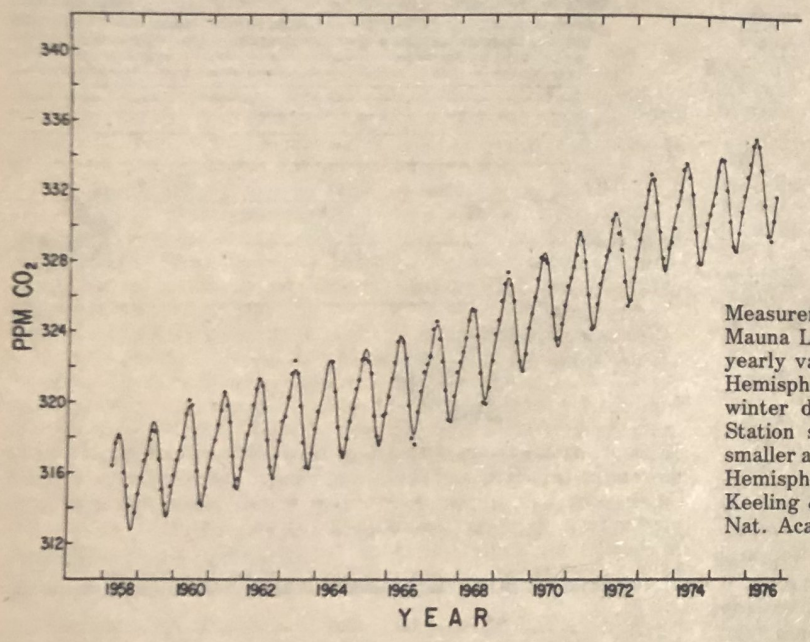
CO_2 Newsletter©

Volume 1 - number 1 **October - November, 1979**

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



Measurements of the atmospheric concentration of CO2 taken at Mauna Loa Observatory, showing the overall increase of CO2 and yearly variations due to uptake by growing plants of the Northern Hemisphere in spring and summer and the return of CO2 in fall and winter due to respiration and decay. Data from the South Pole Station show a similar upward trend with yearly oscillations of smaller amplitude and reflecting the inverted seasons of the Southern Hemisphere. From 'Impact of Industrial Gases on Climate', by C.D. Keeling & R.B. Bacastow in Energy and Climate, Nat. Res. Council, Nat. Acad. of Sci., 1977.

Why the CO_2 Newsletter?

The accelerating buildup of CO2 in the atmosphere—primarily from the combustion of fossil fuels—is causing growing concern among scientists the world over. The greenhouse effect of this buildup is forecast to cause a 1°C average global warming in about two decades and a 2.5°C warming in about four decades if the past trend of CO2 buildup is allowed to continue.

What effect would this warmup have on the world's climate? Estimates vary considerably, but probably the simplest way to visualize the potential change is to note that only a 5° average global warming destroyed vast Pleistocene ice sheets covering much of North America and Eurasia to create the temperate climate of today. Also sea level rose approximately 135 meters to the present level. A high probability exists that centuries-long drought will occur in much of the world's wheat belts, and that sea level will begin to rise due to polar ice melt **during the lifetime of many people living today**, if man's consumption of fossil fuels continues unabated. Symposia have actually been held to assess the impending famine and social and political upheavals which could result from a CO2-induced climate change.

When the public perceives that the CO2 problem is not imaginary and that the impacts are expected rather soon, political policies regarding energy production, energy consumption and energy research will probably change greatly from current policy which essentially pays no attention to the CO2 problem. The promoting of coal-electric generation of electricity and the making of synthetic fuels from coal and oil shale may lose public support, and ideological arguments against development of conventional nuclear energy and the breeder reactor may lose all popular appeal. Wasteful consumption of gasoline in large vehicles and for purposes of pleasure may be curtailed by price or tax restraints.

When the public becomes fully enlightened about the present scientific views of CO2-induced environmental impacts, revolutionary changes may begin in energy-use patterns. Nothing short of revolutionary changes in energy production and usage appear capable of averting the adverse impacts which are expected.

For the energy industries which plan to make large investments in production facilities having a long lead time and a longer productive lifetime, no central source of information exists on current research concerning the CO2 problem and the revolutionary changes in energy policies which scientists are now proposing. Much research information is now circulated internally within the scientific community without being published, and in many cases without reaching the world's largest libraries. Environmental administrators are often not aware of some of the important information presently available.

CO2 NEWSLETTER is intended to fill this communications gap by capsulizing both the published and unpublished reports on the CO2 problem which are deemed important. This newsletter will also publish original material, invited articles, and letters of inquiry, fact, and opinion.

