environmental costs and benefits of action and inaction.

The IPCC issued its First Assessment Report in 1990, providing a scientific and technical basis for the United Nations Framework Convention on Climate Change (hereinafter "Framework Convention"). The ultimate objective of the Framework Convention, set forth in Article 2, is "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."

¹ Throughout this paper the term climate change is used. While the public generally perceives the issue as one of the earth's warming, climate scientists refer to the phenomenon as climate change, since the warming is accompanied by other changes of climate (precipitation and storms as well).

The IPCC's Second Assessment Report was issued in December, 1995, and served as a wake-up call to the world on the risks posed by climate change.

This paper sets forth the most important of the IPCC's conclusions and discusses the areas of uncertainty that continue to exist. Agreements that have already been reached at international political conventions to address climate change are reviewed, while steps being taken to prepare for this December's signing of an international treaty to curb greenhouse gas emissions in Kyoto, Japan are discussed. Particular attention is paid to the contribution and role of the electric utility industry in the climate change debate.

No one can predict with certainty whether a binding agreement will in fact emerge from Kyoto, or what the treaty will provide. However, both the science and the politics surrounding climate change have advanced to a point suggesting that a legally binding, verifiable treaty will be produced in the near future, and that it will require nations to take action to curb greenhouse emissions to prevent dangerous human interference with climate. The scientific findings indicate that to do so would require substantial reductions in carbon emissions from the burning of fossil fuels, particularly coal and petroleum. This paper examines the issues being discussed at the international negotiations, and what their resolution could mean for the electric utility industry.

I. The Scientific Case for Human-induced Climate Change Mounts

IPCC Working Group I issued a formally agreed upon statement entitled “Climate Change 1995: The Science of Climate Change, Summary for Policymakers” in Madrid in November, 1995 concerning its current understanding of the science of climate change.²³ They concluded that the warming of the earth’s atmosphere and other climatic changes that are occurring are in part due to the releases of greenhouse gases from human activities. Working Group I also analyzed future scenarios for the earth’s climate. This section reviews the sources of greenhouse gases and their role in climate change (temperature, precipitation, and storms); climate models’ projections about the future; and, uncertainties that remain.

1.1 The Sources and Role of Greenhouse Gases in the Atmosphere

The four principal greenhouse gases are produced from a broad range of human activities — particularly burning fossil fuels, but also clearing forests and other lands. Concentrations of these gases have increased dramatically since pre-industrial times (around 1750), and different sectors of the economy produce varying amounts of greenhouse gases. Per capita emission rates around the world vary widely as well.

a. The Greenhouse Gases

The primary greenhouse gases are carbon dioxide (CO₂), methane, nitrous oxide, and chloroflourocarbons (CFCs) and the substitutes hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs). While CFCs and the substitutes have only anthropogenic (human) origins, carbon dioxide, methane and nitrous oxide have natural as well as anthropogenic origins. These gases act like a blanket over the earth’s atmosphere, trapping the sun’s radiation near the earth’s surface. (See Figure 1) In understanding this phenomenon, it is important to bear in mind that our earth’s atmosphere is incredibly thin, most of it extending only 50 kilometers from the surface. To put this in perspective, if the earth were the size of an apple, the atmosphere would be roughly as thick as its skin.

² Climate change as used by Working Group I refers to any change in climate over time whether due to natural variability or as a result of human activity. This differs from the usage in the Framework Convention, where climate change refers to a change of climate that is attributed directly or indirectly to human activity and that is in addition to natural climate variability observed over considerable time periods.

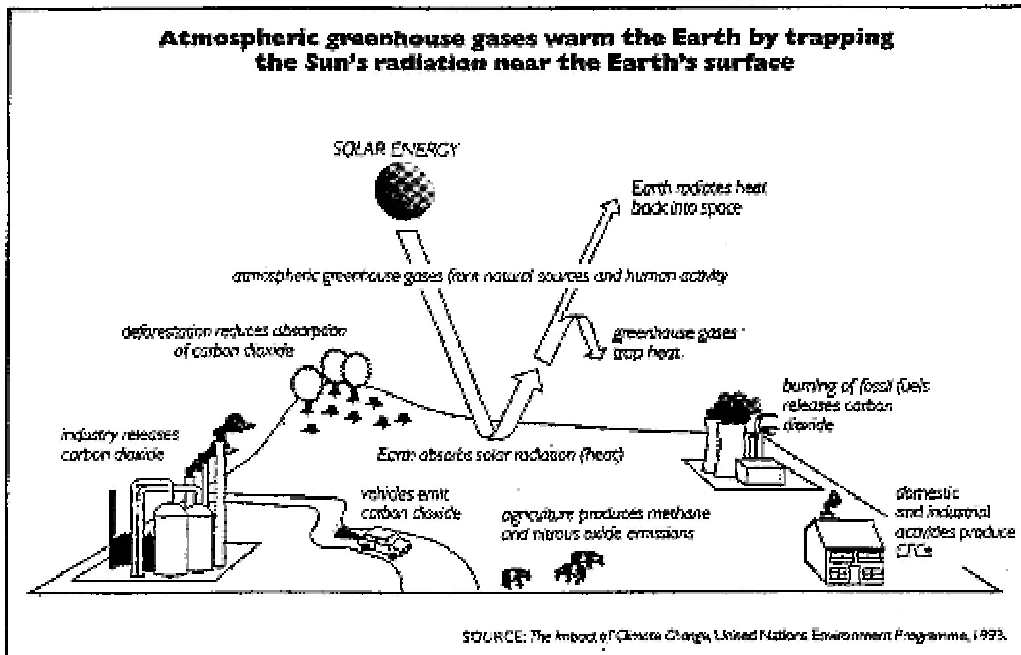


Figure 1

Each greenhouse gas has a different global warming potential, depending on its potency, the length of time it remains in the atmosphere, and other factors. Scientists measure greenhouse gases by their “CO₂ equivalence,” or how releasing one ton of a particular gas would affect the radiative properties of the atmosphere relative to the release of one ton of carbon dioxide.

b. Human Origins of Greenhouse Gases

Nearly all human activities result in the emission of greenhouse gases—whether it be turning on a light, driving a car, or clearing a field. Some activities contribute more than others. Burning fossil fuels—which account for 80 percent of the world’s energy supply—is the major contributor to greenhouse gas emissions. Worldwide, industrial processes generate about 40 percent of total emissions, transportation roughly 20 percent, residential and commercial buildings 20 percent, and the remaining 20 percent comes from a broad range of activities including agriculture, forestry, and land clearing (Flavin, 1996, 32; hereinafter “WW Paper”).

In the United States, petroleum products are the leading source of carbon emissions from energy use while coal is the second leading source of these emissions (U.S. Department of Energy, 1996,72; hereinafter “AEO97”). Electricity use is a major cause of carbon emissions, accounting for 36 percent of total carbon emissions in 1995, with projections that this figure will rise to 38 percent in 2015. Coal, which is predicted to account for about 50 percent of electricity generation in 2015 (excluding cogeneration), will produce 80 percent of electricity-related carbon emissions. In 2015, gas-fired generation is projected to account for 29 percent of total electricity but only 18 percent of electricity-

related carbon emissions (AEO97). Use of petroleum, mainly in the transportation sector, is projected to contribute to 42 percent of U.S. carbon emissions in 2015 (AEO97).

Methane contributes to about 12 percent of the total U.S. greenhouse gas emissions, while nitrous oxide emissions account for about 3 percent of U.S. greenhouse gas emissions (The Climate Change Action Plan, 1993).

c. Greenhouse Gases on the Rise

Atmospheric concentrations of these gases have increased significantly since pre-industrial times, primarily due to human activities. Carbon dioxide concentrations have increased 30 percent, from about 280 to almost 360 ppm. Two-thirds of the buildup has occurred since World War II, when combustion of fossil fuels began to skyrocket (WW Paper, 11). Methane concentrations have risen 145 percent, from 700 to 1720 ppb. Nitrous oxide concentrations have grown 15 percent, from about 275 to about 310 ppb.

U.S. carbon emissions from fuel combustion (the primary source of carbon emissions) are expected to increase from 1990 levels of approximately 1,340 million metric tons to 1,799 million metric tons in the year 2015, with the transportation sector accounting for 40 percent of the increase and the industrial sector accounting for 28 percent (AEO97, 5). Between 1995 and 2015, 38 gigawatts of nuclear capacity are expected to be retired (33 percent decline in nuclear generation). To compensate for this and new demand, 294 gigawatts of new fossil-fueled capacity (excluding cogeneration) are expected to be needed, resulting in increased carbon emissions of 172 million metric tons, or 34 percent, from 1995 levels (AEO97,72). These projections include analysis of U.S. efforts to reduce carbon emissions through its Climate Change Action Plan, discussed in section V(B), but not any future mitigation actions that may be proposed.

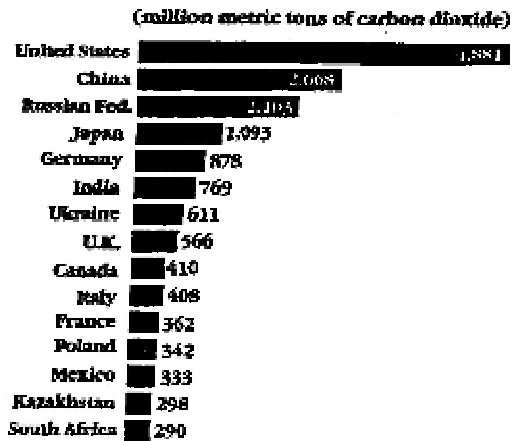
d. Large Differences in Emissions throughout the World

Annual per capita emissions of CO₂ from fossil fuel combustion are currently about 1.1 tons (1990) on a global average basis. About 0.2 tons per capita are emitted from deforestation and land use change. The average annual fossil fuel per capita emissions in developed and transitional economy countries are about 2.8 tons, and ranges from 1.5 to nearly 5.5 tons. For developing countries the average is 0.5 tons, and ranges from 0.1 to above 2 tons (See Figure 2).

The 15 Countries With the Highest CO₂ Emissions

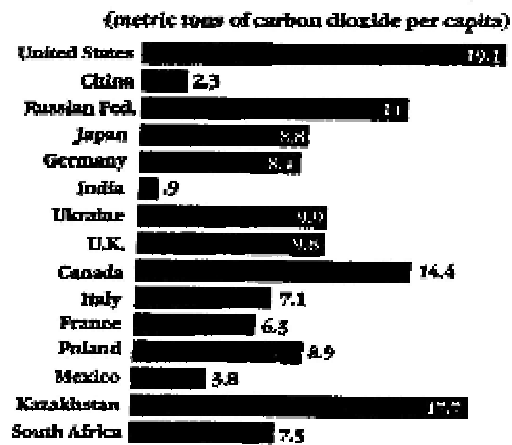
Highest Total CO₂ Emissions, 1992

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 CO₂ by 2010.



Highest Per Capita CO₂ 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 CO₂ 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.

Figure 2

The United States emits more CO₂ in total—1,371 mil tons (1994)—and per capita—5.26 tons (1994)—than any other nation in the world (WW Paper, 34; CQ Researcher, 1996, 968). By way of comparison, per capita emissions in Japan are 2.4 tons, and in India 0.2 tons. (WW Paper; CQ Researcher, 1996). Emissions of CO₂ are growing at dissimilar rates throughout the world depending on the level of development and fuel sources used (WW Paper, 31-35).

1.2. Greenhouse Gases Linked to Warming, Other Changes

Great progress has been made in attempts to differentiate between natural and human influences on climate since 1990. While the world's scientists have known for some time that the earth's atmosphere is warming and that sea level is rising, until 1995 they did not agree that human activities played a part. Attribution of climate change to human activities is made difficult by the fact that human-induced effects on climate are superimposed on the background "noise" of natural climate variability resulting from internal fluctuations and external causes, such as solar variability or volcanoes. Inclusion of the cooling effects of sulfate aerosols in climate models has led to more realistic estimates of human-induced effects. New simulations with coupled atmosphere-ocean models provide important information about decade to century time-scale internal climate variability. Another major area of progress is the shifting focus from studies of global-

mean changes to comparisons of modeled and observed spatial and temporal patterns of climate change.

While some skeptics still remain, the 2,500 world climate scientists that make up the IPCC have concluded that the observed warming trend is unlikely to be entirely natural in origin or occur by chance as a result of natural internal variability.

a. Greenhouse gases cause positive “radiative forcing” of climate

The increases of greenhouse gases have led to a positive “radiative forcing”³ of climate, warming the surface and producing other changes of climate. The direct radiative forcing of the long-lived greenhouse gases is 2.45 Wm^{-2} , and is due primarily to increases in concentrations of CO₂ (1.56), methane (0.47) and nitrous oxide (0.14). The anthropogenic emissions of these gases have contributed about 80 percent of the additional climate forcing due to greenhouse gases since 1750, and the contribution of CO₂ is about 60 percent of this forcing. The importance of CO₂ to climate forcing increases with time to 75 percent in the scenarios the IPCC has developed for the future.

