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

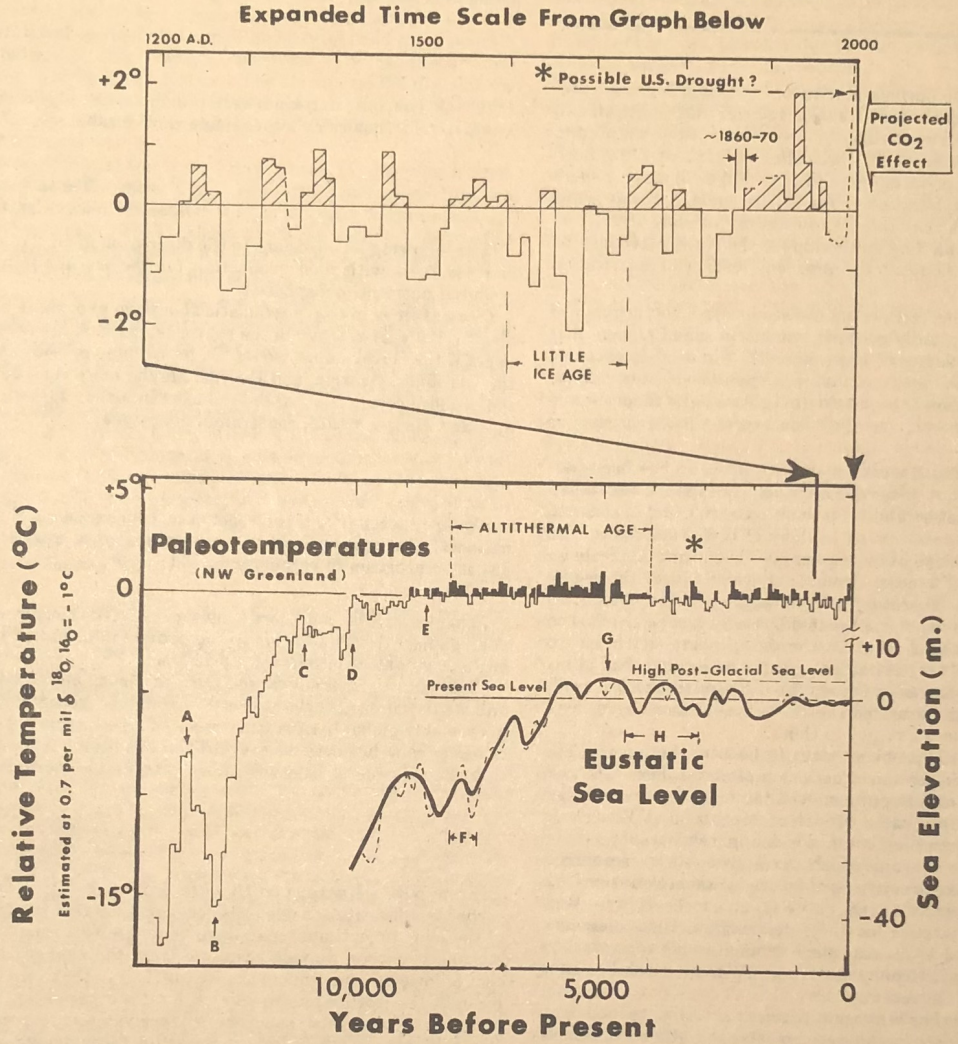
In 2025, the family of Mr. Barbat donated an original set of all issues to Dr. Marc Hudson, and agreed that these could be digitised and placed online as a resource for anyone who wants to understand how long we've known about the carbon dioxide and global warming problem.

CO_2 Newsletter©

Volume 1 - number 3 **February - March, 1980**

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

RESPONSE OF SEA ELEVATION TO PAST TEMPERATURE CHANGES



The relative temperature shown is that of precipitation which had fallen on the Greenland Ice Sheet over the past 14,000 years, as deduced by W. Dansgaard and associates from measurements of oxygen isotope concentrations in the Camp Century ice core at 77 degrees 10'N, 61 degrees 08'W (from Chapter 3 in *Late Cenozoic Glacial Ages*, 1971).

The former sea elevations are based on dated occurrences of raised or submerged beaches, wave-cut benches, coral reefs and submerged terrestrial deposits. The compilation of sea elevations was made by Rhodes W. Fairbridge in *Physics and Chemistry of the Earth*, volume 4, 1961.

Approximate dates of paleoclimatological data and glacial data from other regions are shown for comparison:

A. A few trees return to England and Denmark after glacial retreat.

B. Scotland and Scandanavia are covered again by an ice sheet.

C. Warming brought birch forests to England and willows to Holland.

D. The retreat of the European ice sheet halted at the great Fennoscandian moraine.

E. End of the ice age in Scandanavia.

F. Extremely rapid disintegration of the central portion of the Laurentide Ice Sheet centered over Hudson Bay (Bryson, et al).

G. End of the recession of the West Antarctic Ice Sheet (Thomas).

H. Open water at McMurdo Sound (Denton, Armstrong & Stuiver).

The "Altithermal" designation of Ernst Antevs has been applied here to the period of general global warmth from about 8000 to 4000 years before present, when the Great Plains region of the U.S. is believed to have become virtually an uninhabitable desert. The contemporaneous period of abnormal warmth in Scandanavia, demonstrated by fossil pollen in peat bogs, is often referred to in northern European literature as the 'Climatic Optimum'.

The position of "Possible U.S. Drought?" threshold as shown has been inferred from SRI Project EGU 6375, (an unpublished DoE report of July 1, 1977, prepared by the JASON group, G. MacDonald, Chairman) as being a recurrence of warmth-caused drought similar to the 1930s drought.

CO_2 Newsletter is published bimonthly by William N. Barbat Associates (Energy Consultants), P.O. Box 24, Teton Village, Wyoming 83025. Deadlines for contributed articles and letters are January 31, March 31, May 31, July 31, and September 30. Subscription rates: (revised 12/1/79): Companies, institutions, or agencies $40 per year, which allows for unlimited 'in-house' reproduction rights; individuals and university libraries $20 per year. Back issues $5 each as available. Foreign airmail, add 20%.

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". . . . therefore care would be had that . . . the good be not taken away with the bad, which commonly is done when the people is the reformer."
—Francis Bacon

Editorial

The new decade begins on an optimistic note as the CO_2-greenhouse problem is beginning to receive deserved attention in scientific, political, and economic institutions. Also this particular environmental issue may unite former adversaries in a common effort. David Burns, head of the AAAS Climate Program, has noted a great increase in the number of major papers which are being prepared for publication on the CO_2 problem. Also our growing readership indicates to us that the Newsletter is fulfilling its role of enlightenment. Soon a European distributorship for the Newsletter may be established. Most heartening though is the apparent absence of polarization toward the CO_2 problem.

