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

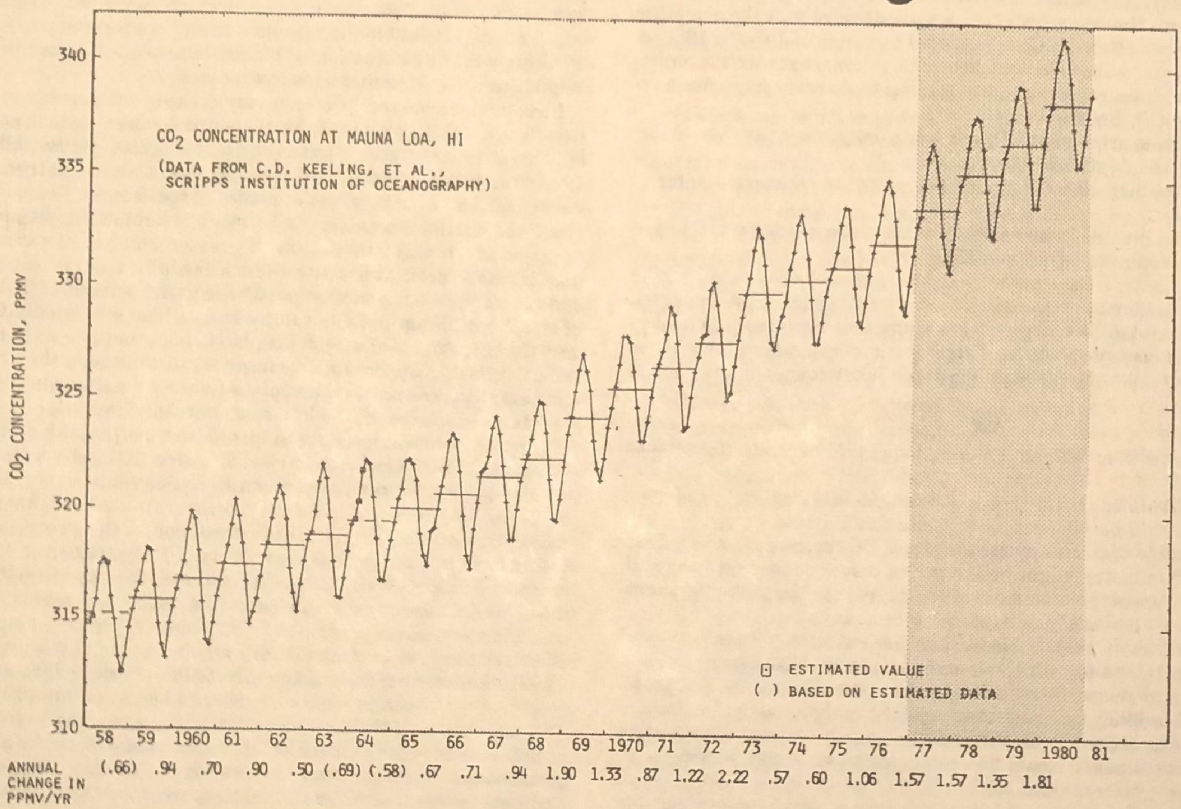
In 2025, the family of Mr. Barbat donated an original set of all issues to Dr. Marc Hudson, and agreed that these could be digitised and placed online as a resource for anyone who wants to understand how long we've known about the carbon dioxide and global warming problem.

CO_2 Newsletter©

Volume 2, Number 1 **Nov.-Dec., 1981**

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

CO_2 Continues Skyward



Hopes that the rate of rise in the atmospheric concentration of CO_2 would decline with greatly increased prices for oil and natural gas so far have not shown up in CO_2 monitoring.

A recent graph of measurements by C.D. Keeling and associates from Mauna Loa air samples is shown here with the shaded portion representing information added to the CO_2 graph published in the first issue of the **CO_2 Newsletter**. The 1980 average concentration of 339 ppmV is 11% higher than the 1958 value of 315 ppmV, and is 17% higher than the estimated CO_2 concentration of 290 ppmV of 1890.

The causes of the observed variations in the annual change (bottom line of figures) are not well understood but may reflect large-scale variations in uptake of CO_2 in response to variations in upwellings of subsurface waters or in rates of exchange at the air-sea boundary. Detailed global monitoring of CO_2 recently begun may evaluate this possibilitly.

The annual down-swings in the Mauna Loa curve show little change over the 23-year period, which suggests that the annual uptake of atmospheric carbon by photosynthesis in the Northern Hemisphere has not changed appreciably in that time.

The Newsletter is grateful to J. Murray Mitchell, Jr. (NOAA) and Fred Koomanoff (DoE) for supplying data.

Antarctic ice shrinks, Arctic warms

George Kukla and Joyce Gavin of the Lamont-Doherty Geological Observatory report that the summer icepack around Antarctica has shrunk since the 1930s and that temperatures in the Arctic have risen.

By comparing satellite pictures to atlases and ship reports, they found that Antarctica's summer ice pack extended about 150 miles further north in the 1930s than in the late 1970s. Also average spring and summer temperatures in the Canadian Arctic and Siberia were 2°F warmer in the mid-1970s than in the mid-1930s, according to an article in the Jan.-Feb. SCIENCE 82 (published December 1981).

Kukla stated that such changes might be explained by vagaries in the weather, but that polar regions were expected to be the first to show the effects of increasing carbon dioxide. V. Ramanthan of the National Center for Atmospheric Research stated, "It is premature to immediately assume it is due to CO_2. But if it continues for another decade, CO_2 might be the cause."

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"Never does Nature say one thing and Wisdom another"

—Horace

Editorial

For many years CO_2 scientists have alluded to political inaction on the CO_2 problem. However, that ball is now decidedly in the scientific community's court after the Congressional hearings of July 31, 1981. A panel of scientists contended that insufficient consensus exists on impacts, timing and desirable countermeasures to warrant immediate action to halt the CO_2 buildup.

Statements from prominent CO_2 scientists (not present at those hearings) illustrate the depth of controversy:

-"We have another 10 to 15 years before we must start planning" (Lester Machta).

-"If the carbon dioxide-induced changes are to be headed off, changes must begin immediately" (William Kellogg).

Our position is that the public should be allowed a voice in making such decisions under uncertainty, for they can expect to be impacted directly or otherwise. We urge all governmental agencies involved in the CO_2-greenhouse problem to distribute understandable brochures and pamphlets to enlighten the public about what is known and what is unsolved.

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Another quote from William Kellogg jogged us to confront a serious problem openly:

-*"We're unlikely to limit the use of fossil fuels. There are vested interests that would be opposed to (a reduction)".*

Can we identify possible opponents of anti-CO_2 measures and analyze their motives? Industry might be the prime suspect based on the venal industrialist stereotype commonly portrayed in the entertainment world. However, our analysis is more optimistic.

-Large petroleum corporations face an extremely rapid rate of capital reinvestment for survival, and even large infusions of outside capital have not reversed the decline of domestic oil supplies. Such companies appear willing to direct that capital to other energy (or to non-energy investments) for a comparable return on investment. Requisites for energy investments would be economies of scale and public acceptance.

