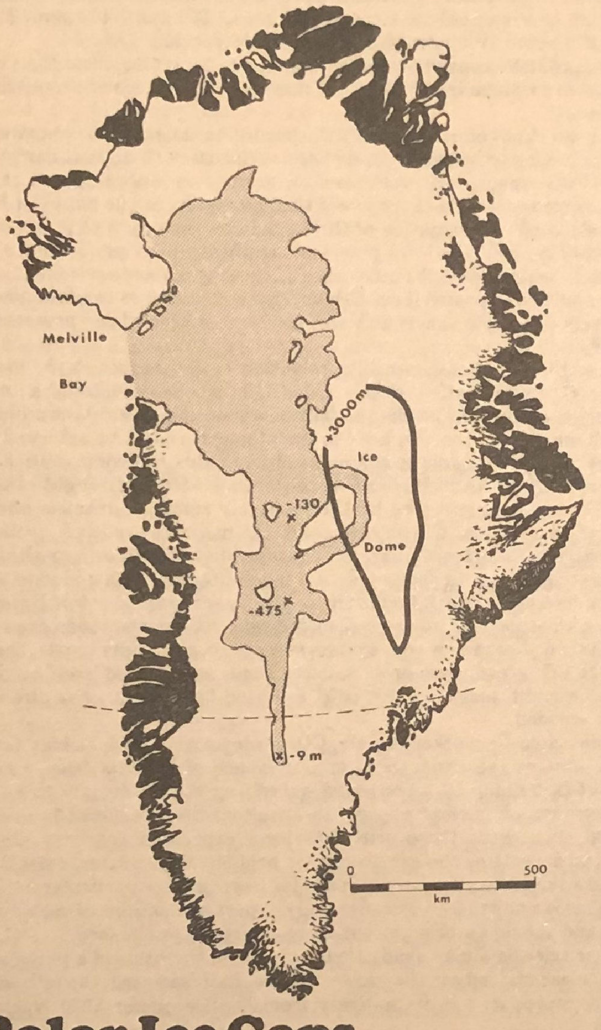
The CO2 Newsletter, created, published, and edited by William N. Barbat, ran from 1979 to 1982.

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.

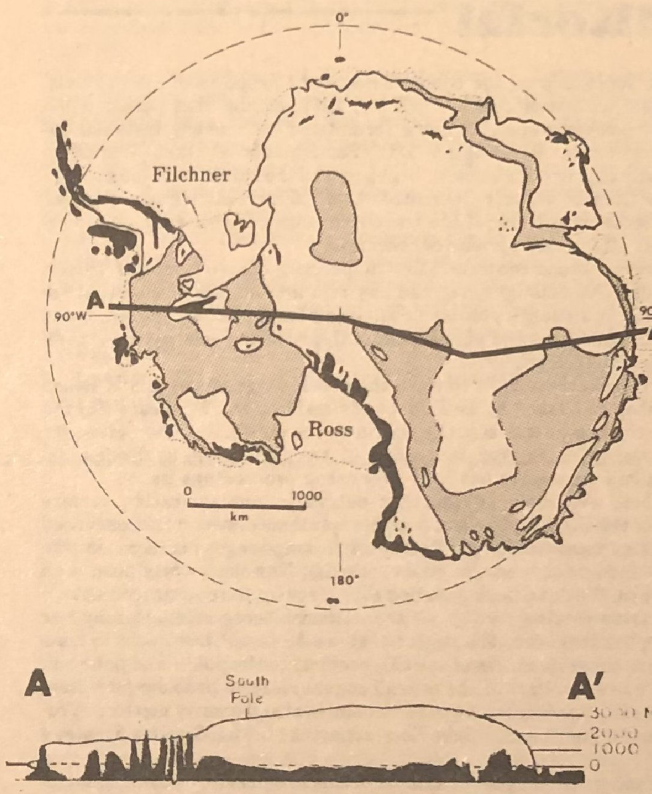
CO₂ Newsletter©

Volume 2, number 2 **Dec. 1980 - Jan. 1981**

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



Modified after Denton Armstrong and Stuiver (1971):



Bedrock not covered by ice.

Ice Grounded above Sea Level

Ice Grounded below Sea Level

Edge of Floating Ice Shelf

Polar Ice Caps - 'Sword of Damocles' to a Warming World

While the debate continues whether a warmer world climate will be better or worse on the whole, the anticipated destruction of glacial ice which is now perched above sea level can only bring a worldwide loss of coastal land areas.

The West Antarctic Ice Sheet is considered to be the most vulnerable to a warming of the oceans and atmosphere in polar regions because the large ice streams which are grounded far below sea level are protected and buttressed by ice shelves whose temperatures are not far below freezing in summer.

The Greenland Ice Sheet is considered to be second in vulnerability. The West Coast of Greenland is warmed by a branch of the Gulf Stream as far north as Melville Bay, where the glacial ice is grounded below sea level. Much of the interior ice is also grounded below sea level nearly to the dome of the ice sheet.

The East Antarctic Ice Sheet is also grounded partly below sea level, and summer temperatures presently reach 0°C or slightly higher at the coastal fringe. George Denton of the University of Maine has found that major outlet glaciers from the East Antarctic Ice Sheet, such as the Byrd and Darwin, have been up to 1000 m thicker in the past. At the same time the Ross Ice Shelf was much thicker and acted more effectively as a dam to outlet glaciers of the West Antarctic Ice Sheet.

Shrinkage of the East Antarctic Ice Sheet at the end of the last ice age is believed to have been due to coastal destruction of ice mechanically as sea level rose. The ice sheet then adjusted to a new profile of equilibrium and the adjustment apparently continued between 1000 and 1500 years after the disappearance of the Laurentide Ice Sheet. Consequently sea level rose worldwide on the order 10 m after global temperature appears to have stabilized during the Hypsithermal Age.

CO_2 Newsletter is published bimonthly by Wm. N. Barbat Associates (Energy Consultants), P.O. Box 24, Teton Village, Wyoming 83025. Deadlines for contributed articles and letters are Jan. 31, March 31, May 31, July 31, Sept. 30, and Nov. 30. U.S. subscription rates: Companies, institutions, or agencies $40 per year, which allows for unlimited 'in-house' reproduction rights; individuals and university libraries $20 per year (6 issues). Back issues $5 each as available. Foreign airmail, if sent from the U.S., add $4.
European subscription rate inclusive of postage: Swiss francs 48.—per year (6 issues).
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"... you must not neglect doing a thing immediately good, from fear of remote evil—from fear of its being abused."

—Samuel Johnson

Editorial

The 'Workshop on the Global Effects of Carbon from Fossil Fuels' was held at Miami Beach April 3-7, 1977, during that period when energy policies were still being formulated by a newly installed administration in Washington D.C. Participants at that Workshop generally expressed a sense of urgency, and the somber warning issued by the Climate Effects Committee that "significant climate changes could occur by the end of the twentieth century" was a consensus arrived at after much serious deliberation.

However, these concerns about impending climatic impacts from a continued CO_2 buildup never had any meaningful influence on that administration's energy policies or environmental policies. Indeed, many previous gains toward supplanting CO_2-producing energy have been reversed since April 1977.

We repeatedly sought to have the proceedings of the Miami Beach Workshop published by DoE in timely fashion, but 2½ years elapsed before the report was actually issued to the public. A reason given for that lengthy delay was that none of the prominent environmental groups had pressed to have the Workshop proceedings issued.