Still much skepticism remains concerning the seriousness and urgency of the CO_2 problem. Although a rapidly growing number of scientists feel that we now have sufficient knowledge of impending CO_2 induced impacts on which to base energy policies, others feel that much more concrete evidence must first be gained throughout the world to substantiate theories and models. Some non-technical people grossly misinterpret this skepticism as representing negative proof.

From the very beginning, much work on the CO_2 problem has been performed under adverse conditions or severe financial restraints. Tyndall had to trouble-shoot his galvanometers and have them reconstructed in order to measure the absorption and radiation of heat by CO_2. He found that the green dye used in the silk covering of the copper coils of the most delicate instruments of his day contained some iron compound which caused the needle to deviate. Arrhenius lacked laboratory determinations of the absorption coefficients for CO_2 and water vapor at plus 15 degrees C, and he also lacked the laboratory equipment needed to make the determinations. "Such experiments . . . would require very expensive apparatus beyond that at my disposal." Ingeniously, Arrhenius used the earth's atmosphere instead as his laboratory. Ernest Rutherford described the challenges of those days clearly: "We haven't the money, so we've got to think."

Modern workers on the CO_2 problem seem to be little better off. The federal funding of Keeling's invaluable monitoring of atmospheric CO_2 concentrations fell victim to the race to put a man on the moon for several months in 1963. The General Circulation Model of Manabe and Wetherald reportedly contained a programming error, which apparently could only be eliminated by a computer rerun which exceeded their resources. Glaciologists are asked to make predictions of future ice sheet behavior from very sparse data. As far as we can tell, the only available forecast of the warming threshold for West Antarctica Ice Sheet destruction relies solely on a temperature datum provided by a map made from Russian observations taken during the International Geophysical Year. Polar research has been funded meagerly by the U.S. in recent years.

Meetings which bring together atmospheric scientists, climate modelers, terrestrial and marine biologists, ocean geochemists, and other workers to analyze the CO_2 problem collectively are greatly limited as to frequency and numbers of invited participants. Publications concerning such meetings are usually incomplete and much delayed. Some important results of the scientific analyses are not even available for purchase through normal channels because some agencies seem to act more as a sink than a source of information. Thus, we owe a great debt of gratitude to the relatively small number of scientists who have brought us so much understanding with so little.

CORRECTIONS

Two large errors slipped through on those copies of the 2nd issue of the CO_2 Newsletter which were mailed out the earliest. "East Antarctic Icemelt" should read "West Antarctic Icemelt" and the headline should refer to the CO_2 buildup, not Co. On page 4, Kellogg's article "Influences of mankind on climate" should bear the date 1979.

From our readers

"Thank you very much for sending me the copies of CO_2 Newsletter. I am very pleased to see this publication and hope that you can continue to publish it . . . ."

J.H. Mercer
Institute of Polar Studies
Ohio State University

"Thank you for your kind words about my study in no. 2 of your "CO_2 Newsletter". Your calculations make considerable sense."

Herbert Inhaber
Scientific Adviser
Technology Impact Division
Atomic Energy Control Board (Canada)

(The following letter refers to the discussion in no. 2 of the competition of biomass fuels with food production for the world's finite deposits of the essential nutrient, phosphate.)

"Stowasser is overly pessimistic about the phosphate situation. We have about a 100 year reserve in the southeastern U.S. in my opinion. Maybe 200 years if the Government would . . . let us mine on the Continental Shelf off the Carolinas, Georgia, and Florida. Maybe more than 200 years. But then, too, we lose reserves to other land use (Suburban sprawl, shopping centers, etc.) and environmental constraints every year."

Henry S. Johnson
Sandhill Resources
Charleston, SC

(We are grateful for these comments from a geological consultant of international reknown who has actually managed a large-scale phosphate exploration program in recent years.-Ed.)

"Thanks for the 'collectors issues' of CO_2 Newsletter—most thought provoking and a timely addition to the body of information being generated on our energy and environmental problems.

"Two questions: What caused the altithermal period (4000-8000 years ago) and what was (were) the cause(s) of the most recent ice cap melting (and, presumably global temperature rises)? I'd be interested to know what relationship your projections have to the conditions (atmospheric, solar, etc.) that are believed to have prevailed in those two periods."

Bruce M. Putnam
Arthur D. Little, Inc.
Cambridge, MA

(From NRC's *Energy and Climate*, 1977, page 11: "Studies of oxygen and carbon isotope ratios in deep-sea cores suggest that the higher temperatures of the climatic optimum may have been due to a temporary increase in atmospheric carbon dioxide resulting from the changes in ocean circulation that followed the melting of the ice cap." As to the cause of the warming that brought the last ice age to an end, most workers seem to think that an increase in the amount of solar energy received was responsible. At the Miami Beach Workshop (1977) Robert Bacastow (Scripps) was asked if he thought that there was an *increase* in atmospheric CO_2 in the last ice age. He thought there was. -Editor)

We wish to compile a complete list of references on all aspects of the CO_2 problem and to make the bibliography available to everyone. We will include pertinent references on past climates, recent meterological observations, previous sea elevations, and anything bearing on the response of glaciers and icecaps to temperature change.

If the bibliography turns out to be of moderate length, we will issue it as a supplement to the Newsletter. If lengthy, we will make it available to contributors and subscribers at our cost, and to all others at a reasonable charge.

Please send us your lists.

Glacial icemelt - how soon? how fast?

Thick ice sheets perched above sea level cover more than 10% of the earth's area, which is about equal to the total area devoted to farming. The Antarctic and Greenland icecaps contain about 99% of this ice. According to George Denton, complete melting of the Greenland ice sheet would raise sea level 6.5 meters, the West Antarctic sheet 5.5 meters, and the East Antarctic Ice Sheet 54 meters, for a total of 66 meters (217 feet).

Vulnerability to destruction appears to be the reverse order of formation, with the East Antarctic Ice Sheet having formed first and now extending from the Transantarctic Mountains across a low bedrock plain to the sea. The Greenland Ice Sheet apparently formed much later, and now covers a smooth low plain fringed by mountains, so that most of the ice flows to the ocean through about 20 large outlet glaciers. The ephemeral West Antarctic Ice Sheet formed last between the Transantarctic Mountains and the West Antarctic Archipelago so that its ice is partially grounded below sea level to depths as low as 2500 meters.

Mercer has hypothesized that the West Antarctic ice may have been wholly destroyed in the last interglacial age, and Fairbridge reports that sea level was 6 meters higher than present at the peak of that warm period, approximately 125,000 years ago. The ice sheet which replaced it is believed to have been partly destroyed during the Altithermal Age, when sea level is reported to have been about 3 meters higher than present.