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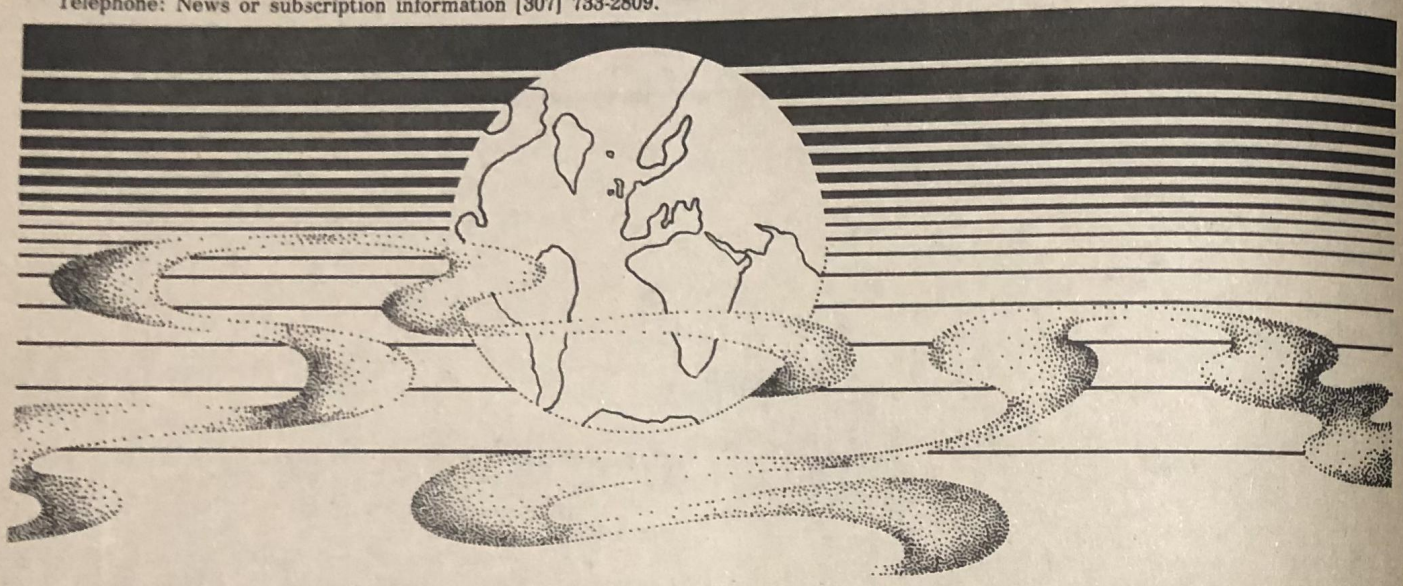


EDITORIAL

Until recently the CO2 problem has been relegated to research laboratories, remote monitoring stations, oceanographic vessels, and to small conferences of concerned scientific workers. Strong warnings are beginning to come out of these studies. Increasing numbers of scientists in many countries are beginning to realize that the composition of the earth's atmosphere can control climate and that the cumulative actions of several billion people can actually change the composition of the earth's atmosphere.

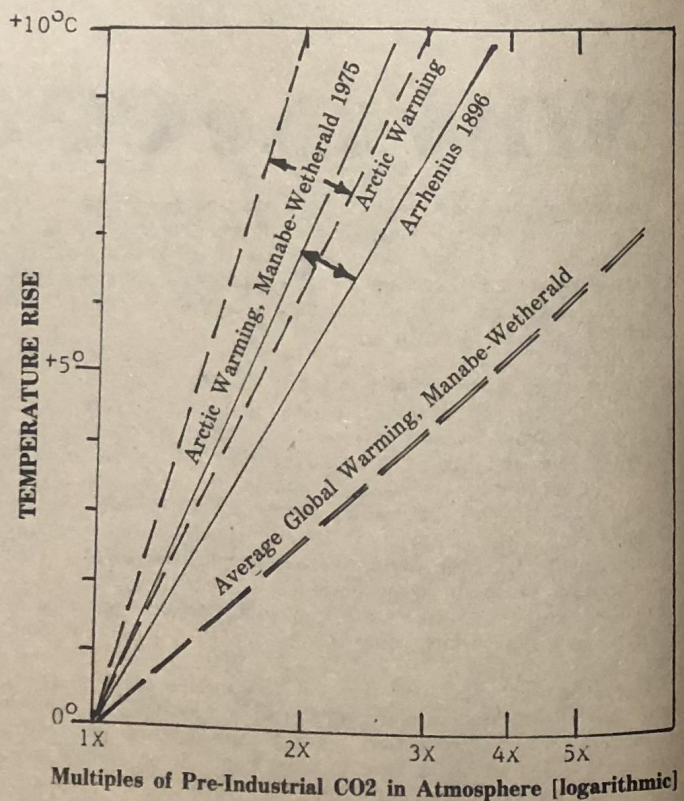
Time may be of the essence in regard to the CO2 problem. It may be vital that research be hastened and debate shortened if the people of the world are to retain control of their environmental destiny. Energy policy and environmental policy cannot be used as convenient vehicles for advancing political or personal aims, and 'ecology' must be treated as a scientific discipline rather than as a game between adversaries. Empathy and trust must be restored between politicians, administrators, businessmen, and activists groups if the CO2 buildup is to be halted in timely fashion, judging from the timetables of adverse impacts which are beginning to emerge from the laboratories.

