

The CO2 Newsletter, created, published, and edited by William N. Barbat, ran from 1979 to 1982.

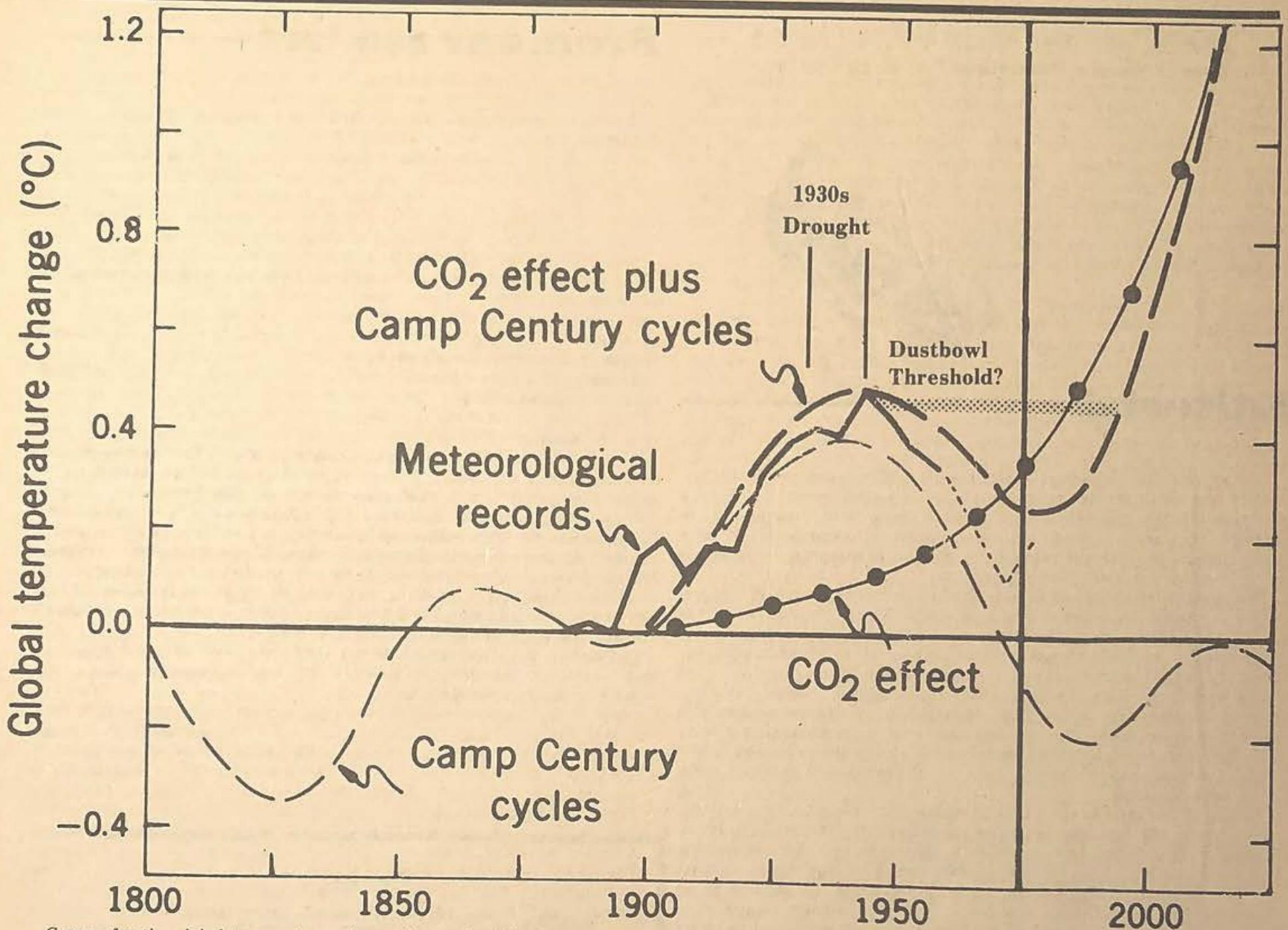
In 2025, the family of Mr. Barbat donated an original set of all issues to Dr. Marc Hudson, and agreed that these could be digitised and placed online as a resource for anyone who wants to understand how long we've known about the carbon dioxide and global warming problem.

CO₂ Newsletter

Volume 1, number 4

April - May, 1980

A bimonthly summary of advances in knowledge of the CO₂-greenhouse problem, and of the social, political, and economic implications.



Curves for the global temperature change due to fossil fuel consumption, natural climatic cycles, and the sum of the two effects, from Wallace Broecker (*Science* 8 August, 1975).

The CO₂ effect is the greenhouse contribution expected from a continued CO₂ buildup based on a 2.4 degree Centegrade temperature rise per doubling. (The 'signal')

The 'Camp Century cycles' represent an extrapolation of the cyclic temperatures reported by W. Dansgaard from paleotemperature data covering the last eight centuries, based on oxygen isotope data measured in the Camp Century (Greenland) ice core. By use of Fourier analysis, Dansgaard and associates found two dominant frequencies, 78 years and 181 years. These cycles appear to be related to sun activity. (The 'noise').

'CO₂ effect plus Camp Century cycles' represents signal plus noise. Actual global temperatures averaged over 5-year intervals, as derived from meteorological records, are shown for comparison, as originally published. Actual world temperatures have been extended here with NOAA temperature data, as determined from radiosonde 'thickness' for the 0-16 km layer (data furnished by James K. Angell, Air Resources Laboratories).

As Broecker reported, "the last half 'cycle' in Greenland is about the same as that recorded by meteorological observations (both give about 1.5 degree Centegrade warming... Also the ice core is roughly in phase with the global change recorded meteorologically... The amplitude of the (cyclic) curve is reduced so that, when summed with the CO₂ effect, it yields a reasonable match to the global temperature curve for the last century (that is, a fourfold reduction due to polar amplification is made).

"The resultant curve obtained by combining the CO₂ effect with the simulated natural curve shows dramatically what will happen if the natural cooling bottoms out and swings into the next warming phase according to the schedule postulated here... This warming should by the year 2000 bring average global temperature beyond the range experienced during the last 1000 years."

The 1930s Drought period has been added to Broecker's graph. The threshold temperature which is estimated here to correspond to temperature-induced drought in the Great Plains region has also been added, and has been labeled 'Dustbowl Threshold'.

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"Loyalty to petrified opinion never yet broke a chain or freed a human soul." — Mark Twain



Editorial

The only feasible method for halting the CO₂ buildup soon — while still permitting large scale mechanization — would place nuclear energy in the dominant role. Whether civilization will be allowed to use nuclear energy on a sufficiently large scale depends on nuclear energy overcoming its military legacy and on an informed public being allowed to make energy decisions rather than socioeconomic lobbying groups.

The impetus for the scientific pursuit of nuclear energy early in this century was clearly the desire to find a substitute for the chemical energy of fossil fuels. Unfortunately, nuclear weapons were developed first because a succession of scientific breakthroughs happened to culminate in the discovery of the fission chain reaction on the eve of World War II.