On a worldwide basis, a 3 meter rise would dislocate all existing port facilities, inundate low-lying coastal structures, cause the disappearance of most of the world's beaches, and disrupt the habitat of fauna now existing in coastal wetlands. In the U.S. a 3 meter rise—if not blocked by dikes—would submerge the fertile delta farmlands in the Great Valley of California, and would submerge virtually the entire land surface at Galveston, Port Arthur, New Orleans, Naples, the Florida Keys, Miami, Charleston, Norfolk, Portsmouth (VA), and Atlantic City. A 6 meter rise would submerge virtually all of Sacramento, Biloxi, Gulfport, and Mobile, and would inundate Washington DC from the Lincoln Memorial to the base of Capitol Hill. In other parts of the world, low-lying river deltas which are heavily farmed and densely populated are particularly vulnerable to a rise in sea level. These include the deltas of the Rhine, Nile, Ganges, Mekong, Yangtse, and Huang Ho.

A band of very strong westerly winds has prevented sea ice from building a protective fringe around most of the East Antarctic Ice Sheet, whereas in West Antarctica, the large Ross and Filchner-Ronne Ice Shelves have formed in relatively protected bays. Ice shelves there rise and fall with the tide to produce large 'strand cracks' where they adjoin grounded glaciers.

The Ross and Filchner-Ronne Ice Shelves are thickest where they are fed by these glaciers, so that they presently act as buttresses to the large ice streams feeding into them. Weertmen has found that these large ice streams have a lubricating bottom-water layer, so that the ice streams are moving at a 'small-scale surge' velocity of about 0.6 kilometers per year. What has concerned Mercer and other knowledgeable glaciologists is that any environmental change that diminishes or destroys the buttressing ice shelves would also diminish or destroy the ice grounded below sea level. As Hughes describes it, the West Antarctic marine ice sheet is inherently unstable and can be rapidly carved away by calving bays which migrate up surging ice streams, so that a "relatively minor climatic fluctuation along the ice shelf calving barrier can unleash dynamic processes independent of climate that can cause calving bays to remorselessly carve out the living heart of a marine ice sheet." Thus while very large continental ice sheets such as the former Laurentide Ice Sheet may waste away slowly over millenia by in situ melting and peripheral retreat, the West Antarctic Ice Sheet may be destroyed catastrophically.

Weertman has suggested that large scale surge may cause the West Antarctic Ice Sheet to discharge one third to one half its volume into the oceans in possibly 100 years. CO_2-induced warming might therefore result in sea level rising as fast as 0.2 to 0.3 meter per decade (8 to 12 inches) if catastrophic destruction results. For comparison, Fairbridge's data show rises of 0.2 meter per decade to have been common in the past and 0.3 meter per decade to be the most rapid calculated.

How much CO_2 buildup can the earth tolerate before the iceshelf buttresses are destroyed? Glaciologists have ventured some educated guesses which generally fall within the next 50 years if the CO_2 buildup continues at present.

Robin has noted that ice shelves are absent from coasts of the Antarctic Peninsula where sea temperature rises above −1.5 degrees C during the warmest month. Mercer notes that the average midsummer air temperatures at the fronts of the Ross and Filchner-Ronne Ice Shelves are now about −4 degrees to −5 degrees C, so that with the anticipated amplification of a CO_2-induced warming at polar latitudes, the threshold of ice shelf destruction may have been surpassed substantially before atmospheric CO_2 has doubled. This conclusion is consistent with that part of the paleotemperature record at Camp Century which corresponds to the Altithermal high stand. While the peak warmth noted at Camp Century a half century ago exceeded the Altithermal temperatures shown by ice core, we note that the Southern Hemisphere generally experienced less warming a half century ago, possibly due to the flywheel effect of the greater amount of ocean waters in that hemisphere.

A more conservative school of thought concerning the possibility of a CO_2-induced sea level rise is represented in the National Research Council's *Energy and Climate* (1977), prepared by a panel chaired by Roger Revelle. This report suggests that high latitude warming might well bring increased snowfall to Antarctica and perhaps to parts of Greenland also. A similar hypothesis was advanced by G.C. Simpson in 1929, except that Simpson theorized that if temperatures continued to rise, summer melting would increase and a greater proportion of precipitation would be in the form of rain. The NRC panel thought it likely that the temperature in the Antarctic would still remain below the freezing point, so that "melting at or near the surface of the ice probably would not occur".

The geological record seems to indicate that the effects of global warming are far more likely to cause ice sheet shrinkage than ice sheet growth. The major retreats and advances of the former Northern European Ice Sheet between 10,000 and 14,000 years ago appear to correlate directly with temperature fluctuations at Camp Century, although the accuracy of datings may not be great enough to demonstrate this conclusively.

Any added ice buildup due to increased precipitation will cause an ice sheet to establish a new profile of equilibrium due to the plastic flow of ice. The rate is highly dependent on temperature. Figures from Paterson's *The Physics of Glaciers* (1969) show the response time of glacial ice at −50 degrees C to be about 2500 years, at −27 degrees C about 250 years, and at −6 degrees C about 25 years. The slowest response time (2500 years) would correspond to ice at the surface of the high East Antarctic Plateau, but owing to the constant influx of geothermal heat at the base, the characteristic response time for the ice sheet as a whole is not known. The response time of the bulk of the Greenland ice is generally between 25 and 250 years. For short response times, adding greater and greater amounts of snow on top is like piling wet sand on wet sand—rather than getting higher, it spreads out at the base.

A unique feature of a very large ice sheet is that it is generally immune from traveling barometric depressions which bring precipitation as snow. Because of the dryness of air over very cold ice and reflection of most of the solar radiation, barometric pressure tends to remain high to create a nearly permanent anticyclone. Air descends in the central portion and flows outward in every direction. Thus the geographic center of Antarctica receives only about 3 centimeters of precipitation annually in the form of hoar frost. Winds drift the frost crystals to give a deceptive appearance of snow piling up on man's installations.

Because the Greenland Ice Sheet is relatively small, it may diminish rapidly in response to a CO_2-induced warming similarly to the former Northern European Ice Sheet. Thus it may not be far behind the West Antarctic Ice Sheet in terms of vulneratility, especially in view of the fact that it is situated at relatively low latitudes with a branch of the Gulf current flowing along the west coast. The southern and western flanks appear to be particularly vulnerable to warming. On the central plateau at elevations of 2000 to 3000 meters, the mean maximum temperatures in June presently reach −4 degrees to −8.5 degrees C. Radiation, which is the most important source of heat during the ablation season, increases greatly from the sky and clouds as the atmospheric temperature increases above 0 degrees C.

Whereas half of the ablation in Greenland occurs as meltwater runoff and half as iceberg calving, most of the ablation in the East Antarctic occurs by iceberg calving. It has been surmised that an increase in air temperature there of 15 degrees C may be required to create a zone of ablation wide enough to diminish the area of that vast ice sheet.

A meeting of knowledgeable glaciologists will soon be held under the auspices of AAAS and DoE at the University of Maine at Orono to analyze further the vulnerability of the West Antarctic Ice Sheet to a CO_2-induced warming, and to recommend further research. Heading the meeting will be Charles R. Bentley of the Geophysical and Polar Research Center, University of Wisconsin.