-Utilities had been converting rapidly from fossil to nuclear for economic reasons before anti-nuclear activism and the delays and excessive, non-prioritized regulation imposed by governments effectively halted the programs. Many utility companies are installing **new** fossil-fired plants in place of cancelled or delayed nuclear plants.

-Auto manufacturers might oppose restrictions which deter sales of petroleum-fired cars unless they foresee a profitable business in producing alternative transportation forms.

-Companies deriving a large share of revenues from coal (including railroads which haul coal) might understandably oppose the supplanting of coal unless they perceive a profit in some way from an energy shift, as by possibly instituting tax incentives for non-coal investments in energy and by cessation of hidden subsidies such as building grade crossings for coal trains with tax monies.

Less obvious vested interests may create considerably more opposition to anti-CO_2 measures if the measures involve nuclear energy. Fear is a highly marketable commodity; it can raise funds, sell books, increase circulation of periodicals, attract theater patrons, increase viewership, and hold classes of students spellbound. Fear of unfamiliar risks and calamities seems to be more sellable than fear of ordinary hazards which may affect a much greater number of victims. Thus it may be more profitable to dwell on a few potential, latent victims of a sudden large radiation leak than on the great number of instant victims of small petroleum fires and explosions which continually fill morgues and the burn units of major hospitals. A potential earthquake-caused radiation leak may provide a more marketable fear than fear of fires from earthquake-ruptured gas pipes in homes, public buildings and city streets or of a sudden flood from an earthquake-ruptured dam.

Staged demonstrations can provide a marketable form of sensationalism. The recent rise in civil disorders and mob intimidation may be abetted by the publicity given to such events in the name of news coverage. A sense of political power can develop among the participants which is greatly out of proportion to their representation. Extremists from such groups may actually feel justified in thwarting the will of a democratic majority. For instance, the day after the Swiss anti-nuclear initiative was defeated at the polls, a bomb caused $600,000 damage at a nuclear plant site near Basel. People may oppose the siting of a nuclear plant in their vicinity not from fear of the plant itself or of radiation, but from fear of the effects of civil disorders and terrorism.

Whatever opposition may develop to the adopting of practical anti-CO_2 measures—if they involve nuclear energy—might be counteracted effectively by a program of enlightenment of the public about the CO_2-greenhouse problem and by actively seeking support of those businesses which tend to dominate communications with the public.

Feedback

"Dear Bill:

"Last April, I stepped down from my task of USGS Climate Program Coordinator to accept a 6-month Fulbright Research Grant to work in Australia. I returned last month, finding (in the mountain of mail) several copies of the 'CO_2 Newsletter' waiting for me. It now occurs to me that you may want to sent the Newsletter to the new coordinator instead. His name and address is:

"Richard Z. Poore, MS 908
Coordinator, Climate Program
US Geological Survey . . . Reston, VA

"I have, however, enjoyed receiving the Newsletter for the last two years. It is a very handy source of data and ideas gleaned from the diverse places as scientific and engineering journals, governmental records, published books, and thought-provoking letters to (and from) the Editor. Hope you keep it up. I am going to check with our USGS librarian here in Menlo Park to see if we can subscribe, so if you send future copies to Dick Poore instead, I will still have access to the series—just not on a personalized basis.

"Your question on the Hypsithermal (and earlier Sangamon) climates finally prodded me into asking our 'GEOREF" service to make literature searches, using the key words 'Hypsithermal', 'Holocene, early', 'vegetation', and 'climate' for the younger period and 'Sangamon' etc., for the older one. I should have done this (for **my** benefit) long ago. Copies of the printouts are enclosed. By coincidence, today I received a manuscript from a geologist in Australia that reminded me of several additional papers that contain data on the early Holocene conditions in Australia, India, Near East, and Africa that are not included in the GEOREF list. Copies of their cover pages and/or the articles are enclosed.

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"Best regards,
"George I. Smith"

Dear George:

Your comments are greatly appreciated, and we appreciate receiving a subscription order from Menlo Park. However, our unadvertised policy is to send extra copies (within reason) to members of our regular paid subscribers, such as the USGS, at no additional charge.

After making copies for our use, we are forwarding your Holocene references to the U. of Colorado at Boulder, which has recently received a $42,000 grant from DoE to produce an annotated bibliography for Holocene paleoclimatic literature. A similar DoE-funded effort which readers may wish to know about is the compilation and publication of bibliographies on selected subjects on carbon cycles and climate by the Environmental Sciences Division of the Oak Ridge National Laboratory.

Gratefully yours,
Bill (-W.N.B.)

Excerpts from recent reports

From **'Along U.S. coasts old solutions fail to solve beach problems', adapted from a position paper that resulted from the Skidaway Institute of Oceanography Conference on America's Eroding Shoreline held March 25-27, 1981, in Savannah, Georgia, convened by Orrin H. Pilkey, Jr. and James D. Howard (this statement has been signed by 99 participants), published in GEOTIMES December 1981:**

"Widespread erosion is occurring on the U.S. shoreline, and in some areas the rate of erosion has significantly increased in the last 2 decades. Many factors are responsible for coastal erosion, but it is so widespread that sea-level rise appears to be a primary cause. Specific evidence of sea-level rise is indicated by tide-gauge records not only in American waters but throughout the world. Sea-level rise is probably due to melting of ice in high latitudes, and it must be assumed that the rise will continue for decades to come. The National Academy of Sciences recently warned of continued or accelerated melting due to climatic changes related to increasing atmospheric carbon dioxide from consumption of fossil fuels.

"Sea-level rise along the American coast is believed to be about 1 foot per century . . . Shoreline retreat along mid-Atlantic, southeast Atlantic and Gulf sandy barrier coasts tends to be fairly regular and continuous . . . Cliffed shorelines occasionally retreat in catastrophic 'jumps' . . .

"Urbanization and construction on barrier islands, cliffed coasts, beaches, and coastal floodplains of the U.S. have increased markedly in recent years . . . Development of barrier islands on the Atlantic and Gulf coasts has brought about the installation of numerous stabilization structures (seawalls, revetments, groins, etc.) to protect coastal property . . .

"Between 1948 and 1978, California experienced a benign and quiescent period characterized by few storms capable of generating large storm swells or heavy surface runoff . . . Studies of tree rings in Southern California show that it was the longest drought period since the 1520's. With urbanization, the groundwater level has risen along the coast due to extensive watering of non-native vegetation, irrigation, septic tanks, leach lines and cesspools: the equivalent of 50 to 60 inches of precipitation per year. That has added weight to cliff material and contributes to landslides and cliff failures. The failures result in immediate and costly stabilization measures that in turn may greatly accelerate beach erosion.

"Development of the American coastline has led to an endless program to protect investments . . . Many stabilization structures have been used, but the most common are seawalls, rip-rap revetments, groins and offshore breakwaters . . . their performance is poor in protecting communities and municipalities from beach retreat and destruction. Even more damaging, the shoreline structures frequently enhance erosion by reducing beach width, steepening offshore gradients, and increasing wave heights. As a result they . . . eventually help destroy the areas they were designed to protect . . .