To help overcome any further delays in communicating various views of the CO_2 problem and possible solutions between the concerned scientists, responsible public officials, long-range planners in the energy industries, and the public, the CO_2 Newsletter was born soon afterward. We have been gratified ever since by the encouragement we continue to receive and by all the material being sent to us by our readers for inclusion. We regret that we have not been able to communicate the seriousness of the CO_2 problem to the public and public officials, however. Part of the overall communication problem may stem from the deep politicization of environmental and energy matters in recent years. As Stephen Schneider reported in **The Genesis Strategy** (1976):

"Let me give one recent example of this problem of separating scientific and political opinion on issues with public policy overtones. A respected meterologist who had engaged in computer modeling of the earth's climate often strongly opposes those who use his (or anybody else's) estimates of the potential climatic impacts of human activities, if these estimates are given as an input to the political process to affect policy. He recently stated his opinions on this matter quite clearly to a scientific panel that was examining potential climatic consequences of long-term energy use. During one of the discussions, he complained that too little is known of climatic theory to say very much with any certainty about the potential impacts of, say, projected CO_2 increases. On the other hand, some scientists there, including me, felt that current knowledge of CO_2 effects was sufficient to consider this problem a potential climatic barrier to long-term energy growth. Although most of us agreed fairly closely on much of what is wrong and missing in present theories of climatic consequences of increasing CO_2 concentrations, we exchanged differing views over the question of whether existing knowledge has relevance to political decisions about the future growth of industrialization. These differences of opinion, then, were much less ones of technical substance than of how to act in the face of uncertainty . . . . I think that the dangers of waiting for certainty can often be greater than the risk of prematurely releasing disturbing theories to the public."

A contrasting outlook is presented by the JASON report recently released by SRI International that a more credible scientific case must be built concerning expectations of CO_2 impacts on climate before the attention of public authorities would be required "for possible national or international action on a large scale."

How much weight should be placed by scientists on the degree of credibility and how much on social responsibility? Is there some definite point in our understanding of the CO_2 problem at which public authorities should be expected to accept responsibility for averting or mitigating CO_2 impacts, but not before that point is reached? Such philosophical questions as these might be more easily answered if they could be restated as quantified questions:

- What atmospheric concentration of CO_2 can be tolerated without resulting in irreparable environmental harm? 350 ppm? 400 ppm? 500 ppm? 600 ppm? 1200 ppm? (And who should decide?) Or,
- Would it be considered environmentally benign to allow the CO_2 buildup to continue indefinitely but maybe at a much slower rate than at present?

Such questions effectively shift the burden on the scientific community from having to 'prove' to everyone's satisfaction that great dangers exist if atmospheric CO_2 continues to increase to a requirement that they assure the people of the world that great dangers do not exist for some elevated concentration of CO_2 in the atmosphere, if that is what they believe. It is doubtful that any significant number of informed scientists would offer the assurance that no grievous environmental harm would be expected if the CO_2 buildup were allowed to continue indefinitely. Or, if they have such a view, the case hasn't been presented publicly.

Thus the immediate scientific problem is to determine a 'safe' maximum CO_2 concentration, if any added CO_2 can be considered as not leading to serious environmental harm. Responsibility for determining what limitation on the CO_2 level in the atmosphere can be achieved in the real world then falls to the political and industrial communities.

A case can be made that the warmth-related Great Drought of the 1930s had been aggravated by the relatively small greenhouse effect then of man-made CO_2 added onto a natural peak of cyclical temperature variation. To assess the probability of such an hypothesis, it is first necessary to determine how much CO_2 had been added to the atmosphere by deforestation prior to 1900, when large areas of Europe and North America had been denuded and little carbon was sequestered as wood or in new root-system storage. A possibility exists, then, that the CO_2 greenhouse problem has already manifested itself by this Great Drought, and that any 'safe' elevated level of CO_2 has already been exceeded.

Some scientific workers on the CO_2 problem may wish to bias their evaluations of the seriousness or imminence of impacts from a continued CO_2 buildup by a perceived overriding ethical duty to halt the development of nuclear energy as an alternative to fossil fuels. In several such cases these scientists have expressed concerns about technical aspects of nuclear energy (as proliferation, wastes, safety) or comparative energy forms which are far beyond their particular expertise. This is unfortunate, because truly expert evaluations of such risks could and should be brought out more clearly in public fora.

Other scientists may shade their opinion on the basis of a perceived anti-nuclear majority in the general public. In this regard, the following item is reproduced in its entirety from the December 1980 Nuclear News:

"Surprise. One item in a poll taken late in the campaign by the [President] Carter forces reportedly came as a great surprise to senior aides Ham Jordan and Jody Powell. This sample revealed that 65 percent of the American people believed we should 'get moving again on nuclear power.' These same aides are reported as saying: 'This is a complete turnaround from what we have been hearing.' "

Whether or not historians will remember the current era of scientific effort on the CO_2 problem as the scientific community's 'shining hour' may depend both on credibility and responsibility.

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CORRECTION

On page 3 of the Oct.-Nov. 1980 issue (v.2, n.1), we mistakenly attributed the authorship of 'Background and Purpose Statement for the Carbon Dioxide Workshop' held at St. Petersburg, Florida, October 30-31, 1980, to the wrong persons.

The statement had been prepared by the consulting firm of Schwartz & Connolly, Inc., and by the staff of the National Commission on Air Quality under James Fairobent.

CO2 Theory of Ice-Age Origin, Revisited

The main objective of Svante Arrhenius in his climate modeling of the CO_2 greenhouse effect in 1896 was to assess the possibility that the ice ages had resulted from a lowered content of CO_2 in the atmosphere.

"In the Physical Society of Stockholm there have been occasionally very lively discussions on the probable causes of the Ice Age; and these discussions have, in my opinion, led to the conclusion that there exists as yet no satisfactory hypothesis that could explain how the climate conditions for an ice age could be realized in so short a time as that which has elapsed from the days of the glacial epoch. The common view hitherto has been that the earth has cooled in the lapse of time; and if one did not know that the reverse has been the case, one would certainly assert that this cooling must go on continuously. Conversations with my friend and colleague Professor Hogbom, together with the discussions above referred to, led me to make a preliminary estimate of the probable effect of a variation of the atmospheric carbonic acid on the temperature of the earth. As this estimation led to the belief that one might in this way probably find an explanation for temperature variations of 5°-10° C, I worked out the calculation more in detail, and lay it now before the public and critics."

From his calculations, Arrhenius concluded: "In order to get the temperature of the ice age between the 40th and 50th parallels, the carbonic acid in the air should sink to 0.62-0.55 of its present value (lowering of temperature 4-5°C)." The general consensus today is that the CO_2 concentration was about 290 ppmV in the late 19th Century, so that Arrhenius's calculation translates to a concentration of 160 to 180 ppmV corresponding to maximum ice-sheet advance. (Arrhenius did not publish a figure for global average temperature to allow a comparison of global sensitivity to modern models, but his Arctic warming estimate for a given CO_2 increase above present generally fits models with an overall sensitivity of 2-3° warming for a CO_2 doubling over the pre-industrial level.)

