The CO_2 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.

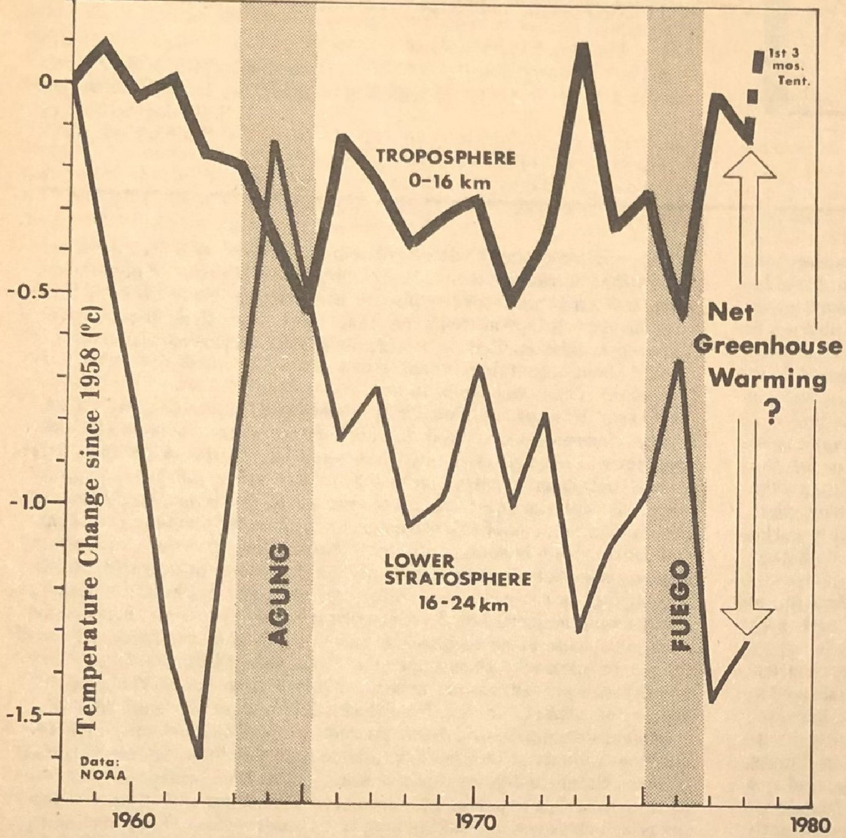
CO_2 Newsletter

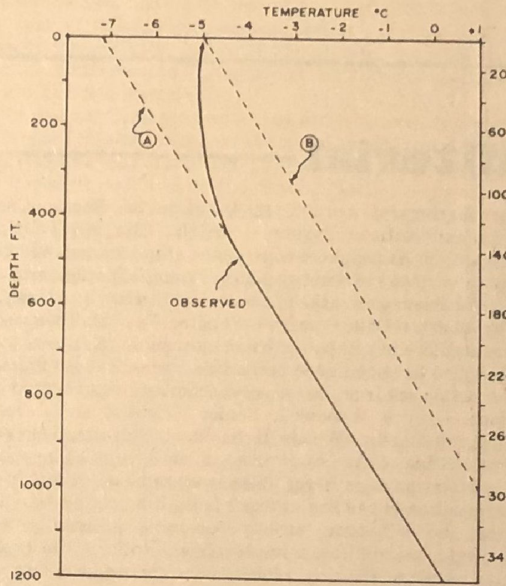
Volume 1, number 6 ©

August - September, 1980

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

MEAN RADIOSONDE TEMPERATURES - WORLD





Ground temperature profiles at Cape Thompson, Alaska (A) shows the hypothetical original profile prior to recent warming and (B) shows the equilibrium profile for the present conditions.

(From R.G. Barry after Lachenbruch, et al 1966)

Can CO2-induced warming be detected yet?

Can a CO_2-induced warming (signal) be detected above the natural temperature variability (noise) of the earth's surface? Using predictions of warming from climate models, Roland A. Madden and V. Ramanthan (NCAR, Boulder, Colorado) concluded that zonal mean surface temperature observed at 12 stations at 60°N exhibits no detectable warming above interannual variability. The period spanned by these surface temperature observations (1906-1977) was only 72 years compared to the natural temperature cycles of 78 and 181 years observed in the Camp Century (Greenland) ice core by W. Dansgaard and his associates.

Madden and Ramanthan theorized that a CO_2-induced warming may have been delayed a decade by ocean thermal inertia or has been compensated by a cooling due to other factors. They noted, however, that "uncertainties remain because our current knowledge of climate does not allow us to distinguish between changes due to CO_2 and those not to CO_2. In order to prove or disprove the existence of the theoretically predicted effects of increasing levels of CO_2, it may be necessary to monitor several variables and formulate arguments based on physical as well as statistical grounds to minimize the effect of the many uncertainties involved."

Worldwide compilations by NOAA of radiosonde measurements of temperatures of selected layers of the atmosphere may presently allow measurements of an increase in the greenhouse effect of CO_2. Manabe and Wetherald had noted from their climate-model studies (1967, 1975) that while the troposphere exhibits warming with a CO_2 increase, large cooling should simultaneously occur in the lower stratosphere due to an "increase in the emission from the stratosphere to space resulting from the increase in the concentration of CO_2."

The graph above, based on data supplied by James K. Angell of the Air Resources Laboratory, NOAA, shows that lower stratosphere (16-24 km) has generally cooled with respect to the troposphere (0-16 km) since 1958. The introduction of large amounts of volcanic ash into the stratosphere by Agung (Bali) and Fuego (Guatemala) is seen to cause the opposite effect. That is, more sunlight energy is intercepted in the stratosphere and less sunlight reaches the troposphere. A similar blocking of sunlight has been hypothesized for man-made particulates and aerosols reaching the stratosphere. However, the divergence of temperatures shown between the troposphere and lower stratosphere may be a measure of the net increase in greenhouse effect over cooling by ash, smoke and dust.

A long term warming trend at a latitude more northerly than 60°N is suggested by studies of Lachenbruch, Green, and Marshall (1966), based on disequilibrium exhibited by temperature profiles in permafrost at Cape Thompson, Alaska. The authors inferred that a warming of 2°C has occurred over the last 75 to 100 years.

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Small reforms are the worst enemy of large reforms.