"Frequently, the response to continued beach loss is to begin bigger and more expensive 'stabilization' endeavors, which continue to aggravate the problem . . . It seems clear that we cannot proceed with the 'bigger is better' coastal-defense scenarios . . . Our crisis approach to coastal management must end.

"A major shortcoming of design and planning for shoreline stabilization has been the short design-life consideration. Commonly a shoreline erosion problem is considered in a 15- to 35-year context . . . Simple approaches, such as bulldozing sand from the lower beach to the upper beach after storms, have proved unwise. Such a procedure steepens the beach and **increases** the rate of shoreline retreat. Beach-community officials apparently find this impossible to believe and, despite geologic advice to the contrary, continually use this technique.

"**All immediate solutions** should include these principles: (1) sea-level rise and coastal erosion are inevitable, (2) most stabilization and nourishment projects are untenable and indefensible in terms of physical realities, cost/benefit ratios, and escalating budgets, (3) increased public awareness through education is becoming paramount, not only of coastal residents but also of regulatory agencies, legislators, and the general public, and (4) new and, in many cases, sweeping legislation is required to reverse the trend of costly shoreline-management practices . . .

"The general public is unaware that the sea level is rising or that most of the nation's beaches are retreating, whether cliff or barrier island, and that the process is inevitable. For example, few people realize that over the past 150 years rates or erosion on the Atlantic coast have ranged from 1 to 3 feet per year to more than 100 feet per year, as documented by such federal agencies as the U.S. Geologic Survey, National Oceanographic and Atmospheric Administration, and the Corps of Engineers. The likelihood of continued sea-level rise, predicted by the National Academy of Sciences, must be communicated immediately to the public . . .

"Economic estimates are that the long-term debt borne by the nation—especially in view of the federal flood-control act, which is stimulating acceleration of building in the coastal zone—will lead to costs on the order of many billion dollars during the next several decades . . .

"Most current efforts at stabilization should stop now. Obvious exceptions include certain military reservations, industrial complexes, harbor entrances, densely populated urban areas, and selected resort communities with high economic value, with which the general public is not willing to part. Justification for cessation of these efforts hinges on the inevitabilitly of beach-erosion problems, uneconomical cost/benefit ratios, and projected exponential increases in coastal-management budgets, especially on a long-term basis . . .

"As the sea level continues to rise, an artificially stabilized beach becomes more and more out of equilibrium with the sea level. This means that more and more heroic efforts (bigger sea walls) will be needed.

". . .Finally, the solution should include the promise that no more developments be allowed in the same area in the future. . .

"Public funds should not be used for redevelopment after the 'next' storm. Destruction of shoreline development by a storm is essentially the only way that artificial stabilization can be halted or reversed. . .

"Dauphin Island, Alabama, has been affected by 20 hurricanes in this century. Three (1916, 1947, 1979) produced maximum damage at the same place, a location controlled by nearshore bathymetry that focuses stormwave energy. Taxpayers paid millions of dollars for flood insurance for Dauphin Island buildings destroyed by Hurricane Frederick in 1979. We taxpayers have just committed well over $50 million to build a new bridge and to reestablish the major development of Dauphin Island at this most senseless of all locations.

"There is an immediate need for measures to prevent redevelopment after storms. No longer should local, state, and federal governments spend public funds in redevelopment; on the contrary, governments should assume responsibility for the protection of the public (as opposed to private) interest, not recreate an untenable situation or guarantee recurrent destruction of such properties . . .

"Deeds should state hazards, or buyers should sign 'hazard documents', or both . . .

"**It is readily apparent**, from the numerous submerged and stranded jetties, multiple sea walls, and groins now detached from the shoreline, that many stabilization projects have failed. . . Too often those expensive attempts at stabilization occurred because of (1) an engineering solution to problems created by natural processes that was undertaken without considering the magnitude and significance of the process itself, (2) failure to consider how artificial structures affect the environment, (3) failure to measure, describe and accurately interpret processes that occur in the vicinity of the stabilization project, (4) lack of appreciation of the fact that coastlines are systems, not components, and (5) completely ignoring the solid evidence for sea-level rise . . .

"An immediate need exists to determine realistic costs and cost/benefit of shoreline management. Granted, we already may be tied to some programs, but it is not too late to blow the whistle on some and refuse to initiate others. Future cost/benefit studies need to include experienced geologists, economists, and engineers who have no vested interest and who can (1) dig out subtle realities of hidden costs, (2) put into their estimate the role of sea-level rise and (3) apply state-of-the-art knowledge of coastal processes."

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From **'Climatic Changes and Food Production: Observations and Outlook in the Modern World', by H.H. Lamb, presented at the 24th International Geographical Congress in Tokyo, 1980, and published in GEOJOURNAL (Wolf Tietze, Editor-in-Chief, Akademische Verlagsgesellschaft, Weisbaden) 1981:**

"During the first sixty years of this century it was generally supposed that for all practical purposes climate could be taken as constant . . .

"The supposition that climate in modern times could be taken as constant had been in sharp contrast to the attitudes of most previous generations to mankind.

"Stabilization was introduced at the 1935 Conference of the old International Meteorological Organization . . . which recommended use of the observations of the years 1901-30 as the 'climatic normal period' . . . In due course, the next 30-year period, 1931-60, was substituted as the 'new climatic normal period', and the statistics were different. We

know now that both periods were highly **abnormal** in terms of the experience of the past thousand years, on a global view probably the warmest time of such long duration for 600 years or more past.

". . . One is . . . now forced to take some view as to the likelihood or otherwise of the climate becoming altered by side-effects of Man's activities.

". . . From about the 1890s, for sixty years or so, a rather strong change of climate was in progress, but it was in the direction which tended to make things easier for most human activities in most parts of the world. Prevailing temperatures were rising, especially strongly in the Arctic where the extent of sea ice decreased by 10 to 20%. More rainfall was reaching the dry places in the interiors of the great continents (except in the Americas, where the 'rain shadow' of the Rocky Mountains and the Andes meant that the increasing westerly winds increased the dryness, culminating in the disastrous 'Dust Bowl' years in the United States Middle West in the 1930s). The monsoons became much more regular and reliable in their performance in India and West Africa. And the variability of temperature from year to year in northern countries decreased, so that Europe had some decades of near-immunity to severe winters . . .

"The Working of the Climate System and some Effects on Food Production

"Rainfall changes almost as abrupt, and as long-lasting, as those in equatorial Africa have also affected the area of Soviet grainlands in central Asia. Rainfall there from about 1890 to 1950 had been on average twice as great as in the period 1850 to 1880 . . . After 1950 it dropped somewhat again and has been more variable since. The variations of the total cereal production in the USSR from 1960 to 1979 . . . show serious shortfalls in at least five of the later years—1963, 1965, 1972, 1975 and 1979—resulting mainly from the fluctuations in moisture availability . . .