Excerpts from recent reports

From 'Carbon Dioxide Accumulation in the Atmosphere, Synthetic Fuels and Energy Policy - A Symposium', Committee on Governmental Affairs, United States Senate, July 30, 1979:

"CO_2 SYMPOSIUM: FINDINGS AND RECOMMENDATIONS

"On July 30, 1979, the Committee . . . held a one-day symposium on the issue of Carbon Dioxide Accumulations in the Atmosphere, Synthetic Fuels and Energy Policy. . . .

"During the course of the hearings on S. 1377, the Committee received disturbing testimony regarding the detrimental impact of a crash synthetic fuels program on the nation's—and the world's—climate and environment. Dr. Gordon MacDonald, chief scientist of the Mitre Corporation and a former member of the President's Council on Environmental Quality told the Committee:

" 'Man, through the burning of carbon-based fuels, is setting in motion a series of events that seem certain to cause a significant warming of world climates over the next decades. The use of synthetic fuels will accelerate and intensify these climatic changes. Such changes will have far-reaching implications for human welfare in an ever more crowded world, will threaten the stability of food supplies and will present a set of intractable problems to organized societies.'

"On July 19, the President's Council on Environmental Quality issued a report which further underscored the dilemmas posed by a massive synthetic fuels production program. This CEQ report was co-authored by Dr. MacDonald, and three other distinguished scientists in the fields of climatology and oceanography: Dr. George Woodwell of the Woods Oceanographic Institute; Dr. Roger Revelle, of the University of San Diego; and Dr. C. David Keeling, of the Scripps Institute of Oceanography.

"The Report laid out, in language understandable for the laymen and average citizen, the scientific questions at issue and the potential consequences at risk. The four scientists concluded that:

" 'The CO_2 problem is one of the most important contemporary environmental problems as a direct product of industrialization, threatens the stability of climates worldwide and therefore the stability of all nations, and can be controlled * * * However, if we wait to prove that climate is warming before we take steps to alleviate the CO_2 build-up, the effects will be well underway and * * * more difficult to control. The earth will be committed to appreciable changes in climate with unpredictable consequences. The potential disruptions are sufficiently great to warrant the incorporation of the CO_2 problem into all considerations of policy in the development of energy'.

"The CO_2 issue transcends national boundaries and constitutes an international environmental problem of major dimensions and consequences. Indeed, one of the early warnings received by the Committee came from Chancellor Helmut Schmidt of West Germany. During his visit to Washington in June, Chancellor Schmidt told Chairman Ribicoff that, in his judgment, CO_2 accumulation in the atmosphere represented a major threat to the future of mankind. . . .

"As a result of the testimony received during hearings on S. 1377, the CEQ Report and the concerns expresssed by Chancellor Schmidt, Chairman Ribicoff contacted Philip Handler, President of the National Academy of Sciences, for his opinion on the gravity and consequences of the CO_2. By coincidence, a meeting of the Academy's Climate Research Board was then in progress in Woods Hole, Massachusetts, and at Dr. Handler's request, the Board sent to the Committee a statement on CO_2 Concentrations and Energy Policy. What follows are excerpts from the statement:

" 'The scientific basis for judging the consequences of increasing CO_2 emission into the atmosphere is as yet quite uncertain * * * Nevertheless estimates have been made which indicate that noticeable climatic effects are likely toward the end of the century. CO_2-induced changes in temperature and rainfall patterns during the next century with significant implications for the nations of the world, represent a definite possibility * * * A major program of synthetic liquid fuels production for coal would somewhat speed up the rate at which CO_2 is added to the air, particularly if similar programs were followed by other industrialized nations, such as the USSR with its large coal reserves. We recognize that synthetic fuel program based on coal is a major energy supply option. If, in the future, it appears that continuing increases in atmospheric CO_2 are likely to have significant deleterious effects, then it may be necessary to shift to other alternatives which introduce less CO_2 into the atmosphere. We therefore urge that provision be made now to assure that such other alternatives will be available if and when they are needed.'

"Events during the summer—particularly the long gasoline lines in June and the President's endorsement of a massive synthetic fuels production program in July—greatly increased the pressures on Congress to act on additional energy legislation in the near future. Yet, it is also quite clear that, at least with respect to synthetic fuels, the nation needs more analysis and understanding of the climate and other environmental impacts before launching a massive and potentially irreversible effort to create a large new synthetic fuels industry. . . .

"THE NATURE OF THE PROBLEM

". . . If the present concentration of CO_2 doubles, world climate models predict the average global warming may be about 2-3 degrees Centigrade. The warming at the poles would be greater by a factor of 3-4, but less in the tropics. However, the rapidity, magnitude and impact of such a warming are uncertain.

"For purposes of comparison, historic climate records indicate that fluctuations in the global mean surface air temperature over the last 100 years have been less than 1 degree Centigrade. There is also evidence that in the past a global temperature of only 1 degree Centigrade higher than at present was accompanied by a sea level about 20 feet higher than today.

"When will the warming occur, be measurable and become significant? Some members of the panel felt it would begin occurring within the next decade and be measurable by the end of the century. If this is the case there should be detectable climate change shortly before or after the turn of the present century, and it could become significant between 2025 and 2055. . . .

"The models utilized by the scientists predict substantially greater warming at the poles. This could start the melting of the West Antarctic Ice Sheet, which in turn could raise the sea level by as much as 20 feet. There is, however, no consensus in the scientific community as to when or even if this sheet would melt. The predictions range from decades to over a century.

"The effects on agricultural zones, growing seasons and marine productivity are still in the realm of speculation. It does seem clear, however, that the most serious effects would be felt in the arid and semiarid regions where precipitation is highly variable. The models show a general poleward shift of agroclimatic zones.

"A particularly troublesome uncertainty is that we do not know how climate changes, whether in abrupt steps from one stable climate system to another, or by a more gradual continuum. The ability of societies to adapt is largely dependent on how this process occurs. Abrupt transitions would have especially destabilizing impacts on populations in marginal agricultural zones. The adjustment period will be measured in terms of decades for every society. The ability to adjust will, unfortunately, be the least in those areas which would be likely to experience the most radical changes. Advanced countries will have the advantage of social organization, capital and educational resources to make the necessary adaptation under most conditions. . . .

"The panel felt that it would be difficult, if not impossible, to dismantle a synthetic fuels industry once billions of dollars had been invested. The consensus of the panel was, then, that we must ensure that alternate sources of energy will be made attractive as well as available through government support, research, development and financial incentives of various kinds. This was the dominant theme of the symposium.

"RECOMMENDATIONS

". . . **Energy decision-making.** - Massive investments into synthetic fuels from fossil sources, coupled with continued emphasis on traditional fossil fuels, may have severe climatic consequences. These consequences could be severe enough to require us to make a complete shift to other sources of energy within the next few decades. We may have to make a decision to do so within 10-20 years because of the long leadtime involved in such a monumental effort. . . .