The world's revulsion at the slaughter of civilian populations by ruthless military dictatorships — which had succeeded democratic governments in times of economic depression — caused many peace-loving scientists to work wholeheartedly to produce the atomic bomb first. The ardent pacifist Albert Einstein was influential in persuading the U.S. government to launch nuclear weapons research.

Adding to the grief in the scientific community over what they had created, a bid by the Japanese for peace was relayed by Josef Stalin to Harry Truman at the Potsdam conference before the bombs were dropped on Hiroshima and Nagasaki. This bid was not followed up by inquiries or a discussion between the combatants of mutually acceptable terms, but by an ultimatum for unconditional surrender and then atomic bombs. (The Japanese reportedly were mostly concerned with being allowed to retain their emperor.)

Much of the present sentiment in the U.S. against the use of peaceful nuclear energy appears to be an attempt to atone that use of military explosives. A public declaration against nuclear plant construction and supporting the suspension of nuclear plant exports, signed by more than 2000 prominent scientists and engineers, was presented to Congress and the President of the United States on the 30th anniversary of the Hiroshima bombing.

It is time to place those bombings and the world's present need for non-fossil energy in perspective. In all, less than 200,000 deaths resulted from the two atomic bombings, whereas 55 million people — including 38 million civilians — died as the result of all the World War II military actions.

Bringing the peaceful nuclear program to a halt in the U.S. and stopping exports of nuclear fuels have not begun to solve the proliferation problem, and such measures may actually be creating military tensions by aiding economic depression.

If civilization should be denied the peaceful use of nuclear energy to halt the CO₂ buildup, the military legacy of nuclear energy would only be compounded.

From our readers

"I would like to receive the 'CO₂ Newsletter' regularly. Thank you for thinking of me.

George E. Brown, Jr.
Member of Congress

(The following letter came to us from its signer, and we wish to share it with our readers.)

Dr. Charles D. Keeling
Scripps Institution of Oceanography
University of California/San Diego
La Jolla, California 92093

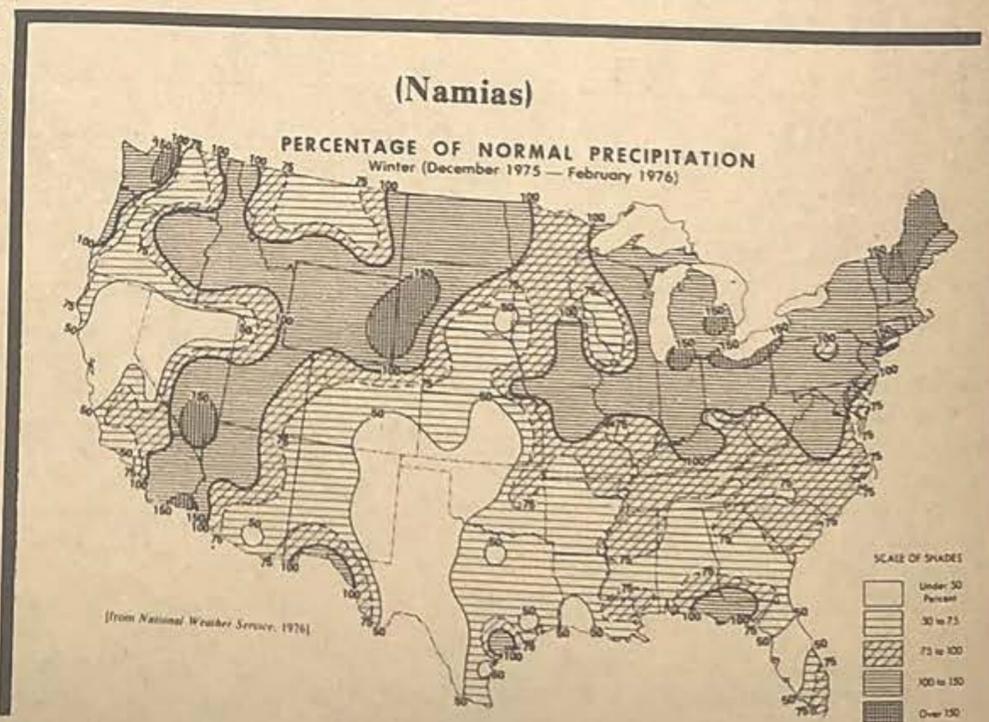
Dear Dr. Keeling:

At a meeting at MIT on "CO₂ and Climate", George Woodwell made the comment that you should receive the Nobel prize. Since I believe that second-hand praise is better than first hand, I am sending this note along.

A group of us in Cambridge are trying to initiate a mechanism to enable the American public and their policymakers, via electronic and print journalism, better to understand the problems associated with energy. With the help of a mountain of verbomass and a lot of free tutoring, I have come to the conclusion that the CO₂ problem may be controlling. If you are at all interested in what we are trying to do, I can send you a draft of a proposal that some of us are putting together.

Do you have any data which is more recent and more legible than appears in -----'s article in -----? I would appreciate receiving anything you think is appropriate.

Yours very truly,
Jerrold R. Zacharias
Educational Development Center
Newton, MA



Why global warming is expected to spread mid-latitude drought

If the CO₂ buildup continues and global warming results, climatologists generally expect a decrease in precipitation throughout much of the U.S. The expectation of general drought in the western half of the U.S. is based on climatic analogues from warm episodes of the historic and geologic past, and on climate models.

The wide climatic belts which encircle the globe approximately parallel to the equator have varied greatly in latitudinal position and width throughout geologic time. As meteorologist Jerome Namias has noted, the short-term fluctuations of climate in the recent past — which have resulted from shifts of these climate bands towards the poles or equator — differ in degree and not in kind from great fluctuations of the past.

Any global temperature rise — no matter what causes it — has been found to be amplified at polar regions. Global warming therefore brings about a decrease in the pole-to-equator temperature gradient, thus causing a decrease in the potential energy of the world's weather-generating system. The climate of tropical regions seems to be affected least by global warmings, whereas precipitation patterns of mid-latitude regions may change greatly with small fluctuations of global temperature.

Natural global warmings of the past have been accompanied by a poleward shift of semi-tropical anticyclone belts whose high pressures generally repel the moisture-delivering cyclonic storms which migrate from polar regions to temperate latitudes. Also those belts often have downdrafts of very dry air. Thus these anticyclone belts are noted for their arid conditions in both the northern and southern hemispheres on the *central* and *western* portions of continental areas. In the semi-tropical anticyclone bands are deserts of the southwestern U.S. and northern Mexico, the Sahara-Arabian-Gobi desert belt, the desert belt of northern Chile, southern Peru, and parts of Bolivia and Argentina, the Namibian Desert, and the Australian Desert.

In contrast, the *eastern* portions of continents are favored by monsoonal rainfall in this anticyclone band. Hence, a global warming may actually bring increased moisture to marginally monsoonal areas.