The direct radiative forcing of CFCs and HCFCs combined is 0.25 Wm^{-2} ; however their net effect is 0.1 Wm^{-2} lower because these compounds also cause stratospheric ozone depletion, which causes global cooling. Moreover, the growth in concentrations of CFCs has slowed to nearly zero since the signing of the Montreal Protocol banning this substance. Consequently, ozone depletion is expected to decrease significantly by 2050. However, emissions of HFCs and other CFC substitutes are projected to grow, and their projected growth could contribute several percent to radiative forcing during the 21st Century.

b. The cooling effect of aerosols

Tropospheric or sulfate aerosols (microscopic airborne particles), which also result from burning fossil fuels, biomass burning, and from other sources, form a haze that reflects sunlight back into space. This has a cooling effect equivalent to a negative radiative forcing of about 0.5 Wm^{-2} as a global average. The effect of these aerosols is focused in specific regions and subcontinental areas, but can have continental to hemispheric scale effects on climate patterns. Locally, the cooling effects can more than offset the warming effects of greenhouse gases. These aerosols are short lived in the atmosphere (less than a week), and increases or decreases in their emissions produce quick adjustments in temperature.⁴⁵

³ Radiative forcing is a simple measure of the importance of a potential climate change mechanism. It is the perturbation to the energy balance of the Earth-atmosphere system in watts per square meter (Wm^{-2}).

⁴ The affect of sulfate aerosols on global temperatures was not incorporated into global warming computer models until 1994 when they were used at the Hadley Centre for Climate Prediction and Research at the Meteorological Office in Bracknell, England. The "Hadley" model succeeded in mimicking global temperature records over the past century far more closely than earlier models.

Comparisons of the modeled climate response to combined radiative forcing and sulfate aerosols with observed geographical, seasonal, and vertical patterns of atmospheric temperature change show that the pattern correspondences increase with time, as one would expect as anthropogenic signals increase in strength. Moreover, the IPCC concludes that the probability is very low that these correspondences could occur by chance as a result of natural internal variability only.

c. The Earth's atmosphere is warming

Limited available evidence from proxy climate indicators suggests that the 20th century global mean surface temperature is at least as warm as any other century since at least 1400 A.D., the first time there was reliable data to estimate global mean temperature. Assessments of the statistical significance of the observed global mean surface air temperature trend over the last century, using a variety of new estimates and complex models, has led Working Group I to conclude that the observed warming trend is unlikely to be entirely natural in origin.

Global mean surface temperature has increased by between 0.3 to 0.6 degrees Centigrade (.5 to 1° F) since the late 19th Century. (See Figure 3) The 1990s is the warmest decade on record so far, despite the cooling effect of the 1991 Mount Pinatubo volcanic eruption, while the 1980s are ranked second (WW Paper, 12). All ten of the warmest years since record keeping began have occurred since 1980 (WW Paper, 12). 1995 was the warmest year on record, and 1996 was among the top ten warmest years on record (Stevens, 1997).

Global Average Surface Temperature, 1866-1995

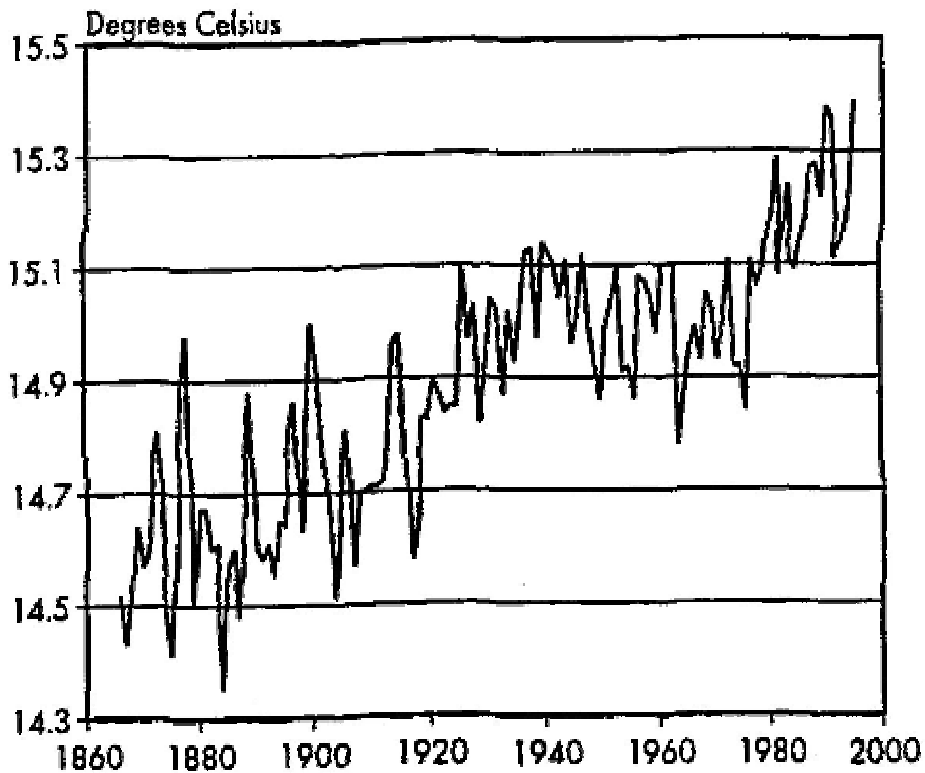


Figure 3

The temperature changes have not been uniform. The recent warming has been greatest over the mid-latitude continents in winter and spring, with a few areas of cooling, such as the North Atlantic Ocean. Nighttime temperatures over land have generally increased more than daytime temperatures. Furthermore, the minimum temperature is rising 50 percent faster than the maximum temperature, lengthening the frost-free season in many parts of the U.S. (Karl, 1997, 80).

d. "Fingerprints" detected

According to some, "fingerprints" of global warming have been detected. Antarctica is warming rapidly, as climate models projected (WW Paper, 15). In early 1995 a 2,700 kilometer chunk of the Larsen Ice Shelf collapsed into the South Atlantic (WW Paper). Scientists there estimate five of nine ice shelves attached to the Antarctic Peninsula have disintegrated in the past 50 years (WW Paper). Siberia is also warming quickly, and is now 3 degrees C (5° F) warmer than at any time since the Middle Ages (WW Paper). A 5,000 year old frozen corpse was discovered by hikers in the Alps in 1992, uncovered because of the retreat of the Alpine glaciers (WW Paper).

Marine snails and other mollusks are expanding their ranges north along the Pacific Coast, according to oceanographers at the Hopkins Institute in Monterey, California (WW Paper, 15-16). An 80 percent decline in zooplankton off the southern California

coast is linked to a minor increase in local surface water temperature. In northern Finland, pine trees are moving into the tundra at a rate of 40 meters per year in apparent response to warmer temperatures. The mosquito that carries dengue fever and yellow fever has been found at over 2,000 meters above sea level, 1,000 meters higher than its previous range. One scientist who has traced the timing of the seasons back to the 13th century says that after centuries of relative stability, the timing began to shift in the 1940s (WW Paper). Global sea level has risen by between 10 to 25 cm over the past 100 years, and much of the rise may be related to the increase in global mean temperature.

1.3. Predictions about the Future Climate

The IPCC has developed a range of scenarios of future greenhouse gas and aerosol emissions and atmospheric concentrations and then used climate models to project the future climate.⁵

a. A warmer world

Global mean surface temperatures are projected to rise between 1 and 3.5 degree C (1.8 to 6.3° F) by 2100. The mid-range IPCC emission scenario models, combined with the “best estimate” value of climate sensitivity, project an increase in global mean surface air temperature relative to 1990 of about 2 degrees C by 2100.⁶ Actual yearly to decadal changes could differ substantially from the global mean value. In all cases, however, the average rate of warming projected would probably be greater than any seen in the last 10,000 years. By way of comparison, during the last ice age the global average temperature was just 3 to 5 degrees C (5 to 9° F) cooler than it is today.

Climate models predict that a general warming is expected to lead to an increase in the occurrence of extremely hot days and a decrease in the occurrence of extremely cold days. A 3 degree C increase in the average July temperature in Chicago would increase the probability from 1 in 20, to 1 in 4 that the heat index (a measure that includes humidity and reflects overall discomfort) would exceed 49 degrees C (120° F) sometime during the month (Karl, 1997, 80).

b. Sea level rise

Average sea level is projected to rise on the order of between 15 cm (low emission scenario combined with low climate and ice melt sensitivities) to about 95 cm (high

⁵ These scenarios necessarily depend on assumptions made about population and economic growth, land use, technological changes, energy availability and fuel mix for the period.

⁶ This estimate is about one-third lower than the IPCC's "best estimate" in 1990, due to inclusion of aerosols in the model, improvements in the treatment of the carbon cycle, and lower emission scenarios, particularly for CO₂ and CFCs. The revised temperature projections assume that sulfate aerosol emission will continue to increase, and this has an important effect on projections. Generally, aerosols reduce the magnitudes of temperature and precipitation changes, especially in northern mid-latitudes. Regional projections are more uncertain because of the influence of aerosols as well.

emission scenario) by 2100. The best estimate projects a sea level rise of 50 cm from today to 2100.

c. More Precipitation

As temperature increases more evaporation occurs, leading to more precipitation across the globe. Precipitation is not projected to increase everywhere and throughout the year, however (Karl, 1997, 81). Most climate models predict lower precipitation in southern Europe in summer and increases in average precipitation in winter at high latitudes (Karl, 1997). In addition to more precipitation, the warmer world is likely to experience more intense downpours and snowfalls (Karl, 1997, 82). This increases the potential for flooding. In January 1997, Thomas Karl, a senior scientist at NOAA's National Climatic Data Center, reported that "[o]bservations since the beginning of the 20th century for the United States indicate that intense precipitation events have already increased by about 20 percent, and cold season precipitation has increased by nearly 10 percent" (NOAA, 1997).

Precipitation has in fact increased over land in high latitudes of the Northern Hemisphere, especially during the cold season.

d. Storms

Early projections of the impacts of a warmer world predicted more frequent and more intense tropical cyclones resulting from warmer oceans. Recent work with climate models and historical data suggests that this may not be so, and that it is unlikely that tropical cyclones will increase significantly on a global scale (Karl, 1997, 82-83). Regional changes cannot be ruled out however (Karl, 1997).

1.4 Skeptics Remain

The IPCC's conclusions have gained wide acceptance worldwide, but climate change skeptics still remain. They argue that computer-generated models are too flimsy to be predictive, that the temperature record shows a slower rate of warming than the models suggest, or that "negative feedbacks" will protect us from climate change. In one article, two University of Virginia professors argued that "[D]ire 'global warming' predictions arise from fuzzy generalities—since it will be warmer, there will be more atmospheric moisture and more heavy precipitation, including snow—reasoning that deftly avoids the actual physics of a snowstorm" (Michaels, 1996). These same authors publish a bi-weekly report on global climate change entitled "World Climate Report," funded by the Western Fuels Association and associated individual companies. While their arguments are not regarded as plausible by most of the world's climate scientists, they continue to receive press coverage by media striving for "balance" (WW Paper, 17). The coverage given these skeptics is often disproportionate to their numbers in the scientific community and to the merits of their arguments.

1.5 Uncertainties Remain, but Should not Prevent Action

The IPCC recognizes that many uncertainties limit the ability to project and detect future climate change. The climate system is non-linear and subject to unexpected behavior, so future climate changes may involve “surprises.” The IPCC identifies the need for further work on the following: estimating future emissions and biogeochemical cycling of greenhouse gases and aerosols; representation of climate processes in models, especially feedbacks associated with clouds, oceans, sea ice and vegetation; and collection of long-term observations of climate system variables such as solar input, atmospheric energy balance components, hydrological cycles, ocean characteristics and ecosystem changes. An added set of challenges include: long time lags between emissions and effects, wide regional variations in causes and effects, a global problem, a multiple of greenhouse gases and aerosols to consider, and the need for international and intergenerational cooperation.

Despite the fact that significant scientific uncertainties remain, the IPCC warns that they should not preclude action today, in light of the fact that climate-induced environmental changes cannot be reversed quickly, if at all, due to the long time scales associated with the climate system. Furthermore, decisions made in the near term may limit the range of policy options available later because higher emissions today will require deeper cuts in the future to meet a given target concentration. Delay might reduce the costs of mitigation, but could increase the ultimate magnitude and damage costs related to climate change. Furthermore, many of the policies and investments needed to reduce greenhouse gas emissions require long planning horizons. For additional discussion of the appropriate abatement path, see section 4.

The Framework Convention provides guidance on decision making in light of the lack of full scientific certainty in Article 3.3. The Parties are instructed to “take precautionary measures to anticipate, prevent or minimize the cause of climate change and mitigate its adverse effects. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures, taking into account that policies and measures to deal with climate change should be cost effective so as to ensure global benefits at the lowest possible cost.” The IPCC also recognized the importance of timely decision making in its 1995 Second Assessment Report given the long residence time of greenhouse gases in the atmosphere, the time necessary for replacement of infrastructure, and the lag of many decades to centuries between stabilization of concentrations and stabilization of temperature and mean sea-level.