". . . Yet, by the time climatic effects become significant, the die may well have been cast and the time for decision have passed. . . .

"If should be noted, however, that the panel had no general sense of confidence that a definitive assessment of the effects of CO_2 accumulation would be available by the time the most critical decisions would have to be made. . .

From 'A CO_2-climate sensitivity study with a mathematical model of the global climate', by Syukuro Manabe and Ronald J. Stouffer, *Nature*, 29 November 1979:

"An increase in the CO_2-content of the atmosphere resulting from man's activity could have a significant effect on the climate in the near future. . . .

"The standard experiment successfully reproduces the observed basic characteristics of geographical and seasonal temperature variation, encouraging the assertion of realism for the model sensitivity to CO_2 changes. . .

"In low latitudes, the warming due to the quadrupling of CO_2 content in air is relatively small and depends little on season, whereas in high latitudes, it is generally larger and varies markedly with season particularly in the Northern Hemisphere. Over the Arctic Ocean and its neighborhood, the warming is at a maximum in early winter and is small in summer. . . .

"The maximum warming of the early winter over the Arctic Ocean and its neighbourhood is caused by the change in sea ice thickness, and the relative-

ly large warming over the continents in spring is produced by snow albedo feedback. . . .

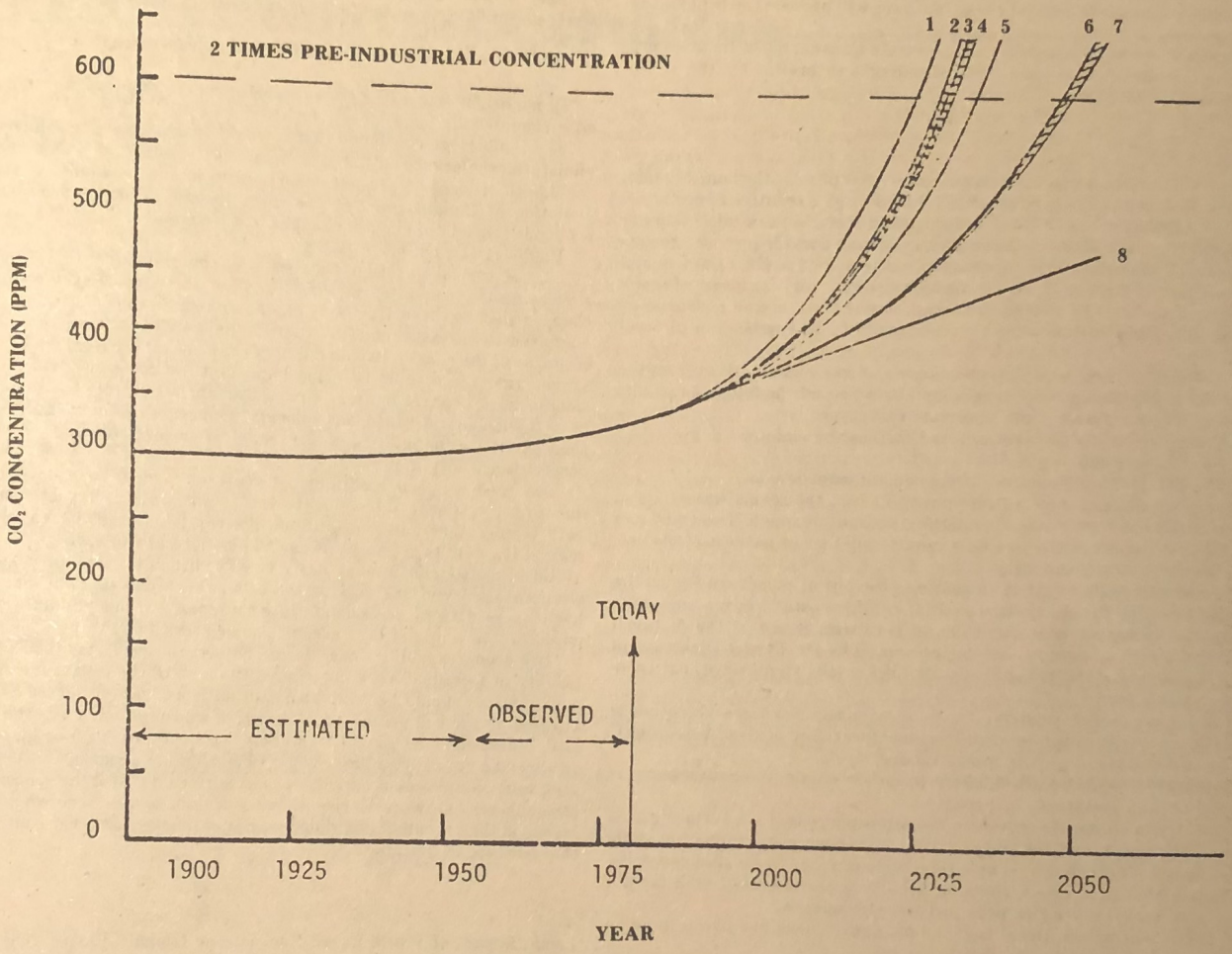
"In view of the assumption of fixed cloudiness and various simplifications contained in the sea ice modelling, the quantitative aspect of the present results should be received with caution. However, this study suggests that the warming of the atmosphere in response to an increase in CO_2-content of the air will have significant seasonal and interhemispheric asymmetries."

From the report of A Workshop on Energy/Carbon Dioxide Issues and Impacts held in Toronto, Canada, August 28-29, 1979, sponsored by the Canadian Climate Program, F.K. Hare, Chairman; Summary Comments by Editorial Review Board, Gordon McKay, Chairman:

"The complications of man-induced climatic changes, both positive and negative, make imperative its consideration in policy and planning. The effects of carbon dioxide increases on climate will be gradual and the perception of change for some time to come may not be great. Nevertheless the ultimate effect could alter agriculture, settlement, transportation, water and other renewable resources irreversibly, and should be considered globally in today's decisions regarding major capital works and regional development. The time scale for the introduction of alternative energy technology requires that consideration be given now to the potential consequences of increased atmospheric carbon dioxide.

"At the Workshop no attempt was made to assess the effects of climate change on the Canadian economy and institutions. However, the present

continued on page 6



SCENARIOS OF FUTURE FOSSIL FUEL USAGE, from 'Carbon Dioxide Emissions from Synthetic Fuels Energy Sources', Prepared by U.S. Dept. of Energy, Office of Assistant Secretary for Environment, Office of Technology Impacts, Policy Analysis Division and Office of Health and Environmental Research, Carbon Dioxide and Climatic Effects Research Program, August 8, 1979.