Arrhenius had no way of determining what the CO_2 level in the atmosphere may have been during the ice ages, but he cited Hogbom's excellently researched memoir to justify the geological implications of his calculations. Subsequently the CO_2 hypothesis of ice age cause has been obscured by more popular ideas. Largely because the cold periods alternated several times with warm periods, the Milankovitch hypothesis (that oscillatory changes in tilt, wobble, and orbit of the earth relative to the sun resulted in climatic oscillations) has gained much scientific attention. This concept requires that the ice age oscillated from the Northern Hemisphere to the Southern Hemisphere and back, and it fails to explain why the ice age developed only recently. (The observed simultaneous advance and retreat of glacial ice in both hemispheres has been difficult to explain away.)

Determinations of CO_2 in air entrapped in ancient polar ice from Greenland and Antarctica generally have given rise in the past to a belief that the atmospheric CO_2 concentration during the last ice was actually higher than the present level, but those results had poor reproducibility.

In an article in **Nature** 13 March 1980, Robert J. Delmas, Jean-Marc Asencio, and Michel Legrand reported that possibly the initial content of CO_2 could have been modified during storage of those samples as from the HCO_3 in sea salt at coastal sites. Simply by rinsing copiously the surface of solid samples with double permuted water or ethylalcohol, they "considerably reduced the carbonation." Subsequently they developed a dry extraction method on very finely pulverized ice from which potentially contaminated exterior portions had been removed mechanically. Their new determinations on two deep ice cores from the Antarctic "strongly suggest that during the last Ice Age (20,000-15,000 years ago) the atmospheic content was half (0.016%) that of today's level (0.033%)," that is, 160 ppmV. The authors noted that Berner et al. have recently analyzed two deep ice cores from Camp Century, Greenland, and from Byrd, Antarctica, by a similar method, and that these results were in good agreement.

Excerpts from recent reports

From **'The Carbon Dioxide Problem: DOE Program and a General Assessment', Technical Report JSR-80-06 of SRI International by the JASON Group, H. Abarbanel, J. Chamberlain, H. Foley, G. MacDonald, W. Nierenberg, and M. Ruderman, October 1980:**

"I. INTRODUCTION. While the effects of the presumably increasing CO_2 content of the atmosphere due to fossil fuel burning have been speculated on for a century, the hard data from Keeling et al. in the last 22 years have clearly demonstrated that the level of concentration is rising at a fairly rapid rate . . .

"Urgency: Before summarizing our conclusions we discuss here the appropriate time scale and the kinds of 'urgency' in this problem. Our position, supported in the detailed argument of this paper, is as follows. We do not know of any matters which may arise from increasing CO_2 in the near future (5-10 years) which would require the attention of public authorities for possible national or international action on a large scale. *In this sense there is no immediate urgency.* The long term effects of CO_2 rise, however, are potentially serious. We have identified several needed additional projects, mostly new monitoring observations and experiments, for which no time should be lost in setting them into motion. Some of these projects, in our opinion, deserve a higher priority than do parts of existing programs. This second kind of urgency, with respect to the introduction of new observations and experiments, represents the single most important need to move the program forward. .

"II. CONCLUSIONS AND RECOMMENDATIONS . . . [T]he pressing need now is to improve greatly this data base in order to understand the reservoirs of carbonic substances and their shifts in time . . . We first mention the importance of monitoring the net CO_2 production from the biosphere by direct measurement of O_2 concentration (high precision) and also the C^{12}/C^{13} ratio in the atmosphere. To complement this measurement of O_2 and carbon isotope ratios it is probably important also to undertake measurements of O_2 and CO_2 in the ocean at various depths. The flux downward of organic material in the ocean may be a hitherto underestimated sink of carbonic matter. . . A potentially important reservoir of CO_2 may be the frozen methane hydrate in the arctic tundra. The magnitude of this reservoir is certainly large; its temperature sensitivity for release of carbon should be determined. LANDSAT monitoring of forest cutting should be studied from the existing data on some understood area, and an assessment made before a commitment to world-wide program is undertaken.

"There has existed for some decades a well developed community of climatologists who have developed machine models of varying complexities, mostly for the purpose of describing and explaining existing world and regional climates. . . There remain potentially important technical deficiencies—the most obvious being the inadequate treatment of oceanic and atmospheric interaction, ocean currents, the role of the deeper ocean below the 'mixed layer,' and the properties of the 'mixed layer' itself.

"The most troubling aspect of this situation, however, is the unknown degree of credibility that should be given to a prediction of an altered climate by present day climate models, all of which have been to some extent 'tuned' to present climate, and are judged by their replication of this climate. The validation of any theory in physical science lies in its predictive power; we are not aware of any such success as yet for existing climate models. Possibly some 'predictions' of past climates or statistically successful seasonal forecasts can be made. Without better verification from the real world, however, it will be difficult for outside observers, including public authorities, to be convinced sufficiently of the accuracy of these predictions, in regional and seasonal detail, to propose public responses when these may be unduly alarming or put mis-placed burdens on society. For these reasons we believe that support for convincing verification of climate models is a more pressing question than is their further elaboration and multiplication. . . .

"Given the uncertainty in climate prediction, an extended program in the monitoring of climate variables should be instituted without delay. The pressure of time derives from the fact that the measurement of any climate change requires a well established baseline from which to make comparisons. . . Even the very simple models all agree that the CO_2-induced temperature rise increases toward the poles. Accurate circumpolar measurement of temperature should be maintained over the coming decades. It has been suggested that the thickness of the 1000 to 700 mbar layer is an accurate measure of troposphere temperature, free of many ground station errors. It has also been suggested (Charney et al., 1979) that accurate measurement of temperature in the deep ocean layers is an indication of world-wide warming. Finally, the uncertain fate of the West Antarctic Ice Sheet . . . will require on-site study and monitoring. A study of the history of the present ice shelf would be of value in a determination of whether or not it survived the post-glacial alti-thermal period. The dynamics of the ice flow in this area should be known in detail, and continually monitored satellite surveillance of the surrounding sea ice may give an early warning of possible instability.

"We have no specific recommendation concerning studies on economic or social effects of CO_2-induced climate change. One may well anticipate that in a generally warmer, wetter world there will be substantial regional diversity in the changes of climate and, perhaps equally important, in weather. In the face of this diversity and the political fragmentation of the world, response may well be limited to adaptation. If these changes are rather rapid, say on a time scale of 50 years, the regional and perhaps world-wide costs may be heavy, e.g., through the effect on agriculture of a serious mismatch between climate, soil, population, and technology in various parts of the world. . . .

"From the above discussion it is clear that we propose expanding the date base, initiating new experimental research, and monitoring of climate chanages, rather than very greatly extending paper studies and computer modeling. . . ."

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From **Book Report by Philip Morrison on 'Coal - Bridge to the Future: Report of the World Coal Study', Carroll L. Wilson, project director, Volume I, in Scientific American, September 1980:**

"One barrier stands in the way of coal: the unknown but suspected risk of worldwide climate modification by the influx of manmade carbon dioxide into the atmosphere. *Coal - Bridge to the Future*, a quick, clear and lively report that summarizes the work of small expert teams from 16 coal-consuming and -producing countries, finesses that issue sensibly if sketchily. These experts recognize the danger, and they argue only that by the year 2000 no large effect can be expected. A long-run solution must go beyond their exercise in continuity. Hence the title: coal is only a bridge to another stage, no sure causeway to an indefinite future, in spite of the huge reserves. Only nuclear energy, whether that released on the earth or that released within the sun, can promise more until we have sure forecasts of climatic change. . . .