Climatologists often compare the threatened CO₂-induced warming to the mostly natural 0.6 degree Centigrade temperature rise which occurred in the Northern Hemisphere between 1890 and 1940. (Since 1940 half that rise has been offset by a natural cooling trend.) In discussing the CO₂ greenhouse effect, the U.S. Council on Environmental Quality noted in its First Annual Report (1970): "Associated with rising temperature . . . pronounced aridity gripped the south central parts of Eurasia and North America. This led to the dustbowl conditions and a northward displacement of polar fronts."

In 'Prairie Plants and their Environment, a Fifty Year Study in the Midwest' (1968), J.E. Weaver notes that the 1930s Drought came on gradually over three or four years, and by the summer of 1934 conditions were the severest ever recorded. Drought continued until 1941 with only slight interruptions, causing a great decrease or virtually complete destruction of plant cover in the Great Plains, even on ungrazed fields. Many trees died or were injured in Minnesota, Iowa, Missouri, Oklahoma, northern Texas, Kansas, Nebraska, and the Dakotas due to lowered water tables. Cacti increased greatly on the High Plains, and winddrifted soil choked out short grasses.

The long period of record-breaking temperatures, extremely low humidity, exceptionally high rates of evaporation, high winds, proliferations of grasshoppers, and great dust storms caused more than 300,000 people to emigrate from the Midwest. Many cattle herds were sold off or destroyed in the mid-1930s because of a lack of water, pasture and feed. Great clouds of dust were carried from the High Plains out over the Gulf of Mexico and the Atlantic Ocean.

Some climatologists question whether hemispheric warming was the true cause of the 1930s drought in the Great Plains or whether this was merely a recurrence of cyclic drought. Droughts have been found to recur on the High Plains every 20 to 22 years — following every other sunspot minimum — as Walter Orr Roberts has noted from records dating back almost two centuries. As Roberts predicted, cyclic drought recurred on the High Plains in the mid 1970s. Studies by Namias show that this drought (and the drought conditions of northern California and Nevada) resulted from the 'blocking' of cyclonic storms during the rainy season by a subtropical anticyclone over the East Pacific Ocean. The anticyclone was associated with an abnormally high sea surface temperature anomaly which subsequently became abnormally cool along with the rest of the ocean in the entire northern Pacific.

While the severest year of the 1930s Drought did follow a sunspot minimum in conformance to Robert's observed cyclicality, the 1930s Drought was far more severe and much longer enduring than other cyclic High Plains droughts. The 1930s Drought bears a closer resemblance in its extent and severity to the 'Altithermal Long Drought' as described by Ernst Antevs (1948, 1955), George Frison (1978) and others. (Altithermal is a provincial term which is applied in the western half of the U.S. to the warm period of 4000 to 8000 years ago, while the term Hypsithermal which was introduced by the Italian botanist Chiarugi in 1936 is given priority by climatologists to this episode globally.)

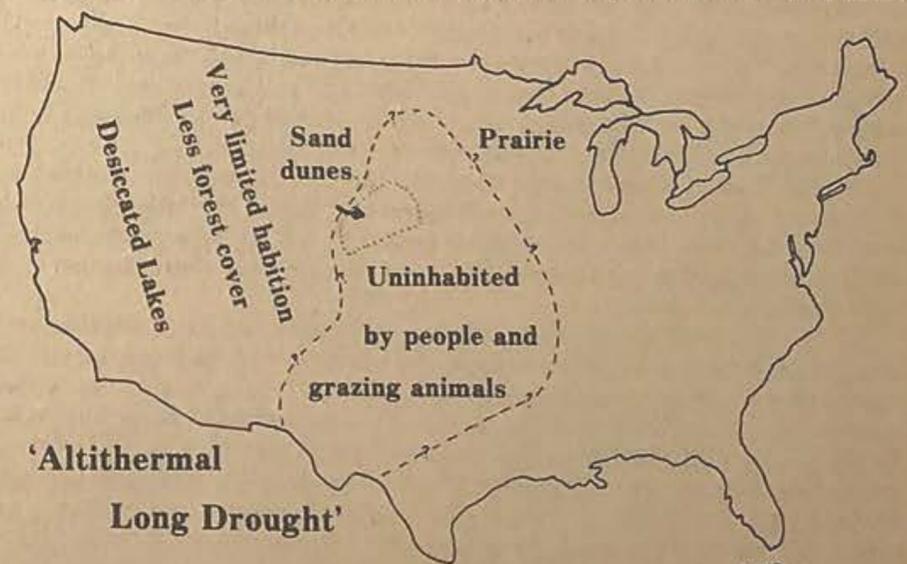
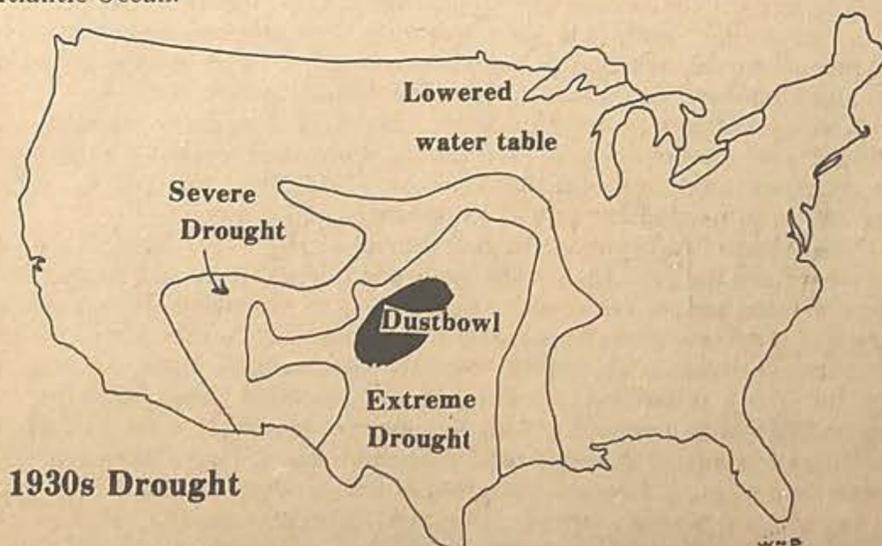
The Altithermal drought conditions are demonstrated to have extended from the Midwest to the Far West by caliche (evaporative) deposits and other desiccated soils, desiccated lakebeds, extensive sand dunes now stabilized by vegetation, and extensive gulleying attributed to lowered water tables. Except for a few archeological finds marginal to mountain uplifts, the Altithermal Age has yielded no remains whatsoever to indicate that man or grazing animals occupied the Great Plains during the Altithermal. Archeological finds from the Great Plains have invariably been dated as having been occupied either before or after the Altithermal. The very arid climate extended from California and Oregon to central Texas and Iowa. Only the high mountains received much precipitation.