". . . Neither the Scandinavian mountains nor the Urals provide such a pronounced anchoring effect upon the wind circulation patterns as the Rocky Mountains. It is probably largely for these reasons that the Soviet cereal production is so very much more variable from year to year than that of the United States . . .

"There is unfortunately a tendency for wheat yields in the world's main wheat-producing countries to be below expectation in the same years. Similarly . . . the correlations between the rainfall in different parts of monsoon Asia tend to favour failures of the rice harvest in much of that great region in the same years. . . There is . . . a prospect that in a few years from now, because of rising populations in the producing countries, there may no longer be grain surpluses for export from Australia and even from North America. . .

"Diagnosis of the Nature of Observed Changes in the Climate

"The most fundamental aspect of climatic changes is presumably any changes of overall world temperature and therewith in the location and intensity of the temperature gradients, which provide energy for the wind circulation. The best available assessments of changes of global temperatures over about the last hundred years are believed to be those in Fig. 11. The changes in the northern hemisphere are known to have been 3 and 10 times greater in the Arctic than elsewhere, as may be seen in the case of the 1970s . . . Unlike most other parts of the earth, there seems to have been some warming since 1950 in the Antarctic and extending to middle latitudes over New Zealand. (Warming south of 40°S is known to have been a feature of other periods in recent centuries which were colder, or cooling, periods in the northern hemisphere).

"On balance, the global mean temperature in the 1970s seems to have been between 0.10 and 0.15°C below the highest level which was maintained from about 1940 to the early 1950s. The temperature in the 1970s is still about 0.3 to 0.4°C higher than in the 1880s. . .

"A number of works . . . have demonstrated how changes in the intensity of development of the subtropical anticyclones and the belt of westerlies in middle latitudes, as well as the subpolar cyclonic activity, have been accompanied by changes in the precipitation in various latitudes, and on the west and east sides of the continents in middle latitudes in particular, as well as the amount of snow deposited on the icecaps in Greenland and Antarctica.

"These considerations indicate that the first key to forecasting climate must be to forecast the level of global temperature and from that to proceed to basic features of the large-scale wind circulation.

"Approaches to Forecasting

". . . Schneider and Mass (1975) found it possible to simulate the variation of world temperature over the last 100 years by an equation involving only

"(i) an index of the amount of volcanic dust in the stratosphere,

"(ii) warming attributed to the continual addition of extra carbon dioxide to the atmosphere by human activities (burning of fossil fuels), and

"(iii) an index of solar disturbance.

". . . These suggestions can best be understood by considering how convincingly (or otherwise) they explain the curves in Fig 12. (In Fig 12) the temperatures measured in central England are used as a proxy for the source of average world temperatures before 1870) . . . Certainly the latest part (Fig 12) of the record, since about 1950, seems to contradict the hypothesis that the effect of increasing carbon dioxide should be becoming, or about to become, the dominant influence . . . The conventional explanation of this puzzle [the recent cooling tendency in the northern hemisphere, and especially in the Arctic] is that the range of natural climatic fluctuation is so wide as to mask the CO_2 effect at present. While it is true that this must mask any incipient (new) effect until it has become big, the difficulty about accepting this explanation is that the range of climatic variation itself varies with time so widely that it cannot be defined in any way that is meaningful in relation to the problem of climate development over the decades ahead.

"It is this discrepancy in the latest thirty years of the record with the supposed carbon-dioxide-influenced temperature trend that underlies the differences of opinion about the probable future climate development which have been voiced by climatologists in recent years . . .

". . . Even the range of some of the rapid variations of prevailing temperature seen in Fig 12 in the last three hundred years could have very disruptive effects on the modern world economy. There are scientifically respectable reasons for the hypothesis that the drought troubles in recent years in sub-Saharan Africa and irregularities of the Indian monsoon are linked with the cooling of the Arctic since 1960."

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From **'Carbon Dioxide and Climate: the Greenhouse Effect', Report of the Joint Hearing before the Subcommittee on Natural Resources, Agricultural Research and Environment and the Subcommittee on Investigations and Oversight of the committee on Science and Technology, U.S. House of Representatives, July 31, 1981:**

. . .

"OPENING [prepared] STATEMENT OF HON. JAMES E. SCHEUER

". . . Today we will examine the evidence of the potential impact on the environment from the increasing levels of carbon dioxide in the atmosphere. . .

"Effects which have been projected for the United States include a warmer and drier climate in the grain producing areas of the Midwest, with a consequent decrease in productivity.

"Some studies have projected a loss of arable land as a direct impact of climate change, and a threat of flooding and perhaps even loss of some coastal areas due to warming of polar regions and thinning of polar ice caps . . .

"[Hon. Albert] GORE: . . . It is difficult to come to grips with this issue. Quite frankly, my first reaction to it several years ago was one of disbelief. Since then I have been waiting patiently for it to go away, but it has not gone away. The evidence continues to indicate that this nation may be on the way to a natural disaster of unprecedented proportions.

"The increasing concentration of carbon dioxide in the atmosphere . . . has the potential to radically alter our climate, upset our agriculture, and change the economic base of our society in fundamental ways. Ironically, though, the Greeks might call it the result of our civilization's hubris, that this effect should be caused by the flowering of our industrial society.

"In a very direct way we may be heading for a clash between human desires and the forces of nature, a clash that will finally require us to come to grips with the interaction between ourselves and the environment. But we are not helpless. There is still time to understand the implications of this change in our atmosphere and still time to make the kinds of energy choices that could forestall energy problems. At the most basic level, we need to understand more completely the effect of carbon dioxide creep in the atmosphere. . .

"I was operating on the assumption that the evidence was of at least a marginally questionable nature. But as that chart indicates, the scientific observations have been very, very thorough . . . The connection then between the burning of fossil fuels by our industrial society and the increasing concentration of carbon dioxide in the upper atmosphere would seem to be quite obvious.

"If we are going to face this problem, we are going to ask a number of questions, insist upon thorough answers and complete answers to them.

"First of all, how much carbon dioxide do we expect to put into the atmosphere in the future?

Second, what will happen to the carbon dioxide 'sinks'? Will the oceans be able to take in more carbon dioxide as more is put into the atmosphere or will the oceans take less carbon dioxide?

- From 'Climatic Changes and Food Production: Observation and Outlook in the Modern World', by H.H. Lamb, GEOJOURNAL, 1981.