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From **'Sensitivity of a Global Climate Model to an Increase of CO_2 Concentration in the Atmosphere', by Syukuro Manabe and Ronald J. Stouffer, Journal of Geophysical Research, October 20, 1980:**

"This study investigates the response of a global model of the climate to the quadrupling of the CO_2 concentration in the atmosphere. The model consists of (1) a general circulation model of the atmosphere, (2) a heat and water balance model of the continents, and (3) a simple mixed layer model of the oceans. It has a global computational domain and realistic geography. For the computation of radiative transfer, the seasonal variation of insolation is imposed at the top of the model atmosphere, and the fixed distribution of cloud cover is prescribed as a function of latitude and of height. It is found that with some exceptions, the model succeeds in reproducing the large-scale characteristics of seasonal and geographical variation of the observed atmospheric temperature. The climatic effect of a CO_2 increase is determined by comparing statistical equilibrium states of the model atmosphere with a normal concentration and with a 4 times the normal concentration of CO_2 in the air. It is found that the warming of the model atmosphere resulting from the CO_2 increase has significant seasonal and latitudinal variation. Because of the absence of an albedo feedback mechanism, the warming over the Antarctic continent is somewhat less than the warming in high latitudes of the northern hemisphere. Over the Arctic Ocean and its surroundings, the warming is much larger in winter than summer, thereby reducing the amplitude of seasonal temperature variation. It is concluded that this seasonal asymmetry in the warming results from the reduction in the coverage and thickness of the sea ice. The warming of the model atmosphere results in an enrichment of the moisture content in the air and an increase in the poleward moisture transport. The additional moisture is picked up from the tropical ocean and is brought to high latitudes where both precipitation and runoff increase throughout the year. Further, the time of rapid snowmelt and maximum runoff becomes earlier."

—Abstract.

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From **'Economically Efficient Energy Futures', by Amory B. Lovins, presented at the International Workshop on Energy/Climate Interactions, Munster, FRG, March 3, 1980, and pending publication with the Proceedings (Energy/Climate Interactions, W. Bach, et al., editors) by Reidel (Dordrecht, Netherlands):**

"The integrated burn of fossil fuel, and the associated risk of global climatic change, can be minimized by economically efficient energy policies based on very efficient energy use and rapid deployment of appropriate renewable energy sources. Such policies can stabilize the rate of burning fossil fuel and gradually, over a half-century or so, reduce it to approximately zero. Economically and technically sophisticated recent studies in many industrialized countries have shown that it is cheaper, faster, and easier to increase national energy productivity by severalfold than to increase energy supply. If such studies are taken as an existence proof, a worldwide Western European material standard of living for 8 X 10^9 people could be maintained with today's rate of world energy use (8 TW) or less, even with unchanged life-styles in the developed countries and complete industrialization of the developing countries. At these cost-effective levels of energy productivity, virtually all long-term energy needs can be met by appropriate renewable sources that are already available and that are significantly cheaper, faster, and otherwise more attractive than competing power stations and synthetic-fuel plants. Only major efficiency improvements and, secondarily, appropriate renewable sources can substantially change the timing of, or reduce the risk of, CO_2 problems."

—Abstract.

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From **'Increased CO_2 Effects on the Environment and in Turn on Agriculture and Forestry' by David Pimental, presented at AAAS-DOE Workshop on Environmental and Societal Consequences of a Possible CO_2-Induced Climate Change, Annapolis MD April 2-6, 1979, published by DoE October 1980:**

". . . The possibility of managing the CO_2 problem if all the sources and sinks were understood is not encouraging. This is true if the major contributions of CO_2 to the atmosphere are from burning fossil fuels and reducing the forests of the earth. . . . The rapidly growing human population and extensive poverty in most of the world necessitates the use of greater amounts of fossil fuels to improve the quality of life of the poor. The same applies to the removal of more forests for agriculture and for fuel wood . . .

"The 1.3 billion tonnes of carbon released from fossil fuel consumption [in the United States, annually] is nearly equal to the amount of carbon that is cycled annually in the biotic community of the United States . . . This assumes that the amount of carbon fixed in plant productivity equals the amount released by the biotic community. . .

"Most of the about 85% of the carbon that is fixed as biomass in plants is in U.S. agriculture and forestry. . . Little carbon is associated with the biomass of other vegetation.

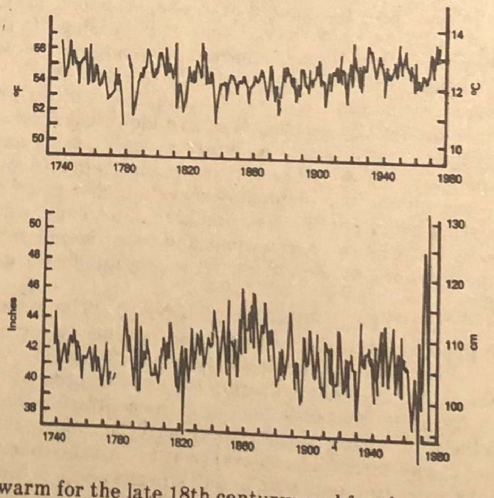
"The bulk of the carbon that is stored in U.S. plants is in the standing forests. . . This amounts to about 95% of the carbon and indicates the vital role that forests play in this environmental aspect. . .

"An estimated 62 X 10^{15} kcal of fossil energy is consumed annually in the world. . . This releases nearly 5 billion tonnes of carbon in to the atmosphere. The carbon released from fuels represents about 1/5th of the amount of carbon utilized in annual plant biomass productivity in the world. . .

"Most (65%) of the carbon utilized by the world plants is utilized by agriculture and forest plants. . . Also 91% of the carbon that is held in the standing biomass of the world is held by the forests. . .

"Temperature Change and Rainfall Relationship

"An examination of the temperature and rainfall trends on the eastern (U.S.) seacoast from 1738 to 1975 does not suggest any major departures from the mean (Figure 1). However, temperature conditions were



Annual average temperatures and precipitation totals for the eatern seaboard of the United States for the period 1738 to 1975. The data are from a representative, reconstructed series centered on Philadelphia from Lansburg (1970) for 1738 to 1967 and from 1967 to 1975 for the Philadelphia Station (NOAA, 1968-1975).

warm for the late 18th century; cool for the 19th century; and warm for the first half and last 7 years of the 20th century. The warming trend was about 2°C over the last century.

"Although there is a great deal of noise in the rainfall pattern, the general relationship is that higher rainfall is usually associated with cool weather . . . (Figure 1). Precipitation was generally high from 1840 to 1860. The trend in rainfall during the past 100 years appears to be down and the amount is calculated to be about 15%. (Thompson, 1975.) Note the extreme fluctuations in rainfall during the last 10 years, dur-

Graphs by David Rose showing the respective amounts of fossil and non-fossil energy needed 1) to halt the CO_2 build-up asymptotically at certain limits and 2) to meet the projected world energy demands described in the World Coal Study by Carroll Wilson. Retained fraction of CO_2 in atmoshere is 54%. These were presented at the Carbon Dioxide Workshop, St. Petersburg, Florida, October 30-31, 1980.