At the beginning of the Altithermal, the hunting tribes of the Great Plains are thought to have migrated to the Atlantic coastal region as grazing animals dwindled. After moist conditions returned, occasional droughts apparently kept the overall population small. By the time of Columbus the drought-free areas of Central and South America had about 15 million Amerindians compared to about one million in all of the present U.S.

As the semitropical desert bands moved poleward in the Hypsithermal, some other areas may have become moister. William Kellogg and John Kutzbach have noted that a belt extending from Lake Chad (on the Sahel in Central Africa) through southern Arabia to northwest India was considerably wetter in the Hypsithermal than at present. Also the mild Hypsithermal climate of northern Europe is referred to as the 'Climatic Optimum'.

George I. Smith, head of the U.S. Geological Survey's Climate Program, points out that available paleoclimatological information — accurately dated — is still too sparse to make an integrated assessment of global temperatures of the Hypsithermal.

The global temperature threshold that brought on the 1930s Drought may actually be about the same value as the threshold temperature of the Altithermal. Thus an average global warming of possibly as little as 0.3 degrees Centigrade above present temperature might conceivably turn much of the world's wheat belts — which now border the anticyclone belts — into deserts.



Excerpts from recent reports

On April 3, 1980, the Senate Committee on Energy and Natural Resources, Paul Tsongas, Chairman, held hearings on the CO₂ problem. Testifying were George Woodwell (Woods Hole Marine Biological Laboratory), Gordon J. MacDonald (Senior Scientist MITRE Corporation and Chairman of the JASON group of independent scientists consulting for the government), Wallace Broecker (Lamont-Doherty, Columbia), William Kellogg (National Center for Atmospheric Research), David Rose (MIT), David Burns (AAAS), Gus Speth (Chairman, Council on Environmental Quality), Ruth Clusen (Secretary of Energy for the Environment), and William Hayne (Deputy Assistant Secretary of Environment and Health, Department of State).

The following is from 'Testimony on the impacts of increased carbon dioxide levels in the atmosphere' by Gordon MacDonald. (Excerpts from other testimony will be forthcoming when the transcripts have been printed and made available to the public.)

"... I am honored to appear before you to discuss one of the most critical issues that will confront mankind over the next few decades. . . .

"After some years of disagreements as to the magnitude of the [CO₂-induced] warming, scientists studying the problem have come to an almost universally accepted conclusion that doubling of the carbon dioxide will lead to an average increase of temperature over the surface of the earth of two to five degrees centigrade and that this increase will be accentuated by a factor of three to five in the higher latitudes.

"While the concentration of carbon dioxide in the atmosphere has changed by only seven percent in twenty years, the change has accelerated year by year as the world continues to increase its use of carbon based fuels by 4.3% compounded annually despite the rapidly escalating costs of these fuels. . . . Most models indicate that the doubling will take place sometime between 2030 and 2050. If coal and synthetic fuels are employed and a high rate of increase of energy use is maintained, the early dates apply. . . .

"The doubling time is used as a convenient date; however climatic changes can be anticipated long before a doubling takes place. A 50% increase in carbon dioxide would raise average temperatures between one and three degrees Centigrade and such an increase could take place as early as 2005 or as late as 2040 depending on future energy use, energy sources and biospheric and ocean responses. . . .

"While we cannot forecast in detail the climate in the coming decades, we can with some confidence predict that there will be significant changes. . . .

"The dilemma we face is of historic proportions. Economies around the world depend on the use of energy derived from carbon based fuels. The continued use of these fuels will irreversibly change global climate placing heavy stresses on societies around the world. . . . I would recommend four steps:

"1) Consideration of the carbon dioxide problem should be an integral part of the development of energy policy both in the United States and abroad. Scientific uncertainties will always be present and it will take between ten and twenty years before warming due to carbon dioxide can be detected against natural fluctuations in climate. By that time, commitments by industrialized countries to coal and synthetics could only be reversed at substantial economic loss.

"2) The Executive Branch in its energy planning should reconsider the relative contributions of conservation and solar energy to meet energy needs both here and abroad. Further consideration should be given to enhanced use of natural gas which generates significantly less carbon dioxide per unit of energy delivered than other carbon based fuels and which at present is demand rather than supply limited. The future role of nuclear energy, which does not emit carbon dioxide, should be reconsidered taking full account of the safety and waste disposal problems.

"3) The United States should take the initiative in various international fora such as OECD and the United Nations not only to increase awareness of the carbon dioxide issue, but develop means by which the energy policies of individual countries can be coordinated so as to include consideration of the carbon dioxide question.

"4) The United States in collaboration with other countries should pursue a vigorous research effort to reduce the uncertainties in predicting future carbon dioxide levels and the impact of enhanced levels. At present the lead responsibility for carbon dioxide research is assigned to an office buried fairly deep within the Office of the Assistant Secretary for the Environment within the Department of Energy. Much of the relevant research is funded by other agencies including NSF and NOAA. I believe that research program can be strengthened by giving the responsible DOE office higher visibility. . . ."

From 'Carbon Dioxide Research Progress Report', U.S. Department of Energy, April 1980:

(Executive Summary, Roger C. Dahlman) "It is still unclear how much CO₂ is contributing to the atmosphere from deforestation and other changes in land use. Direct sensing of secular forest changes will be attempted, but it will be some time before it can be determined if the proposed methods meet the required standards of accuracy. . . .

"Preliminary data suggest that temperate forests may act as a sink for CO₂. Information about the slash-and-burn agriculture of the tropics indicates that some storage of carbon in refractory charcoal may be occurring. None of these studies is as yet definitive, but they do indicate that it is too early to accept the hypothesis that land-use practices contribute a significant amount of CO₂ to the air. . . ."

(Carbon Cycle Research, Lester Machta and William Elliott) ". . . The historic growth rate of the release of fossil fuel (plus cement manufacture and flaring of natural gas) has been just over four percent per year. Preliminary data suggest that in the past two or three years there has been a strong tendency toward leveling off, but such changes in long-term trends have occurred in a few previous periods. . . .

"The projections made by IEA, however, suggest that annual energy usage over longer time spans will continue to grow, and in one estimate for the year 2025 A.D., the annual release of CO₂ from fossil fuel combustion would be almost four times the 1975 values. . . .

"None of the trends based on data collected during the past year differ significantly from those of the past. Those (CO₂ monitoring) stations with records extending backward in time for over 10 years exhibit a larger year-to-year increase in more recent periods than in earlier times. In fact, an analysis of the Mauna Loa record suggests that the growth rate can be explained without a net biospheric source of CO₂. . . .

"Their (Institute of Tropical Forestry in Puerto Rico and Cornell University) work also suggests that slash-and-burn agriculture may result in a net transfer of carbon from living vegetation to the soil or large boles (dead tree trunks or large branches). They tentatively believe that man's activities may make tropical forests a net sink for atmospheric carbon rather than a source, as is usually thought. . . . They find data somewhat variable throughout the world, but reach the conclusion that extratropical forests may be storing carbon at a rate nearly 20 percent of the current fossil fuel emission."