2. Projected Climate Change Impacts

IPCC Working Group II was charged with reviewing the state of knowledge concerning the impacts of climate change on physical and ecological systems, human health, and socioeconomic sectors, and with reviewing available information on the technical and economic feasibility of a spectrum of potential adaptation and mitigation strategies. It released its Second Assessment Report Summary for Policymakers: Impacts, Adaptation and Mitigation Options in October, 1995. This Assessment provides a basis for determining whether the projected range of realistic impacts constitutes “dangerous anthropogenic interference with the climate system,” under Article 2 of the Framework Convention. It also can be used in evaluating adaptation and mitigation options.

2.1 General Conclusions about Climate Change Impacts

Human health, terrestrial and aquatic ecosystems, agriculture, forestry, fisheries, and water resources are all sensitive to the magnitude and rate of climate change projected by the IPCC’s Working Group I. Working Group II reviewed the sensitivity, adaptability, and vulnerability of ecological and socioeconomic systems to changes in climate. While many regions are likely to feel adverse and sometimes potentially irreversible effects of climate change, some effects may be beneficial.

Quantitative projections of climate change impacts are difficult because of the uncertainties noted above. Working Group II concluded generally that:

- Human-induced climate change adds an important new stress to the many already stressed ecological and socioeconomic systems already affected by pollution, increasing resource demands, and nonsustainable management practices;
- Natural ecosystems, socioeconomic systems, and human health are all sensitive to the magnitude and rate of climate change;
- While qualitative estimates of the impacts of climate change can be developed, quantitative projections on any particular system at any particular location are difficult because regional-scale climate change predictions are uncertain;
- The efficacy and cost-effective use of adaptation strategies will depend on the availability of financial resources, technology transfer, and cultural, educational, managerial, institutional, legal, and regulatory practices, both on a domestic and international scale. Adaptation will be facilitated by incorporating climate change concerns into resource use and development decisions as well as plans for regularly scheduled investments in infrastructure;
- The vulnerability of human health and socioeconomic systems and, to a lesser extent, natural ecosystems, depends on economic circumstances and institutional infrastructure, implying greater vulnerability to climate change in developing countries. Certain peoples are more vulnerable to climate change, particularly those who live on arid or semi-arid

lands, in low-lying coastal areas, in water-limited or flood-prone areas, or on small islands;

- Unambiguous detection of climate-induced changes in most ecological and social systems will prove extremely difficult in coming decades because of the complexity of these systems; and,
- Further research and monitoring are essential to improve regional-scale climate projections, understand responses to climate change, and obtain a better understanding of the efficacy and cost-effectiveness of adaptation strategies.

2.2 Specific, Pervasive Impacts on Natural and Human Systems are Likely

The IPCC Working Group II concluded the following about the likely specific impacts of climate change on natural and human systems.

a. Impacts on Terrestrial and Aquatic Ecosystems

The composition and geographic distribution of many ecosystems will shift as individual species respond to changes in climate, and there is likely to be a decrease in biological diversity and in the goods and services ecosystems provide society. Some ecosystems may not reach a new equilibrium for several centuries after the climate achieves a new balance. Specifically, potential impacts on the following ecosystems were identified:

1. Forests Climate models show that a sustained increase of 1 degree C in global mean temperature (the low end of Working Group I's range of estimates) is enough to cause changes in regional climates that will affect the growth and regeneration capacity of forests in many regions, and will alter the function and composition of forests significantly. A global average of one-third of the existing forested area of the world will undergo major changes in broad vegetation type, and entire forest types may disappear, with the greatest changes in high latitudes and the fewest in the tropics. For mid-latitude regions, a global warming of 1-3.5 degrees C over the next 100 years would be equal to a poleward shift of the present isotherms by approximately 150-550 km (or an altitude shift of 150-550 meters), compared to past tree species migration rates believed to be on the order of 4-200 km per century. Net primary productivity could increase, but more frequent pest and pathogen outbreaks and more fires may limit a productivity increase in standing biomass. Forests in transition will release large amounts of carbon.

2. Deserts Deserts are likely to become hotter but not significantly wetter. Impacts on water balance, hydrology, and vegetation are uncertain. Warmer deserts could threaten desert species living near the limit of their heat tolerance. Desertification is more likely to become irreversible if the environment is drier and the land is further degraded through erosion and compaction. Adaptation to drought and desertification may demand diversified production systems.

3. Rangelands In tropical rangelands, major alterations in productivity and species composition should not occur as a direct result of temperature increases. However, altered rainfall amount, seasonality and increased evapotranspiration will cause such changes. In temperate rangelands, shifts in temperature and precipitation may result in altered growing seasons and boundary shifts between grasslands, forests and shrublands. The carbon-to-nitrogen ratio of forage for herbivores may rise with increasing CO₂ concentrations, reducing its food value.

4. Cryosphere Climate models project that one-third to one-half of existing mountain glacier mass could disappear over the next 100 years, affecting the seasonal distribution of river flow and the water supply for hydroelectric generation and agriculture. Anticipated hydrological changes and reductions in the extent and depth of permafrost could lead to large scale damage to infrastructure. Reduced sea-ice extent and thickness would increase the seasonal duration of navigation on rivers and in coastal areas and may increase navigability in the Arctic Ocean.

5. Mountains Projected decreases in the extent of mountain glaciers, permafrost, and snow cover will affect hydrologic systems, soil stability, and related socioeconomic systems. Altitudinal distribution of vegetation is expected to shift to higher elevations, and some species with climatic ranges limited to mountain tops could become extinct. Mountain resources that provide food and fuel for indigenous population may be disrupted in developing countries; recreational industries (e.g., skiing and tourism) are also likely to be disrupted.

6. Freshwater aquatic ecosystems Altered water temperatures, flow regimes and water levels will affect inland aquatic ecosystems. In some lakes and streams, warming will increase productivity, although in shallow lakes and in streams warming could increase the likelihood of anoxic conditions. Increases in flow variability, particularly floods and droughts, would tend to reduce water quality and biological productivity and habitat in streams. Extinctions would be greatest at the low-latitude boundaries of cold- and cool water species. The geographical distribution of wetlands is likely to shift with changes in temperatures and precipitation.

7. Coastal ecosystems Coastal systems are economically and ecologically important and are expected to respond very differently to sea level and climate changes. Impacts include erosion of shores and associated habitat, increased salinity of estuaries and freshwater aquifers, altered tidal ranges in bays and rivers, changes in sediment and nutrient transport, different chemical and microbiological contamination, and increased coastal flooding. Saltwater marshes, mangrove ecosystems, coastal wetlands, sandy beaches, coral reefs, coral atolls, and river deltas are most at risk. Changes would have major negative impacts on tourism, freshwater supplies, fisheries, and biodiversity.

8. Oceans In addition to rising sea levels, climate change will lead to altered ocean circulation, vertical mixing, wave climate, and reductions in sea-ice cover, resulting in potential impacts to nutrient availability, biological productivity, the structure and functions of marine ecosystems, and heat and carbon storage capacity. Such changes

would have implications for coastal regions, fisheries, tourism and recreation, transport, off-shore structures, and communication.

b. Impacts on Hydrology and Water Resources Management

Climate change will lead to an intensification of the global hydrological cycle, which might have major impacts on regional water resources. Ground and surface water supply for domestic and industrial uses, irrigation, hydroelectric power generation, navigation, in stream ecosystems, and water-based recreation would be affected. As noted above, changes in the total amount of precipitation and in its frequency and intensity will directly affect the intensity of floods and droughts. Specific regional effects are currently uncertain and will depend in part on a catchment's physical and biological traits. A warmer climate could decrease the proportion of precipitation falling as snow, leading to less spring runoff and more winter runoff.

In many regions of the world the quantity and quality of water supplies are already a serious problem, and these regions are the most vulnerable to any additional reduction in water supply. The impacts of climate change will depend on the baseline condition of the water supply system and the ability of water resource managers to respond not only to climate change but also to population growth and changes in demands, technology, and economic, social and legislative conditions. In wealthier nations with integrated water management systems, water users may be protected from the impacts of climate change at minimal cost through improved water management. However, in many nations that are water-limited, and where there is a great deal of competition between water users, there could be substantial economic, social and environmental costs. Experts disagree over whether water supply systems will evolve enough in the future to compensate for the anticipated negative impacts of climate change on water resources and for potential increases in demand.

Options identified to deal with climate change's impacts on water supply include more efficient management of existing supplies and infrastructure, limits on future demands through water conservation, improved monitoring and forecasting systems for floods and droughts, rehabilitation of watersheds, especially in the tropics, and construction of new reservoir capacity.

c. Food and Fiber Impacts

Working Group II also reviewed the likely impacts of climate change on agriculture, forestry, and fisheries, and reached the following conclusions:

1. Agriculture Regional differences in crop yields and changes in productivity as a result of climate change are expected. Productivity is expected to increase in some areas and decrease in others, particularly the tropics and subtropics. Existing studies—without taking into account changes in agricultural pests and possible effects of climatic variability—show that, on the whole, global agricultural production could be maintained in the face of doubled equivalent CO₂ equilibrium condition. However, at the local and

regional levels, there are serious potential consequences. Increased risk of hunger and famine is possible, and many of the world's poorest people are at the most risk.

Working Group II concludes that adaptation will be important to limit negative effects and take advantage of beneficial climate changes. Adaptation measures identified include changes in crops and crop varieties, improved water management and irrigation systems, and changes in planting schedules and tillage practices. The incremental costs of adaptation could create a serious burden for developing countries, while some adaptation steps could produce cost savings for some countries. Significant uncertainties remain about the capacity of different regions to adapt successfully to projected climate change.

Livestock production may be affected by changes in grain prices and rangeland and pasture productivity. Analyses indicate that intensively managed livestock has more potential for adaptation than crop systems, except for pastoral systems where the rate of technology adoption is slow and technological changes are seen as risky.

2. Forest Products Global wood supplies during the next century may become increasingly inadequate to meet projected consumption due to both climatic and non-climatic factors. Boreal forests are likely to undergo irregular and large-scale losses of living trees because of projected climate change impacts, severely reducing standing stocks and wood-product availability over the long term. The exact timing and extent of this pattern is uncertain. The production of temperate forest products is projected to be relatively small as a result of climate and land-use impacts. In tropical regions, the availability of forest products is projected to decline by about half for non-climatic reasons related to human activities.

3. Fisheries Climate change impacts interact with pervasive overfishing, diminishing nursery areas, and extensive pollution. Globally, marine fisheries production is expected to remain about the same. High latitude freshwater and aquaculture production are likely to increase if natural climate variability and ocean currents remain roughly the same. Principal impacts will be felt at the national and local levels as species mix and production centers shift. The positive effects of climate change (longer growing seasons, lower winter mortality, faster growth rates in higher latitudes) may be offset by negative factors (changes in established reproductive patterns, migration routes, and ecosystem relationships).

d. Potential Impacts on Human Infrastructure Worry Some in Insurance Industry

Climate change and sea level rise can have a number of negative impacts on energy production, industry, transportation infrastructure; human settlements; the property insurance industry; tourism; and, cultural systems and values. Those sectors and activities most sensitive to climate change include agroindustry, energy demand, production of renewable energy such as hydroelectricity and biomass, construction, some transportation activities, existing flood mitigation structures, and transportation infrastructure located in many areas, including vulnerable coastal zones and permafrost regions.

Increased vulnerability to flooding and erosion will be felt by some coastal populations on account of climate change. Estimates put about 46 million people per year currently at risk of flooding due to storm surges. A 50 cm sea level rise (mid-range IPCC estimate) would increase this number to about 92 million, while a 1 meter rise would increase the number at risk to 118 million, without adaptive measures. These estimates increase substantially if anticipated population growth is incorporated. Sensitivity to a 1 meter sea level rise (at the top of the IPCC range) has been evaluated in a number of studies. About 70 million people each in China and Bangladesh would be affected; estimated land losses range from 0.05 percent in Uruguay to 80 percent for the Majuro Atoll in the Marshall Islands. Many nations face lost capital value in excess of 10 percent of their GDP. The high cost of providing storm surge protection would make it infeasible for some island nations.

Effective coastal zone management and land use regulation can help direct population shifts from vulnerable locations such as flood plains, steep hillsides, and low-lying coastlines. Disaster assistance can offset some of the more serious negative consequences.