—French Proverb

From our readers

". . . Thanks for copies of the *CO_2 Newsletter*. You have done an impressive job of collecting information from diverse sources that bears on the CO_2 problem, and I hope you are able—and encouraged—to keep it up . . ."

George I. Smith
Coordinator, Climate Program
Branch of Sedimentary Mineral Resources
U.S. Geological Survey
Menlo Park, Calif.

Editorial

The hearings of April 3, 1980, before the Senate Committee on Energy and Natural Resources on the Effects of Carbon Dioxide Buildup in the Atmosphere represent a step forward in introducing the CO_2 problem into U.S. energy policy. Prominent scientists familiar with the CO_2 problem were asked "what we politicians and Congress need to do" by Senator Dale Bumpers. Senator Paul E. Tsongas noted that "Current U.S. energy policy has long-term implications, and what we are going to have to figure out is how bad will those impacts be."

The responses from the several scientists represented a variety of opinions. George Woodwell, Senior Scientist and Director of the Ecosystems Center, Woods Hole, Massachusetts, believed that the general outline of the CO_2 problem is unlikely to change as new scientific information is gathered. Woodwell came out strongly for a world-wide recuction in the use of fossil fuels, but relying heavily on his experience he felt that nuclear power is inherently a dangerous technology that could not be developed without the proliferation of nuclear weapons. He also recommended the sequestering of carbon by the development of forests.

Gordon J. MacDonald, Chief Scientist of MITRE Corporation, McLean, Virginia, recommended that the CO_2 problem be considered as an integral part of the development of energy policy both here and abroad. "[I]t will take between 10 and 20 years before warming due to carbon dioxide can be detected against natural fluctuations in climate. By that time commitments by industrialized countries to coal and synthetics could be reversed at substantial economic loss. MacDonald encourages enhanced use of natural gas "which generates significantly less carbon dioxide per unit of energy delivered than other carbon-based fuels and which is presently demand limited rather than supply limited." While he expressed reservations about nuclear with regard to proliferation, safety, and waste disposal, he would not rule out nuclear as a possible contributor to our energy needs of the future.

William W. Kellogg, Senior Scientist at NCAR, Boulder, Colorado, considers it necessary to reduce uncertainties in how the climate system will behave with increased CO_2 and what impact the climate change will have on social and economic systems. Kellogg has been an energetic influence for more than a decade in getting people and organizations involved in the CO_2 problem at national and international levels, with notable contributions to the early conferences studying man's impact on climate, the formation of the United Nations Environmental Programme, and involving the World Meterological Organization in the CO_2 problem.

Kellogg feels that the U.S. National Program and the World Climate Program (which he helped draw up) can reduce those uncertainties which now complicate the decision-making process. He recommended that the electorate be informed through colloquia, workshops, briefings for the media, and pamphlets to explain the CO_2 problem to the public and thereby provide a basis for political leaders to make good decisions. Kellogg "would also put nuclear fuel as one of the energy options which we should keep open."

Wallace S. Broecker of Lamont-Doherty Geological Observatory, Palisades, New York, expanded on Kellogg's observation that it is hard to get people together to do interdisciplinary work with his own observation that "most good interdisciplinary work is done by people who were trained in an interdisciplinary atmosphere. They do it in their own heads." Broecker believed that more interdisciplinary understanding is first needed on a warmer earth, that more knowledge is needed about acceptable alternatives to fossil fuels, and that is too early to close off any energy options.

David J. Rose of the Nuclear Engineering Department, MIT, Cambridge, Massachusetts, noted that any additional knowledge on the CO_2 problem will only complement what we already know. He stated that most climatologists accept the view that an increase of CO_2 to 500 ppmv may well imply long-term serious trouble, and 600 ppmv surely would. If so, the time remaining to change over the world's energy systems and consumption is alarmingly short. Rose noted that the sacrifices in energy usage which some people would impose on others to halt CO_2 outpourings is not conservation but *deprivation*, and that in the long run the only major available energy options will be solar and nuclear.

The need for more research funding is obvious to anyone who attempts to work with the meager data available. The trend is not very favorable, however, as one notes that the House appropriations subcommittee cut $14.3 million from the NOAA budget for fiscal 1981. The subcommittee disallowed NOAA's request for $400,000 to launch the National Climate Program Office, deleted $6.4 million for the National Oceanic Satellite System, eliminated $1.5 million scheduled for the oceanic heat flux experiment, eliminated $900,000 planned for developing new techniques for making long-term observations of ocean climate, and eliminated $500,000 that the National Weather Service had requested for new oceanic service units. But such research is only part of the solution. What may be really needed is a decade-long effort similar to the International Geophysical Year.

Despite the research deficiencies, there appears to be no justification whatsoever for waiting until better impact scenarios are developed representing higher concentrations of CO_2 before taking action to halt the CO_2 buildup as soon as possible. In many cases no real sacrifices would be required, and significant side benefits may result. The biggest obstacle is to reduce energy misunderstandings and to eliminate political and ideological bias concerning energy production, particularly in regard to nuclear fission.

Some people have taken the attitude that the CO_2 problem and related energy supply and environmental problems are too complex for the general public to understand. Furthermore, some people feel that decisions regarding energy changeovers needed to halt the CO_2 buildup should be made by a small group of knowledgeable people without public participation. Our position is that a serious problem of worldwide magnitude as the CO_2 problem should be explained to the general public as thoroughly and as quickly as possible, if for no other reason than this is the spirit of democracy. The people are entitled to know what is known, without having the painful parts filtered out. The people should then be allowed to choose their environmental and energy destinies on the basis of honest representations of tradeoffs.

Assessing the instability of the Greenland Icecap

Greenland's icecap contains about 10% of all the world's glacial ice situated above sea level and is more accessible to scientific study than the Antarctic. Complete destruction of the Greenland icecap would raise sea level 6.5 m. Yet little is known about how unstable Greenland's ice might become with a CO_2-induced warming.

A domal sheet of ice reaching 3400 m in thickness and about 3000 m in elevation rests on a smooth low interior plain fringed by mountains. At places the elevation of the bedrock plain is 275 to 360 m below sea level.

About 20 large outlet glaciers, the biggest of which (Humboldt) is 100 km wide, allow glacial ice to escape to the surrounding seas. Large parts of these outlet glaciers are grounded below sea level and former retreat of these glaciers has left long, deep fiords. About half the present ablation occurs as iceberg calving in these fiords, and half occurs as meltwater runoff. Glacial marks such as striated and polished rocks, moraines and erratic blocks show that the whole of Greenland and adjacent islands had been completely covered by an ice sheet in a colder epoch.