From testimony of Stephen H. Schneider, National Center for Atmospheric Research given before the CO₂ Symposium of the Senate Committee on Governmental Affairs, Abraham Ribicoff, Chairman, July 30, 1979:

"... in what I have read I have seen estimates (of making the West Antarctic ice sheet unstable) ranging from decades to centuries depending upon which process created the breakup. It is very, very hard to say, but we may be committing ourselves to the initiation of this process as soon as the end of the century — if you neglect uncertainty and accept climate model estimates of a five degree Centigrade polar warming. The process of breakup could begin. We would then over decades and centuries, watch it happen and not be able to do anything about it. That is a definite possibility. . . .

"I was asked by a reporter at the meeting of the American Association for the Advancement of Science last January what was the most striking thing to me about the evolution of the CO₂ issue. I think the most striking thing is we have yet been unable to make it go away in our models.

"The reason it is beginning to gain attention now . . . is that we have tried as we refined the processes in the models to find out if the old estimates are true or false, and we keep coming out about the same place. Of course, there are still some crucial assumptions that are rooted in these models, that they all share in common. That is why we have uncertainties and speak cautiously. But there is no real threshold in the scientific sense when the CO₂ estimates will be accepted as fact. It is more or less when we can't make the problem go away, that people tend to accept it more. That I think is why you have seen so much interest and groundswell of concern over CO₂. It is that many of those of us who are skeptical and try to make the CO₂ effect go away scientifically have had trouble doing so."

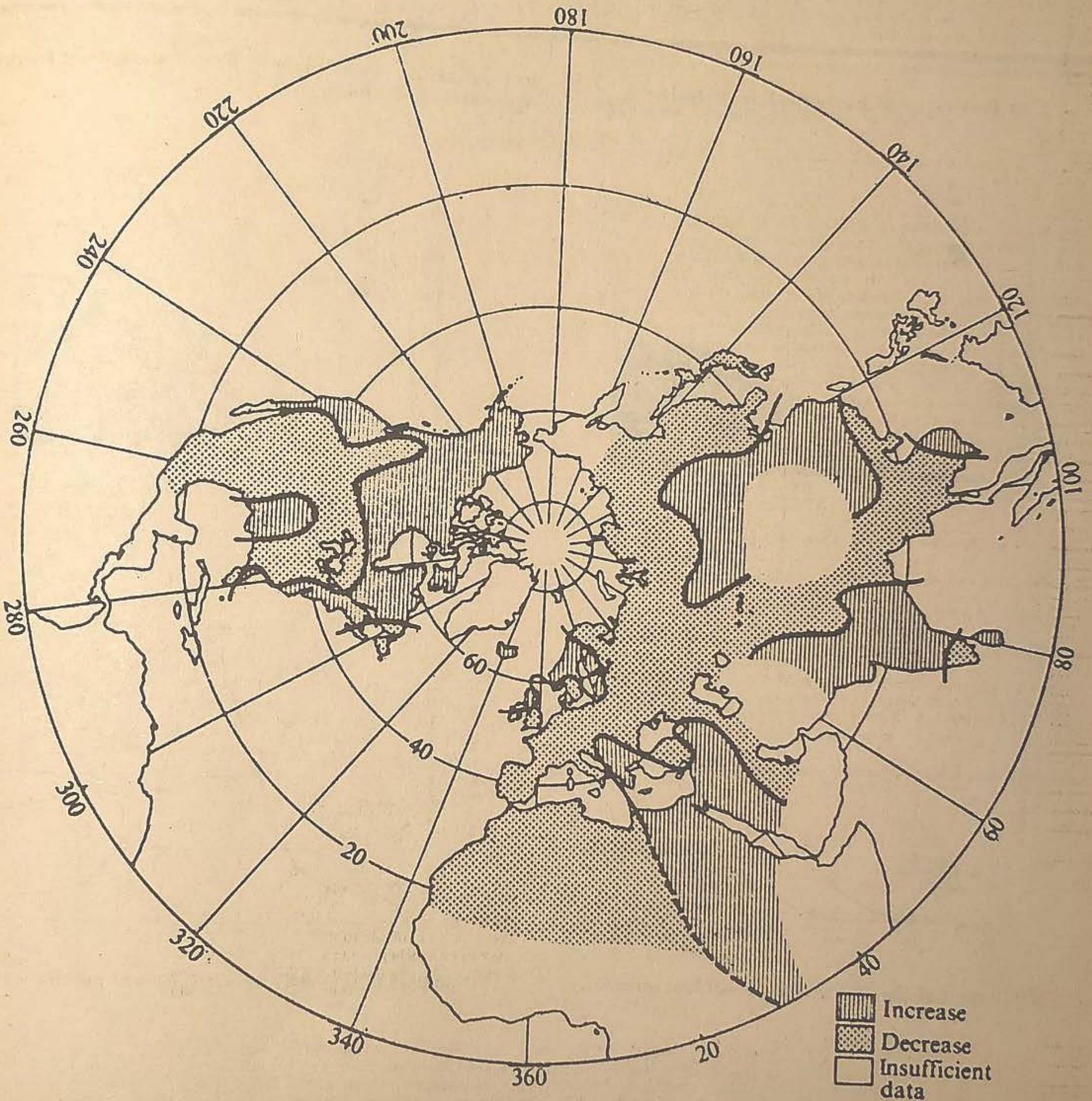
From 'Scenario for a warm, high-CO₂ world', T.M.L. Wigley, P.D. Jones & P.M. Kelly, Climatic Research Unit, University of East Anglia, Norwich, UK, *Nature*, 3 January 1980:

"Plausible patterns for temperature and precipitation changes accompanying a general global warming, such as might occur due to a large increase in atmospheric carbon dioxide levels, are presented. The patterns are determined by comparing the five warmest years in the period 1925-74 with the

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five coldest in this period. Temperature increases are indicated for most regions, with maximum warming over northern Asia. A few isolated regions show cooling. Precipitation changes are fairly evenly distributed between increases and decreases; the most important features being an increase over India, and decreases in central south-central USA and over much of Europe and Russia. The latter decreases, should they occur, could have considerable agricultural impact." - Abstract.

Mean annual precipitation changes from cold to warm years.



(from 'Scenario for a warm, high-CO₂ world', by T.M.L. Wigley, P.D. Jones & P.M. Kelly, *Nature* 3 January 1980).