A higher risk of extreme weather events due to climate change would leave the property insurance industry vulnerable and could lead to higher premiums or withdrawal of coverage for property in some vulnerable areas. Higher losses do strongly reflect increases in infrastructure and economic worth in vulnerable areas, as well as a possible shift in the intensity and frequency of extreme weather events. The insurance industry is currently under stress from a series of “billion dollar” storms since 1987⁷, resulting in dramatic increases in losses, reduced availability of insurance, and higher costs. (See Table 1)

The number of weather-related catastrophic property losses over the past eight years has raised speculation that the early effects of enhanced climate change may be a factor. Discussions are underway in Europe, and insurers and some banks there are voicing concerns about the potential for climate change liabilities, as well as for physical damage that could lead to potential business failures (Gordes, 1996). Some European insurers have called for reductions in greenhouse gas emissions (Gordes, 1996). Fewer such discussions have taken place in the United States, although there is agreement that the costs of a hurricane of the magnitude of Hurricane Andrew—which killed 54 people, left 250,000 homeless, and caused \$30 billion in damages—could be so large as to bankrupt a number of the nationally known firms and reduce surpluses by almost two-thirds, as well as limit the insurance industry’s ability to take on further exposures, if it were to hit a far

⁷ During the period 1987-1993, 16 separate events led to losses of at least a billion dollars apiece, 11 of them directly weather-related. Prior to this time, the industry had never experienced a single billion dollar event (Leggett, 1993). While insurance losses from natural and man-made disasters fell 22 percent in 1996, to \$12.3 billion, 1996 is still regarded as a continuation of the record series experienced since 1989, according to the Swiss Reinsurance Company. The year's largest single loss was due to Hurricane Fran, costing \$1.6 billion (New York Time, 1997).

more populated area with greater monetary assets⁸ (Gordes, 1996). Lack of insurance availability could preclude individuals' ability to obtain a mortgage, secure financing, or start a business (Gordes, 1996).

Table 1

Weather-related Disasters with Damages over Three Billion Dollars, 1990-1995				
Disaster	Location	Year	Deaths	Estimated Damages (Billion dollars)
Windstorm Daria	Europe	1990	-	4.6
Windstorm Vivian	Europe	1990	-	3.2
Cyclone	Bangladesh	1991	140,000	3.0
Flood	China	1991	3,074	15.0
Typhoon Mireille	Japan	1991	62	6.0
Hurricane Andrew	N. America	1992	74	30.0
Cyclone Iniki	N. America	1992	4	3.0
Winter storm	N. America	1993	246	5.0
Mississippi floods	N. America	1993	41	12.0
Winter storms	N. America	1994	170	4.0
Spring floods	China	1994	1,846	7.8
Flood	Italy	1994	64	9.3
Winter flood	Europe	1995	28	3.5
Flood	China	1995	1,390	6.7
Storm, flood	N. Korea	1995	68	15.0
Hurricane Opal	N. America	1995	28	3.0

e. Human Health Impacts

Climate change is likely to have wide-ranging and mostly adverse human health impacts through direct and indirect pathways, with significant loss of life. Indirect impacts are likely to predominate in the longer term. Direct health impacts include increases in mortality and illness due to anticipated increases in the intensity and duration of heat waves, although fewer cold weather deaths are projected as well. An increase in extreme weather would cause a higher incidence of death, injury, psychological disorders, and exposure to contaminated water supplies.

Indirect effects of climate change include increases in potential transmission of vector-borne infectious diseases (e.g., malaria, dengue fever, yellow fever, and some viral encephalitis) from an expansion in the geographical ranges and seasons of vector organisms. Were the world temperature to rise by 3 to 5 degrees C by 2100 (the upper

⁸ Franklin Nutter, president of the Reinsurance Association of America, is one of the most outspoken in the insurance industry. He has said that "The insurance business is the first in line to be affected by climate change. It is clear that global warming could bankrupt the industry" (Linden, 1994, 79).

end of the range projected) potential malaria transmission would increase from approximately 45 percent of the world population to approximately 60 percent by the latter half of the next century. This is a potential increase in malaria incidence of the order of 50 to 80 million additional annual cases relative to an assumed global background total of 500 million cases. Some increases in non-vector-borne infectious diseases such as salmonellosis, cholera, and giardiasis also could occur from elevated temperatures and increased flooding. Respiratory and allergic disorders could result from climate-enhanced increases in some air pollutants, pollens, and mold spores.

The projected human health impacts are difficult to quantify because climate-induced health disorders are influenced by a number of factors, including a population's immune status, nutrition, environmental and social circumstances, density, and access to health care. Adaptive options to reduce health impacts include housing, air conditioning, water purification, vaccination, disaster preparedness, and appropriate health care.

3. Options to Reduce Emissions and Enhance Sinks of Greenhouse Gases

Dramatic new policy measures will be needed to reduce and stabilize greenhouse gases at safe levels. The IPCC concludes that significant reductions in net greenhouse gas emissions are technically possible and economically feasible through adoption of policies and use of technological measures that accelerate technology development, diffusion, and transfer in all sectors of the energy, industry, transportation, residential/commercial, and agricultural/forestry sectors. This section sets forth the policy measures discussed by the IPCC.

3.1 Stabilization Entails Large Cuts in Emissions

The ultimate objective of the Framework Convention is “stabilization” of greenhouse gases at safe levels, or levels that will not lead to dangerous interference with climate. This goal may sound easier than it actually will be, for a variety of reasons.

Many scientists believe that anything above an increase of 0.1 degrees C (0.2 ° F) per decade would present unacceptable risks (WW Paper, 43). This is one-half the actual rate of temperature increase experienced in recent decades. To achieve this rate, the total concentration of all greenhouse gases would have to be held to a maximum of less than 550 ppm CO₂ equivalent at mid-century. The current level of all emissions is roughly 430 ppm CO₂ equivalent. If emissions of all greenhouse gases were to be held at 550 ppm CO₂ equivalent, CO₂ emissions alone would have to level off at 450 to 500 ppm. This compares to current levels of 360 ppm, and projections of over 600 ppm by late in the next century under a “business as usual” scenario.

Complicating stabilization is the fact that many greenhouse gases remain in the atmosphere for a long time. Carbon dioxide remains for a century or more. Even if CO₂ emissions were kept at near 1994 levels, there would be a nearly constant rate of increase in atmospheric concentrations for at least two centuries, reaching about 500 ppm by the end of the 21st Century. This is the upper end of the “safe” level described above. Stabilization of CO₂ concentrations at present levels (360 ppm) could only be achieved through an immediate reduction in emissions of 50 to 70 percent, and subsequent further reductions. Working Group I’s review of carbon cycle models leads them to conclude that stabilization of CO₂ concentrations at 450, 650, or 1000 ppm can be achieved only if global anthropogenic CO₂ emissions drop to 1990 levels by 40, 140, or 240 years from now, respectively, and then drop substantially below 1990 levels subsequently. (See Figure 4a and 4b) (WW Paper, 44-45).

Stabilizing concentrations of the other greenhouse gases also requires significant emission reductions. Like carbon dioxide, nitrous oxide remains in the atmosphere for decades to centuries. Stabilization near current levels would require a 50 percent reduction in anthropogenic sources immediately. If held constant at current levels, its concentration would rise to about 400 ppb over several hundred years, increasing its incremental radiative forcing by a factor of four over its current level. Methane concentrations would remain at today’s levels if emissions were immediately reduced by

about 8 percent of current anthropogenic emissions. If methane emissions remain constant, concentrations will rise from 1720 to 1820 ppb over the next forty years. Stabilization of the concentrations of the very long-lived gases, like some of the CFC substitutes, can only be achieved by eliminating their emissions.

Accumulated emissions between now and stabilization are the biggest factor in determining the eventual stabilized concentration—higher emissions in early decades require lower emissions later on. Even after stabilization is achieved, temperatures and sea level are predicted to continue to rise for centuries.

3.2 Technical Savings Potential in Different Sectors of the Economy

The IPCC identified, through their review of the existing literature, the following savings in the energy-consuming, energy supply, and agricultural/forestry sectors:

Atmospheric Carbon Dioxide Concentrations, 1900–95, with Projections to 2200

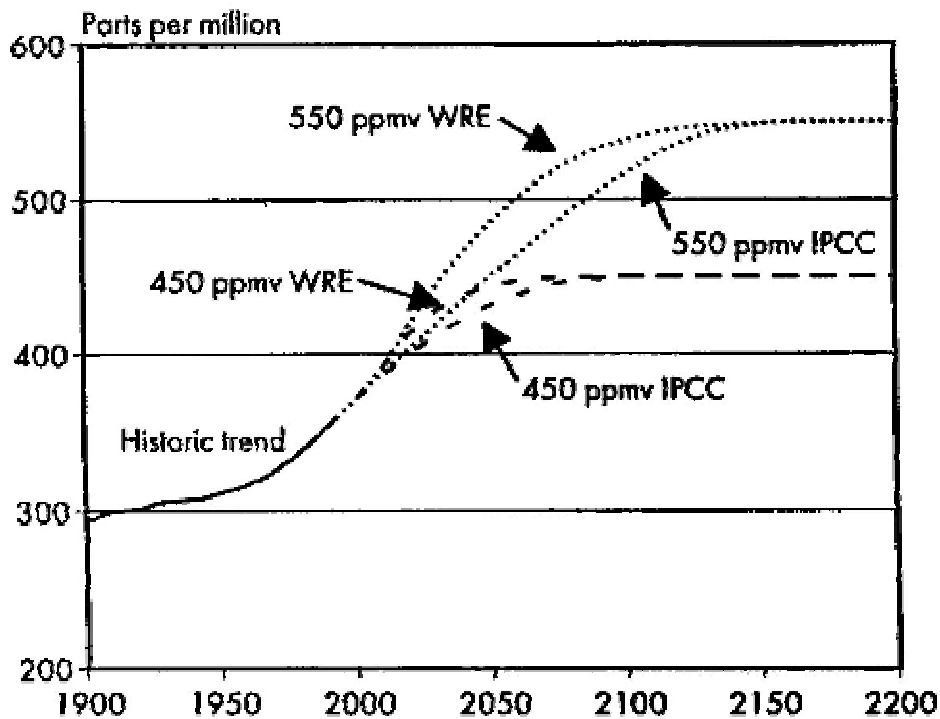


Figure 4a

World Carbon Emissions, 1900–95, with Projections to 2200

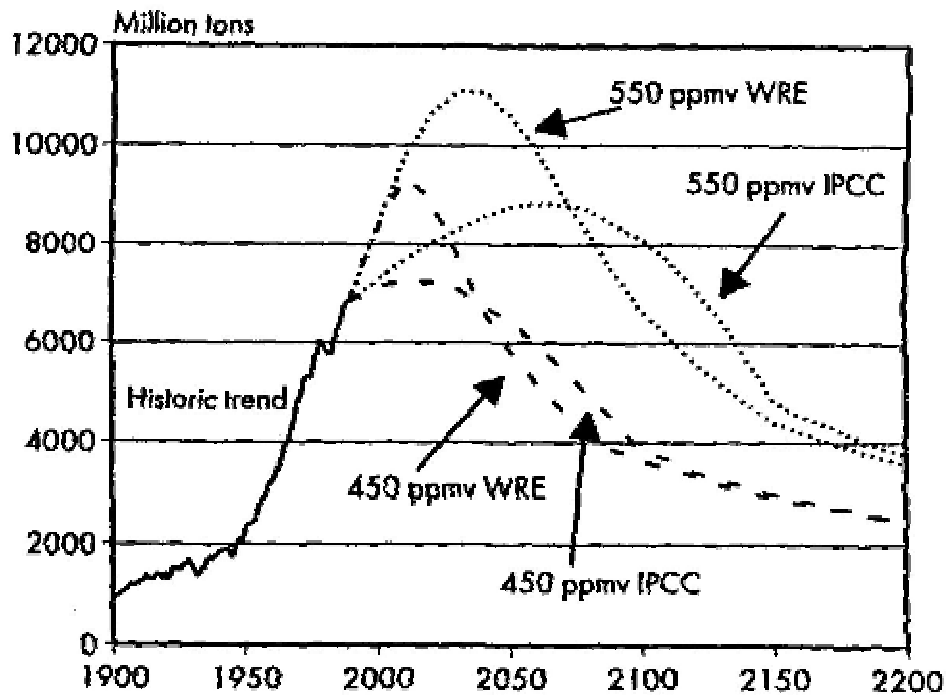


Figure 4b

a. Technical Potential for Savings in Energy-Consuming Sectors

Global energy demand has grown at an average rate of about 2 percent per year for almost all energy-consuming sectors, and transportation; transportation has experienced the most rapid growth of all the sectors. The IPCC concluded in 1992 and 1994 that, without policy intervention, significant growth in emissions from these sectors would occur.

The IPCC examined studies of potential energy and greenhouse gas emission reductions from energy-consuming sectors. Numerous studies have shown that 10 to 30 percent energy efficiency gains above present levels are feasible at negative to zero net cost in many parts of the world through conservation and management over the next 20 to 30 years. Gains of 50 to 60 percent^{9,10} would be technically feasible using technologies yielding the highest output of energy services in many countries, but achieving such potentials depends on future cost reductions, financing, technology transfer, and measures to overcome non-technical barriers. The potential for greenhouse gas emissions

⁹ In a comprehensive study of the role energy efficiency and renewables could cost-effectively play in America's energy mix, it was estimated that the U.S. could cut CO₂ emissions by more than 70 percent over the next forty years through efficiency, shifts from coal to gas for electricity generation, greater use of renewables, more efficient heating technologies, and shifts from coal to electricity as an industrial power source. At the same time, U.S. consumer would cut oil use by two-thirds and would save \$2 trillion (Union of Concerned Scientists et al., 1991).

reductions exceeds these energy efficiency potentials because of fuel-switching possibilities.