Rain can occur on the icecap in summer at elevations up to 2000 m. Most of the rainfall occurs in the southwest and most of the snowfall occurs in the southeast. On most of the ice sheet, precipitation is slight, averaging less than 25 cm per year. Numerous crevasses up to 50 m deep occur near the margin of the ice sheet.

Greenland's ice is considerably warmer than the ice of the East Antarctic. Ice flows as a viscous mass (similar to the deformation of metal rather than the flow of a fluid), and velocity of flow increases greatly as the melting point of ice is reached. Thus the movement of the outlet glaciers varies considerably as temperatures vary. Maximum velocities presently reach about 1 km per month in summer.

Glacial ice at Spitsbergen surged 21 km at the peak of the warm 1930s period, that is between 1935 and 1938. In the warm 1930s, the Greenland ice sheet began to recede inland and glaciers were seen to be melting somewhat faster. No one has yet speculated in print about what might happen to the Greenland ice sheet if glacial ice retreated inland to where the ice is grounded below sea level, thus making it a marine ice sheet. Conceivably, the development of a body of sea water in the interior might change the climate to a much warmer state. The climate is now controlled largely by the presence of a semi-permanent barometric high situated over the icecap.

The Interim Paper issued by Panel I of the Annapolis Workshop (Francis P. Bretherton NCAR, Chairman, April 2-6, 1979) speculated on how fast a marine ice sheet might disintegrate, using the collapse of the central dome of the North America ice sheet as possibly a useful guide for marine ice sheets elsewhere. "Radiocarbon ages of marine shells from the northern and southern parts of the Hudson Bay differ by only about 200 years, suggesting deglaciation during that interval. Such an event would explain the increasing evidence for a rapid rise in sea level at that time."

Heat wave speculation: Is climate changing?

The 'snow-drought' in the northeastern U.S. till mid-February 1980 and the record high temperatures in the eastern U.S. accompanied by drought in the Great Plains region, have raised the question of possible climate change. In late July, NBC's *Meet the Press* program interviewed Stephen H. Schneider of NCAR, Boulder, Colorado, in regard to the hot, dry summer. That program was never run, but was displaced by political interviews.

Moderator Bill Monroe asked Schneider whether the heat and drought conditions represented weather abberations or did they signify a long-range ominous pattern of some kind? Schneider explained that the climatologists' understanding is still not sufficient of how the climate system works and what the human effects on the climate are in order to replace current predictions based on statistical occurrences of extremes. When he was asked to predict further into the future, Schneider said that based on projections of 10 to 20% more CO_2 by about the turn of the century, present theory suggests that man becomes a major factor in the future of the climate, probably on the warming side. He further noted that warming isn't always good, as the summer of 1980 has demonstrated.

Is it possible that the 1980 heat wave and drought were expressions of global warming? The answer appears to be 'no,' based on information supplied by Jerome Namias of the Scripps Institution of Oceanography, La Jolla, California. A *cool* area in the central North Pacific at about 40°N appears to have caused a slight ridge of high pressure in the upper atmosphere (above 700 mb). Beneath this ridge clear skies and light winds allowed the sea surface to warm considerably, which greatly reinforced the ridge to make it of the type which usually has led to a drought-producing high over the continental U.S. in the past. Through May 1980 the slight ridge over the cool ocean surface did not block cyclonic storms, thus allowing much rainfall in the U.S. this spring. Beginning about June, a marked reversal took place in sea-surface temperatures in the central North Pacific and in the continental weather patterns.

The 1930s drought, which occurred at the time of greatest global warming in several centuries, differed by being consistently short of rainfall in spring, which was then followed by extensive summer heat and drought in the U.S. and southern Eurasia. The 'snow-drought' in the northeast last winter accompanied temperatures above normal throughout much of Canada, northern Europe and Russia according to *Climate Change*. The west coast of Greenland experienced an exceptionally mild winter, with rain at high latitudes in January. Since records began in 1873, last winter was one of the warmest on record for all three winter months. In previous years when Greenland had recorded warmth, the winters were cold in Europe, while 1979/80 was not.

While good spring rainfall in 1980 in the Great Plains and summer rains in the Northwest provided for a near-record wheat crop, the recent heat wave and drought caused a 15% decline in U.S. corn production and an 18% decline in soybeans. More than 1200 heat-related deaths were recorded in the South, Southwest, and Midwest.

Excerpts from recent reports

From **Testimony before the Senate Committee on Energy and Resources, April 3, 1980, by George M. Woodwell:**

". . . I have worked on aspects of the CO_2 problem for more than ten years and believe that the continued increase in concentration of atmospheric carbon dioxide poses a serious threat to climate, economic and political stability over the next 50 years. The problem may be the preeminent international issue in management of resources during the early decades of the next century. . . .

"The source of CO_2 that is accumulating in the atmosphere is in part the combustion of fossil fuels. The amount of carbon dioxide produced by burning oil, coal, and gas is reasonably well known. . . . There is a substantial body of data that suggests that the terrestrial biota and the organic matter held in soils are both decreasing in total mass. . . . If there is considerably more carbon dioxide being released into the atmosphere than has been assumed, the models used to predict the future CO_2 content of the atmosphere are in error. . . .

"My colleagues and I in Woods Hole have reviewed the literature on forest harvests for the major forests of the earth. . . . We have summarized the information by use of a simple mathematical model that incorporates both the ability to sum the changes in the varous forests worldwide and the ability to incorporate the regrowth of forests once they have been harvested or once agriculture has been abandoned. . . .

". . . according to this analysis there was over the century between 1860 and 1960 no period during which the net release from fossil fuel combustion exceeded the releases of carbon dioxide from the destruction of forests. In 1960 for the first time the combustion of fossil fuels reached a point where the total carbon released into the atmosphere exceeded the release from forests and soils.

". . . the best estimates at present suggest that the CO_2 content of the atmosphere may be in the range of 500-600 parts per million sometime in the first half of the next century. It is difficult to see how any change in the data or in interpretation of current data will alter that prediction significantly.