When heated arguments give way to cool logic, we find that the overall goals of conservationists, humanists, and industrialists actually converge to represent the desires of the general public. A common problem of worldwide scope and great duration, as the CO2 problem, must be combatted by a common effort—guided by the wishes of a fully enlightened public.

The editor wishes to thank the many persons who have responded to requests for published and unpublished material to help advance this enlightenment.

"We should therefore pay no less attention to the undemonstrated assertions and opinions of old and experienced or prudent persons than to demonstrations, for their experience gives their eyes the power of correct vision."

—Aristotle, 4th Century, B.C.



Revival of a 19th century concern

The idea that man could cause a significant change in the earth's climate by altering the composition of the atmosphere began in the 19th Century. This concern has been revived in recent years as the buildup of CO2 has become noticeable.

In 1827 the French physicist Jean Fourier recognized that the atmosphere acts like the glass of a hothouse by letting through light rays while retaining the 'dark rays' from the ground. Subsequent work by others showed that the highly selective absorption of infrared by carbon dioxide and water vapor caused this greenhouse effect, yet the chief gases of air caused no effect.

In 1861, the British physicist John Tyndall made the first accurate measurements of the absorptive capacity of CO2 and other gases in the laboratory. He also noticed that the gases re-radiated heat in proportion to their absorptive capacity. Tyndall suggested that a change in the atmosphere's concentration of CO2 could actually change the earth's climate.

The first systematic study to predict climate change in response to differing amounts of CO2 in the atmosphere was made in 1896 by the Swedish scientist Svante Arrhenius, who later was awarded the Nobel prize for his work in the field of physical chemistry. Arrhenius took the observations of the American physicist Samuel Langley on the varying intensity of infrared radiation received from the moon at certain angles above the horizon and at differing conditions of surface humidity. (At a certain phase of the moon, the infrared spectrum is identical to that radiated by the earth.) By using the earth's atmosphere as his laboratory, Arrhenius determined the amount of heat that had been intercepted by differing optical thicknesses of CO2 and water vapor.

Arrhenius then created the first complex model of the earth's climate system to test (in theory) the effects of lesser or greater amounts of CO2 on the temperature of the earth's surface. He took into account certain factors affecting the earth's heat balance including the reflectance of sunlight (albedo) from the ground, oceans, clouds, and snow-covered areas; the percentage of cloud cover at various latitudes; the mean height of clouds; cloud-top temperatures; the effects of ascending air currents; and the humidity in various regions at various seasons. He assumed that absolute humidity would increase to maintain constant relative humidity if the air is warmed, which is still debated today among climate modelers. Water vapor causes its own greenhouse effect, so an increase of water vapor with a CO2-induced warming creates a positive feedback.

Arrhenius calculated that the temperature in the Arctic regions would rise about 8°C to 9°C if CO2 increased to 2.5 or 3 times the value at that time. This would correspond, he figured, to the average Arctic temperature during the Tertiary Period before icecaps developed. Interestingly, the most sophisticated computer model of today, the General Circulation Model of Manabe and Wetherald, leads to an expectation of about 7° to 10°C rise in Arctic temperature if CO2 increases to double the pre-industrial level, which is not far from Arrhenius's estimate. (See graph, page 2.)

The greenhouse effect of CO2 is dramatically illustrated by the atmosphere of the neighboring planet, Venus, whose atmosphere consists of almost pure CO2 at a pressure about 100 times that of the earth's atmosphere. Temperatures on the dark side of Venus are hot enough to melt lead! Without the greenhouse effect of CO2 and water vapor, the earth's temperatures today could be much colder than during the ice ages. The earth could have developed an atmosphere similar to Venus if CO2 had not been locked into the lithosphere by limestone formation and buried organic matter concurrently with the outgassing of CO2 from the earth's crust by volcanism.

Excerpts from recent reports

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From 'Energy and Climate', by the Geophysics Study Committee of the National Research Council, National Academy of Sciences, Washington, D.C., 1977 (158 pages):

"A rise in average annual global air temperatures, increasing toward higher latitudes as predicted in the model of Manabe and Wetherald (1975) would result in a general poleward movement of agroclimatic zones. At higher latitudes, there would be a longer frost-free growing season than at present, and the boundaries of cultivation could be extended northward in the northern hemisphere. At the same time, summer temperatures might become too high for optimum productivity of the crops presently grown at middle latitudes, such as corn and soy beans in Iowa, Illinois, Indiana, and Missouri, and it might be necessary to shift the Corn Belt toward the north. But the acid podzol soils over large areas in these higher latitudes are badly leached, and extensive and expensive soil amendments would be required even to approach the yields now obtained in the remarkable soils of the Corn Belt.

"The model predicts a global rise in average annual precipitation, which at first glance would seem to benefit agriculture. But the accompanying higher temperatures would also increase evapotranspiration from cultivated lands, and some part, perhaps all, of the benefits from the additional water supply would be lost . . . .