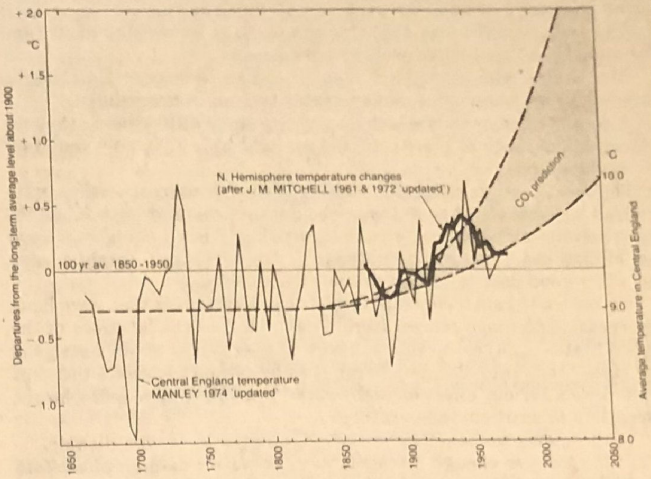

Fig. 12 World temperature: the past record and the predicted effect of increasing carbon dioxide.
The bold line shows the variation of temperature averaged over the northern hemisphere by successive 5-year periods since 1870 (after Mitchell 1961, updated as in Lamb 1977).
The thinner line shows the much longer record of average temperature in central England, which seems to parallel the world average at least roughly when 5-year periods are used (as here).
The broken lines show the temperature changes past and future attributed to the increase of carbon dioxide in the Earth's atmosphere as a result of human activities, using the currently preferred value of a 1.9°C increase for a doubling of the CO_2 in the atmosphere (Manage and Wetherald 1975, Mitchell 1977, Smith 1978).
The late nineteenth century CO_2 increase is attributed largely to the clearing of forests for agriculture in various parts of the world (Wilson 1978). The various estimates of future CO_2 effect hand on differences of supposed fossil fuel consumption rates and differences of strategy about alternatives sources of energy and economy of fuels. Some current estimates of the supposed futu.e temperatures rise greatly exceed those represented in the figure. The upper line on the figure is approximately the median line of Mitchell's range of estimates..

"Third, what other effects are at work on our climate besides the concentrations of carbon dioxide that might exacerbate or lessen the potential problems with which it is associated?

"Fourth, what beneficial as well as what harmful effects might we see?

"I might add there, from a nationalistic point of view, it is of little comfort if the world as a whole has good effects and bad effects, but the bad effects are concentrated in nations sharing the latitudes that we share. If our grain belt is moved to Canada, that may be fine, on the average, looking at it from the point of view of both the United States and Canada, but it is not too pleasant looked at from the point of view of the United States alone.

"What kind of technology like genetic engineering might we use to divert the worst effects?

"While we are still uncertain about the answers to these questions, we must do the work now that will insure that we can handle the problems that we have created. As a science committee, we would be failing in our responsibility to the people of this Nation if we did not take this quintessential policy problem seriously.

"Many of our witnesses today are from the academic environment. But the greenhouse effect is not merely an academic question. The paths we take today I hope will help us to determine whether we have disasters or merely manageable problems in our future . . .

"[Hon. Robert S.] WALKER . . . I think we have become more and more aware over the years of the risks that are associated with energy production of all kinds. This hearing will serve to demonstrate that the production of fossil fuels in our society carries with it perhaps some inherent risk, as well, and that we need to examine all of these things in order that our energy future is balanced by what we regard as acceptable and unacceptable risks . . .

"[Prepared] OPENING STATEMENT BY CONGRESSMAN WILLIAM CARNEY

". . . you have again chosen a hearing subject that represents a problem of global proportions, yet one for which the nature of the problem and the necessary solutions are not well understood . . . I again have the feeling that we had better do something and perhaps do it quickly, but I am not sure just what it is that needs to be done . . .

"One point that is often overlooked in carbon dioxide discussions is that of the relationship between decisions we make now and the atmospheric situation 20, 30 or 40 years from now. There are those who believe that it is not until well after the turn of the century that CO_2 levels may reach 'critical' levels (whatever they might be). However, it is the actions we take now with regard to our energy problem, and the decisions we make now with regard to how much nuclear, how much fossil, and how much solar energy we will employ in future years, that will determine the atmospheric levels of carbon dioxide in those years.

"If we err on the side of too much fossil fuel and too much carbon dioxide, the environmental consequences may be substantial. On the other hand, if we overreact and, for example, require overly stringent pollution protection equipment, the situation may be just as catastrophic in an economic sense. . .

"One of the reasons why we are holding this hearing . . . is to determine where the emphasis is in the Department of Energy's program on carbon dioxide. These are several questions that the Department has been looking at, including how much can CO_2 levels increase before the temperature increase becomes significant, whether increasing temperatures pose serious problems, and whether anything can be done to reverse the trend toward more CO_2 in the air? I personally feel the last question is the more critical, and would ask our witnesses to comment as to whether they agree or disagree with that assumption . . .

"STATEMENT OF [Dr. Roger] REVELLE"

". . . One of the major projects of the International Geophysical Year in 1957-58 became an attempt to actually measure the atmospheric carbon dioxide . . . Charles David Keeling . . . set up two monitoring stations, one on the top of Mauna Loa and one at the South Pole.

". . . (Keeling) managed by sheer persistence and guts and by making a nuisance of himself, to make these extremely accurate measurements, and they have been continued for nearly now on Mauna Loa and at the South Pole for nearly 25 years.

". . . you will notice the annual fluctuations . . .

"The other thing you will notice is a continuous rise . . .

"So far the climate has not responded in a measurable way to this increased carbon dioxide . . . the noise level is too high.

"One of the important problems from the scientific point of view is to find an early warning signal . . .

"Another problem is to find out how much of the carbon dioxide will remain in the air . . . the airborne fraction . . . is only about half of what it would be if all the carbon dioxide produced by the burning of fossil fuels had remained in the air.

". . . What has been getting it is probably partly the biosphere . . . but more important probably is the take-up by the ocean . . .

"As time goes on, nearly all of the added carbon dioxide will go into the ocean but that will take quite a long time, maybe as much as 1,000 years . . .

"Mr. SCHEUER. Although it may be true that, of the fuels you have mentioned, gas may be less damaging environmentally from the standpoint of carbon dioxide, doesn't this also emphasize the importance of achieving nonfuel sources of energy: tidal, wind.

"Mr. GORE. Nuclear.

"Mr. REVELLE. Yes. Nuclear is No. 1, perhaps, but biomass is also a major possibility. It would be possible to produce all the energy that the world uses now from less than a quarter of the forested area of the earth.

"Mr. SCHEUER. You are advocating cutting down our forests?

"Mr. REVELLE. I am advocating that we husband our forests by planting them just like farmers plant corn, having forest plantations.

"Let me just cover in a general way the kinds of research that I think are very important for us to understand this problem and to understand its implications for human beings.

"The first one . . . can we assess the risks and can we balance these against possible benefits?

". . . Perhaps the most worrisome is the possible disappearance of the West Antarctic ice cap . . . it might disappear again with a rise in the average air temperature by 3° to 4° C . . . Another piece of evidence which I do not know how to evaluate is that the sea level seems to have been rising lately faster and faster. Forty years ago, the sea level was rising on the average about 1 millimeter per year. According to Professor Emery at Woods Hole, sea level during the last 10 years has been rising at about 1 centimeter per year, 10 times as fast.

"The only possible way that this can occur is by melting of ice, and the addition of the melted water to the ocean.

"Mr. Etkins who is in the audience, and his colleague Ed Epstein, have written a paper that demonstrates this quite beautifully.

"A second phenomenon which may create equal difficulties is the possible disappearance of the Arctic sea ice (which) . . . has a profound effect on climate.