From 'How long is coal's future?', by Ralph M. Rotty and Alvin M. Weinberg, in *Climate Change*, volume 1 number 1, March 1977:

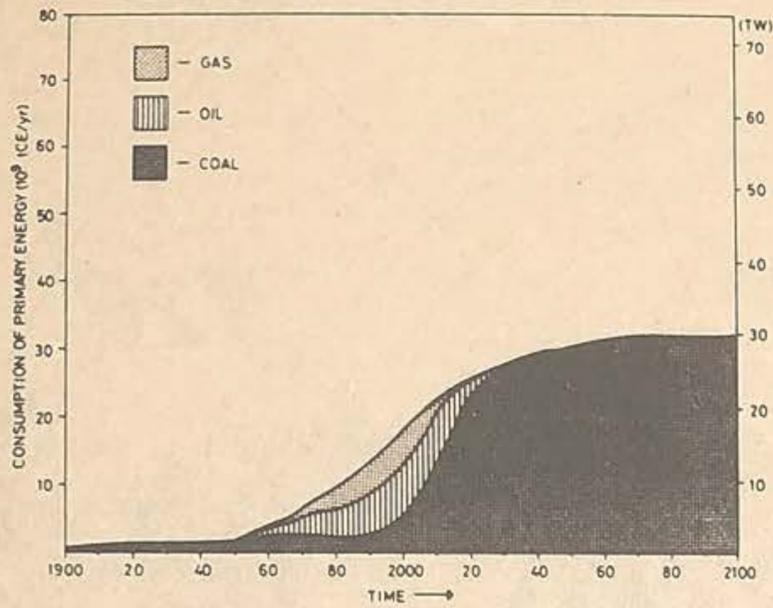
"If one examines other predicted disasters — ozone depletion, catastrophic reactor accident, perhaps even nuclear war — one must admit that the serious climate shifts caused by CO₂ may be at least as likely as these, and more likely than some of them. What is so surprising and alarming is Niehaus' projection that CO₂ concentration reaches 475 ppm by A.D. 2050, even if we allow consumption of fossil fuel to peak at little more than twice its present value by A.D. 2000. Even the most conservative world energy scenarios do not project increases of this order — that is, growth of less than 3% per year to A.D. 2000.

"Perhaps the most disturbing aspect of the CO₂ problem is that the ocean reservoirs restore the CO₂ in the atmosphere to equilibrium only after hundreds of years. Thus there is serious possibility of the society's putting CO₂ into the atmosphere in amounts that we later discover cause undesirable climatic change. Because of the long recovery time, this climatic imbalance might be with us for centuries.

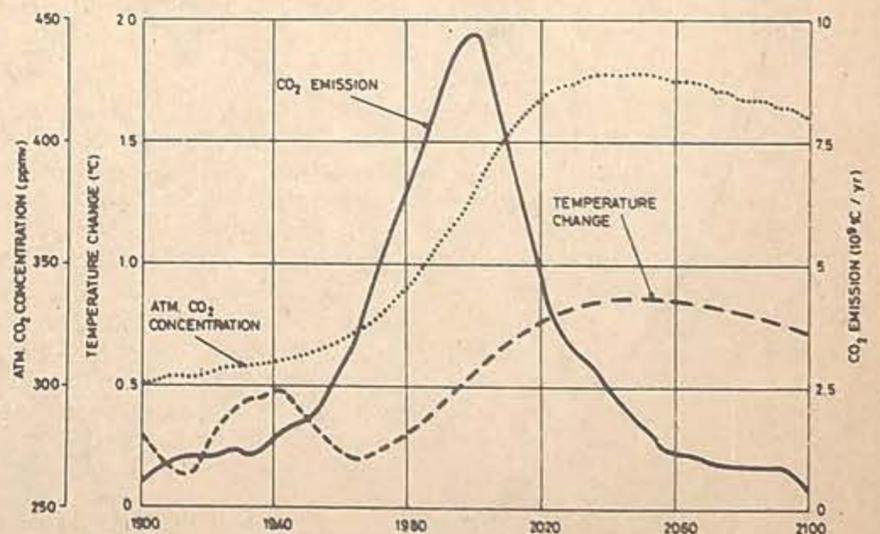
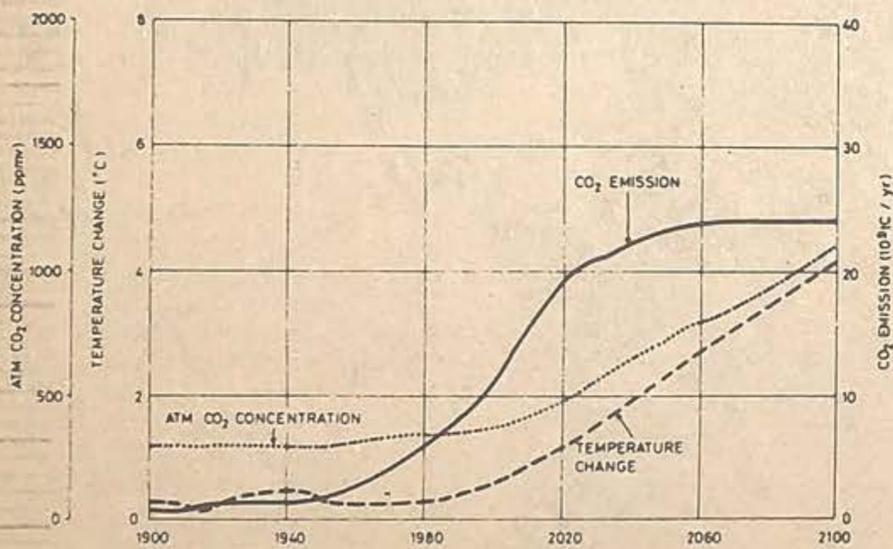
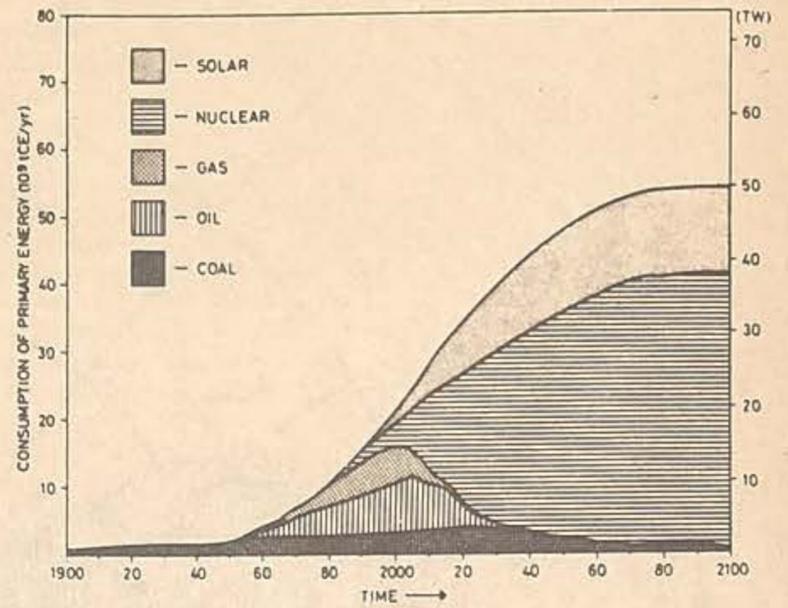
"What would the world do if, say 10 years from now, an international panel of distinguished climatologists proclaimed that the concentration of CO₂ places serious limits on the amount of energy man can generate from fossil fuel each year — possibly to no more than the present level or less?"