However, with a world population projected to grow from 5.7 billion in 1996 to 8-10 billion in the next forty years, with a global economy likely to triple in size, and with people in developing countries looking forward to the same amenities those in industrialized nations have, substantially reducing carbon emissions will mean an end to a world economy that relies on fossil fuels for 80 percent of its energy supply to one that relies on these fuels for only a minor portion (WW Paper, 46).

Energy efficiency improvement potentials for each sector were examined by the IPCC in its Second Assessment Report. Strong policy measures would be required to achieve these potentials.

1. Industry Energy use is estimated to grow from 98-117 EJ in 1990 to 140-242 EJ in 2025 without new measures. In most industrialized countries, industrial sector emissions are expected to be stable or declining due to technology and restructuring, but in developing countries they are projected to increase. The short-term potential for energy efficiency improvements in manufacturing of major industrial nations is estimated at 25 percent, with larger potential for greenhouse gas emission reductions. Identified measures include: improving efficiency (e.g., energy and materials savings, cogeneration, energy cascading, steam recovery, use of more efficient motors and other electrical devices); recycling; switching to materials with lower greenhouse gas emissions; and, developing less energy-intensive processes.

Large reductions in process-related greenhouse gases released during manufacturing and industrial processes are possible in some cases. Measures include elimination of solvents, capping and using methane from landfills and sewage treatment plants, reducing the leakage rate of halocarbon refrigerants from mobile and stationary sources.

2. Transportation 1990 energy use of 61-65 EJ is projected to grow to 90-140 EJ in 2025 without new measures. This could be reduced by about one-third through vehicles with very efficient drive-trains, light weight construction, and low air resistance design. Smaller vehicles, and changes in land use, transport systems, mobility patterns, lifestyle and modes of travel could further reduce transportation-related energy use. Alternative fuels and electric vehicles (powered by renewable sources) could reduce greenhouse gas emissions per unit of energy used. This combination of measures could lead to as much as a 40 percent reduction in global transport emissions from projected 2025 emissions. These actions would also improve local air quality.

3. Commercial/Residential Energy use is expected to grow from 1990 levels of 100EJ to 165-205 by 2025 without new measures. This could be reduced by about 25 percent through energy efficiency, with larger greenhouse gas reductions possible. Reduced heat transfers through building structures, more efficient space conditioning and water supply systems, lighting, and appliances have been identified as technical changes, while vegetative plantings and reflective building surfaces could reduce temperatures in urban

areas and reduce energy use for air conditioning. Changing energy sources would provide greater greenhouse gas reductions.

b. Potential Energy Supply Savings

The IPCC assessed the potential impacts of combining individual measures at the energy system level to reduce carbon emissions, and concluded that: deep reductions in CO₂ emissions from energy supply systems are technically possible within 50 to 100 years using alternative strategies; many combinations of identified options could reduce global CO₂ from fossil fuels from about 6GtC in 1990, to about 4 by 2050, to about 2 by 2100, with cumulative emissions from 1990 to 2100 ranging from about 450 to 470 GtC ; higher energy efficiency is underscored for achieving deep CO₂ reductions and for reducing overall energy system costs; and, interregional trade in energy grows.

The IPCC assessment focused on new technologies for capital investment rather than on retrofitting existing capital stock to use less carbon intensive forms of primary energy. The world's commercial energy system will be replaced at least two times by the year 2100, and significant amounts of capital stock in other sectors will also be replaced, making a change in the energy system possible without premature retirement of capital stock. Deep reductions in greenhouse gas emissions can be achieved in the energy supply sector in conjunction with the normal timing of capital investments to replace equipment and infrastructure. Many of these actions will also reduce emissions of sulfur dioxide, nitrogen oxides, and volatile organic compounds.

Greenhouse gas reductions can be achieved in the use of fossil fuels through the following steps: more efficient conversion of these fuels can increase the efficiency of power production from the present world average of 30 percent to more than 60 percent over the long term. Combined heat and power production for process and space heating offers a significant rise in fuel conversion efficiency. Switching from coal to oil or natural gas, and from oil to natural gas, can reduce emissions; CO₂ emission rates per unit of energy are 14 kgC/GJ for natural gas, compared to 20 for oil and 25 for coal. Low capital cost combined-cycle technology has reduced electricity costs in some areas considerably. In the transportation sector, natural gas could replace oil. Methane emissions from natural gas pipelines and wells and mines can be reduced. Decarbonization of flue gases and fuels and storage of carbon dioxide are technically possible, but the costs and environmental impacts of CO₂ storage are largely unknown. The future availability of conversion technologies such as fuel cells would increase the attractiveness of some approaches.

Switching to non-fossil fuel sources of energy would also reduce greenhouse gas emissions. The IPCC mentions switching to nuclear energy as an option in many parts of the world if concerns about safety and radioactive waste transport and disposal, and nuclear proliferation, can be addressed adequately. Renewable sources of energy (solar, wind, hydro, biomass, geothermal) contributed about 20 percent of the world's primary energy consumption in 1990, mostly from wood and hydro. The IPCC concludes that technological advances offer new opportunities and declining costs for energy from these

sources, and that renewable energy sources could meet a major part of the world's energy demand over the longer term.

According to the IPCC, within the wide range of future energy prices, one or more of the variants would plausibly be able to provide demanded energy services at projected costs approximately the same as estimated future costs for current conventional energy. Strong support exists in the literature for being able to achieve the assumed performance and cost characteristics within the next two decades, with a strong and sustained investment in research, development, and demonstration, although it is impossible to be certain until research and development is complete.

c. Emission Reductions in Agriculture, Rangelands, and Forestry

The IPCC identifies a number of measures that could conserve and sequester substantial amounts of carbon over the next 50 years in these sectors. Land use and management measures include: sustaining forest cover, slowing deforestation, natural forest regeneration and tree plantings, altered management of agricultural soils and rangelands, improved efficiency of fertilizer use, restoration of degraded lands, methane recovery from manure storage, and improved diet for ruminants. The costs of these measures depend on the costs of land, plantings, nurseries, annual maintenance and monitoring, and transaction. The net amount of carbon conserved or sequestered under a particular forest management practice and present climate is relatively well understood, but uncertainties with estimating a global value exist because of many unknowns about land availability and long-term security of these lands, and other factors.

3.3 Strong New Policies Needed to Reduce Greenhouse Gases

Converting from a world that is 80 percent dependent on fossil fuels for energy to one that uses just a fraction of that amount will not only require new technologies, but also new public and private sector policies and programs. The IPCC concludes that mitigation depends on reducing barriers to the diffusion and transfer of technology, mobilizing financial resources, supporting capacity building in developing countries, and other approaches to assist implementing behavioral changes and technological opportunities.

Actions for policymakers to consider in accordance with applicable international agreements to implement low cost and/or cost-effective measures to reduce greenhouse gas emissions include:

- energy pricing strategies (e.g., carbon or energy taxes, and reduced energy subsidies);
- implementing energy efficiency measures and utility demand-side management programs;
- voluntary programs and agreements with industry;

- stimulating research, development and demonstration to make new technologies available;
- renewable energy incentives;
- phasing out existing distortionary policies that increase greenhouse gas emissions, such as some subsidies and regulations, non-internalization of environmental costs and distortions in transport pricing;
- implementing cost-effective fuel switching to less carbon-intensive and carbon-free fuels;
- implementing measures to enhance carbon sinks; and,
- promoting development of national and international energy efficiency standards.

Most economists believe that economic instruments such as carbon taxes and tradable emission permits would be more cost-effective approaches to reduce greenhouse gas emissions than would regulatory policies (U.N. Environmental Programme Overview). The 2,000 economists who signed the Statement on Climate Change in February, 1997 agreed that the most efficient approach to slowing climate change is through market-based policies, such as carbon taxes or the auction of emissions permits (Economists Statement, 1997). They pointed to economic studies showing that policy options exist that would slow climate change without harming American living standards, but would instead improve U.S. productivity in the longer run.

The world economy and some individual national economies suffer from a number of price distortions that increase greenhouse gas emissions, such as agricultural and fuel subsidies and distortions in transport pricing. A number of studies indicate that global emissions reductions of 4 to 18 percent, together with increases in real incomes, are possible merely from phasing out existing fuel subsidies.

Beyond doing away with subsidies, economists have also estimated the effect different levels of carbon taxes would have on emissions, and the firmest conclusion from this work is that the tax would have to be high (US \$100 per ton of carbon) if it were to reduce emissions substantially in the long run. This level of tax would raise the current price of crude oil (US \$20/barrel) by about two-thirds (U.N. Environmental Programme Overview).

Adoption of emissions caps with tradable emissions entitlements may be a more politically acceptable approach, at least in the United States, than adoption of a carbon or energy tax. Under this approach, the government would start by deciding how many tons of a particular gas can be emitted annually, allocating emission entitlements to sectors or firms, and then letting the market take over through trading. Those nations or sectors that can cut emissions relatively cheaply may sell emissions permits to those who find it expensive to do so. This system is used to regulate emissions of CFCs and sulfur dioxide

(acid rain precursors). Tradable permits could be implemented internationally, with trading between nations as well as within nations allowed. Issues of allocation of emissions limits between countries have to be addressed.

Policies that reduce greenhouse gases while at the same time addressing other pollution or land use concerns (e.g., air pollution or soil erosion concerns) appear easier to implement than policies that only reduce greenhouse gases. Political support for such dual-purpose policies may be greater than it would be for policies that only address climate change. In addition, such dual-purpose policies probably provide greater benefits than climate change only policies for the same or equivalent cost, and are thus more cost effective.

4. The Socio-economics of Climate Change

IPCC Working Group III assessed the existing literature on the socio-economics of climate change, identifying areas of consensus and disagreement, and released its Summary for Policymakers in October, 1995. Assessment of the economic, social and environmental costs and benefits of action and inaction are detailed, with specific attention to the applicability of cost-benefit analysis, equity and social considerations, and intergenerational equity issues. The Working Group III Report is an assessment of the state of knowledge for use by countries in their decision-making processes, rather than a prescription for policy implementation.

4.1 General Conclusions about Mitigating Climate Change

While recognizing the contribution of economics to the debate, Working Group III acknowledges that assessing costs and benefits may be hard, and is sometimes impossible, due to large uncertainties, possible catastrophes with very small probabilities, or simply because there is no available consistent methodology for monetizing effects. The global, regional, and intergenerational nature of the problem add additional complexities, as do widely divergent estimates of costs of physical damages due to climate change and of mitigation options. Despite these imperfections, economic analyses are used to answer questions regarding to what extent, when, and how emissions should be reduced.

Working Group III provides a number of insights. First, analyses show that a prudent way to deal with climate change is through a portfolio of mitigation actions, adaptation, and improving knowledge. Second, early mitigation may increase flexibility toward stabilization of greenhouse gases; the choice of abatement paths entails balancing the economic risks of rapid abatement now against the corresponding risk of delay. Delaying response involves costs. Some studies suggest the cost of delay to be small, while others emphasize that delay would result in the greater use of limited atmospheric capacity, the potential deferral of desirable technical development, and would impose risks on all parties, specifically the most vulnerable. There is no consensus on the appropriate abatement path.

Third, the literature indicates that significant “no regrets,” or “measures worth doing anyway,”¹⁰ opportunities are available in most countries, and that the risk of climate change damages provides rationales for actions beyond “no regrets” considering risk aversion and precautionary principles. Fourth, the value of better information is likely to be great. Finally, analysis of economic and social issues related to climate change is a high priority for research. Research is needed on integrated assessment and analysis of decision-making, economic understanding of non-linearities and new theories of economic growth, energy efficiency technologies and non-fossil energy options, and sustainable consumption patterns.

¹⁰ These are measures where the benefits (e.g., reduced energy costs and emissions of pollutants) equal or exceed their cost to society, including the climate change mitigation benefits.

4.2 Valuing the Costs of Climate Change

The social costs of climate change include non-market impacts such as human health, risk of mortality and damage to ecosystems. There is no consensus on how to value such impacts, and estimates are highly speculative and not comprehensive. It is important to note that damages from possible catastrophes are not reflected in the climate change cost estimates. The literature quantifying total damages from a 2 to 3 degree C warming provides a wide range of point estimates. While Working Group III acknowledges that Gross Domestic Product (“GDP”) is a deficient measure of society’s well-being—because of its failure to account for environmental and natural systems degradation—this is nevertheless the yardstick used. Aggregate estimates of damages, which are subject to considerable uncertainty and their range cannot be determined from the literature, tend to be a few percent of world GDP, with considerably higher estimates of damage to developing countries as a share of their GDP. Although estimates of just a few percent of GDP may represent small differences in GDP growth rates, they are substantial in absolute dollar terms.

Regional or sectoral estimates include a much wider range of estimates of net economic effects. For some areas, damages are estimated to be significantly greater and could negatively affect economic development. For others, climate change is estimated to increase economic production and present opportunities for economic development. Estimates of damages for countries with a diversified, industrial economy and an educated and flexible labor force are on the order of one to a few percent of GDP, while estimates for countries generally having a specialized and natural resources based economy, and a poorly developed and land-tied labor force are several times higher. Small islands and low lying coastal areas are the most vulnerable.