"In general, the most serious effects on agriculture would arise not from changes in global average conditions but from shifts in the location of climatic regions and changes in the relationships of temperature, evapotranspiration, water supply, cloudiness, and radiation balance within regions . . . . Large changes in climatic relationships within regions such as might be brought about by a doubling or quadrupling of atmospheric carbon dioxide would almost certainly exceed the adaptive capacity of presently grown crop varieties . . . .

"The most serious effects of possible future climatic changes could be felt along the boundaries of the arid and semiarid regions in both hemispheres. These are the zones of atmospheric subsidence where precipitation is scanty and highly variable: the southwestern United States and northern Mexico; the belt of relatively dry lands extending from southern Europe and northern Africa (including the Sahara), eastward across Arabia and south Asia to Pakistan and northwestern India; northeastern Brazil, northern Chile and southern Peru, western Argentina, southwest Africa, and Australia."

—from 'Overview and Recommendations'

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From 'A Comprehensive Plan for Carbon Dioxide Effects Research and Assessment, Part I: The Global Carbon Cycle and Climate Effects of Increasing Carbon Dioxide,' an unpublished but circulated report of the Office of Carbon Dioxide Effects Research and Assessment, Assistant Secretary for Environment, U.S. Dept. of Energy, May 1978 (53 pages plus appendices):

"The perception that there might be a serious CO2 problem stems from the following:

- "There has been a well-documented world-wide increase in atmospheric CO2 concentrations since 1958; this growth has probably been occurring since the middle of the last century.
- "The CO2 increase in the atmosphere is equivalent to about 50% of the fossil fuel CO2 released to the atmosphere.
- "CO2 transmits solar radiation but absorbs some of the outgoing long-wave radiation from the earth, the so-called 'greenhouse' effect. Thus, qualitatively, CO2 should act to warm the lower atmosphere and, by radiating more outgoing energy, cool the stratosphere.
- "Different calculations of the greenhouse warming indicate that doubling of the CO2 content of the air would result in a 1.5-3°C warming of the lower atmosphere. This global warming is sufficient

Continued next page

to cause significant alteration of the present climate.

• "While such climatic effects would be world-wide, they would likely not be uniform: some regions of the globe would experience greater changes from the present climate; others less.

• "The doubling of atmospheric CO2 could occur as early as 2030. There are sufficient fossil-fuel reserves to raise the atmospheric CO2 many-fold if they are used.

• "Natural rates of removal of CO2 from the air are calculated to be so slow that it would take many centuries before atmospheric CO2 levels returned to 'normal' after additions ceased.

"No responsible scientist will positively assert that climate changes will occur if we continue burning fossil-fuel or that the predicted climate changes would be catastrophic. On the other hand, no one can ignore the possibility that undesirable climate changes will occur. It is imperative that society be able to anticipate the consequences of future fossil fuel consumption."

—from the Introduction

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From 'Sociopolitical Impacts of Carbon Dioxide Buildup in the Atmosphere Due to Fossil Fuel Combustion,' prepared by O.W. Markley, A.L. Webre, R.C. Carlson, B.R. Holt for Inexhaustible Energy Resources Planning Study, Energy Research and Development Administration, Washington, D.C., Stanford Research Institute Project EGU-6370, July 1, 1977, (56 pages), unpublished:

"Worldwide releases of carbon dioxide from high (annual average of 4.5%) growth in fossil fuel combustion could cause concentrations of atmospheric CO2 at least 7.5 times the preindustrial level and could plausibly be attended by major sociopolitical impacts such as the following:

• "Large, persistent fluctuations in global food supply—due to repeated crop failures in various regions of the world which are caused by chronic and severe weather variability (high probability, large affected population, within 50 years).

• "Disruption of U.S. economic system—due to chronic water shortfalls below levels needed to sustain energy technologies and agriculture (low but significant probability, large affected population, within 50 years).

• "Increasingly regulated demographic migration between regions and across national borders—due to climate-related collapse of selected webs in regional economies (high probability, small affected population, within 50-100 years) . . . .

• "Widespread concern and political dissension about prevention of atmospheric buildup—due to chronic disruptive climate effects for which the CO2 effect is blamed, emerging evidence of marine ecology problems, and potential sea level rise (high probability, uncertain size of participating population, uncertain timing of occurrence)."

—from the Executive Summary

"Reducing fossil fuel use enough to affect CO2 levels is extraordinarily difficult. If the United States alone reduced its fossil use by half, to 35 quads, in 2000 and remained at that level until 2040, the doubling of CO2 levels in the atmosphere would be delayed by roughly five years. Such a reduction in fossil fuel use would require an incredible national commitment where no consensus is likely. The climatic impacts of CO2 would not become apparent until 2020, but action would be required beginning today . . . .

"An international scenario halving projected energy growth to 1.6% would require a freeze in Japanese and Western European fossil use, a 50% per capita reduction in U.S. use, and only 1% per capita growth in the Third World . . . . If such a solution began in 2000, the projected doubling would be delayed roughly 20 years."

—from Part IV.

The timetable for major CO2-related effects (high impact case) from this report is included in the Newsletter in its entirety on page 5.