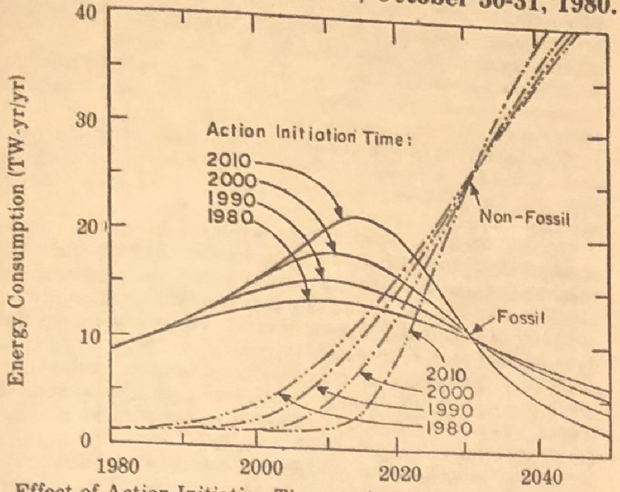


Figure 1. Effect of Action Initiation Time on the Fossil and Non-Fossil Components of World Energy Supply for Asymptotic CO_2 of 500 ppm and High Energy Scenario (WOCOL Study Case)

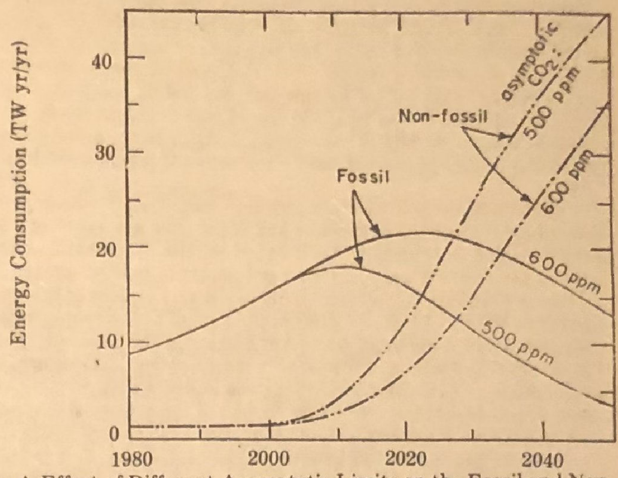


Figure 4. Effect of Different Asymptotic Limits on the Fossil and Non-Fossil Components of World Energy Supply (High Energy Scenario, WOCOL Study and AIT equals 2000). The 500 ppm Fossil and Non-Fossil curves are the same as Figure 1.

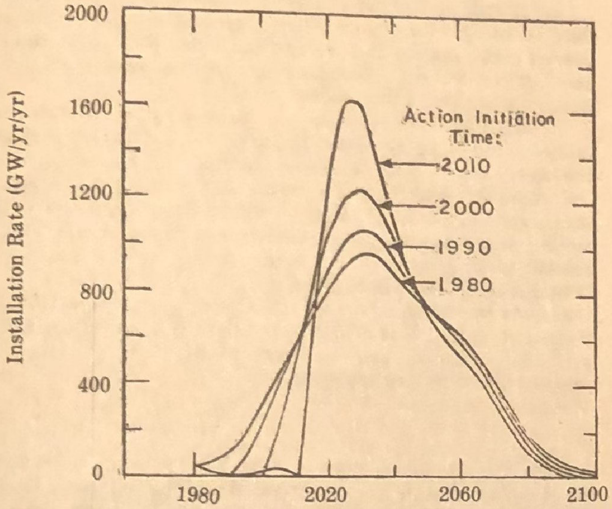


Figure 2. Effect of Action Initiation Time on Required *Rate of Installation* of New Non-Fossil Energy Technologies for Asymptotic CO_2 of 500 ppm and High Energy Scenario (WOCOL Study Case).

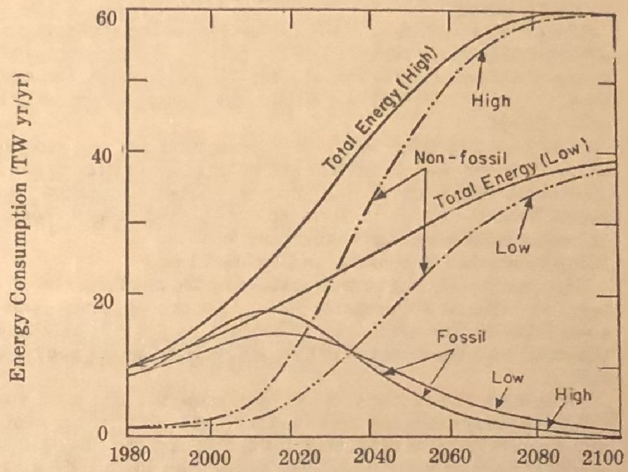


Figure 5. Fossil and Non-Fossil Components of World Energy Supply for High and Low Energy Scenarios for Asympototic CO_2 of 500 ppm and Action Initiation Time of Year 2000. (AIT 2000 corresponds to the WOCOL 'High Coal, Low Nuclear' Case.)

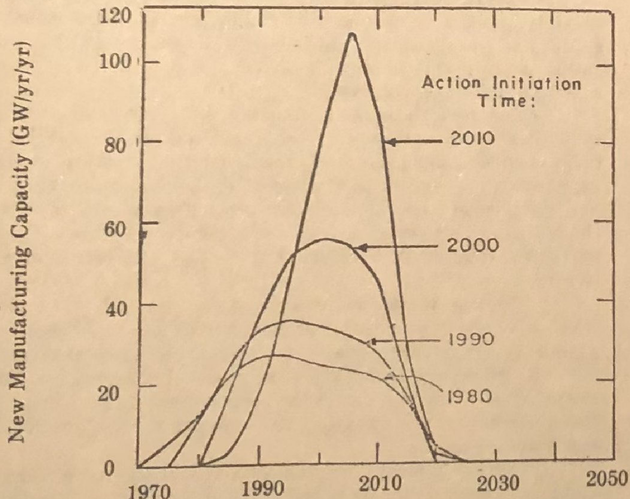


Figure 3. Effect of Action Initiation Time on the Required *Rate of Buildup of New Manufacturing Capability* for Asymptotic CO_2 of 500 ppm and High Energy Scenario (WOCOL Study Case). This incorporates a 10 year lead time. (Note: the graph shows *how much new manufacturing capacity would have to be created each year.* The entire capacity of the U.S. nuclear plant-building industry at present is only about 30 GW per year.)

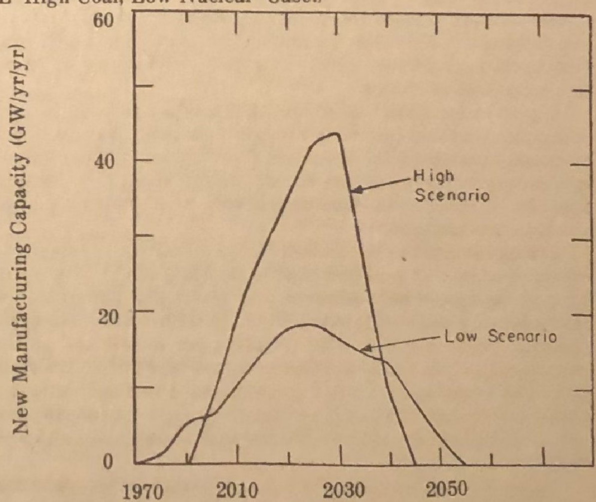


Figure 6. Required *Rate of Buildup of New Manufacturing Capability for Energy Facilities* to Meet a CO_2 Asymptote of 500 ppm and AIT equals 2000 for High Coal-Low Nuclear Case. The High Scenario curve is the same as Figure 3 for AIT 2000.

ing which time the lowest and highest rainfall occurred (Figure 1).