"We would first try to conserve energy; but conservation for the United States with an annual per capita production of 350 X 10⁶ Btu is a much easier proposition than is conservation for the rest of the world, which uses about 50 X 10⁶ Btu/capita. It is inconceivable that the developing countries will remain content with the pittance of energy now allotted them; it is equally unlikely that the developed countries will reduce their energy consumption sufficiently in such a short period. We would thus be forced to examine the non-fossil options, not as matters of choice, but as matters of urgent necessity. This CO₂ Sword of Damocles, if indeed it exists, requires development of solar (including its children — wind, ocean thermal, etc.) fission, fusion, and geothermal, much more quickly than is generally recognized.

30 Terawatt scenario with all fossil fuels



50 Terawatt energy scenario with solar and nuclear energy supplanting fossil fuels.



CO₂ impact of the 30 Terawatt fossil fuel scenario.

CO₂-impact of the 50 Terawatt solar and nuclear scenario.

From F. Niehaus, (1979) (Reprinted in "Carbon Dioxide Accumulations in the Atmosphere, Synthetic Fuels and Energy Policy", A Symposium held by the Senate Committee on Governmental Affairs, July 30, 1979.

From: 'The Problem of Carbon Dioxide', by F. Niehaus, *IAEA Bulletin*, volume 21, number 1 (1979):

"Decisions on further energy supply systems should be made with regard to the alternatives available. Therefore, information is needed on the risks and benefits of these systems. The risks of nuclear power have been discussed at great length; in this discussion, nuclear power has played the role of a symbol expressing concern about technological development in general.... However, to arrive at rational decisions, nuclear power has to be seen in perspective, i.e., with regard to the benefits and risks of the alternatives. One of the risks of possible long-term global concern is the emission of carbon dioxide (CO₂) from fossil fuel consumption....

"The principal risk of an increase in atmospheric CO₂-concentration is its impact on the radiation balance of the atmosphere, the so called 'greenhouse' effect.... As the reflectivity (albedo) of the atmosphere is about 29%, the theoretical equilibrium temperature can be calculated as -19°C, or 34°C less than the observed average of about +15°C. This is important difference, which is necessary for life on earth, is caused by the fact that the at-

mosphere provides a window (48% transparent) for the incoming solar radiation but absorbs (20% transparent) the infrared radiation emitted from earth's surface....

"Models simulating this behavior of the atmosphere have been used to calculate the effect of a change in carbon dioxide concentration. All calculations agree quite well that the temperature increase due to a doubling of atmospheric CO₂-concentration will be about 2°C and 3°C, depending on assumptions about other parameters....

"The temperature change decreases with altitude and even becomes negative beyond a height of about 10 km.... This relationship has been a point of great confusion in the past as it has been pointed out... that today's CO₂-concentration would already absorb 98.5% of the radiation in the relevant absorption bands. This led to the wrong conclusion that the CO₂-effect would be minimal. However,... although this is true for the total atmosphere, a significant warming occurs in the lower troposphere because for a doubling of CO₂-concentration only half the pathlength is required for the same absorption."

What would be needed to bring the CO₂ buildup to a halt

Many scientific uncertainties still exist concerning the thermal effects of increased CO₂, the uptake and loss of CO₂ by the biosphere and oceans, and the potential temperature thresholds at which climate change may take place or at which ice sheets may become unstable. These uncertainties are being narrowed as CO₂-related research accelerates.

For environmental analyses and long range energy-planning, it is desirable that these uncertainties be translated into comparative risks and tradeoffs in a systematic manner. In particular, when studies are published such as those by S.B. Idso (*Science* 28 March 1980) and R.E. Newell and T.G. Doplick (*Journal of Applied Meteorology*, 1979), which suggest that the existing scientific consensus about the global thermal response to a CO₂ doubling should be reduced by about a factor of ten, such radical departures from the consensus must be factored in. If a CO₂ doubling should produce a global average warming of only ¼ degree Centigrade, as these workers suggest, then halting the CO₂ buildup before the temperatures of the 1930s are reproduced would not present a difficult challenge. However, as Stephen Schneider of the National Center for Atmospheric Research notes, Newell and Doplick's surface energy budget response requires that air temperature and humidity remain fixed over the evaporative surface of the ocean as it receives energy. This hypothesis maximizes the energy which leaves the ocean surface and thereby minimizes the calculation of surface warming. Until real world evidence shows that air temperatures and humidity do not rise to an equilibrium value—and thereby provide a warming feedback—planners are likely to assign a much higher probability to conventional models.

Schneider also notes that Idso's basic model treats a non-closed energy system which permits unmeasured energy to flow in and out laterally. Therefore, until Idso's experiments can be performed simultaneously at many symmetrically-spaced stations throughout the world, or until the total energy flow can be accurately measured at a single station, planners are likely to continue basing decisions on conventional models which treat closed

energy systems.

Nevertheless, these works are valuable in pointing out that certain assumptions and limitations necessarily exist in all theoretical models. Only with continual questioning and scientific feedback can the best technical assessments of CO₂ effects be arrived at.

Presently the consensus estimates of greenhouse warming provide some very sobering expectations of environmental impacts. It may not be humanly possible to halt the CO₂ buildup before a ½ degree warming occurs, which might mean that Hypsithermal or Dustbowl conditions cannot be headed off, and sea level may rise three meters at eventual equilibrium.

To halt the CO₂ buildup before a one degree Centigrade warming occurs may be a formidable task. Broecker correlates a one degree Centigrade rise with climatic conditions which prevailed at the warmest time of the last interglacial, when sea level was about six meters higher than present. Niehaus has described an energy mix which is estimated to be able to halt the CO₂ buildup slightly below that level (see the accompanying graphs). This scenario calls for fossil use to peak at twice the present value by 2000 and requires that by 2010 non-fossil sources provide as much energy as is consumed today over the entire world.

Energy and environmental planners in the U.S. have only a few alternative courses to choose between:

- 1) Postpone the decision to halt the CO₂ buildup (inaction itself may be a form of action);
- 2) Deliberately allow the CO₂ buildup to continue (slowing the rate of buildup would delay impacts only a short while);
- 3) Halting the CO₂ buildup by eliminating all fossil-fuel use and substituting solar, wind, hydroelectric, and animal power;
- 4) Instituting a highly accelerated nuclear energy program to replace fossil fuels. The program would need to develop recyclable chemical fuels for airplanes, trucks and tractors. It would have to provide electrified mass transit on a massive scale. Companies might have to be assisted to turn out

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battery-operated autos competitively and profitably in place of gasoline powered cars. Industry might have to be assisted to convert to non-fossil sources of process heat, as by replacing coal-fired steel-making furnaces with electric crucibles.

The public would need some straightforward answers before deciding on the nuclear option.

- Would there be enough fuel?
- What are the radiation risks?
- What are the safety risks?
- What are the proliferation risks?
- What about waste disposal?
- How do costs compare with benefits?