●

From 'Workshop on the Global Effects of Carbon Dioxide from Fossil Fuels, Miami Beach, Florida, March 7-11, 1977, W.P. Elliott and L. Machta, editors, U.S. Department of Energy (122) pages), published May 1979 and available from the National Technical Information Service (NTIS):

"The consequences of CO2-induced climate changes on global agriculture, water supply, energy demand, and, not least, global sea level are less well understood than potential climate changes, even though there are reasons to believe that such consequences could be immense . . . . State-of-the-art estimates based on climate models suggest that, for example, such a doubling of CO2 (in roughly 50 to 75 years) can cause an increase in global mean temperature of roughly 2 to 3°C, probably with a larger temperature at polar latitudes. Based on these estimates, **significant climate changes could occur by the end of the twentieth century**." —from Panel IV: Climate Effects; emphasis added. The Climate Effects Committee wrestled at great length with the question, 'What effects can we expect **before** a CO2 doubling?', and the consensus (tentative) was that a 1°C warming could occur within a quarter century!

"It is necessary to consider seriously the possibility that rising atmospheric CO2 levels might lead to such severe ecological consequences that we will need to arrest, or even reverse, the growth of atmospheric CO2 over a short time span . . . .

"The worst mistake that could be made now is simply to wait and thereby possibly invite disaster before putting the specialized pieces of research together into an integrated assessment. The timetables of decisions of fossil biomass, solar, and nuclear energy research, development, and demonstraion cannot await the usual pace and mode of scholarly work."

—from Panel II: Biological Effects

"Obviously, the global problem becomes that of providing fuel for the developing countries to assure their progress without such heavy dependence on fossil fuels. Perhaps this is an area in which the United States can make a contribution through research and development on new energy supply systems and on small (decentralized) nonfossil systems.

"One might suspect that growth to the magnitude indicated (26 X 10^9 tons of carbon) for the year 2025 will heavily tax the fossil fuel reserves of the world. This is simply not true; **recoverable** fossil fuels (and oil shale) contain 7.3 X 10^{12} tons of carbon."

—from R.R. Rotty paper

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From 'West Antarctic ice sheet and CO2 greenhouse effect: a threat of disaster,' J.H. Mercer, **Nature**, volume 271, 26 January 1978, pages 321-325:

"If the global consumption of fossil fuels continues to grow at its present rate, atmospheric CO2 content will double in about 50 years. Climatic models suggest that the resultant greenhouse-warming effect will be greatly magnified in high latitudes. The computed temperature rise at lat 80°S could start rapid deglaciation of West Antarctica, leading to a 5 m rise in sea level."

—Abstract

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From 'Is mankind warming the Earth?'. William W. Kellogg, Bulletin of the Atomic Scientists, February 1978, pages 10-19:

"On the basis of the expectation that mankind will continue on its present course, we can predict that an **external** factor (anthropogenic input of carbon dioxide) will cause a major climatic change in the next few decades . . . .

"The nuclear versus fossil fuel debate is being hotly pursued while little attention (it would seem) is being paid to the carbon dioxide-climate question . . . .

"After agreeing that energy **conservation** should be a major national goal (who would dispute that?) and that **solar energy** in its various guises should be sought as an alternative energy source . . . (but will it pay for itself?), we must evaluate the agonizing issue of

Continued on page 6

APPROXIMATE TIMING OF MAJOR CO_2-RELATED EFFECTS

(HIGH IMPACT CASE)

CO_2 CONCENTRATION (ABOVE PREINDUSTRIAL IN ATMOSPHERE)	1.1X	1.3X	2X	4X	7.5X	6.5X	6X	5.25X	1.5X?
APPROXIMATE DATE	(1975)	(2000)	(2025)	(2050)	(MAX.2100)	(2300)	(2500)	(2800)	(4800)
MAX.AVG.TEMP.INCREASE (°C)	.3	.9	2.8	5.8	8.6	8.5	7.5	6.6	1.5?
POLAR ICE MELT/ SEA LEVEL RISE			POLAR SEA ICE MELTS		POLAR LAND ICE SLOWLY MELTS				
					PERIODIC FLOODING OF LOW COASTAL AREAS		SEA LEVEL RISE OF 1-5M/100 YEARS?		
pH IN OCEAN SURFACE/ EFFECT ON PHYTO-PLANKTON	8.1		7.8		7.53				
			INCREASING DISSO-LUTION OF MARINE CARBONATES; SELEC-TIVE EFFECTS ON MARINE ECOLOGY		PHYTOPLANKTON METABOLISM SEVERELY DISTURBED				
CLIMATE CHANGES	GRADUALLY INCREASING AVERAGE GLOBAL PRECIPITATION								
		DECREASING PRECIPITATION IN MUCH OF U.S.?							
		HIGH CLIMATE VARIABILITY DURING PERIOD OF MAXIMUM CO_2 RISE							
	25 YRS.	← 250 YRS. →				← 2500 YRS. →			

From SRI Project EGU-6370, Sociopolitical Impacts of Carbon Dioxide Buildup in the Atmosphere Due to Fossil Fuel Combustion [unpublished DoE Report, July 1, 1977].

plutonium and proliferation of nuclear weapons in an age of terrorism. The tradeoffs here, as pointed out by John Holdren . . . are immensely complicated. Are we in the United States merely postponing an inevitable decision to move toward a long-term and sustainable nuclear economy involving the breeder reactor? Or will we turn to depend more heavily on coal, as President Carter has said in his energy policy statements? . . . .