"Such an increase is important because it is expected to raise the average temperature of the earth 2-3°C. The warming will be differential; the poles will be warmed more than the tropics. There is a possibility that the melting of polar ice . . . will occur in a relatively short time and will be sufficient to raise the sea level by as much as 20 feet over the course of a century or so . . . A warming can be expected . . . to shift the arable lands poleward, and to change patterns of precipitation. . . The details are complex and awkward to predict . . . There is very little in them, however, that appears to be of benefit to man. Most scientists agree that man is on the verge of making large and substantially irreversible changes in the biosphere as a whole and that these changes will not be to his advantage . . .

"While the CO_2 problem is sufficiently serious to require limitation on the total amount of carbon-based fuels used in the world and the restrictions may throw attention more intensively on nuclear power, I reject the argument that the choice must be one or the other. Nuclear power is an inherently dangerous technology, unforgiving of errors, and requiring the utmost vigilance in regulation. . . There is virtually no possibility of developing nuclear power without enabling the proliferation of nuclear weapons . . . The conclusion from analyses such as this one is likely to be that there is no reasonable possibility of continuing the current rate of energy use over the next decades . . ."

From **Statement of David J. Rose submitted to the Senate Committee on Energy and Natural Resources, April, 1980, revised 22 April 1980:**

"In briefest summary we conclude:

"1. There is plenty of fossil fuel in the world to get us into much CO_2 trouble, but the gas and oil alone probably would not do it. The big resource is coal, and the CO_2 question is really a coal question.

"2. We generally accept the view of most climatologists that an increase of the CO_2 level from its present atmospheric concentration of 338 parts per million by volume (ppmv) to 500 ppmv may well imply serious long term trouble, and 600 ppmv most surely would.

"3. Even the most energy-frugal global strategies that we can find would force the world to get its energy 50% from new non-fossil sources by about the year 2010, if a CO_2 level of 500 ppmv is not to be exceeded, and about 2020 if a CO_2 level of 600 ppmv is not to be exceeded. . .

"Patterns of energy consumption do not change easily in the short term, but in the longer term many opportunities exist to use energy more efficiently and rationally, most prominently in the industrialized countries, but also in less industrialized ones. This is often inaccurately called conservation. . .

"We assume that if less total fossil fuels are used during all future time, we have big social trouble from unmet demand. . .

"What can we do? The outlook is bleak. The possibilities are:

"1. The allowed value of CO_2 is too low? (i.e., upper limit is uncertain . . .). 800-1000 ppm is grossly excessive, because many plants die. 450-500 ppm sets most climatologists on edge.

"2. The energy growth can be reduced. . .

"3. Let the CO_2 increase with time, if we find we can adapt to a changing climate, or are willing to bear the cost of its consequences after all.

". . . Some of the climatological consequences will be delayed, possibly by a couple of decades; the upper layers of the oceans hold a lot of heat, and warm up slowly, and the West Antarctic ice sheet will take some time to melt (if it does). This makes the problem socially and politically more difficult, because effects are distant. But we gain no more assurance against later disaster than did the man who fell off the top of the World Trade Center and remarked as he passed the half-way point, 'So far, so good.' . . .

"What is alarming . . . is the rate of growth of non-fossil technologies that are supposed to replace the fossil sources.

"It is often, explicitly or implicitly assumed that new technologies could grow without limits. This is not so. . . Wood dominated the marked in 1880. It took 60 years before wood lost 50% of the world market. It was taken by coal which in turn was displaced by oil and gas. For more recent technologies such as oil and gas the market penetration . . . the period for gaining or losing a market share of 50%, starting at 1% share, was globally 80-90 years; for the U.S. it was (about) 50-60 years. . . In a low growth future it will be more difficult to replace the industrial equipment and capital stock, thus leading to longer (replacement time). Normal replacement time for industrial equipment under historical growth rate has been 30-50 years.

". . . the 50% mark (where 50% of the energy demand must be met by non-fossil means) occurs in the years 2008, 2011 and 2018 for the 5%, 4% and 2.4% growth respectively. . . the difference between 4% and 2.4% is only 7 years, not more. . .

"Within the limits of the scenarios developed in this presentation, the situation demands immediate attention, if the 500 ppmv limit is not to be exceeded.

"However, for the 600 ppmv limit, action initiation time ranges from NOW to less than a decade hence, depending on the initial energy growth rate. . .

"Hence, we conclude that keeping the CO_2 concentration below 500 ppm will not be possible, except under conditions of prompt world-wide collaboration on new non-fossil, energy sources, coupled with a global collaboration on using energy more wisely and efficiently than we do now.

"Should we 'Accept' the Climatic Change?"

"This means measuring the 'cost' of CO_2 buildup as a function of time and implicitly deciding that we can accept it, or adjust. It corresponds to deciding that we can tolerate a higher upper limit to carbon dioxide than we now imagine.

"An argument often offered is that some areas will benefit, some will lose, and it will all come out about equal. Or if it isn't equal, we don't know enough about the details, so the best thing is to do no more than study the problem.

"Such lines of reasoning, that tend to keep these issues safely locked up in National Academies or Academia, are false. First, global agriculture, by complicated geographic, social, and institutional arrangements, matches crops to particular areas. Experience coupled with simple analyses shows that total production decreased in times of changing climate, because neither the pattern of land use nor the fertility can change rapidly enough to accommodate. The system has inertia. For example, if rainfall and other weather conditions suitable for growing corn shifted from Iowa to Manitoba, the corn would not, for a very long time, because the soil and other favorable conditions would take a long time to develop. And what about moving the entire agricultural infrastructure? While the world energy problem is severe, the world food problem is even more critical, with fluctuations of a few percent in the global food production presently bringing misery to many. . .

"How to increase global awareness and find consensus on the problem will be extraordinarily difficult. The CO_2 problem has all the features that lead to present inaction: Not easily definable, no closely affected group (now), no strong institutional mechanism, disputed models, long time before bad consequences, many uncertainties. . . Significant change comes easiest after a consensus based on general understanding has developed. In this case, we need something more: a concern for future times that has few parallels in human history. . .

"Domestically, this CO_2 issue has vast repercussions; for example, if we must start reducing our dependence on fossil fuels in one or two decades, then why are we discussing vast plans to **increase** our dependence via vast synfuels programs based on coal and oil shale: A transition expedient, one might say. But massive technologies take several decades to grow . . . Once grown, powerful constituencies arise to preserve and continue the action. We should have learned that lesson from our recent experience with oil. Let us not start a domestic fossil fuel program so large that we could not start disassembling it in thirty years if necessary.