"The third possible risk is the melting of the permafrost on the northern land . . . permafrost contains a good deal of peat, and the peat might oxidize if the temperatures go above freezing. Also it contains a good deal of methane, in a form of methane hydrate (that) . . . might escape and add a good deal of carbon to the atmosphere.

". . . One (risk) I am inclined to think is most serious is that if we have an increase in average temperature by 4° or 5° C at the latitudes of the United States . . . the extreme summer temperatures might be a good deal higher than they are now. There is some reason to believe that this would have a serious effect on many elderly people and people who are susceptible to extreme temperatures.

". . . there may be beneficial effects of additional carbon dioxide.

". . . If you have enough nitrogen, enough water, enough phosphate and enough sunshine, then plants are limited in their growth by the amount of carbon dioxide in the air.

"So if we increase the atmospheric carbon dioxide, what might happen is that we will get higher yielding crops . . . What we need to do is to teach plants by genetic manipulation to produce more seed if they produce more synthetic product.

". . . a second major problem is to develop crop plants by research which will be resistant to water stress and temperature stress.

". . . Most livestock are produced at latitudes corresponding to that in the northern part of the United States. Here we expect temperature to rise perhaps as much, on the average, as 6°C if atmospheric carbon dioxide is doubled. We know that cattle, chickens, and other livestock don't produce as well . . . when temperatures are too high. Again the problem is a research problem, to find breeds and varieties of livestock which will be resistant to higher temperatures.

". . . We need to find fast-growing trees that will grow faster under conditions of increased carbon dioxide . . .

"One of the major practical research problems here is to find ways for better use of water, better water management in countries like Pakistan, India, the African countries, which are often water short. At the present time . . . only about 25 percent of the water used in irrigation actually does any good to the crops. That could probably be raised to about 50 percent by better understanding of how to use water . . .

"In the United States the river that we westerners are most concerned about is the Colorado River. The existence of the West to a very large extent depends upon the use of the Colorado River water and its tributaries.

"I have given a table . . . on which I show that at 40° north latitude precipitation might decrease by as much as 14 percent and temperatures might increase by as much as 6°C . . .

". . . there are two places, one at about 40° north latitude, the other about 10° south latitude where there would be, according to (Hermann Flohn's) computations and modeling, a very marked reduction in precipitation.

"The flow of a river depends not on precipitation but on the difference between precipitation and evaporation . . .

"The two things combined might cause as much as a 50-percent reduction in the flow of the Colorado River . . .

"In other parts of the world, at this latitude of about 40°, which goes through Europe pretty close to Lisbon, Naples, Ankara, and Athens . . . a great reduction in riverflow—the flow of the Po, for example, and of the Rhone—might occur because of the decrease in precipitation and increase in evaporation.

"In China, the Hwang Ho would be subject to the same kind of change, and the basins of the Amur Darya and the Syr Darya, two of the major areas of irrigated agriculture in the Soviet Union might again have as much as a 50-percent fall in river runoff . . .

"One thing we might have to do is to change the allocation of water from agriculture to other uses. Or we might have to introduce such things as interbasin transfers, for example, from the Northwest to the Colorado River watershed. Both these things are political issues that make people see red on both sides and we have to learn somehow to plan and to convince people that things like this need to be done and make them politically acceptable to do . . ."

"[Dr. Stephen H.] SCHNEIDER . . . What I want to talk about is the question primarily of so what, if carbon dioxide increases? . . .

"We have to ask how the costs of mitigation of carbon dioxide or its effects stack up against the costs, in some pricing way, of doing nothing . . .

". . . Also there is a value part . . . because often the costs that we incur to do something about it now are paid in this year's dollars whereas the costs from anything that may go wrong might be incurred decades in the future.

"Mr. SCHERER. Dr. Smagorinsky remarked that the range of effects between the present concentrations and a doubling covers no significant thresholds and our conclusions are not completely dependent on the time of carbon dioxide concentrations. If there doesn't seem to be a significant effect to a doubling, where is the critical mass? Where do we run into a real problem? How far away? What will the problem be? What are the mitigation or controlling policies that we should be formulating now, if any?

"Mr. SCHNEIDER. Yes. Well in partial answer . . . that question is a creeping or incremental kind of issue . . .

"The . . . question which I personally spent a lot of time on, is that question of the global climatic response to CO_2 increase. The number you often hear is if carbon dioxide doubles the surface temperature will increase something like 2°, 1 to 4 or various ranges; . . . what does that mean? . . .

". . . what will happen in the midlatitudes? What happens in the graineries, or to water supplies? We need such information if we are ever going to do any juggling as to cost and benefit analysis?

"Mr. GORE. May I interrupt you there?

"I want to focus that particular set of questions in a more narrow way. What happens to the United States as policymakers on this committee. I want to address the questions within that framework which may be one of several contingencies.

"Mr. SCHNEIDER. Fine, I agree completely. Unfortunately, the difficulty is we will never have a perfect consensus on CO_2 climate impacts . . . Consensus has been developing fairly nicely on the global climatic response to CO_2, but we are far away from that consensus on the regional question because it is tougher and more expensive to try to answer it since one has to use more detailed models which become less certain as one gets more fine detail. So what you need most, we have the greatest difficulty in providing with great reliability . . .

". . . we look at paleo climates and computer models and try to combine these things to give us a scenario of what regional effects could be.

"if we had a scenario, with the change in the precipitation or soil moisture or some element, we then could use the models and theories we have now, and the experience of the past to figure out what would it mean to crop yields, to water supplies, and so forth? But in order to do that, we also have to guess if we are talking 20 years or 50 years in the future, what kind of new genetic crop strains will be available . . . and will they have in fact different responses to the climate change we project than our present one . . .

". . . some people have said that CO_2 is far enough away so that studying it is where we should draw the line simply because it is at least 10 or 15 years before a CO_2 effect becomes clearly detectable, and it could even be 20 or 30 years. So we could comfortably wait this 20- or 30-year period during which we study before we have to take any actions more strong than that . . .

"But if we go back and say we even have 20 or 30 years before the CO_2 effect is clearly detected, we are still going to face a risk. That is, we will have to adapt to a larger dose of carbon dioxide and its consequences, good or bad, if we wait until we are sure than if we act now and reduce the carbon dioxide burden.

"The next most active policy step, which is the one I personally advocate, is to try to what I call 'build resilience' . . . namely, do whatever you can now to increase the number of options you will have available in the future so as the information comes in and the problem becomes clearly a problem or not, you have the flexibility to move.

"Mr. SCHEUER. Are you going to describe what those options are?

"Mr. SCHNEIDER. Yes. Well, very briefly, one of them . . . is to work vigorously on the development of crop strains which can be widely adapted to a variety of environments . . .

"A second one to me is to try to maintain the soil horizons and minimize soil erosion because you are going to need every drop of productivity you can get in the future . . .

"Another way you can build resilience is to develop vigorously alternative energy systems stressing renewable and efficient technologies . . . To me the basic principle is: You don't get hooked on one source.