"If we wait to let the atmosphere 'perform the carbon dioxide experiment,' we will finally learn how well our models have served in making these predictions of climate change. But then it will be too late to do much about it, if the warmer Earth should prove to be a sadder Earth."

This report was based on a monograph that William W. Kellogg prepared for the World Meteorological Organization in Geneva, Switzerland. Dr. Kellogg is a senior scientist at the National Center for Atmospheric Research (NCAR) in Boulder, Colorado.

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From 'The consequences of a hypothetical world climate scenario based on an assumed warming due to increased carbon dioxide,' Report of a Symposium and Planning Workshop held at the Aspen Institute for Humanistic Studies at Aspen, Colorado, 8-14 October 1978 (65 pages), Aspen Institute for Humanistic Studies, 1919, Fourteenth Street, Boulder, Colorado:

"Climate change may well bring about altered distributions of influence and power, alterations traceable in part to altered resource configurations and demands. Reductions in the use of fossil fuels will increase the importance of biomass, solar, nuclear, and other energy sources, with significant impacts on domestic and international political and economic systems. Changes in food or water resources could also shift regional and international balances."

—from 'Climate Scenario, Working Group, A Report'

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From 'An Overview of the Impact of Carbon Dioxide on Climate,' Gordon J.F. MacDonald, The MITRE Corporation, McLean, Virginia (17 pages), December 1978:

"A warmer climate will affect agriculture primarily through lengthening the growing season in higher latitudes and increasing summer temperatures, providing precipitation patterns are not greatly altered. Higher summer temperatures will not necessarily increase productivity of all crops, since increases of respiration could exceed increases in photosynthesis. In high latitudes a movement north of a viable growing season does not imply greater productivity, since the soils on formerly glaciated terrain are generally poor.

"Some historical evidence suggests that warming could result in prolonged mid-continental drought (Lamb, 1977). 'Dust bowl' conditions could threaten range lands and semiarid agriculture over large areas of North America, Asia and Africa."

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From 'Carbon Dioxide and Future Climate,' J. Murray Mitchell, Jr., EDS, Environmental Data Service, U.S. Department of Commerce, March 1977:

"I agree with those climatologists who say that another ice age is inevitable. I strongly disagree, however, with those who suggest that the arrival of the next ice age is imminent, and who speak of this as the proper concern of modern civilization in planning for the next few decades or centuries . . . .

"We are no longer persuaded that particles introduced by man have an important cooling effect. In fact, in virtually all instances, the effects of man's activities on climate are now recognized as contributing to warming, not to cooling . . . . The fact that the Earth has actually been cooling in recent decades implies that nature—not man—is still firmly in the driver's seat where global-scale climate change is concerned . . . .

"The consequences to climate are likely to become noticeable by the end of this century, but not become a serious problem until well into the next century . . . . All of this may strike you as a problem too far removed from the present day to merit our concern. I would, however, like to close with a few additional thoughts. Suppose we elect to ignore the problem of carbon dioxide until it is staring us in the face—perhaps in another 20 years—in the form of a clear signal that a global warming has begun that is unmistakably attributable to the further accumulation of carbon dioxide in the atmosphere. If we delay until then to take action to phase over our principal energy sources from fossil fuels to other kinds of fuels, on an orderly rather than a crash basis, the transition will be likely to take another 40 to 50 years to complete. That puts us at least a half century into the future before we will have managed to shut off the problem at its source. By then, much of the damage will already have been done!

"To make matters worse, the effects of carbon dioxide would endure for thousands of years after we have abandoned our fossil fuel economy, because it would take thousands of years for the atmosphere to rid itself of any excess carbon dioxide. A thousand years of unusually warm climate would be likely to result in substantial melting of the Greenland and Antarctic ice caps, raising sea levels around the world enough to submerge many of our coastal population centers and much productive farm land.

"The alternative is clear. Ours is the generation that must come to grips with the carbon dioxide problem and mount a vigorous research effort to allow us to understand all of its ramification for the future. Ours is the generation that may have to act, and act courageously, to phase out our accustomed reliance on fossil fuels before we have all the knowledge that we would like to have to feel that such action is absolutely necessary. If we harbor any sense of responsibility toward preserving spaceship Earth, and toward the welfare of our progeny, we can scarcely afford to leave the carbon dioxide problem to the next generation."