"We learn from these analyses that the U.S. should keep alive more energy options, rather than less. That means in particular both solar and nuclear power. Both those technologies tend to make the country more electric than before, a point not always recognized. . . ."

From **Why wait for the climate to heat up before doing anything? by William W. Kellogg and Robert Schware, Denver Post, April 28, 1980:**

". . . In his zest for modernization and industrialization, man has been adding more and more carbon dioxide into the atmosphere through the ever-increasing use of coal, petroleum and natural gas . . . and through deforestation of tropical woodlands.

"Few heads of government seem to grasp the hugeness of the problem and the difficult policy choices ahead. It now appears very likely that the 'greenhouse effect,' which is now well under way, may early in the next century produce an average temperature greater than any which has occurred in the past 10,000 eyars.

"THIS YEAR Food, Climate and the World's Future Program of the Aspen Institute for Humanistic Studies in Boulder embarked on a preliminary study, sponsored by the Department of Energy, of the political, social and economic consequences of the climatic change that may be in store for future generations—consequences that will probably begin to be felt in the next 20 years.

"There are many significant social and economic activities which could be affected by a carbon dioxide-induced climatic change. World crop losses, shifts of fisheries, and changes in the frequency, severity and geographical distribution of plant and human diseases are a few likely consequences which must be considered in anticipation of marked changes in the temperature of the earth's atmosphere. . .

"One of the most ominous events concerns the environmental, socio-economic and legal implications of coastal submergence as a result of the possible disintegration into the surrounding ocean of the huge and presently unstable West Antarctic ice sheet. . .

"THE PROSPECT of a global warming could be dashed by a dramatic shift in our use of fossil fuels and forests.

"It has been argued—perhaps rightly—that the rich dveloped countries should bear the brunt of control costs, mitigation strategies and economic impacts, either because they have been principally responsible for the rising concentrations of atmospheric carbon dioxide or because developing countries cannot be expected to devote as high a proportion of the scarce resources to controlling carbon dioxide production as the wealthier countries.

"Furthermore, from what is known about the probable climate change, there are suggestions that the privileged position that developed countries (especially in Western Europe and the United States) now have in agricultural production could be lost.

"In any case, bewailing our impending climate change, foot dragging or horse-and-buggy policies will not provide future generations with the strategies that could reduce the adverse impact. There are many

Graphs from 'On the Global CO_2 Problem' by David J. Rose, presented to U.S. Senate Committee on Energy & Natural Resources April 3, 1980 (Revised 22 April, 1980.)

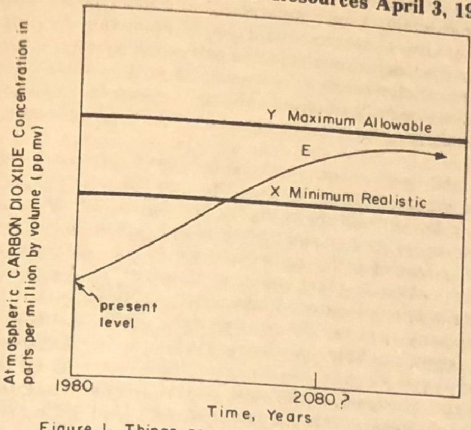


Figure 1. Things as some imagine and many wish.

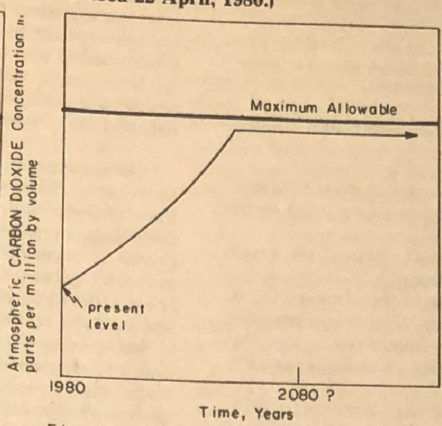


Figure 2. Can we go up almost to maximum allowable CO_2 level, then control it like this ?

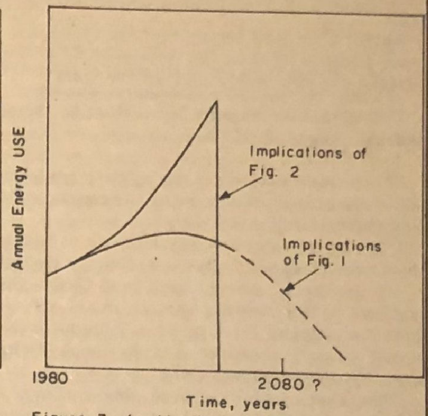


Figure 3. Implications of the two scenarios in Figures 1 and 2. A sudden stop is impossible.

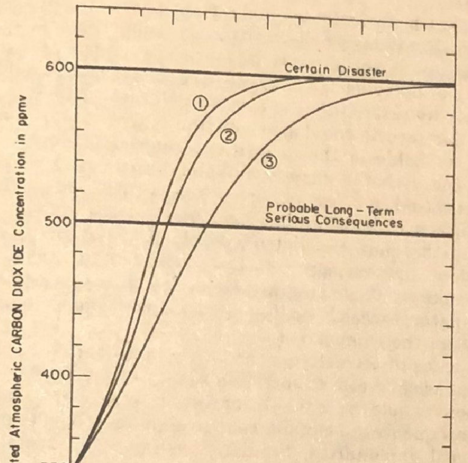


Figure 4. Closer to reality: Here the 600 parts per million concentration is approached by three different initial growth rates of fossil fuel (globally). Curve ① is the "historical" growth rate of 4.3%/yr since 1860. Curve ③ is 1.7%/yr corresponding roughly to population growth only (our very lowest estimate). Curve ② is intermediate.

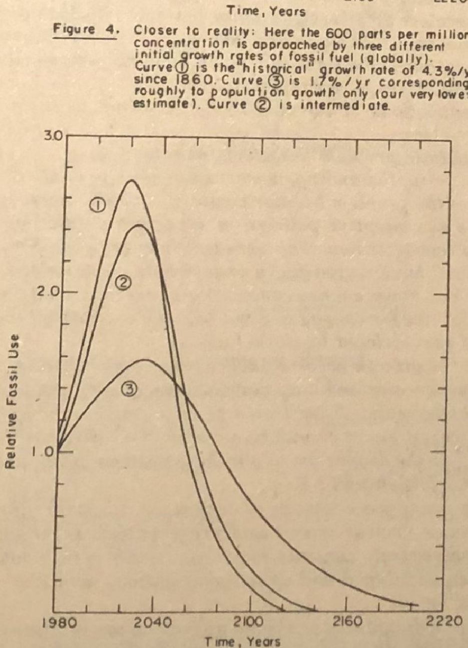


Figure 5. Fossil energy use implied by the curves ①, ② and ③ of Figure 4. In our opinion curves ① and ② would require highly coordinated global action to change the technological carbon-base quickly; curve ③ allows more time; but who will ration the energy use ?