Key to description of curves:

1. Synfuels replaces all world oil, coal replaces all world natural gas; growth rate equals 4.3% per year for each.
2. Historic mix and amount of fossil fuels plus 6 million barrels of synfuels per day; growth rate equals 4.3 percent per year for each.
3. Shaded area is contribution from 6 million barrels of synfuel per day.
4. Historic mix and amount of fossil fuels (no synfuels); growth rate equals 4.3% per year.
5. Natural gas replaces all world coal and ½ of oil (no synfuels); growth rate equals 4.3% per year for each.
6. Shaded area is synfuel contribution to National Energy Plan 2 scenario.
7. DOE National Energy Plan 2 (without synfuels) using an assumption of greater oceanic uptake of CO_2 than in the other scenarios.
8. No growth in fossil fuels after 1985.

level of Canadian understanding and effort was assessed with a view to proposing action where major gaps are apparent in understanding and application. Overall there was a consensus that:

"- The level of atmospheric carbon dioxide is increasing and will continue to increase over the foreseeable future. The levels are controlled by activities and processes which are global in scale and mainly external to Canada.

"- . . . Changes of global mean surface temperature of one or two degrees Celsius or of regional precipitation patterns can have major socioeconomic consequences affecting areas such as: land and water transportation systems, settlement patterns, resource management, water supplies and regimes. . . .

"- Fossil fuels are the major but not the whole source contributing to this increase. Canadian energy use will not be decisive in determining the future levels of atmospheric carbon dioxide.

"- . . . A significant fraction of the global biomass is located in Canada.

"- . . . major knowledge gaps exist on the understanding of how the climate system is and will be affected, and the socio-economic consequences of such changes.

"- . . . The greatest surface temperature changes due to increasing atmospheric carbon dioxide will occur in high latitudes, and monitoring of the climate and its manifestations in these latitudes will provide the best signals of change.

"- Excellent scientific capability exists within Canada, but little of its present effort is directed toward understanding and predicting the consequences of climatic change."

From 'DOE Advisory Committee on Atmospheric Carbon Dioxide, Minutes, Meeting of January 10, 1980', R.M. Rotty, Executive Secretary:

". . . (Chairman Alvin M. Weinberg) quoted from the amended charter: 'The Advisory Committee on Atmospheric Carbon Dioxide provides recommendations and advice to the Assistant Secretary for the Environment and the Secretary of Energy, from the viewpoint of the highest levels of scientific policy, on the DOE role in the social, environmental and economic effects of increasing carbon dioxide resulting from the combustion of fossil fuels. . .'

"Dr. Weinberg then read the conclusions and recommendations from the report the Study Group made a year ago. He stressed the following points:

"1. The CO_2 situation is both uncertain and urgent.

"2. Energy options that produce less CO_2 must be maintained.

"3. The CO_2 problem is global.

"4. The CO_2 problem requires strong central management.

"Some committee members questioned to whom the report was sent and did the DOE take these recommendations seriously enough. The point was stressed that the committee should communicate the seriousness of the problem directly to the policymakers. . .

"The committee then turned to hearing a review of recent studies on the CO_2 problem. The first of these was on the '*ad hoc* study group on carbon dioxide and climate' under the Climate Research Board of the National Research Council. . . . the report was presented by Dr. Robert Dickerson of NCAR, a member of the *ad hoc* group. Dr. Dickerson listed four primary conclusions of this study:

"1. A carbon dioxide doubling in the atmosphere (to a concentration of about 600 ppm) will probably result in a global warming of about 3 degrees C with an uncertainty of plus or minut 1.5 degrees C.

"2. Possible feedbacks are unlikely to either eliminate the warming or cause a runaway temperature increase.

"3. There is a connection between the atmosphere and the surface mixed layers of the ocean and the upper layers of deeper waters (down to 1000 meters, or so). This connection on a time scale of years to decades can delay the climate change in the systems of providing an additional sink for the energy that would otherwise heat just the atmosphere.

"4. There will be additional regional changes. These are likely to be as large or even larger than the global changes. . . .

"Dr. Donald Scroggin of the Council on Environmental Quality was called upon to discuss CEQ's activities on CO_2. Their main concern is that if CO_2 turns out to be a problem—CEQ is not yet convinced that it is an immediate governmental problem—what are the responses of government that would be appropriate and what contingency plans should the government consider? CEQ is examining what the CO_2 implications are of avoiding certain levels of atmospheric carbon dioxide. CEQ is very much interested in what is implied by a set of detailed responses in a prudent course of action—what do you do to keep options open? . . .

"Dr. Dahlman (DOE) explained that the present (DOE) program is organized around two main questions: What will be the atmospheric concentration of CO_2 for various scenarios of carbon dioxide release to the air? What will be the climatic response to the elevated CO_2 concentration? . . . The program is now beginning to look at the additional issues of environmental and social impacts, and what society can do about it. DOE has been following a procedure of inviting preliminary proposals in order to encourage or discourage certain areas of effort in early stages. . . .

"(Committee member) Mr. Pomerance observed that we know more about this issue than many and that the committee members may underestimate what is known in relation to what needs to be known to affect policy. . . .

"The ensuing discussion centered on the point of whether or not we know enough about the consequences of increased atmospheric CO_2 to be able to make (or recommend) policy decisions on this basis. It was pointed out that there are ways in which CO_2 knowledge can be incorporated into policy decisions. . . .

". . . Professor Dyson emphasized that the issue is more complicated than just burning (or not burning) fossil fuel, and Dr. Patrick reminded the committee that the international imprint is very important—the U.S. must convince others that we take it seriously."

From the WMO Bulletin, April 1979:

"THE WORLD CLIMATE CONFERENCE

"REPORT BY THE CONFERENCE CHAIRMAN

"The World Climate Conference was convened by the World Meterological Organization in Geneva (Switzerland) from 12 to 23 February 1979. . . .

"The first week attracted over 350 experts from more than 50 countries. . .

"Of particular interest is the agreement concerning the impact of increased carbon dioxide upon global climate. . . .

"The Conference concluded that it would be premature to call for a global ministerial conference on climate related matters until such time as research could both reduce the present uncertainties in our knowledge of the future evolution of climate and provide more specific information on the socio-economic impacts of climate changes and variability. . . .

"REPORT ON DISCUSSIONS

". . . A crucial question debated was the reliability of the models in simulating the response, or 'sensitivity', of the climate system to induced changes such as these. One body of opinion felt that great caution should be exercised in assessing model experiments which indicated the theoretical response of the climate to a doubling of the atmosphere's CO_2 content. It was argued that there could be some important feedback mechanisms such as cloudiness or changes in ocean circulation which were not treated adequately in the models. A consensus seemed to emerge, however, that in spite of their extensive simplifications, the models were probably approximating the correct sensitivity fairly well.

"The need was repeatedly emphasized for more refined models able to display the response of the climate on a *regional* scale. Expected changes in both temperature and precipitation distributions must be known on this scale if the results are to be of use to planners at the national level. . . .