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From 'The Long Term Impact of Atmospheric Carbon Dioxide on Climate,' JASON Study prepared for the U.S. Department of Energy, Washington, D.C., SRI International, 1611 North Kent Street, Arlington, Virginia (184 pages), April 1979:

"Means of ameliorating the effects of carbon dioxide increases are available, but application of these are unlikely to alter the above conclusion except for lengthening the time scale over which expected climatic changes would take place. The increased use of natural gas, if available would lengthen the time available for a shift to non-carbon based fuels. Clearly a significant shift to a nuclear or solar economy would postpone carbon-induced climate shifts. Increasing the standing crop through massive reforestation could provide temporary storage for carbon, but land and water availability limit this measure. In principle, carbon dioxide in stack gas could be

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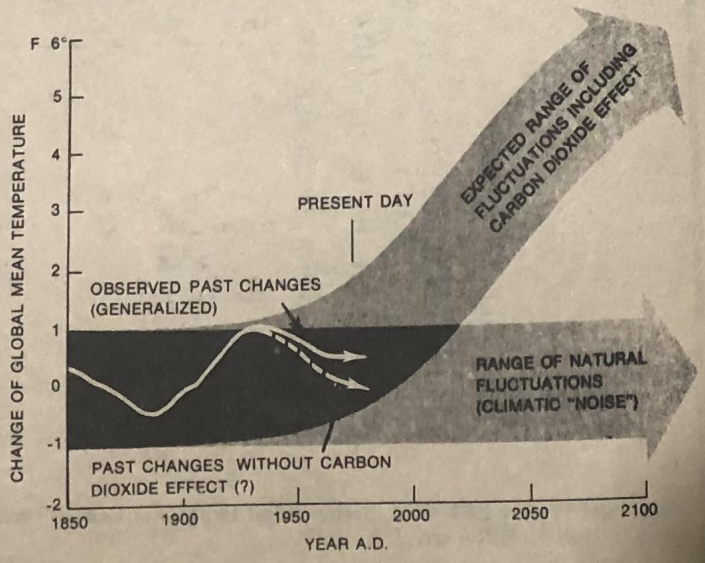


From J. Murray Mitchell, Jr. [EDS, March 1977].

Is nuclear energy an acceptable alternative?

Studies generally show that nuclear fission would have to carry the biggest load in substituting for fossil fuels in order to halt the CO2 buildup in timely fashion. Relying exclusively on solar, wind, and biomass to supplant fossil fuels would probably amount to default. (Most geothermal energy, unfortunately, is also a source of CO2.) Therefore truly effective countermeasures against the CO2 buildup may be delayed until the nuclear controversy is settled.

The proliferation of nuclear arms and the danger of terrorists obtaining nuclear explosives are pressing concerns. Nuclear energy cannot be made technically safe from the diversion of materials for explosive uses, so these concerns must be addressed directly in the political world. Only by preventing large-scale wars of aggression and by denying terrorists financial gain and protective havens may we hope to prevent the use of nuclear explosives against people. These are not impossible tasks.

The fear of cancer induced by radiation from nuclear facilities and from long-lived nuclear wastes is also a valid concern. However, such radiation appears to be within reasonable technical control in comparison with other potential cancer sources (particularly tobacco products). Studies generally show that coal energy is now a greater source of cancer exposure to the public than nuclear energy, including Three Mile Island.

The Three Mile Island accident may have appreciably delayed the widespread acceptance of nuclear energy. However, important lessons have been learned about reactor design and the ability of people to react to emergency situations as opposed to automated controls, so fear of similar accidents does not appear to justify abandoning the nuclear option.

The greatest block to nuclear development may now be posed by idealogical objections. Nuclear energy has become symbolic of three major points of ideological contention.

Firstly, energy consumption in general has been associated with the increase in consumption of material goods and with the general increase of pollutants in the environment. Nuclear energy is seen by many people as merely adding another environmental insult rather than replacing a much greater insult. It is becoming evident, however, that imposing constraints on the domestic production of energy and material goods does not really curtail consumption. Instead consumers turn increasingly to imports.

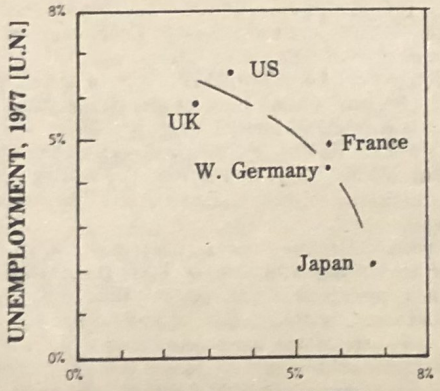
Secondly, nuclear energy is portrayed as an instrument of 'big business' to increase profits. Companies invest in nuclear developments only if nuclear appears capable of providing a favorable return in comparison with other investments. Governmental disincentives in recent years have soured many nuclear investments, so that few companies are now actively promoting nuclear energy. Instead they have quietly turned to more profitable business pursuits, and the United States' nuclear manufacturing capacity is rapidly eroding.

Thirdly, the antinuclear movement has become increasingly devoted to selecting those energy sources which 'provide more jobs.' Capital-intensive nuclear energy (whether private or governmental) is portrayed as destroying jobs, and labor-intensive sources are portrayed as creating more job opportunities. The basic idea is that large increases in workers' productivity result in less employment.