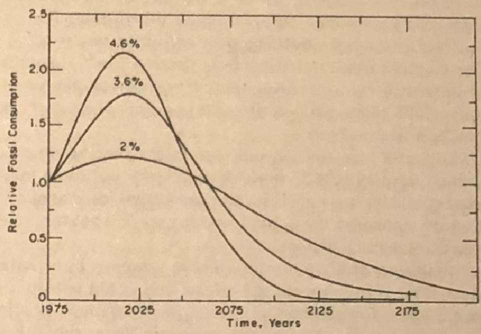


Figure 8. Pathways of projected fossil use in the rest of world to meet the 500 ppmv limit, for various initial fossil growth rates of 4.6%, 3.6% and 2% corresponding to Annual Total Energy Growth of 5%, 4% and 2.4%.

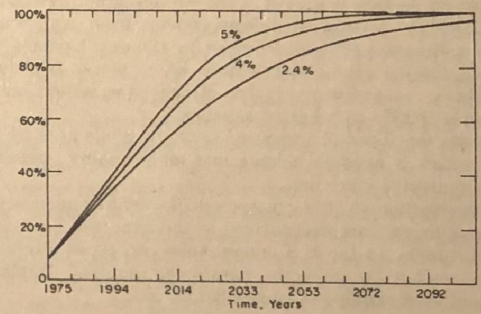


Figure 9. Required growth of non-fossil share (in total energy demand of the rest of the world) to meet the 500 ppmv limit on CO_2, for various projected energy growth of 5%/yr, 4%/yr and 2.4%/yr, as derived from the curves of Figure 8.

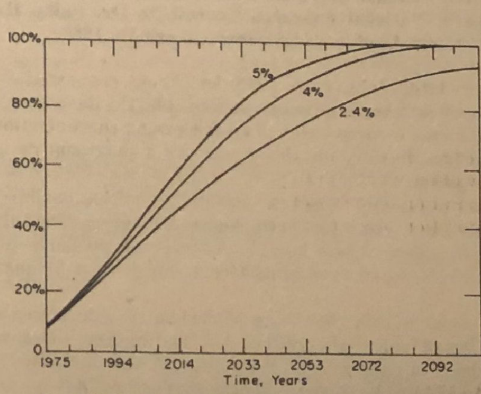


Figure 10. Required growth of non-fossil share (in total energy demand of the rest of the world) to meet the 600 ppmv limit on CO_2, for various projected energy growth of 5%/yr, 4%/yr and 2.4%/yr.

decisions that could be made now to help us to adjust to an uncertain future.

"Rather than wait for appreciable changes in climate to heat up the future political climate, the issue should become a focus for all energy and land-use policies throughout the world."

From **Weather Report: More Heat by Arlen J. Large, Wall Street Journal, August 1, 1980:**

"*There seems to be a growing consensus that carbon dioxide warming of the earth is really going to happen, and there's a growing suspicion that nothing much can stop it.*

" 'It's as enormous as anything we can do on the face of the earth short of nuclear war,' says U.S. Energy Department's David Slade.

" 'If the theory is true,' says Prof. David Rose of the Massachusetts Institute of Technology, 'that means big trouble.' The world possibly faces 'an international problem of enormous dimensions,' says Environmental Protection Agency boss Douglas Costle, requiring 'massive corrective measures.'

"The theory inspiring these dire warnings is that increased world-wide burning of coal and other fossil fuels would double the amount of carbon dioxide in the atmosphere in the next 50 years. . . traditional patterns of crop production would be altered, . . . while fishermen would find nothing to catch in their accustomed seas and new kinds of bugs would infest new places. Scariest of all is the predicted inundation of major coastal cities if a warmer ocean melts a lot of polar ice.

". . . Current U.S. policy is abetting production of manmade carbon dioxide. . . The Carter administration is trying to push through Congress a bill bribing utilities to change over their power plants to burn coal, which emits 25% more carbon dioxide per unit of energy than oil and 50% more than natural gas.

"Moreover, Congress has just passed legislation setting up a new industry for production of synthetic fuels, which spew out even more carbon dioxide than coal; the law carries a tacit acknowledgement of possible carbon dioxide consequences by ordering still another scientific study of the earth-warming theory. . .

" 'There's a growing pessimism among people who are knowledgeable about how international law operates on how you could set up a global regulatory mechanism for carbon dioxide,' says William Kellogg, a specialist at the National Center for Atmospheric Research in Boulder, Colorado.

"The National Coal Association, naturally no drum-beater about the dangers of carbon dioxide warming, suggests foreigners already are tired of the constant stream of alarms coming from American environmentalists. 'I have a difficult time seeing the development of any kind of carbon dioxide regulatory regime which works world-wide,' says Joseph Mullan, an environmental monitor for the association. 'The rest of the world thinKs we've gone bananas.'

". . . 'Reforestation is not the answer,' says Mr. Slade at the Energy Department, which is heading a huge and long-running government study of carbon dioxide warming.

"Energy conservation and the greater use of solar and nuclear power are all advanced as obvious alternatives to the expected boom in coal and other fossil fuels. In the U.S. alone, however, these alternatives already have tended to instigate paralyzing political fights that doubtless would be magnified in the global arena. . ."

From **Report of Ad Hoc Panel on Economic and Social Aspects of Carbon Dioxide Increase (Thomas C. Schelling, Chairman), Climate Research Board, National Research Council, to Dr. Philip Handler, President, National Academy of Sciences, April 18, 1980:**

"In a letter dated January 2, 1980, Dr. Press requested that the Academy assess for him, as promptly as possible, the likely foreseeable social and economic consequences of an increasing concentration of atmospheric carbon dioxide. He also requested a judgment on any implications for policy. . .

"There is assuredly enough economically accessible fossil fuel—primarily coal—to inject into the atmosphere several times as much carbon dioxide as it now holds . . . Once established, elevated carbon dioxide levels would then almost certainly persist for many centuries. . .