". . . If one takes a strategic view of energy and says our future options require some degree of nonmarket intervention to develop alter-

natives, this is a way you build resilience . . .

"Finally, the most radical policy options you can take to respond to CO_2 . . . namely, each nation agrees by some negotiation to what its polluting rights are with regard to carbon dioxide. I think this option is about as realistic as, well, getting everybody to agree on everything. . .

. . .

Mr. [Lester B.] LAVE: I think CO_2 is a serious problem. Some of the technologies that we are pursuing with respect to synthetic fuels don't make any sense if this is the case.

"In situ coal gasification produces large amounts of CO_2 per Btu of energy compared with other technologies. If we take the CO_2 matter seriously, then we would eschew such CO_2 intensive technologies.

A more sensible energy policy need not be anything so radical as doing away with fluid fuels or changing our transportation network. There are marginal technologies like in situ coal gasification which look only marginally attractive, if at all; if you add on even a tiny penalty for the CO_2 they put out, they become unattractive technologies . . .

"I think that the natural home for this research is in the Department of Energy. However, the Department of Energy must take it much more seriously than they seem to have been doing lately . . .

"Mr. GORE: By the same analysis, you could be led to conclude that increasing the options for nuclear power and keeping alive the option of breeder technology would be more justified by that amount, would it not?

"Mr. LAVE. It certainly is true . . . when we look to the future, you want to have a lot of options in terms of energy technologies, in part because it takes a long to develop a new option. You may not want to pursue one of them right now for many kinds of reasons, but it is really nice to have the options be open.

. . .

"Mr. GORE . . . I was noticing in Dr. Smagorinsky's statement the following sentence: 'The consensus on the nature and magnitude of the problem has remained remarkably constant throughout this long worldwide process of study and deliberation'.

"Now, that is really a pretty good summary of the reason for this hearing, as I see it. The problem hasn't gone away. It hasn't gone away and the shaky hypothesis which began on the fringes of science has now worked its way into the mainstream of scientific thought.

"Let me ask the panel whether you are aware of any reputable scientist in the atmospheric sciences who takes the position that this whole situation is just a wild delusion?

. . .

Dr. SCHNEIDER. Present dissenting people may prove by accident to be partially right, but not by any argument they have now used.

"It is conceivable something we haven't thought of will come along, but there is one very strong piece of empirical evidence which suggests we may be on the right track and that is the difference between winter and summer.

"The fact that winter is cold and the summer is warm, when the amounts of energy from the Sun increases and decreases with seasons tells us the climate responds if you force it . . .

. . .

Mr. GORE. One of the options that was listed was to do nothing. It seems to me that ought to be rephrased because we are creating the effect, or helping to create the effect by continuing the consumption patterns that we are now pursuing.

"I think it is important at this point in our history to recognize the magnitude of the effect on our global environment of industrial civilization's pattern and that ought to lead us to reevaluate the range of options that are available to deal with this.

"If it is real and if the areas of uncertainty continue to narrow, then I believe we ought to discard all of the smaller options of trying to adapt to it and maybe giving some travel tax credit to these people in Florida who have to move from their homes or adapting agricultural policy in Nebraska to come up with sand flea farms and rather to concentrate instead on looking the large problem straight in the eye, recognizing its global cause and selecting the one obvious solution for the problem if it is determined to be in fact real, which is a rather dramatic change in the energy consumption patterns worldwide. It seems pretty obvious that is the appropriate response, but the areas of uncertainty are still large. What I mean by this is, accelerating a moving away from fossil fuels. It is just obvious that that is in fact what is causing the problem. If the cause and the effect relationship is real and if the impacts of the development are of the magnitude that have been described by this panel today, then the response appears to be obvious.

Dr. SCHNEIDER . . . We have the fact that CO_2 is not the only risk of energy systems. There are other options but they have cost questions, social acceptability questions, questions of the safety of a plutonium economy and one has to weigh all of these obviously complex trade-offs in a gigantic picture . . . One says the obvious solution is to go nuclear -

"Mr. GORE. I didn't say that. I said the obvious solution, if all of those areas of uncertainty are narrowed appreciably, the obvious solution is to move rapidly away from the current rate of fossil fuel consumption rather rapidly . . ."

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From **'Major Climatic Events Associated with a Prolonged CO_2-Induced Warming', by Hermann Flohn, Report No. ORAU/IEA 81-8(M) Institute for Energy Analysis, Oak Ridge Associated Universities, October 1981:**

. . .

SUMMARY AND CONCLUSIONS

"The purpose of this review has been to discuss the geophysical and historical background of two major climatic changes that occurred in the geologic past and may possibly recur in the future under the expected influence of a CO_2-induced global warming. These two events are (A) the disintegration of the West Antarctic ice sheet and (B) the disappearance of the shallow drift ice of the Arctic Ocean.

Event B would lead to a unipolar glaciation, with a high degree of climatic asymmetry. The present climatic asymmetry between the two hemispheres was discussed in Chapter 2, together with some of the particular patterns of atmospheric and ocean circulation in the equatorial regions. Oceanic upwelling of cool water near the equator in both the Atlantic and Pacific Oceans is one of the important geophysical consequences, resulting in the formation of a strong equatorial countercurrent only in the Northern Hemisphere. Averaged over the whole year and all longitudes the meterological equator shifts to lat. 6°N, while the stronger atmospheric circulation of the Southern Hemisphere encroaches on the (geographical) equator during most of the year.

"In recent years, paleoclimatic evidence has revealed a quite different history of glaciation in the two polar regions (Chapter 3). The Antarctic continent, remaining nearly at its present position for more than the past 50 Ma, first become partly glaciated 38 Ma ago. Simultaneously there was a marked cooling at the ocean bottom all over the globe and at the higher latitudes of both hemispheres. During a second marked cooling about 15 Ma ago, associated with a period of high volcanic activity, the glaciation of Antarctica expanded over nearly the whole continent. Only the archipelago of Western Antarctica remained ice-free until the peak of the Antarctic glaciation about 6 Ma ago, when its total volume was probably 50 percent greater than now. This accumulation of ice resulted in a sinking of the world's sea level, repeatedly desiccating the Mediterranean.

"In contrast to that long evolution, the Arctic sea ice was formed only about 2.4 Ma ago, most probably as a consequence of the first large-scale glaciations of the northern continents. The glaciations were triggered by the closure of the land bridge of Panama about 3.2-3.5 Ma ago, which caused an intensification of the Gulf Stream with its moisture transport. One of the main prerequisites for permanent (rather than seasonal) sea ice was the formation of a shallow low-saline upper ocean layer produced by the seasonal melting of glaciers and the internal pro-

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cesses of freezing and melting. The stability of the present sea ice has probably been restricted to the last 0.7 Ma.