Statistical comparisons fail to bear this idea out, as the accompanying graph shows. Countries with the greatest increases in productivity also show the lowest unemployment. If a cause-and-effect relationship exists, it seems likely that productivity growth permits the growth of capital, which in turn leads to increased investments in research and more jobs. An alternative method of reducing unemployment with governmental borrowing to stimulate purchasing power neglects supply in favor of demand and causes inflation.

In today's world of few trade barriers and greatly differing attitudes toward business in various countries, these attitudes are being tested against one another visibly. The public eventually has a chance then to decide which actions are in a country's best interests. Despite all the efforts to bring about the demise of nuclear energy in the U.S., a majority still favors nuclear energy.

W.N.B.



INCREASE IN PRODUCTIVITY
% Annual Increase, Output per Man-Hour 1970-77 [NIER]

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frozen into dry ice for deep ocean disposal or the stack gases could be used to accelerate the growth of certain plants in giant greenhouses. However, elementary considerations suggest that neither of the latter suggestions are economical in competitions with alternative, nuclear or solar, energy systems . . . .

"Even though anticipated alteration would appear to be at least 50 years in the future, the world-wide nature of the changes and their possible adverse effects on man-kind warrant the continued attention of policy-makers to the carbon dioxide climate question . . . .

"We do have, however, serious reservations about housing the [CO2] program management within the Office of the Assistant Secretary of the Environment . . . . The Office of the Assistant Secretary of the Environment is faced with a vast variety of day-to-day issues which may prevent adequate considerations of the longer term questions . . . .

—'Responsibility within the Department of Energy for the management of the carbon dioxide research and assessment program should be given to the Office of Research."

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The International Institute for Applied Systems Analysis consists of one scientific organization from each of 17 participating countries. USA is represented by the National Academy of Sciences. The Energy Systems Program as IIASA is concerned with 'the evolution of the global energy system, particularly its smooth transition, about 15 to 50 years from now, from one based on oil and gas to one based on virtually inexhaustible energy sources—nuclear, solar or coal.' The Proceedings of a IIASA Workshop cosponsored by the World Meterological Organization (WMO), the United Nations Energy Programme (UNEP), and the Scientific Committee on Problems of the Environment (SCOPE) of the International Council of Scientific Unions (ICSU), held February 21-24, 1978, in Laxenburg, Austria, have been published in book form by Pergamon Press (332 pages). Despite the governmental sponsorship (the USA and USSR each granted 1.7 million dollars in 1978, and each of the other member organizations 260,000 dollars each), the Proceedings are protected from reproduction by copyright. A sampling of the contained reports is herein given.

In 'The potential consequences of increasing CO2 levels in the atmosphere' by W. Bach, estimates of future concentrations of CO2 in the atmosphere are given for various controlling conditions, using the best state-of-the-art modeling. The 'no nuclear energy' option, which assumes that gas and oil will be depleted around 2020 and that energy needs after that would be met by coal is thought to result in a CO2 level in the atmosphere in 2050 of 3.5 times the preindustrial level; the 'nuclear power (LWR) and coal' option with 25% nuclear in 2000 and a relative increase in coal until 2100 projected to 2.5 times the preindustrial level by 2050; and the 'Optimistic equilibrium strategy' of Niehaus (1976) which assumes a stabilized population of eight billion in 2050, with energy consumption also stabilized, and fossil fuels replaced by alternative energy sources, projected to a CO2 concentration in 2050 of 1.7 times preindustrial.

In 'The effects of different energy strategies on the atmospheric CO2 concentration and climate' by J. Williams, three energy options are assessed. If the ultimate level of energy consumption is limited to about four times the 1970 consumption, and if the contribution to primary energy consumption by nuclear and solar becomes equal to the world's entire consumption at present by 2008 and becomes equal to twice the world's present consumption by 2018, the CO2-induced temperature change could theoretically become stabilized when the average global warming reaches 1°C. Williams notes that "the dynamics of substitution between primary energy carriers, which depends on technical and economic constraints, has a magnitude of decades."

The report entitled 'Working Group III: the Interaction between Energy Strategies and the CO2 Question,' infers that mankind has a short grace period that allows for more research before countermeasures must be instituted. "The implications of significant climate changes may be so serious that establishment of energy policies that recognize these potentialities and maintain flexibility is the only prudent course of action. It was judged that mankind needs and can afford a time window of between five and ten years for vigorous research and planning to narrow the uncertainties sufficiently so as to justify a major change in energy policies to those that are more responsive to the CO2 problem from those that allow the continued reliance on abundant and inexpensive fossil fuels."

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From 'Market Penetration Characteristics for Energy Production and Atmospheric Carbon Dioxide Growth' by J.A. Laurmann, **Science**, 31 August 1979, pages 896-898:

"Estimates are given for the maximum rate at which fossil fuel consumption can be reduced by the introduction of noncarbon-based energy sources, according to the market penetration time concept. These estimates indicate an immediate need to implement a revised energy policy if major climatic changes induced by increased carbon dioxide are to be avoided in the next century. However, application of market penetration ideas to energy consumption is new and may not be valid for the predictions of future trends."

—Abstract