"If conditions become drier with warmer temperatures, then the implications for agriculture and forestry become important.

"Most agriculture crop plants and forest trees use large quantities of water. An acre of corn, for example, requires about 500,000 gallons (1 gal equals 3.79 liters) of water, and rice culture requires about 1.5 million gallons per growing season . . . Of all the water that reaches the nation's streams (1260 billion gallons per day [bdg]), one-fourth, or 420 bdg, is withdrawn. Of the total 420 bdg of water withdrawn for all purposes, only about 95 bdg is consumed . . . Agriculture alone consumes 83% of the water, whereas industry and urban areas consume less than 17%.

"It should be pointed out that although industry and urban areas return most of the water to streams and lakes after use, much of it is polluted when it is returned. Agriculture on the other hand consumes most of the water it uses and does not return it to streams and lakes.

"Water is already in shorter supply in the arid regions of the western portion of the United States than in the rest of the country. Irrigation consumes about 85% of all water withdrawn in the 17 western states. The conflicting demands for available water among agriculture, urban areas, industry, and fossil energy mining indicate that certain changes in water are inevitable. For example, one of the strongest competitors for water in the West will be fuel production such as coal gasification . . . Among the four competing groups, evidence suggests that the proportion of water allocated to agriculture will decline . . . because the economic yields from of water from agriculture at present are far less than yields from such activities as industry, mining, and recreation.

"Potential Impact of Increased Atmospheric CO_2 on Temperature and Rainfall Patterns

The projected doubling of the CO_2 content of the atmosphere . . . is expected to influence temperature and rainfall. Temperatures in North America are expected to rise at least 2°C (EPA, 1978). The warming trend is expected to affect rainfall patterns and on average result in drier conditions.

"The combined effect of warm temperatures and reduced rainfall, will, if the event occurs, result in low water levels in streams and lakes. The warm temperatures will increase evapotranspiration rates in plants. Thus the warm temperature and reduced rainfall should have an important effect on agriculture and forestry.

"Crop Production Susceptible to Climatic Change

"Assuming a 2°C rise in temperature by the middle of the next century, then rainfall will probably decline. For this assessment rainfall is assumed to decline about 10%. Temperature and rainfall changes of this magnitude are expected to have a significant impact upon food production.

"With corn, for example, it has been projected that a 2°C rise and 10% drop in rainfall might result in a 25% reduction in corn yield in the major cornbelt states of Indiana, Iowa, Missouri and Illinois (Benci, et al., 1975). Certainly, reducing corn yields from about 6.272 kg/ac (100 bu/A) to about 4.704 kg/ha (75 bu/A) would be significant and have a major effect on U.S. agriculture.

"A significant change in temperature and rainfall patterns is expected to reduce wheat yields by about 12% in the four major producing states of North Dakota, South Dakota, Kansas and Oklahoma (Ramirez and Sakamoto, 1975). This amounts to a reduction of wheat from about 1610 kg/ha to about 1410 kg/ha . . . [which] would have a major impact on the nation's food system.

"If pest incidence is taken into consideration relative to an increase in temperature and decline in rainfall, then some changes in pest problems and losses could be expected. First, current annual losses in agriculture and forestry to pests are significant: about 37% for agriculture and 25% for forestry . . . occurring in spite of all chemical pesticidal and non-chemical controls.

"If temperatures in the United States increase an average of 2°C and rainfall declines 10% to 30% due to doubling of CO_2, there will be important changes in pest outbreaks . . . Insect pest populations will generally increase with an increase in temperature. Some insect pests, for example, produce 500 to 2000 offspring per female and go through a generation in 2 to 4 weeks. With a warmer and longer growing season these pests may pass through an additional 1 to 3 generations. The exponential increase of some insect pest populations under the new favorable environment could seriously increase insect losses and make their control more difficult.

"Another contributing factor to insect outbreaks would be changes in winter temperatures and snow cover. If overwintering temperatures are warmer, then insect mortality during the winter would be less and the initial spring populations would be larger. This would result in larger summer populations on the crop, because the initial base populations starting in the spring would be larger than previously with more severe winters.

"Reduced snowfall over winter could have an opposite effect on the insect populations. Reduced snow cover might expose a larger number of overwintering insects to freezing conditions (depending on temperature loss).

"Warm/dry conditions plus the CO_2 fertilization of crop and forestry plants may alter the nutrient make-up of the plants. This in turn may make some plants more nutritious for insects and increase the rate of increase in the pest populations. Hence, the warm/dry conditions of CO_2 fertilization may increase insect pest outbreaks.

"The higher temperatures that are projected may also influence insect control by reducing the effectiveness of insecticides against insect pests. At high temperatures some insects are better able to detoxify insecticides and thus are able to escape control.

". . . The warm/dry conditions . . . will probably increase the intensity of competition between weeds and crops for the limited available moisture. Most important perhaps would be the reduced effectiveness of herbicides on weeds under the warm/dry conditions.

"Weed control under warm/dry conditions would depend more heavily upon mechanical cultivation than present. This would require added machinery and labor and increase crop production costs.

"In general under warm/dry conditions, plant pathogens should be less of a problem. Therefore, losses from plant diseases should be reduced with the projected climatic change.

"Currently, about 13% of U.S. agriculture is irrigated . . . If rainfall did decline 10%, one might expect that more irrigation would be practiced. This I doubt because of the energy intensiveness of irrigation.

"The energy problem with irrigation can be illustrated with corn. About 12 million liters or 12 metric tonnes of water are needed to produce about 5000 kg of corn per hectare under arid conditions. . . The energy cost to pump this water from a depth of about 100 meters is about 21 million kcal. If we use irrigation this increases the energy use in crop production about 400%.

"Clearly a 400% increase in energy use in agriculture production will influence the cropping season in the United States. Already in parts of the United States some low value crops such as alfalfa can no longer be irrigated. The reason is the large amount of water that is required and the current high price of energy. This situation is expected to get worse as fuel prices rise. Hence, irrigation as a means of offsetting reduced rainfall does not appar to be an encouraging alternative.

"CO_2 Fertilization of Crop Plants

". . . At this stage assuming a 2°C increase in temperature and 10% decline in rainfall, it is doubtful that the CO_2 fertilization will fully offset the reduced growth and production of crops due to temperature/moisture changes. . . ."

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From **'The Earth's Climate - We're Finally Doing Something about the Weather, But We Don't Know What', by William W. Kelloggg (NCAR), Robert Schware (Aspen Institute for Humanistic Studies, Boulder CO), and Edward Friedman (MITRE Corporation, McLean VA), published in the Futurist, October 1980:**

". . . Generally, mankind's influence on weather is inadvertent. Unfortunately, it is also largely unpredictable, and, at worst, it may be dangerous and irreversible. . . (I)t is now widely accepted that worldwide gases, notably carbon dioxide, have the potential to affect global climate in unforeseeable ways.