Published estimates for the marginal damage of CO₂ emissions range from \$5 to \$125 (1990 U.S.) per ton of carbon emitted now. The wide range of estimates reflects variations in discount rates and other assumptions, as well as a wide range of uncertainties. The IPCC does not endorse any particular range of values.

4.3 The Cost of Responses

Working Group III also reviewed the literature describing the costs of response options. As with climate change damage estimates, the literature yields a very wide range of estimates for response costs as well. Significant differences in assumptions exist between studies on items such as the efficiency of energy and other markets, the ability of government institutions to address perceived market failures or imperfections, the levels of energy efficiency improvements in the absence of climate policy, consumption patterns, resource and technology availability, the desired level and timing of abatement and the choice of policy instruments. Policymakers are warned not to place too much confidence in the specific estimates from any one analysis.

The costs of stabilizing greenhouse gases at a level and within a timeframe to prevent dangerous human interference with the climate is critically dependent on the choice of

emissions time path. Costs of abatement are influenced by the rate of capital replacement, the discount rate, and the effect of research and development. Implementing emissions reductions to take advantage of normal turnover of plant and equipment are likely to be cheaper than enforcing premature retirement now.

Major infrastructure decisions involving development patterns in transportation, energy system development, urban settlement and land use, and deforestation will be made in the near future in developing countries and many economies in transition. The decisions made are critical in determining long-term emissions and abatement costs since they can enhance or restrict the number and type of future options. The IPCC suggests that if a carbon or carbon-energy tax is implemented to reduce emissions, the substantial revenues raised could be used to reduce existing distortionary taxes, potentially yielding an added economic benefit. International cooperation can also significantly reduce the global cost of emissions reductions, since emission reduction costs vary widely among countries. Substantial savings would be possible if emissions are reduced where it is cheapest to do so. This takes international cooperation. Failure to achieve such cooperation could undermine unilateral attempts by individual nations to limit their greenhouse gas emissions.

A large number of studies address the costs of limiting greenhouse gas emissions. For OECD countries, top-down analyses suggest that the costs of substantial reductions below 1990 levels are as high as several percent of GDP. To stabilize emissions at 1990 levels, most studies estimate that annual costs in the range of -0.5 percent of GDP (a gain of \$60 billion for OECD countries) to 2 percent of GDP (loss of about \$240 billion) could be reached over the next several decades. Bottom-up studies are more optimistic about the potential for low or negative cost emission reductions. Some of these studies show a negligible to negative cost for reducing emissions 20 percent in developed countries in two to three decades, while others suggest a potential to reduce emissions 50 percent in the longer term without increasing, and perhaps even decreasing, total energy system costs.

For economies in transition, there is likely considerable potential for cost-effective reductions in energy use. The realizable potential will depend on economic and technological development paths chosen and the availability of capital. For developing countries, analyses suggest substantial low-cost fossil fuel CO₂ emission reduction opportunities. However, merely increasing energy efficiency, alternative energy technologies, and reducing deforestation are likely to be insufficient to offset rapidly increasing emissions baselines associated with increased economic growth and overall welfare in these countries. Carbon dioxide emissions would have to be cut 60 percent to stabilize CO₂ concentrations in the atmosphere. One study by the OECD suggests that the marginal cost of stabilizing CO₂ concentrations would be about \$1,600 in the year 2020 (U.N. Environmental Programme Overview). Whether this will be more costly than the costs associated with not doing so are not addressed by the IPCC.

Preserving and augmenting carbon sinks offer a substantial and often cost-effective component of a greenhouse gas mitigation strategy. Studies suggest as much as 15 to 30

percent of 1990 global energy-related emissions could be offset by carbon sequestration in forests for a period of 50 to 100 years. The costs of carbon sequestration may differ among regions, but are generally competitive with source control options.

Control of methane and nitrous oxide can provide significant cost-effective opportunities in some countries. Available negative or low cost mitigation options exist to reduce methane emissions 10 percent.

5. International Agreements on Climate Change

The world's scientists have a greater understanding today of the far-reaching impacts of greenhouse gas emissions on global climate than they had when CFCs were banned to protect the ozone layer. Strong and vocal opposition to a verifiable legally binding agreement to limit greenhouse gas emissions comes in large part from entrenched and powerful fossil fuel interests threatened by the need to convert to a world that relies far less heavily on these fuels.

International cooperation is needed to address global climate change. The total costs of achieving a particular global target would decline as more and more countries commit to reductions, since the costs of incremental reductions in emissions increase with the level of abatement. The OECD estimates that the costs of reducing emissions would be about five times higher for the industrialized nations if they proceeded on their own as opposed to pursuant to an international agreement (U.N. Environment Programme Overview).

This section reviews the international political agreements that have been signed, their failure to stabilize greenhouse gas emissions at 1990 levels as proscribed under the U.N. Framework Convention on Climate Change, and the current U.S. position on what form an international treaty to limit greenhouse gas emissions should take. Finally, the possible components of the agreement likely to be produced at December's Kyoto summit are discussed.

5.1 Events Lead to the Framework Convention on Climate Change

Scientists first began monitoring the atmosphere for carbon dioxide and temperature variations in the 1950s. In 1958, scientists from Scripps Institute of Oceanography in La Jolla, California began monitoring CO₂ levels in Hawaii and other sites; their later work showed a steady buildup of the gas. In the 1970s and 80s computer and satellite technologies permitted more precise detection of trends in greenhouse gases. In June, 1988 James Hansen, a climate specialist at the Goddard Institute for Space Studies in New York City, told a Senate committee that global warming is occurring. The United Nations General Assembly set up the Intergovernmental Panel on Climate Change to advise world leaders at that time.

During the 1990s the debate over climate change intensified. In 1990 the IPCC issued its first report, announcing that greenhouse gases were building up at an unprecedented pace. Emission cuts were not recommended at that time though due to political pressure from the U.S. and other industrial countries dependent on fossil fuels.

However, world leaders narrowed their differences over a global treaty to curb greenhouse gases. In May, 1992 the U.S. and about 130 other countries signed the U.N. Framework Convention on Climate Change, the first binding agreement dealing directly with the issue, in Geneva, Switzerland. The ultimate objective of the treaty is to stabilize greenhouse gas concentrations at a level that would prevent dangerous human interference with the climate system. Signatories set a non-binding target of reducing

their greenhouse gas emissions to 1990 levels by the year 2000. Later that year, at the Earth Summit in Rio de Janeiro, Brazil, more countries signed onto the agreement, bringing the total to 165. Different commitments apply to Annex I Parties (OECD countries and the former Soviet bloc nations) and non-Annex I Parties (the developing nations). The U.S. Senate has ratified the Framework Convention.

Unfortunately, since ratifying the Framework Convention, most industrial countries have moved in the opposite direction from the stabilization goal. A 1996 projection by the Department of Energy indicates that without new policy initiatives, U.S. carbon emissions in 2000 will exceed 1990 levels by 11 percent (AEO97). The record in other countries is mixed. Overall, western Europe's CO₂ emissions in 2000 are likely to exceed 1990 levels by 5 percent, according to a 1996 assessment by the European Commission (WW Paper, 1996) Developing countries' emissions are rising rapidly as well. China's CO₂ emissions rose 13 percent between 1990-94, Brazil's 16 percent, India's 24 percent, and South Korea's 44 percent.

On the other hand, there have been some successes. Germany, Europe's leading greenhouse gas producer, established a far tougher target than that required by the Framework Convention. In 1995 it pledged a 25 percent reduction in carbon emissions from 1990 levels by 2005. By 1995, German CO₂ emissions were already more than 10 percent below the 1990 level. Denmark and the Netherlands have adopted the world's strongest climate policies. Denmark has aimed to reduce carbon emissions to 20 percent below 1988 levels by 2005, and is relying on CO₂ and energy taxes and investments in wind power, biomass, and other alternatives. The Netherlands targets a 3 percent reduction in emissions by 2000, much of which is to flow from strong voluntary agreements between government and industry, and a major commitment to capturing waste heat from power plants and improving building and appliance efficiency. Gasoline and automobiles are heavily taxed, and a new energy tax was applied to private households and other small energy consumers in 1996. Subsidies to public transportation have been raised, and bicycle facilities receive 10 percent of the nation's surface transportation budget (WW Paper, 38-39).

5.2 The United States Issues Climate Change Action Plan

In 1993 the U.S. announced its Climate Change Action Plan, a set of voluntary programs aimed at meeting the Framework Convention's target to reduce greenhouse gas emissions to 1990 levels by the year 2000. This Plan included fifty new and expanded initiatives in all sectors of the economy to reduce all greenhouse gases. The Clinton Administration proposed spending \$1.9 billion on the actions outlined in the Plan. Private investment totaling \$60 billion was outlined, with projected energy savings of an equivalent amount in the short term, and additional savings of \$207 billion over the long term. The Plan recognized that investments in energy efficiency are the single most cost-effective way to reduce CO₂ emissions, and proposed an array of public/private partnerships to stimulate deployment of existing energy efficient technologies and accelerate the introduction of more advanced technologies. See **Appendix A** for a Summary Table of Actions proposed in the Climate Change Action Plan.

Unfortunately, the energy savings projected from the programs outlined in the Plan are expected to be 25 to 40 percent lower than originally estimated. Reasons given for lower than forecast emission reductions include: lower oil prices than forecast, higher economic growth, Congressional failure to fund some programs entirely while funding others at reduced levels, and more rapid loss of forests than projected. U.S. greenhouse emissions in the year 2000 are projected to exceed 1990 levels by 100 million metric tons. On the other hand, the U.S. is also implementing programs not included in the Plan that are designed in part to reduce greenhouse gas emissions.

5.3 The 1995 “Berlin Mandate”

In the spring of 1995 signatories to the Framework Convention issued the “Berlin Mandate” at the first Conference of the Parties to the Climate Convention, calling for concrete plans to toughen the agreement by the end of 1997. Treaty members are charged with adopting a protocol to “set quantified limitation and reduction objectives [for industrial countries] within specified time frames, such as 2005, 2010 and 2020” (WW Paper, fn.108).

The Berlin meeting revealed significant disagreements among nations over how to make the treaty tougher. The European Union (“EU”) called for adoption of a carbon tax. The Alliance of Small Island States (“AOSIS”), a group of 37 countries most at risk from rising sea levels, urged industrial countries to cut their emissions 20 percent below 1990 levels by 2005. An agreement was reached at Berlin to start a pilot program to encourage firms in industrial countries to set up renewable energy or reforestation projects in developing countries (“joint implementation”), but this plan came under attack by some developing nations and industry representatives.

In late 1995 the IPCC Working Groups released their Reports, announcing for the first time that the scientific evidence shows a “discernible human influence on global climate.” Meeting in Rome in December, 1995, signatories to the Framework Convention endorsed the IPCC’s findings. Participants at the Rome conference failed to agree to legally binding targets and timetables however.

5.4 The U.S. Calls for Legally Binding Agreements with Flexible Implementation

In July, 1996 Undersecretary of State for Global Affairs Timothy Wirth announced that the U.S. had abandoned its call for voluntary steps to reduce greenhouse gas emissions and would press for legally binding greenhouse gas emissions targets and timetables in treaty negotiations at the third session of the Parties scheduled for December, 1997 in Kyoto, Japan. At the second Conference of the Parties meeting in Geneva, the world’s environment Ministers concluded that the “science provides a compelling basis for action” to address climate change and instructed representatives to accelerate negotiations on a legally binding agreement to be adopted by the December, 1997 meeting in Kyoto. German negotiators pushed for tough, legally binding limits for industrial country CO₂ emissions—a 10 percent reduction by 2005 and a 15 to 20 percent reduction by 2010, but the U.S. and other industrial countries remained reluctant to agree to such strict limits.

Nevertheless, the U.S. call for binding targets and timetables was endorsed by all but 14 countries at the second conference of the parties in Geneva. Those opposed include the 11 OPEC members and Russia, which see a binding treaty as a threat to oil-dependent economies.

In December, 1996 the U.S. issued a “Non-Paper” on climate change, reiterating that the “science provides a compelling basis for action to address climate change,” and again calling for verifiable, binding medium term targets with maximum national flexibility on their implementation. The U.S. acknowledged that the Framework Convention’s existing non-binding aim is not working and that most developed nations, including the U.S., will not achieve the goal of returning emissions to 1990 levels by 2000.

The U.S. reiterated its basic position in March, 1997 in a Climate Change Protocol Proposal. The U.S. is calling for emissions targets that cover a multi-year period, as opposed to single year targets, to smooth year-to-year variability in emissions. The U.S. rejects short-term targets (i.e., before 2010) as unrealistic and unnecessarily burdensome to national and global economic growth and development. The U.S. urges consideration of banking between multi-year average periods to allow emissions below the target in one year to be used to offset higher than target emissions in later periods. The U.S. rejects suggestions for different commitments between Parties and endorses adoption of a common approach with respect to targets. The U.S. also calls for emissions trading between Parties that have assumed a binding target for greenhouse gas emissions and joint implementation among Parties that are subject to targets and those that are not.