"At some point within the range of carbon dioxide increases that known reserves of fuels could produce, the floating Arctic Ocean sea ice would disappear in summer, radically altering the meterology of the northern hemisphere, with consequences that are not now predictable. Another concern is the West Antarctic Ice Sheet. A warmer climate with warmer oceans might cause it to disintegrate over a period of a decade to centuries, raising sea levels by about 15 to 20 feet. . .

"Economic impacts of changing climate would certainly be felt in agriculture. Changes in precipitation would be most significant and most conspicuous, but changes in temperature and growing seasons, sunlight, and the frequency of storms would also be important. Shifts in climate zones and in the loci of agricultural activity may create new combinations of soil and climate to which existing crops and farming practices would be imperfectly adapted. Marine resources, including fisheries are also sensitive to changes in ocean chemistry and climate . .

"Changes in availability of water are the single most significant consequence of climate change that we foresee through the next century. Present use of water for agriculture is highly inefficient in most countries. Improvements in irrigation and water delivery would increase production even in the face of declining precipitation. The obstacles are as much legal and institutional as technological. Changes in water supply also affect the availability of water of adequate quality for industrial and human consumption. However, large-scale, long distance transfers of water currently seem unlikely; most opportunities for large-scale, gravity-fed transfer have already been exploited, and rising energy costs will discourage pumped long-range water transfers. While modest precipitation decreases in areas well supplied at present could be accommodated, similar decreases in some currently marginal semiarid regions and increases in the frequency of drought could have serious impacts.

"Migration has historically been the principal means of adapting to climate change. But today's political barriers hamper migration, and national boundaries are not likely to be more open in the future. . .

"Preventing or delaying the increase in carbon dioxide would have to be done mainly by restricting the use of fossil fuels, although management of land and forests could also contribute. Only coal is likely to be economically available in the quantities required to double or more than double the airborne carbon dioxide. Known coal reserves are mainly concentrated in a few major countries: the United States, the Soviet Union, and China together hold most of the known reserves. Emissions can therefore be controlled only if these countries, which agree on little at present, agree in the future not to exploit for their own use or make available to other countries without restriction this part of their natural wealth, or if most of the consuming countries can agree to restrict their imports. . .

"In the absence of attractive alternative energy sources, voluntary control of coal use and coal exportation by any of the three major coal-holding nations would be unlikely unless it were clear that the unfavorable consequences of climate change significantly outweighed the benefits of coal exploitation. Similarly, self-imposed restrictions on energy demand by countries without coal would hardly find ready acceptance unless this self-denial was obviously in their own best interests; for each nation individually it would not be. Technological aid to fuel-poor developing nations for development of alternative energy sources is therefore an attractive policy to the extent that it can reduce their fossil-fuel needs. *In summary, restraint on fossil fuel will require global cooperation, reductions in energy demand, and the widespread introduction of alternative energy sources. . .*

"*Some implications of increased concentration of carbon dioxide, however, are clear:*

"*Our immediate problem is uncertainty itself. . .*

"*Research notwithstanding, uncertainty will persist. Even as the dimensions of the problem become clearer, it may be necessary to base preventative and adaptive policies on uncertain predictions.*

"*We must recognize now that increases in energy consumption using fossil fuels will have increasingly undesirable climatic effects.*

"*We and the main energy-consuming countries must keep open a number of options for energy and not become committed to an extended period of unrestricted fossil-fuel use. . .*

"*Slowing the growth in fossil-fuel combustion will make adaption to climate change easier and may permit more absorption of carbon into nonatmospheric sinks. It will also permit conversion to alternative energy sources at lower cumulative carbon dioxide concentration, and it is likely that the sooner we begin the transition from fossil fuels the easier the transition will be. . .*

"*There is an intricate linkage of carbon dioxide with other intensely divisive issues: nuclear power and preservation of the environment, markets and central economic planning, 'north versus south' and the gap between developed and developing nations, and even OPEC and the demand for oil. . .*

"*The carbon dioxide issue should appear on the international agenda in a context that will maximize cooperation and consensus-building and minimize political manipulation, controversy, and division. . .*

"Another point of view represented on the panel is that further research will not fundamentally change our perception of the issue; in this view, the need for preventive measures is already apparent and urgent."

A need for rational answers about energy

Two general energy strategies have emerged as the leading choices of scientists to halt the CO_2 buildup:

- Rely largely on solar, wind and biomass without nuclear, and a very subtantial reduction worldwide in fossil-fuel usage; or
- Rely on a greatly accelerated use of nuclear-electric modestly supplemented with solar to supplant oil, natural gas, and coal.

If David Rose's conclusions that 500 ppmv CO_2 in the atmosphere would have "probable long-term serious consequences" and 600 ppmv would cause "certain disaster" are even approximately valid, the time remaining to choose and act is critically short. It then becomes urgent to examine economics, safety, long-term health threats, and political and social side effects in a purely objective manner. Delay and obfuscation may translate into default on the CO_2 problem.

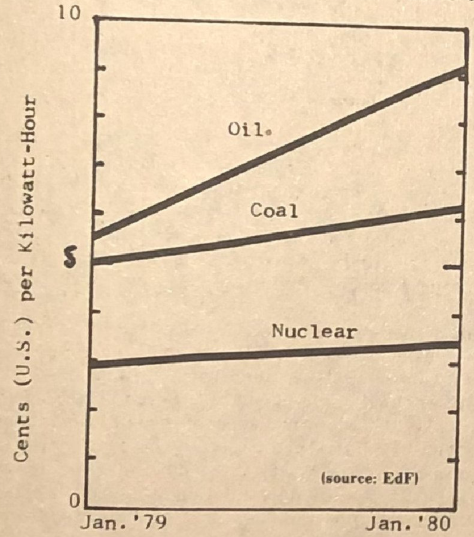
Economics. Energy production from heat sources has evolved from the primitive steam engine through nuclear-fission reactors with a continual increase in human productivity by increasing power densities. Such increases in human productivity have usually brought decreased physical labor, increased personal income and savings, increased leisure time, increased research, and timely replacement of inefficient or obsolete industrial equipment.

Many practical engineers view a turn to solar and wind systems as a great step backwards in productivity because such systems utilize very low power densities. Two pioneers in the field of solar, Aden and Marjorie Meinel, from the University of Arizona, have pointed out the difference of romance and reality of solar energy by stating that several serious technological problems remain unsolved:

- undependability of sunshine
- high capital costs
- unreliability of apparatus
- the need for a backup system
- overoptimism of performance.