". . . At present, the study of climate is well enough developed so that climatologists can attempt the characterization of some general features of climatic change, such as mean winds, temperatures, and water vapor distribution. But, as climatologists themselves are the first to admit, existing theories cannot yet predict with any accuracy the climatic changes that might occur in a given region—say a state in the U.S. or a particular country in Western Europe—as the result of man's activities.

". . . The last decade has witnessed a series of climatic phenomena which have contributed to lower productivity in some fisheries, smaller grain reserves in several parts of the world (in spite of investments in modern agricultural technology), the growth of deserts, and the erosion of fertile soils. Though partly the result of natural climatic variations, these effects may quite possibly have been influenced and reinforced by man's activities.

". . . The single most important of man's influences on climate is the addition of carbon dioxide to the atmosphere from the burning of fossil fuels. . . (M)an has already begun to influence the way that sunlight is absorbed by the earth and retransmitted into space as infrared radiation.

"The consequent change in the heat balance of the climatic system is expected within 20 to 50 years to produce a global warming measurably different from recent climatic trends. The major contributor to this problem, the release of carbon dioxide from burning fossil fuels, could increase the global average temperature by 2-3°C in the first half of the next century. The climate models applied to the problem predict that temperature changes will be smallest in the tropics and largest during polar winters. Polar winter temperatures might increase two or three times as much. And of even greater importance will be the dramatic shifts of precipitation patterns. . .

"(S)ince the industrial age began some 200 years ago, the steady growth in carbon dioxide emissions may have increased the total amount of carbon dioxide in the atmosphere by as much as 20%. . .

"The carbon dioxide problem is unique and important for a number of . . . reasons:

"• So far, no consequences have been identified that can be clearly attributed to the atmospheric buildup of carbon dioxide, since it has been obscured by natural climatic variations. This contrasts with some of the more common environmental problems, such as river and air pollution, where tangible impacts have been measured and where the benefits and costs of various corrective options can be readily projected.

"• The potential long-term effects of the climatic change from increased carbon dioxide and the socioeconomic impacts it may trigger could be very extensive, much more so than the impacts of any purely local or regional environmental problem.

"• The impact of carbon dioxide-induced climatic changes cuts across a wide range of crucial sectors of human activity, and may be essentially irreversible.

"• In the event of a global climatic warming, the likely impacts will probably not be uniformly distributed among different societies or even within societies.

"• The timing and intensity of likely impacts is still poorly understood, in that it is a function of the future allocation of our existing world resources of fossil fuel as well as the somewhat uncertain responses of the climate system itself.

"To add to the problem, the energy strategies that various societies adopt for the transition from present fuels (mostly fossil) to non-fossil fuels have major implications for the amount of carbon dioxide what will be released. It may well take 50 years or more to make the transition to other forms of energy. This is the typical period required to replace one major form of energy with another in market economies. This delay, along with the several decades that elapse between the release of carbon dioxide and its effects on global temperature, suggest that advanced societies have already reached the time when serious action should be considered. . .

"Luckily, the problem of carbon dioxide emissions and their influence on weather and climate has already attracted the attention of policymakers around the world. But the response has not been all that it could be. The uncertainties inherent in the carbon dioxide problem are often interpreted as evidence that it is too distant and vague to have any significance now. On the contrary, action on the carbon dioxide problem can and should be taken now, even though climatologists cannot currently 'solve' the problem with some simple scientific panacea. . .

"Future Climate Change: Impacts and Implications

". . . The following are four examples of areas of serious concern from among the wide array of potential impacts that could occur in the wake of a significant change in global climate, and, more specifically, a global warming brought on by a buildup of carbon dioxide in the atmosphere:

"1. *World Food Production*. . . In warmer periods in the past, there were marked differences in patterns of precipitation. For example, North Africa and the Middle East tended to receive more rain. The U.S. corn belt and the region of the Great Lakes also were distinctly drier during the warm period that occurred 4,000 to 8,000 years ago, and if history were to repeat itself, this general area might expect decreased precipitation, very possibly leading to a significant decline in agricultural production.

". . . (The) northward penetration of the monsoon could be enhanced if the global climate grew warmer, which in turn might improve agricultural conditions in these areas.

"The agricultural productivity of subarctic regions like Russia, Canada, and Scandinavia might also be improved, given enough rainfall. . .

"Changing climate, especially with warmer and longer growing seasons, could also influence the frequency, severity, and geographical distribution of agricultural problems with insect pests. . .

"2. **Human Health and Disease** . . . Altered climatic patterns, including increasing precipitation and seasonal temperature extremes, could have an especially important effect of the breeding conditions, growth rates, and biological diversity of many species of insects that transmit tropical diseases. . .

"3. **Population Redistribution**. . . The drought of the 'dust bowl' years in the mid-1930s produced the largest migration in U.S. history. Migration has also been a common response to climate fluctuations in the African Sahel.

"One of the ominous possibilities that might accompany a global warming trend—a rise in sea level—could make the migrations of the American Middle West and the African Sahel seem almost insignificant by comparison. Many climatologists fear that a warmer polar climate could cause the disintegration of the huge and perhaps unstable West Antarctic ice sheet, resulting in a possibly disastrous rise in sea level. Fortunately, the probability of this is small in the next century, but it merits consideration because its potential impact is so awesome. . .

"Seven of the nine largest metropolitan areas in the United States are within the environmentally critical zone. More than 30% of the world's population lives within a 50-kilometer area adjoining oceans and seas. . .

4. **Considerations of Global Fairness.** In the international arena there may be demands that the developed countries bear the brunt of the costs of controlling carbon dioxide emissions, and of the socioeconomic dislocations that might result from a global warming caused by increased concentrations of carbon dioxide in the atmosphere. . . (T)o a developing nation, the call for limiting the use of carbon fuels can only be interpreted as a roadblock on its path to industrialization, a call that will not be heeded if inexpensive fuel is available.

". . . (T)he international response to a global warming presumed to be the result of man's activities could be a welter of conflicting assertions, claims, counterclaims, accusations, and economic and political maneuvers. . . ."

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From **'Future Climate Change Requires Coping Strategies Now, Scientist Says', information release of Dec. 9, 1980 from the National Center for Atmospheric Research (Boulder, CO):**

"San Francisco, California — Carbon dioxide added to the atmosphere from burning fossil fuels will warm the earth, change rainfall and temperature patterns, alter agricultural production world-wide, and may even cause the sea level to rise. Such effects will not be felt immediately, but some of them may become evident early in the next century—perhaps sooner. These were the subjects of presentations at the All-Union session 'Carbon Dioxide and Climate' at the American Geophysical Union meeting.

"Organized by Dr. William W. Kellogg of the Aspen Institute for Humanistic Studies and the National Center for Atmospheric Research (NCAR), the session moved beyond scientific evidence of climate change to national and international strategies for coping with the necessary adjustments or adaptations in the decades ahead.

. . . " 'It's probably wishful thinking to believe we can avert climate changes simply by stopping the use of fossil fuels,' Kellogg says, since that would involve all the world's countries agreeing to give up this convenient energy source . . . 'Population growth, poor distribution of food and consequent famines, and the depletion and loss of natural resources are serious problems that the people of the world must face in the next several decades, even without the prospect of climate change. But perhaps the changes we now foresee will spur the world's nations to make crucial long-range measures—measures that are long overdue,' Kellogg said.

Hard vs. Soft Energy

'Energy conservation' frequently is proposed to halt CO_2 releases from fossil fuels. Such conservation is often alluded to abstractly so that the social, economic, and environmental tradeoffs cannot be evaluated and feasibility assessed.