The U.S. position has come under attack from both industry and environmental groups, as well as from other nations, see below. Some industry groups oppose binding targets on the grounds of competitiveness (i.e., industrial nations should not be bound if all nations are not bound to the agreements) and lack of complete scientific certainty. A spokesperson for Edison Electric Institute has been quoted as saying that “[W]e oppose legally binding targets and timetables, as well as mandatory command-and-control policies and measures. . . We believe that those types of policies will force premature emissions reductions that will be costly and are not warranted at this time. All the science shows that this is a long-term issue and that there is sufficient time to take action to mitigate climate change” (CQ Researcher, 1996, 964).

The electric utility industry points to the fact that 60 percent of the industry is participating in voluntary programs to reduce greenhouse gas emissions, by encouraging customers to buy more efficient lighting, appliances and building materials, switching from coal to natural gas, and improving the efficiency of coal-fired plants. EEI estimates that these programs will reduce emissions by 44 million metric tons of carbon by 2000 (CQ Researcher, 1996, 975).¹¹ However, as noted above, despite the Climate Change

¹¹ In contrast, voluntary programs have been far less successful in reducing CO2 emissions in the transportation sector, the leading source of greenhouse gas emissions in the U.S. Fuel economy standards adopted in 1975 were reached by 1985, but lower gasoline prices and rising consumer demand for more powerful vehicles are resulting in increases in emissions from this sector. Talks convened by the Clinton Administration, and aimed at improving the standards, broke up without agreement.

Action Plan programs, year 2000 greenhouse gas emissions are expected to exceed 1990 levels by 100 million metric tons.

Many environmental groups are also disappointed with the Clinton Administration's position, particularly its unwillingness to act immediately to reduce greenhouse gas emissions, its lack of specificity regarding emissions reductions targets and timetables, and its insistence on commitments from developing nations while refusing to make commitments itself. The policy options announced by the U.S. (e.g., emissions trading and joint implementation) are seen by some as payments to developing nations to meet industrialized countries' commitments and that use up emissions that would otherwise be allocated to future generations.

5.5 The Likelihood of Agreement at Kyoto

The Ad Hoc Group on the Berlin Mandate (AGBM)—the subsidiary body of the Framework Convention charged with negotiating a legally binding treaty by the end of 1997—met in Bonn in early March of this year to consolidate and streamline the proposals put forth for an international climate change treaty. There appears to be little substantive disagreement that the science provides a compelling basis for action to address climate change. However, there is a large gap between the proposals offered by the U.S. and those offered by other Parties to the Framework Convention.

The U.S. call for a multi-year emissions budget, with a starting date of 2010, without specific targets and timetables, and with maximum flexibility given to nations to design mechanisms to achieve those targets is at odds with the position of the European Union. The EU is calling for a 15 percent cut (from 1990 levels) in CO₂, methane, and nitrous oxide emissions by 2010, and for specific policies and measures to achieve those reductions. However, the EU has proposed to distribute the burden of emissions reductions unequally, with some nations cutting emissions up to 30 percent and others increasing them 40 percent. The island nations have called for a 20 percent reduction in emissions by 2005. Other nations have called for a variety of emission levels within different timeframes. The OPEC nations are asking for compensation for harm they suffer from a decline in fossil fuel exports.

At the March meeting the AGBM did reduce the number of proposals on the table and produced a negotiating text for the next meeting. Ten more days of negotiation are scheduled for this year before the final meeting in December in Kyoto.

There is no way to predict whether what emerges from Kyoto will look more like the flexible U.S. proposal or the more specific EU proposal, what the starting date will be, or what percent reduction below 1990 levels will be required. However, the movement toward some type of binding international agreement to limit greenhouse gas emissions is clearly building, and whatever emerges from these negotiations will send a ripple through the world's energy supplying and consuming sectors. The unanswerable question at this point is simply how large that ripple will be.

6. The Electric Utility Industry Post Kyoto

The electric utility industry is particularly vulnerable to carbon emission reductions because of the industry's significant contribution to these emissions. The move toward increased competition in the industry pushes it in a direction that will tend to increase carbon emissions unless measures are taken to offset these effects. Given the inevitability of new greenhouse gas and criteria pollutant regulations, this industry would be best served by reducing the risks associated with over-reliance on fossil fuels, most especially coal, for electricity generation.

6.1 The Electric Utility Industry's Vulnerability

The electric utility industry is particularly vulnerable to actions to reduce carbon emissions and more stringent air quality regulations, both of which will raise the price of generating electricity from fossil fuels, particularly from coal. Despite the impressive environmental progress that has been made in the reduction of SO₂ and NO_x since passage of the original Clean Air Act in 1970 and the Clean Air Act Amendments of 1990, electricity generation remains the single largest source of air pollution in the U.S. (Natural Resources Defense Council, 1996, 3). Electricity generates not only 36 percent of U.S. carbon emissions, but also 70 percent of sulfur dioxide emissions, 33 percent of nitrogen oxide emissions, 23 percent of point source direct emissions of particulate matter, and 23 percent of mercury emissions (NRDC, 1996).

The largest portion of this pollution comes from older coal-fired power plants that are not required to meet the same Clean Air standards as plants built during the last two decades. Today's coal-fired plants account for more than one-half of U.S. electricity generation and are physically capable of expanding production by more than 30 percent (NRDC, 1996, 13). Coal is projected to continue to account for one-half of electricity generated in the year 2015, and 80 percent of electricity-related carbon emissions, while gas-fired generation will account for 29 percent of total electricity but only 18 percent of electricity-related carbon emissions (AEO97, 73). The difference is attributable to the fact that conventional coal-fired generation averages more than 2 pounds of CO₂/kWh (or 1.6 million tons per year from a medium-sized 250 MW plant), while natural gas produces 44 percent less CO₂/kWh, and oil produces 16 percent less. Non-closed loop biomass and waste to energy facilities are sometimes termed renewable resources. They do emit some carbon. Renewable resources do not emit carbon nor do nuclear power plants.

As noted section I, nuclear generation is expected to decline 33 percent in the next twenty years, and if fossil-fueled capacity is used to fill this gap, carbon emissions would increase by 172 million metric tons, or 34 percent, from 1995 levels (AEO97, 73). The use of renewable technologies is projected to grow, but not enough to compensate completely for the loss in base load nuclear capacity (AEO97, 73). These projections include activities under the Climate Change Action Plan programs that have been announced, but not activities such as additional use of lower carbon fuels, reduced

electricity demand growth, or improved technologies, all of which could reduce carbon emissions from those projected.

6.2 Restructuring and Likely New Environmental Regulations Play Tug-of-War

The electric utility industry is being pulled in different directions by changes currently in progress. On the one hand, industry restructuring and greater competition are putting pressure on utilities to cut prices in the short term rather than to reduce long-run resource costs. The focus on immediate financial profit disadvantages renewable technologies and energy efficiency, which are less cost-effective in the short term but more so in the long term. A more competitive utility industry may also put pressure on utilities to run the older (more depreciated) and dirtier fossil fuel fired plants more often and longer to avoid new capacity expenses.

While increasing competition could provide an opportunity for the dirtiest coal plants to increase their output substantially because of lower financial costs, carbon taxes or emissions caps directed at reducing carbon emissions push in the other direction. Enactment of a carbon or energy tax would increase the annual financial liability for coal plants significantly. A \$20/ton tax (which is at or below the tax already adopted in Norway and Sweden) would cost the 250 MW coal plant \$32 million per year (about 2 cents/kWh) (NRDC, 1996, 6). A recent letter from the oil industry to members warned of possible energy taxes equivalent to \$35/ton of carbon, and predicted that meeting the U.S. climate commitments would require taxes of \$125 to \$170 per metric ton of carbon (equivalent to about \$38 to \$51 per ton of CO₂) (NRDC, 1996). At \$35/ton, the electric industry as a whole would face annual liabilities of over \$60 billion (NRDC, 1996).

Many believe that the Kyoto agreement will not include a mandatory carbon or energy tax, but will provide for other market-based approaches, such as an emissions cap with emissions trading among and within nations to permit global implementation of the least cost carbon reductions. Even if the emissions cap and trading approach is the one ultimately taken, the cost of generating electricity from fossil fuels could increase to the point where non-carbon fuel sources, natural gas, demand-side management, and steps to increase power plant efficiencies become more attractive financially and also reduce utility risk. The more stringent air quality regulations now being considered by the U.S. EPA also serve to increase the cost and risk of reliance on fossil fuels for electricity generation, particularly on conventional coal-fired power plants.

Many mechanisms have been discussed to integrate the move toward electric utility industry deregulation with the need to address global climate change and air quality concerns. Some have suggested that cost-effective demand side management, research and development, and renewable energy resources continue to be funded by regulated distribution companies through a “systems benefit charge,” at least until these resources are adequately provided in a fully competitive market. Another option under consideration is to require unregulated generation companies to purchase or produce a specified percent of their electricity from renewable resources. Mandatory disclosure of energy resources, and the emissions they produce, by unregulated generation companies

would allow consumers to select “greener” electric generation resources. Also under discussion is the notion of requiring older power plants to meet new air emissions regulations in order to continue operation. These mechanisms allow the benefits of greater competition to be realized without sacrificing the electric utility industry’s commitment to minimizing resource and environmental costs in the long run.

7. Conclusion

Ten years ago Dr. Wallace S. Broecker of Lamont-Doherty Geological Observatory of Columbia University testified before a Senate Subcommittee that “[T]he inhabitants of planet Earth are quietly conducting a gigantic environmental experiment. So vast and sweeping will be its impacts that, were it brought before any responsible council for approval, it would be firmly rejected as having potentially dangerous consequences.” The experiment he was referring to was the release of greenhouse gases. Dr. Broecker continued that “[A]s these releases are largely by-products of energy and food production, we have little choice but to let the experiment continue.” After reviewing the evidence from polar ice caps and bog mucks, he concludes that the “major responses of the system . . . will come in jumps whose timing and magnitude are unpredictable” and that coping with the change likely to occur will be far more serious than coping with a gradual warming.

Since this testimony was given, the scientific evidence has mounted to the point that the great body of credible evidence now supports the fact that a “discernible human influence” is being exerted on the global climate, and that, unless major reductions in greenhouse gases are achieved, we risk “dangerous interference” with the Earth’s climate system. The impacts of climate change could touch nearly every aspect of our lives and threaten food and water sources, homes and other infrastructure, health, and the natural world around us. Some of the predicted impacts would threaten the future existence of entire nations and human populations.

Is Dr. Broecker correct that we have “little choice” but to let the experiment continue? The significant cuts in fossil fuel necessary to stabilize carbon emissions at what is finally agreed upon as a “safe” level involves major policy initiatives and technological advances in efficiency and new energy sources. The rapid pace of technological advances in electronics, energy systems, synthetics, and biotechnology provides hope that we can reduce emissions of greenhouse gases cost effectively. The more difficult question may be whether we have the political will to reduce our heavy dependence on fossil fuel for our energy needs and to reform current land use, agricultural and forestry practices. New allies—including some insurance companies, renewable energy firms, and island nations—have emerged in the debate over implementing binding agreements to speed the transition to a world that takes climate change seriously. The answer to the question of our political will should become a lot clearer this year, when the parties debate signing an international treaty in Kyoto.

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Appendix A

Summary Table of Actions:

Description of Column Content

The table summarizes the environmental and financial impacts of the actions contained in the Climate Change Action Plan. The table columns contain the following information.

Action Number: This is a reference number used for the actions throughout the Plan.

Title: The name of the action.

Federal Outlay 1994-2000 (millions of nominal dollars): The Federal budget outlays for fiscal years 1994 through 2000 necessary to implement the option. Note that the dollar values listed in this column are not adjusted for inflation. Note: All other financial columns present values in undiscounted 1991 dollars.

Private Capital Investment 1994 - 2000 (millions of undiscounted 1991 dollars): Investment by the private sector associated with each action for calendar years 1994 through 2000.

Cumulative Value of Energy savings 1994 - 2000 (millions of undiscounted 1991 dollars): The figure shown in this column reflects either the value of energy saved or the change in fuel costs due to additional usage of low- or no-carbon fuels. Explanatory notes for individual actions are provided as necessary.

- For actions that save energy, the column shows the cumulative dollar value of the energy saved during calendar years 1994 through 2000 as a result of investments made during 1994 through 2000.

- For actions that cause additional use of low- or no-carbon fuels, the column shows the cumulative fuel costs differential for calendar years 1994 to 2000 as a result of using the low- or no-carbon fuel as compared to the reference fuel.

Cumulative Value of Energy Savings 2001-2010 (millions of undiscounted 1991 dollars): The concept of energy savings is the same as that reported in the previous column. Note that only those energy savings resulting from investments made in the 1994 to 2000 period are reported. Some of the actions will spur additional investments during the period 2001 to 2010., The energy savings from these additional investments are *not* reflected in this column.