As to fuel availability, an intensive worldwide search would be needed to provide uranium. Recycling of spent fuel would be needed to utilize remaining fissionable uranium and plutonium (the recoverable plutonium in each ton of spent fuel has energy equivalent to 10,000 tons of coal). Development of the breeder reactor would have to be accelerated.

As to radiation risks, few people realize that an oversight in regulations has allowed the public to receive much more carcinogenic and mutagenic radiation from coal plants than from nuclear plants. The exposure to the public from uranium mill tailings is about 55,000 person-rem per year and from all other aspects of nuclear electric generation about 70,000 person-rem per year. (The public exposure from the Three Mile accident is estimated at 2500 to 5300 person-rem.) In contrast, EPA 520/1-77-009 shows a population-integrated dose rate of 400,000 person-rem per year from large coal ash piles, and EPA-520/7-79-006 shows that coal-fired generating plants are greater sources of radiation exposure than nuclear.

Nuclear plant safety can probably be improved greatly with the aid of

governmental and industry research, as the government of France has found by using the carrot more than the stick. So far the nuclear-electric industry in the U.S. has a zero-death safety record.

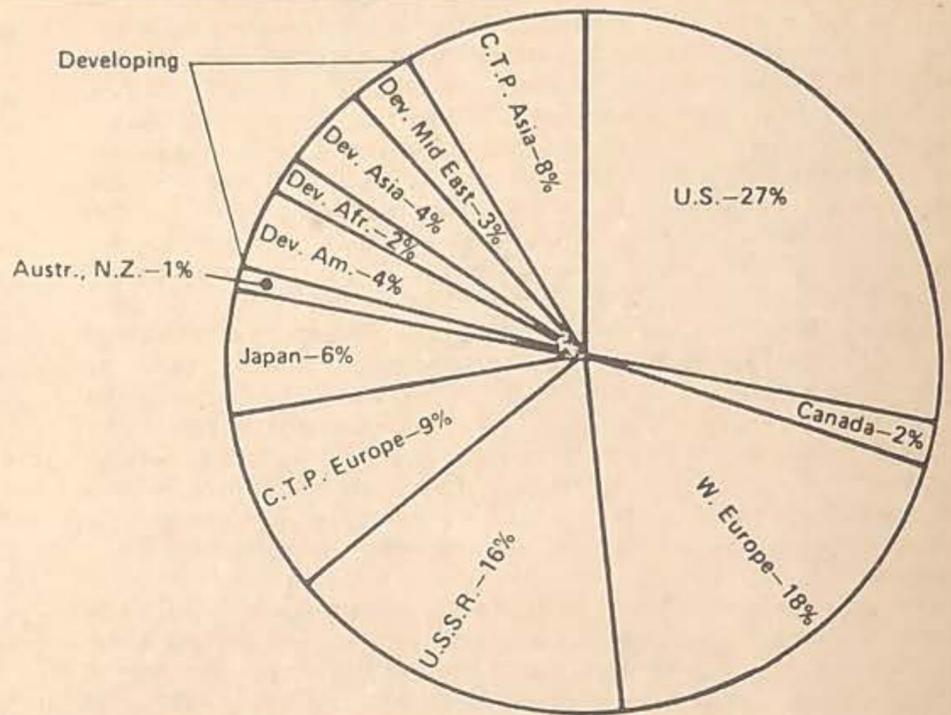
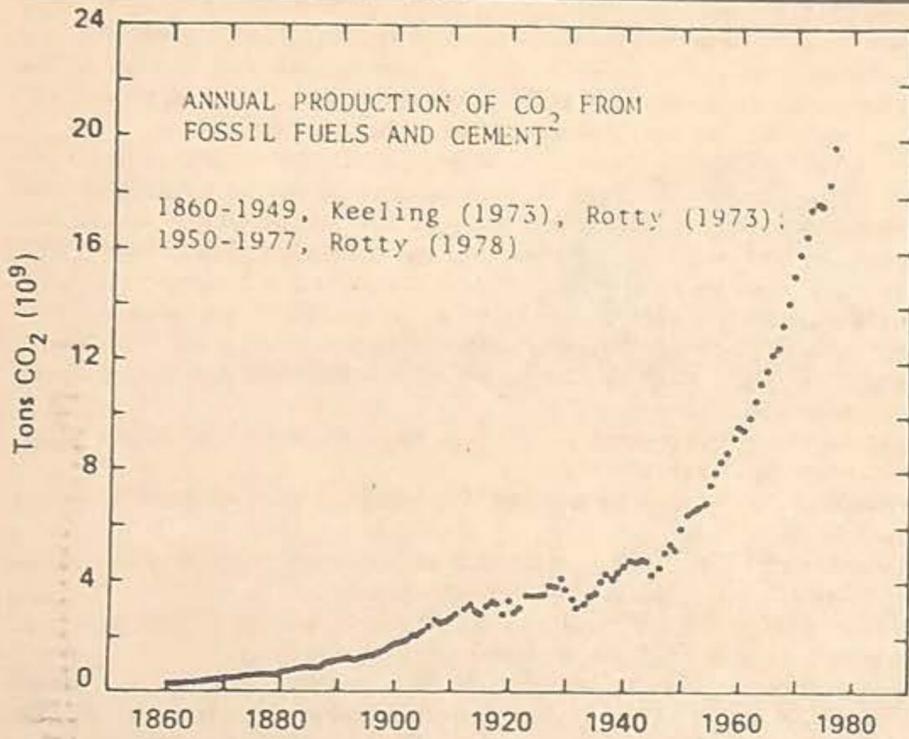
As to nuclear weapons proliferation, the greatest threat today does not come from the countries with nuclear-electric industries but from countries that have no such industry. Power-producing reactors can manufacture military grade plutonium only for a short while at the beginning of each new fuel load. Not long after the fuel has been radiated, unwanted plutonium isotopes are produced in too great a quantity. These isotopes fission spontaneously to make explosive yields very unpredictable.

The cheapest, quickest, most reliable way for a country to produce military grade plutonium for explosives is to employ a special plutonium-breeding reactor which is usually referred to politically as a 'research' reactor. The technology for such reactors has long been available to any country that could afford it. Countries which own 'research' reactors and yet have no nuclear-electric industry are Iraq, Israel, Libya, and South Africa.

As to safe nuclear waste disposal, the current delay in the U.S. program is not caused by a lack of acceptable options, but by having to choose between too many options. Larry Hench of the University of Florida has calculated all the combinations of alternatives that are being considered regarding geologic setting, solid waste forms, buffers and desiccants and found that there are 60,000 different combinations of alternatives.

A large capital investment would be needed for a massive nuclear energy program that has a reasonable chance of halting the CO₂ buildup before a one degree Centigrade warming is caused, amounting to several thousand dollars per person at today's values. Eventually such a program might produce substantial savings. Such a program would require a strong national commitment similar to waging a large-scale war or putting a man on the moon.

- W. N. B.



Global CO₂ production by world segments - 1974

From 'Uncertainties associated with global effects of atmospheric carbon dioxide', Ralph M. Rotty, ORAU/IEA-79-6(0), March 1979.

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