In contrast, Amory B. Lovins has prepared a roughly quantified conservation and substitution program for halting the CO_2 buildup, which follows:

• Decrease the passage of heat into and out of buildings largely with increased insulation, vapor barriers, and heat exchangers on venting systems so that buildings would require "little or no space heating even in a frigid climate."

• Attain considerably higher fuel efficiency in autos and airplanes (and presumably also in trucks and tractors). Lovins suggests that autos could attain 150 to 200 miles per gallon of fuel.

• Convert municipal wastes and farm and forest residues to liquid fuels.

• Allow no increase in the worldwide average per capita electricity production and utilize present hydro sources, more small-scale hydro, individualized photovoltaics and individualized wind generators. 'Oversized' electric motors would be replaced with motors several times smaller.

• For industrial process heat (process steam, direct heat for furnaces) use solar-hydrogen systems (which break down water directly with sunlight and catalysts at several hundred degrees C) and tracking and nontracking sunlight concentrators.

• Augment these sources with woodburners and solar ponds (brine-filled ponds with a dark, sunlight absorbing liner and a heat-exchange system).

• Completely eliminate nuclear energy worldwide because of Lovins' perceived saving of money and the proliferation risks, and halt additions to U.S. generating capacity on the basis that new generators would be unneeded and too costly.

• Lovins concluded that "a worldwide Western European material standard of living for 8 X 10^9 people could be maintained with today's rate of energy use or less, even with unchanged lifestyles and complete industrialization of the developing countries."

• Lovins believes that the substitution of 'soft', labor-intensive energy sources for conventional or 'hard' sources and a halt to further electric growth would decrease unemployment.

Analysis shows several weaknesses in Lovins' program:

• Reducing energy consumed in heating and cooling buildings appears greater in theory than in practice due largely to the air exchange as people enter and leave buildings. This was shown by a 'heat-tight' demonstration house in Regina, Saskatchewan, which consumes 60% more electricity than the average Regina house (assuming average use for the appliances) due to 1000 visitors per week.

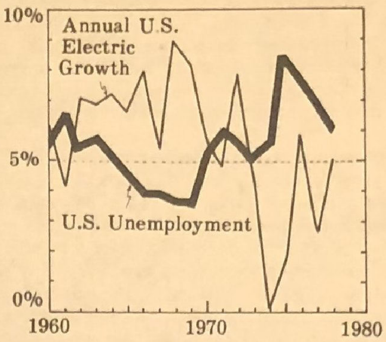
• The regulating of temperatures in offices and factories by the U.S. government above or below the comfort level may reduce work productivity and have detrimental health effects in some cases.

• A several-fold reduction in energy consumed in household appliances appears unfeasible. Cooking solely with microwave ovens at virtually maximum energy-transfer efficiency offers a nominal 4½-fold energy saving over mid-1960s electric stoves and a 3-fold saving over mid-1970s stoves. Microwave offers a nominal 9-fold saving of energy over open-fire cooking in rural villages in India, but probably no real energy saving if manufacturing and shipping energy is taken into account. Householders might be persuaded to return to refrigerators with heat-exchanging coils on top (which results in less eye-level storage and more stooping) to save minor amounts of electricity. But recent increases in energy efficiency gained from better insulation, improved door seals, and smaller motors with lighter parts (which run noisier, faster, and more often) cannot be extrapolated to a several-fold efficiency gain.

• Lovins extrapolates auto efficiency gain from examples such as a turbo-charged diesel engine that turns off on idle or coast. But his several-fold gain in transportation efficiency appears attainable only by low-powered, lightweight motorbikes.

• The potential yield of liquid fuels from municipal wastes (which are 50% agricultural wastes) and from farm and forest residues cannot match the magnitude of present-day liquid-fuel consumption. Much forest 'waste' now goes into 'pressed board', paper and fuels, and if the entire yield of the largest farm product in the U.S. (maize) would be converted to liquid fuel, it could supplant less than 0.3% of the current U.S. gasoline consumption. The residues (stalks, leaves) could yield about the same amount of energy as is consumed by the farms.

• Electric growth has been linked closely with growth in the number of desirable jobs available, so that high electric growth rates generally accompany low unemployment (see graph). The low electric growth accompanying low unemployment in 1974-75 resulted from a sharp increase in efficiency prompted by a big jump in electric rates when the price of imported oil increased four-fold. Only the *growth* decreased, not total electric use, because demand is quite inelastic with respect to price.



• For economic savings some oversize electric motors have been replaced by smaller ones and 'load-following' motors (with complex and costly controls) are being introduced. Most such conversions are in the larger motors, because such conversions appear generally uneconomic in small motors and in many cases (as in drill presses) versatilily of job size would be lost.

• Lovins' prime conservation target is electric generation rather than personal vehicles, which in the U.S. represent 40 times more horsepower than all the electric generation. His soft energy program neglects large energy savings from mass ground-transport, which systems require a large continuous electric supply (even on cloudy days) near enough to densely populated areas to minimize transmission losses.

• The U.S. material standard has continued to grow rapidly with reduced electric growth, but not so much from gains in energy efficiency as by reductions of energy-intensive exports (machinery, nuclear plants) and increases of energy-intensive imports (autos, television sets). The energy which formerly heated, illuminated and operated U.S. factories is now heating, illuminating and operating many foreign factories to supply items consumed in the U.S.

• Replacement of electric energy with human physical labor is termed a 'cost-effective' increase in energy productivity by Lovins, but the decrease in human productivity either requires more hours of labor to produce the same goods or the output of material goods is reduced.

• Major declines in average family size and birthrates have consistently accompanied declines in the parents' use of physical labor to make a living. Those who dispute the link between energy growth and birthrate decline often cite statistics released by China which ostensibly show that governmental birth-limiting programs can succeed without the labor-decreasing benefits of industrialization. China's low birth figures are questionable because the official number of births minus deaths should give a total population of about 950 million, while the actual population is believed to be about 1050 million.

• Industrial process heat consumes one-quarter of all the energy in the U.S. and in some cases the temperature needs are very high (1600°C for steel, 1400°C for cement, 825-1000° for reforming synthetic ammonia); therefore any restriction that only solar-hydrogen systems and sunlight concentrators supply such heat would effectively halt production of chemicals, metals, paper, glass, and many other items. The labor cost of such solar systems is estimated to be about 15 to 30 times as much as nuclear per unit of energy and soft energy systems consume much more structural metal by weight than fossil or nuclear per unit of energy output.

• Lovins cites TVA as a utility which requires no additional generating capacity to meet customers' needs. Yet the heatwave and drought of summer 1980 found TVA's hydroelectric capacity reduced during high demand for air conditioning, so that TVA had to buy electricity from other utilities. According to the news media, some of the 1100 heat-related deaths in the U.S. were people who did not use their air conditioners in order to save energy.

• The favorable economics of nuclear energy are shown by a recent announcement by Britain's Central Generating Board that the cost advantage of nuclear generating capacity is sufficient to justify early retirement or mothballing of fossil fired plants. (Britain imports some of the coal for these plants.)

• To allow the nuclear proliferation issue to bring an end to peaceful nuclear energy would be an admission that the world's political leaders cannot be expected to yield to the universal revulsion against actually using nuclear weapons in warfare.

—W.N.B.