GHG Reductions in 2000 (MMTCE): This is the amount the action lowers greenhouse gas (GHG) emissions compared to the reference case in the year 2000. Reductions are measured in millions of metric tonnes of carbon equivalent (MMTCE). The Global

Warming Potential (GWP) index is used to compute carbon equivalents for other greenhouse gases.

Post-2000 Emission Reduction Potential: This column provides qualitative information on the long-run emission reduction potential of the actions in the plan. The number of stars reflect the ratio of expected outyear GHG reductions to GHG reductions project for 2000. The higher the ration, the more stars are reported.

Summary Table of Actions

Action #	Title	Federal Obligation FY1994-2000 in \$millions	undiscounted 1991\$(millions)		Cumulative Value of Energy Savings: 2001-2010	GHG Reductions in 2000 (MMTCE)	Post-2000 Emission Reduction Potential
			Private Capital Investment 1994-2000	Cumulative Value of Energy Savings: 1994-2000			
	COMMERCIAL DEMAND						
1	Coordinate DOE Rebuild America & EPA Energy Star Buildings	\$190	\$6,300	\$2,800	\$11,900	3.1	*
2	Expand EPZ's "Green Lights" Program	\$98	\$3,300	\$1,900	\$8,100	2.5	
	<u>Development, Commercialization, and Training</u>						
3	Establish State Revolving Fund for Public Buildings	\$55					
4	Expand Cost-Shared Demonstration of Emerging Technologies	\$60	\$2,500	\$1,000	\$4,400	1.1	**
5	Establish Energy Efficiency and Renewable Energy Information and Training Programs	\$42	\$8,400	\$2,900	\$12,300	3.8	*
	Commercial Demand Combined Results	\$445	\$20,500	\$8,600	\$36,700	10.6	
	RESIDENTIAL DEMAND						
6	<u>Appliance Improvements</u>	\$193	\$19,500	\$9,400	\$40,700	11.9	**
7		\$0					

Action #	Title	Federal Obligation FY1994-2000 in \$millions	undiscounted 1991\$(millions)			GHG Reductions in 2000 (MMTCE)	Post-2000 Emission Reduction Potential
			Private Capital Investment 1994-2000	Cumulative Value of Energy Savings: 1994-2000	Cumulative Value of Energy Savings: 2001-2010		
	From “Golden Carrot” Market Pull Partnerships						
	Enhance Residential Appliance Standards						
	<u>Home Improvements</u>						
8	Promote Home Energy Rating Systems and Energy Efficient Mortgages	\$12					
9	Expand “Cool Communities” Program in Cities	\$12	\$11,700	\$5,400	\$21,600	4.4	*
10	and Federal Facilities	\$87					
11	Upgrade Residential Building Standards	\$93					
	Create Energy Efficiency Programs and House Technology						
	Residential Demand Combined Results	\$397	\$31,200	\$14,800	\$62,300	16.3	

For Post-2000 Emission Reduction Potential, (*) reflects static or moderately increasing outyear reductions relative to the projected year 2000 emissions reduction. (**) reflects a 50% or greater increase in projected annual emission reduction over the 2000 level, and (***) reflects increases in projected reductions of more than 200%.

Sources: The greenhouse gas emissions estimates for 1990 are taken from “Emissions of Greenhouse Gases in the United States, 1985-1990” (EIA, 1993) and “Anthropogenic Methane Emissions in the United States, Estimates for 1990” (EPA, 1993). Nitrous Oxide emissions from agriculture were provided by the U.S. Dept of Agriculture. Interpolations and projects are based on analyses conducted by DOE, EPA and the Dept of Agriculture for the Climate Change Action Plan.

Summary Table of Actions

Action #	Title	Federal Obligation FY1994-2000 in \$millions	undiscounted 1991\$(millions)		GHG Reductions in 2000 (MMTCE)	Post-2000 Emission Reduction Potential
			Private Capital Investment 1994-2000	Cumulative Value of Energy Savings: 1994-2000		
	INDUSTRIAL DEMAND					
	<u>Accelerated Efficiency</u>					
	Create a “Motor Challenge” Program					
12	Establish industrial “Golden Carrot” Programs for Industrial Air Compressors,	\$30	\$4,000	\$5,300	\$17,000	8.8
13	Pumps, Fans and Drives	\$14	\$600	\$1,300	\$7,800	2.9
14		\$71				***
15	Accelerate the Adoption of Energy-Efficient Process Technologies including the Creation of One-Stop Shops	\$27	\$160	\$280	\$960	0.5
	Expand and Enhance Energy Analysis and Diagnostic Centers					
16						
17	<u>Pollution Prevention</u>	\$86	\$90	\$5,400	\$31,100	14.2
18	Accelerate Source Reduction, Pollution Prevention, and					**

Action #	Title	undiscounted 1991\$(millions)				GHG Reductions in 2000 (MMTCE)	Post-2000 Emission Reduction Potential
		Federal Obligation FY1994-2000 in \$millions	Private Capital Investment 1994-2000	Cumulative Value of Energy Savings: 1994-2000	Cumulative Value of Energy Savings: 2001-2010		
	Recycling						
	Reduce Use of Fertilizers	\$19	n/a	\$1,900	\$9,000	2.7	*
	Reduce Use of Pesticides	\$0					
	Industrial Demand Combined Results	\$247	\$4,850	\$14,180	\$65.,860	19.0	
	TRANSPORTATION DEMAND						
19	Reform Federal Tax Subsidy for Employer-Provided Paring	(\$2,223)					
20	Adopt a Transportation System Efficiency Strategy	\$89	n/a	\$15,900	\$30,000	6.6	*
21	Promote Greater Use of Telecommuting	\$0	\$0				
22	Develop Fuel Economy Labels for Tires	\$2	\$2,200	\$2,700	\$1,200	1.5	*
	Transportation Demand Combined Results	(\$2,132)	\$2,200	\$18,600	\$31,200	8.1	

For Post-2000 Emission Reduction Potential, (*) reflects static or moderately increasing outyear reductions relative to the projected year 2000 emissions reduction. (**) reflects a 50% or greater increase in projected annual emission reduction over the 2000 level, and (***) reflects increases in projected reductions of more than 200%.

Note: Combined GHG reductions might not equal the sum of the individual actions due to synergistic effects.

Summary Table of Actions

Action #	Title	undiscounted 1991\$(millions)				GHG Reductions in 2000 (MMTCE)	Post-2000 Emission Reduction Potential
		Federal Obligation FY1994-2000 in \$millions	Private Capital Investment 1994-2000	Cumulative Value of Energy Savings: 1994-2000	Cumulative Value of Energy Savings: 2001-2010		
	ENERGY SUPPLY						
	<u>Enhanced Natural Gas Utilization</u>						
23	Increase Natural Gas Share of Energy Use through Federal Regulatory Reform	\$0	\$0	\$1,900	(\$260)	2.2	*
24	Promote Seasonal Gas Use for the Control of Nitrogen Oxides	\$0	(\$930)	(\$460)	(\$940)	2.8	***
25	Commercialize High-Efficiency Gas Technologies	\$62	\$140	\$70	\$630	0.6	
	<u>Enhanced Renewable Commercialization</u>						
26	Form Renewable Energy Market Mobilization	\$432	\$50	\$280	\$1,100	0.8	***
27	Collaborative and Technology Demonstrations	\$39	n/a	\$1,500	\$4,300	1.4	
	Promote Integrated Resource Planning						
28	<u>Improve Performance of Existing Zero Emissions Tech.</u>	Leasing (\$480)	\$1,500	\$550	\$2,500	2.0	

			undiscounted 1991\$(millions)				
Action #	Title	Federal Obligation FY1994-2000 in \$millions	Private Capital Investment 1994-2000	Cumulative Value of Energy Savings: 1994-2000	Cumulative Value of Energy Savings: 2001-2010	GHG Reductions in 2000 (MMTCE)	Post-2000 Emission Reduction Potential
	Retain and Improve Hydroelectric Generation at Existing Dams						
	<u>Improved Energy Efficiency</u>						
29	Accelerate the Development of Efficiency Standards for Electric Transformers	\$0	\$480	\$280	\$600	0.8	
30		\$4					*
31	Launch EPA's "Energy Star Transformers"	\$0	(\$5)	\$270	\$1,040	0.8	
	Reduce Electric Generation Losses Through Transmission Pricing Reform						
	Energy Supply Combined Results	\$57	\$1,235	\$4,390	\$8,970	10.8	
	METHANE REDUCTION AND RECOVERY ACTIONS						
32	Expand "Natural Gas Star"	\$6	\$60	\$100	\$110	3.0	*
33		\$0	n/a	n/a	n/a	4.2	*
34	Increase Stringency of Landfill Rules	\$6	\$180	\$140	\$270	1.1	*
35	Expand Landfill	\$8	\$80	\$90	\$160	2.2	**

Action #	Title	Federal Obligation FY1994-2000 in \$millions	undiscounted 1991\$(millions)			GHG Reductions in 2000 (MMTCE)	Post-2000 Emission Reduction Potential
			Private Capital Investment 1994-2000	Cumulative Value of Energy Savings: 1994-2000	Cumulative Value of Energy Savings: 2001-2010		
36	Outreach Program	\$17	\$200	\$120	\$810	1.5	***
37	Launch Coalbed Methane Outreach Program	\$9	\$200	\$80	\$420	1.0	***
38		\$19	\$140	\$120	\$180	1.5	*
39	Expand 'RD&D for Methane Recovery from Coal Mining	\$28	n/a	n/a	n/a	1.8	*
	Expand "RD&D for Methane Recovery from Landfills						
	Expand AgStar Partnership Program with Livestock Producers						
	Improve Ruminant Productivity and Product Marketing						
	Methane Reduction and Recovery Combined Results	\$93	\$860	\$650	\$1,950	16.31	

For Post-2000 Emission Reduction Potential, (*) reflects static or moderately increasing outyear reductions relative to the projected year 2000 emissions reduction. (**) reflects a 50% or greater increase in projected annual emission reduction over the 2000 level, and (***) reflects increases in projected reductions of more than 200%.

Summary Table of Actions

Action #	Title	undiscounted 1991\$(millions)				GHG Reductions in 2000 (MMTCE)	Post-2000 Emission Reduction Potential
		Federal Obligation FY1994-2000 in \$millions	Private Capital Investment 1994-2000	Cumulative Value of Energy Savings: 1994-2000	Cumulative Value of Energy Savings: 2001-2010		
	HFC, PFC and NITROUS OXIDE REDUCTION ACTIONS						
40	Narrow Use of High GWP Chemicals Using the Clean Air Act and Production Stewardship to Reduce Emissions	\$9	n/a	n/a	n/a	5.0	*
41	Create Partnerships with Manufacturers of HFC-22 to Eliminate HCFC-23 Emissions	\$13	n/a	n/a	n/a	5.0	***
42	Launch Partnership with Aluminum Producers to Reduce Emissions from Manufacturing Processes	\$3	n/a/	n/a	n/a	1.8	*
17	Improve Efficiency of Fertilizer	See Action #17				4.5	*

Action #	Title	undiscounted 1991\$(millions)				GHG Reductions in 2000 (MMTCE)	Post-2000 Emission Reduction Potential
		Federal Obligation FY1994-2000 in \$millions	Private Capital Investment 1994-2000	Cumulative Value of Energy Savings: 1994-2000	Cumulative Value of Energy Savings: 2001-2010		
	Nitrogen Use						
	HFC, PFC and Nitrous Oxide Combined Results	\$26	n/a	n/a	n/a	10.0	
	FORESTRY ACTIONS						
43	Reduce the Depletion of Non-industrial Private Forests	\$4	\$0	n/a	n/a	4.0	
44	Accelerate Tree Planting in Non-industrial Private Forests	\$71	\$40	n/a	n/a	0.5	***
16	Accelerate Source Reduction, Pollution Prevention, and Recycling	see Action #16				5.0	*
9	Expand "Cool Communities" Program in Cities and Federal Facilities	See Action #9				0.5	*
	Forestry Combined Results	\$75	\$40	n/a	n/a	10.0	

For Post-2000 Emission Reduction Potential, (*) reflects static or moderately increasing outyear reductions relative to the project year 2000 emissions reduction.

(**) reflects a 50% or greater increase in project annual emission reduction over the 2000 level, and (***) reflects increases in projected reductions of more than 200%.

			undiscounted 1991\$(millions)				
Action #	Title	Federal Obligation FY1994-2000 in \$millions	Private Capital Investment 1994-2000	Cumulative Value of Energy Savings: 1994-2000	Cumulative Value of Energy Savings: 2001-2010	GHG Reductions in 2000 (MMTCE)	Post-2000 Emission Reduction Potential
Total for Energy Sectors		(\$987)	\$59,985	\$60,570	\$205,030	66.0	
Total for Non-Energy Sectors		\$194	\$900	\$650	\$1,950	42.6	
GRAND TOTAL		(\$793)	\$60,885	\$61,220	\$206,980	108.6	

gap=106.2

Note: Combined GHG reductions might not equal the sum of the individual actions due to synergistic effects.