"On a global and annual basis it was difficult to confirm any recent temperature trend one way or the other, but analysis of recent northern hemisphere data by seasons indicated warmer springs and autumns which might be the origin of the current glacier recession. . . .

"The scenario method has clearly helped to draw attention to the probability of a gradual warming around the turn of the century. Even though past climates should be used with caution in estimating future climates, an interesting and suggestive example which was mentioned was the Late Tertiary (between about 12 and 2.5 million years B.P.) with a fully glaciated Antarctic and a virtually ice-free Arctic Ocean having a marked influence on the atmospheric and oceanic circulations. It appeared that if the concentration of atmospheric CO_2 were to rise above a certain level, there would be an increase in the probability of global warming to an extent that could cause the thin pack-ice to disappear."

From 'Impact of World Fossil Fuel Use on Global Climate: Policy Implications and Recommendations', by Wilfred Bach, Director, Center for Applied Climatology and Environmental Studies, University of Münster, Germany, July 30, 1979 (prepared for the Ribicoff Symposium):

". . . All numerical climate models suggest that an increase in atmospheric CO_2 will cause a general warming of the lower troposphere with large amplifications in polar regions. Should the warming trend continue, the likely result would be a shift in climatic zones with a concomitant disruption of agricultural production especially in marginal areas, and a melting of the West Antarctic ice cap within a period possibly as short as a century causing low-lying coastal areas to become inundated by a sea level rise of about 5m. In a world that is daily becoming more crowded and that is already suffering periodically from severe food shortages any additional climatic stress will aggravate the problems facing mankind.

"Moreover, the present generation is confronted with the dilemma that

the warming trend caused by man's activities will probably not be distinguishable from the natural climatic trend before the year 2000 A.D., and yet countervailing measures, in order to become effective in time, would have to be implemented now because it takes many decades before alternative strategies, such as the use of non-fossil fuel energy and reforestation, can become effective. . . .

"It would thus appear that a shift from one type of fossil fuels to another does not make much difference. A noticeable reduction in the production of CO_2 can only come from a major shift from fossil to non-fossil use. . . .

"Finally, it is important to note from past climatic records that the fluctuations of global mean surface air temperature in the last 1000 years or so have been generally less than plus or minus 1K (Kellogg, 1978). Therefore, the warming expected by the year 2000 A.D. will probably produce a climate that is warmer than at any time in the past 1000 years. . . .

". . . a [temperature] shift may result in summer temperatures too high for crops like corn and soy beans, thereby necessitating the northward shift of the Corn Belt into the acid podzols. . . .

"In order to show the impact of [climate variability] McQuigg et al. (1973) developed a semi-empirical model for U.S. corn production which takes into consideration technology prior to 1973. By varying the climatic impact data which was available since 1890, and by holding technology fixed at the 1973 level, they were able to isolate the impact due only to climatic variables. The results indicate corn yields of about 105 bushels per acre for 'normal weather' decreasing to less than 85 bushels per acre under drought conditions. Of special interest are the low corn yields in the 1930s and the consistently high corn yields over a 15 year period starting in 1958. An explanation for this is indicated by the above-or-below normal summer values of rainfall and temperatures for that period. The low corn yields of the "Dust Bowl Era" in the 1930s are clearly related to an almost uninterrupted 10 year period of below-normal rainfall and above-normal temperatures. Similarly, the "High Yield Era" ending in 1973 was characterized by above-normal rainfall and below-normal temperatures, which are optimum conditions for high corn yields. According to McQuigg et al. (1973) the probability of having another period of 15 years of such favorable weather with high yields would be 1 in 10,000. . . .

"Results from the crop-weather-soil moisture model show that corn production in the U.S. would change by about 11% for each 1 degree C change in average maximum temperature over the summer months, and by about 1.5% for each 10% change in rainfall. . . .

"Rice is the major staple for the world's poorest and most densely populated countries. Estimates by Stansel and Huke (1975) indicate that increase in both temperature and rainfall, would result in a higher world rice production. Thus, while the production of corn and wheat might suffer, the production of rice might increase with the expected future warming. . . .

The cost of halting the CO_2 buildup

The cost of changing over the world's energy systems to halt the CO_2 buildup is frequently described in terms of millions of millions of dollars. However, the term 'cost' in such a case refers to the size of the initial investment to change over. In the long term, the non-fossil energy might even be cheaper.

Much confusion surrounds many other economic terms which are applied to energy systems and to the energy business, so that the public lacks a true understanding of the economic limitations and the supply capabilities of its energy options. The term 'renewable' has been used for solar, wind, and biomass energy systems to imply that the resource demands of such systems are inexhaustible. On the contrary, the large amounts of equipment and human labor that are needed to harness and store such energy fail to qualify as either renewable or inexhaustible.

Hydroelectric power comes close to being an inexhaustible energy system (providing that precipitation patterns do not change greatly). A limit to the useful life is posed only by the filling of the reservoirs with sediment. The sun's energy is continually converted to running water in this case. Much running water remains unharnessed, but the majority of the untapped runoff is situated too far from heavily populated areas—as in the case of undammed rivers in Western Canada and Alaska—to be of value.

The fusion of deuterium with deuterium offers the most inexhaustible energy source due to the vast potential supply of deuterium in the oceans. However, making the deuterium-deuterium fusion reaction a practical energy source is not the immediate objective of fusion research because the reaction requires an ignition temperature of 400,000,000 degrees C as compared to an ignition temperature for the deuterium-tritium reaction of 45,000,000 degrees C. Making the D-T reaction a source of energy under controlled conditions is the first challenge. The abundance of the potential energy supply from the D-T reaction is limited by the world's supply of lithium-6 as its source of tritium. Lithium-6 is far less abundant on the earth than is fissionable and breedable uranium and thorium for fission reactors, and lithium is generally much less concentrated naturally.

Nuclear fission utilizing the breeder reactor can increase the usable energy contained in natural uranium by about 60-fold over conventional reactors. Hence, the fast-breeder reactor represents the least exhaustible energy system available at today's state of technology. In the United Kingdom, the present stockpile of breedable uranium—which has been left over after much of the naturally fissionable uranium has been removed—reportedly has an energy equivalent of 400 years of coal production at the current rate of coal extraction in that country. The present program of conventional nuclear plants in France will give rise to left-over breedable uranium having a reported energy content greater than all the oil reserves of the world exclusive of the Russian bloc.

The rate of fuel breeding is presently too slow for the breeder to supplant fossil fuels rapidly. With present designs, breeders are capable of increasing the supplies of fissionable fuel at an annual rate of only 4 to 4½%, which just matches the world's average growth rate of fossil-fuel consumption in recent years. The main limitations to the growth of conventional nuclear energy supplies in the interim are institutional rather than physical or economic.