"This abbreviated history reveals that during a very long time of more than 10 Ma the Antarctic continental glaciation coexisted simultaneously with an ice-free Arctic Ocean, and that the climatic asymmetry between the poles must have been much greater than at present. There was no tundra nor permafrost at high latitudes in the northern continents; instead a rather rich forest grew there, indicating summer temperatures near 12°C. Since the intensity of the atmospheric circulation and the position of the climatic belts both depend on the temperature difference between equator and pole, the climatic pattern must have been substantially different from now. Indeed, there is evidence for a northward extension of the equatorial rainbelt to the northern tropics; the latter would be correlated with increased aridity in the southern tropics up to near the equator.

"The available paleoclimatic evidence suggests that both major climatic events were associated with a general (global) temperature rise of between 4° and 5°C (Chapter 4). Comparing selected model results of the CO_2-temperature relation (see the appendix) yields a semilogarithmic diagram that describes an approximate relation of these two quantities, dependent only on one combined, model-derived parameter, which also takes into account the greenhouse effect of other infrared-absorbing trace gases and its possible increase with time. **If a 4° to 5°C increase in the globally averaged temperature is assumed as a realistic threshold above which the risk of both major climatic events increases significantly,** this could result from a CO_2 concentration slightly above 600 ppm (e.g., 620 ppm ±10%). This revision of former high estimates (Flohn, 1980: 750 ppm ±16%) is mainly due to the probability of an increasing role of 'greenhouse gases' other than CO_2. The uncertainties of the future development of energy demand and the uncertainties within the carbon cycle regarding the partitioning of carbon among atmosphere, ocean, biosphere, and sediments remain as great as, or greater than, those still within the CO_2-climate a relationship.

"A general global temperature rise of 4-5°C seems to be an appropriate base—even if based on different reasoning—for estimating the risk of both major events A and B. This temperature rise will be 2-3 times as great in high northern latitudes; the expected increase near the Antarctic will be much smaller.

"Both events are part of our climatic history: the last case of a collapse of the West Antarctic ice sheet (Event A) occurred in the middle of the last interglacial warm epoch, about 120 ka ago. The Arctic Ocean was last ice-free (Event B) about 2.4 Ma ago; we do not know if it became ice free again even for shorter time periods, but it certainly did not after 0.7 Ma ago. This seems to indicate that, in the future, Event A should be expected earlier than Event B. However, the author selects several arguments which indicate that a reversed sequence—B earlier, perhaps much earlier, than A—is more likely. His argumentation is mainly based on the different time scales needed for the preparation and for the geophysical processes involved. The high spatial variability of the extent of the Arctic ice during the last 1000 years seems to indicate that the thin sea ice is much more sensitive to climatic change than big continental ice sheets or ice shelves.

"A first-order scenario of climatic changes to be expected in the case of an ice-free Arctic Ocean (Chapter 5) is based on paleoclimatic evidence and on some coherent results from climatic modeling. Expected shifts of climatic belts are derived from a simple relation between the meridional temperature gradient in the troposphere and the position of the subtropical anticyclonic belt, which is related to V. Bjerknes' fundamental circulation theorem. Based on this background, the expected displacements of the major climatic zones are estimated. These serve as a base for a conservative estimate of changes in annual rainfall and temperature, both as a function of latitude. A simple extrapolation of paleoclimatic data cannot be applied, since some climatic boundary conditions—mountain uplift, closing of the Panama land bridge—have changed significantly since the comparison period of the late Miocene and the early to mid-Pliocene (6-3.5 Ma ago).

"Because such an unexpected and strange climatic pattern of a unipolar glaciated earth could occur, after a short transition period (probably in the order of a few decades only), as a result of a limited increase in CO_2 concentration, its investigation should be given a much higher priority. Some suggestions are given (Chapter 6) to modify existing models so as to indicate the possible occurrence of seasonal (instead of permanent) sea ice with storage if incoming solar radiation in a dark sea (with only small amounts of cloudiness during summer) leading inevitably to higher sea surface temperatures and ultimately reducing the regime of seasonal sea ice to a short transition period. The diminution of the freshwater inflow from Siberian rivers will further reduce the formation of permanent ice, but at a much slower rate. Finally, suggestions for intensified paleoclimatic research are given; quantitative and worldwide data can be derived, which, after a critical assessment of the role of changing boundary conditions, may provide educated guesses as well as verification data for climate modeling. . . "

Electric Vehicles

A key problem in halting outpourings of CO_2 is to supplant gasoline- and diesel-fueled vehicles. Biomass alcohol is not yet competitive, as Brazil has found. In addition to the penalty of considerably higher costs for alcohol versus gasoline and poor fuel mileage, drivers report that alcohol vehicles are impossible to start in cold weather, won't climb hills, and need frequent repairs. (One taxi company found the life expectancy of an alcohol motor was only 30% that of a gasoline motor.) Alcohol-powered car sales declined 70% in Brazil in the first 5 months of 1981.

Other forms of chemically-stored non-fossil energy for vehicles could be hydrogen, ammonia or metal hydrides produced from nuclear electricity. Very cheap off-peak nuclear electricity would probably be needed to make such fuels economically attractive.

The storage of nuclear electricity directly in a vehicle's batteries may be the first commercially attractive non-fossil propellant for cars and small trucks, even at today's household electricity prices. Electric vehicles (EVs) using lead-acid batteries have penetrated the market so far only where gasoline and diesel are heavily taxed and where distances are short. More than 45,000 electric vans are being used to deliver milk and other commodities in Great Britain. These slow moving vans are cheaper to operate than diesel trucks because fuel costs are lower and the EVs last 1.5 to 3 times longer than diesels. More than 3000 electric autos presently operate in the U.S. but these are mostly test vehicles sponsored under governmental programs.

Presently the overall cost per kilometer of operating EVs in the U.S. where fuel taxes are low is approximately the same as petroleum-fueled vehicles, but acceleration and range of EVs are not comparable. EVs eliminate air and noise pollution but lack air conditioning. Produced in volume, EVs should cost no more than other vehicles, and then offer substantial savings in fuel costs and less maintenance.

Of the battery types capable of operating at or near ambient temperatures, the overall most attractive type—in terms of low cost, high power density (for acceleration and hill-climbing), and high energy density (for range between chargings)—may be the zinc-chlorine type which Gulf and Western is developing, and which offers a battery life of 4 years or more in daily use. Chlorine is stored as a hydrate slush and the battery requires a system of pumps, valves, refrigerator and a minicomputer to produce a steady flow of power. General Motors may produce the first assembly-line EVs in as little as 2 years from now using an advanced zinc-nickel oxide battery which may offer greater acceleration but smaller range (about 160 km between chargings).

Because 99% of all car trips in the U.S. are for about 160 km or less and about 90% are for about 30 km or less, range between chargings should not be a major drawback for market penetration. Recharging times of 6 to 8 hours now appear to present the greatest obstacle to the wholesale supplanting of petroleum-fueled vehicles.

The slow pace of institutional research to improve EV acceptability might be accelerated greatly if 'backyard inventors' could be encouraged in a competitive way, as by the U.S. Departments of Transportation and Energy offering a large cash prize for the first EV to cross the U.S. from coast-to-coast at an overall average speed of, say, 60 km per hour.

-W.N.B.

BATTERY PROSPECTS - EV APPLICATION -EPRI '79