In comparison with most other systems, the harnessing of solar, wind, and biomass energy is highly consumptive of resources and human labor. In the case of forest biomass, Inhaber's figures indicate that more than one-fourth of the entire U.S. work force would have to be employed full time to cut trees fast enough to provide alcohol that would supplant the gasoline energy presently consumed in the U.S. This is hardly compatible with sustained-yield logging principles. Even the very modest (by comparison) forest-biomass program proposed in DoE's 'Environmental and Regulatory Impacts Analysis Review Draft' dated Jan. 7, 1980 "may perturb up to approximately 50 percent (or 350 million acres) of current land".

Ocean-thermal systems which utilize the temperature difference of sea water above and below the thermocline in the tropics are also resource consumptive. As R.M. Krudener notes, a factor, which could preclude adoption of ocean-thermal systems is their use of Freon gas in the turbine cycle.

which with normal leakage associated with such systems would add to the atmospheric Freon burden that threatens the earth's protective ozone layer.

A major source of confusion about energy economics in the public's mind is the use of imprecise terms in the political world. If the annual rate of return on an energy investment increases, say, from 8% to 16%, this may be described as a '100% increase in profits', while if the inflation rate increases simultaneously from 6% to 12%, this may be described as a '6% increase in inflation'. Even the term 'profits' may be unrelated to real financial gain. This is particularly true in the production of petroleum and other valuable minerals where a continuously high rate of capital investment is needed just to maintain level production capabilities. A significant part of the sale price of these commodities represents the recouping of capital.

In 1978, $3x10^9$ barrels of oil were produced in the U.S. while new oil identified by exploration and development drilling amounted to $1.3x10^9$ barrels. The total investment to find that little amount of new oil is reported to have exceeded the total revenues received from the sale of that great amount of oil, due to governmental price limitations which were unrelated to replacement costs. Yet overall, the U.S. petroleum industry is considered to have made substantial profits that year. Similarly, utility rate regulators in many cases have limited the actual rates of return that were realized on invested capital to a figure less than the inflation rate. Unrealistic accounting methods apparently have concealed the fact that U.S. industry in general has been living off its capital, which has reversed the long-term decline in the number of hours that people must work in order to pay for food, energy and housing and has caused more U.S. capital assets to belong to foreign owners.

The proposed synfuels program involves several simultaneous actions:

1. Price controls would be removed on domestic oil. (The emergency powers permitting the control of domestic oil prices are due to expire anyway in September, 1981.)

2. The oil price then is expected to rise to OPEC levels, which may approximate the current replacement cost of oil in the ground in the U.S.

3. A very large excise tax would then be imposed on the sale of oil from domestic producers to U.S. refiners. No tax would be imposed on the sale of oil from foreign producers to U.S. refiners.

4. From this tax, \$88 x 10^9 would be invested by the federal government in synfuels production facilities solely "to reduce mid term dependence on imported oil".

These synfuels from fossil sources are expected to cost substantially more than conventional fuels, and would result in greater environmental degradation. The program represents a great retreat from past environmental idealism for the sole purpose of furthering a competition over who gets to spend the money from energy revenues. Moreover, as the CO_2 scientists have pointed out, the costlier fuels create more CO_2 per unit of energy output than conventional petroleum fuels.

In virtually all countries, electric energy can be produced from conventional non-fossil sources, hydroelectric and nuclear, at considerably less cost than from fossil sources. The accompanying graph shows a comparison derived from DoE estimates of costs in 1978 dollars for electricity produced from typical U.S. nuclear and coal generating facilities to be completed in 1990. The solid portion of the bars represents the basic production costs, and the dashed portion represents costs added at governmental discretion. For nuclear, the discretionary cost represents the financial burden of extending the construction period from 6 years to 12 years through regulatory delay (estimated here at one third of the total capital outlay). For coal, the discretionary cost is represented by the cost of adding scrubbers to bring the health protection standards closer in line with stringent nuclear standards, which in many cases is called for by the Clean Air Act of 1978 if economic hardship is not created. Only be penalizing nuclear construction and relaxing smoke standards can the cost of coal generation be made comparable to nuclear generation.

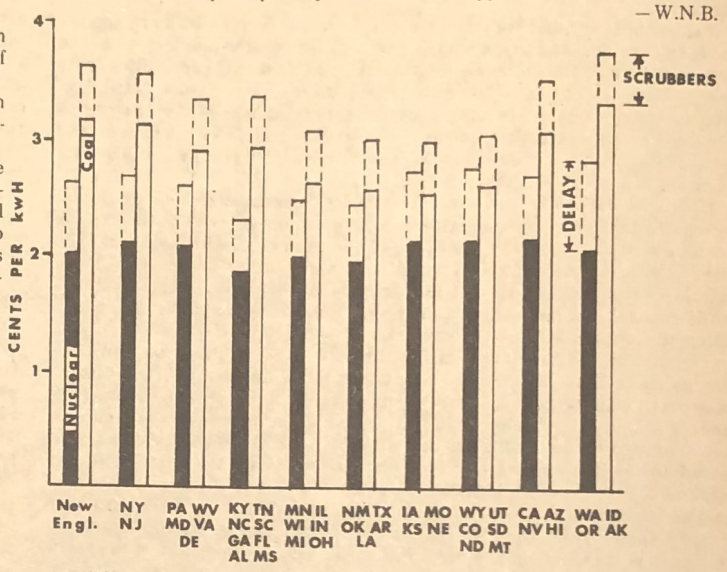
Industrial process heat, which represents a large portion of the U.S. energy demand, might also be made cheaper from nuclear sources than fossil sources. Home heating with nuclear electricity may be competitive with all fossil fuels with the possible exception of natural gas, until a greater proportion of high-priced imported gas enters the distribution system.

Eliminating fossil fuels in other sectors can pose a much greater challenge. To supplant fossil energy in transportation economically would require some imaginative changes in styles of living. Electrified mass transit would have to become commonplace in all densely populated areas too big to be conveniently served by battery-operated autos. Cities would have to be made much safer from crime so that strolling for pleasure could replace driving for pleasure. More areas would have to be provided for people to stroll in, which might require changing parking lots to parks. The clustering of large numbers of people in central offices—which requires the movement of large masses of people twice daily—might be replaced with small offices dispersed in the suburbs by using electronic communications to their fullest potential.

No studies have yet been made which would permit an overall cost comparison between present fossil-fueled transportation systems and non-fossil systems as described. However, if the direct costs of the non-fossil systems are actually greater, they may be offset by a sizeable reduction in health costs as urban air becomes cleansed of fossil-fuel pollutants. Any radioactive pollutants added by nuclear generation would probably be less than the radioactive pollutants now added in many areas in coal smoke and ash.

Opposition to a changeover from fossil-fueled systems may come from those persons who perceive a non-fossil energy policy to pose a personal economic threat. Astute persons will recognize, however, that a non-fossil policy would also open up many new economic opportunities.

—W.N.B.



Modified after DoE

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