They assert that it would be a "fatal mistake" if we were to cut off other energy sources and wait for solar.

Neither solar, wind or biomass is seen as being capable of substituting for petroleum-powered vehicles on a massive scale, where today's largest conservation problem exists. (Depending on whose statistics and what year are referenced, U.S. autos consume one in every nine or one in every ten tons of all the oil produced in the world.) Efforts to introduce solar and wind have therefore been restricted to water and space heating (already commercialized), passive solar (building design, siting) and photovoltaics, which as Governor Dixy Lee Ray of Washington has noted, presently would cost $10,000 to burn four slices of toast.



Comparative energy costs, France.

Whether unintentionally or by design, advocates of the solar and wind options have tended to compensate for the large productivity handicap by dragging down the high productivity of conventional energy through delays, intervention and demonstrations. Unhampered nuclear-fission energy offers economic competition unmatched by solar and wind. Also nuclear costs are substantially less than coal and oil for electric generation, as the accompanying graph for France shows.

For nuclear to become acceptable to outspoken dissidents, however, several critical issues must be resolved in public fora, namely, safety, proliferation and waste disposal.

Safety. Some highly irrational fears exist about nuclear energy largely because it was first used in war. Some people actually think that exposures to elevated radioactivity from nuclear energy is invariably fatal. Maurice Tubiana, chief of the Radiation Department of the Gustave-Roussy Institut at Villejuif, France, has noted from studies on the carcinogenic effects of high-level radiation on 285,000 survivors from the atomic bombs dropped on Japan, that the incidence of cancer is still very low, even for those exposed to levels of radiation that most people assume to be lethal. He noted that among the 1200 survivors who received the highest doses (mean levels of 330 rads), that the incidence of cancer from 1950-1974 was about one percent.

The people of the U.S. have been exposed to so much emotionalism concerning nuclear-energy safety and effects of radiation that a highly charged emotional atmosphere existed at the time of the first and only (so far) accident in a U.S. nuclear plant which experienced core damage—Three Mile Island. Two weeks before the accident, the movie 'The China Syndrome' was released in major cities throughout the U.S. This movie intentionally left the impression that, in a matter of minutes after a reactor core is exposed, the fuel gives off 'incredible heat' so that nothing can stop it from melting its way through the earth except reaching the water table, where *"the amount of steam generated by this incredible heat would send a blast of vapor up through the rock and earth and into the atmosphere. . . Possibly it might render an area the size of Pennsylvania permanently uninhabitable . . . for 25,000 years . . . Within weeks, months, years, the [number of cancer cases] could number in the hundreds of thousands, even millions . . . it is theoretically entirely possible. In fact, highly probable."* —(from dialogue in the ensuing book).

The 'incredible heat' referred to, which is given off by radioactive decay in the fuel elements of an irradiated core, amounts to about 300 kilowatts (thermal) or about the heat given off by 3000 100-watt light bulbs. Concentrated in a small area, it might have melted through the steel container if it had been uncooled for 2½ hours, but it was expected to stop completely at the concrete floor.

Irresponsible claims have been made that 'plutonium is the most toxic substance known to man.' No amount of plutonium has been found to cause instant death in the way that virulent poisons will. Tests on dogs by intravenous injections indicate that the relative toxicity and carcinogenic potency of the much feared plutonium-239 are similar to radium-226 (another alpha-emitter), which is present in most drinking water and food, and in *all* coal smoke and coal ash. If plutonium does escape from a nuclear accident and small amounts of it enter the body, it would pose a cancer hazard that would be expected to show up about 15 to 45 years later.

Nuclear safety hazards have been compared with other common risks in the Rasmussen Report (WASH-1400), the methodology of which has survived much scrutiny. Some critics may wish to add factors which they think were overlooked or underestimated. In Rasmussen's favor, zero accidental deaths are attributed so far to about 500 reactor-years of operation.

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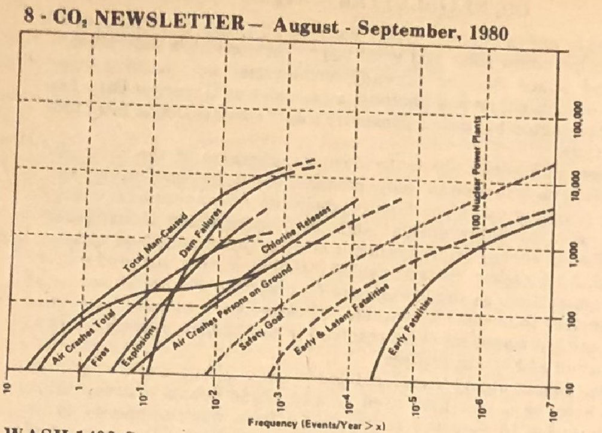


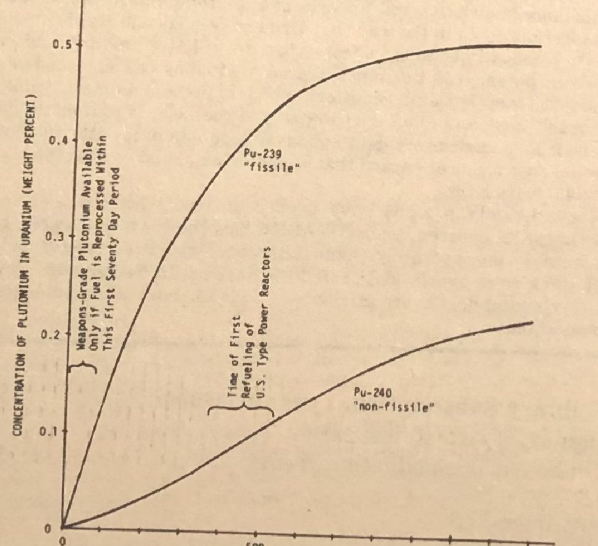
WASH-1400 Comparative risks with two new curves.
(from Nuclear News)

Saul Levine, former director of Regulatory Research at NRC, has added two curves to Rasmussen's (see graph). One includes possible latent cancer fatalities from postulated accidents, and the other is his suggested overall nuclear safety goal arbitrarily set at one-tenth of the lowest of the non-nuclear risks. If WASH-1400 has any predictive merit, the U.S. could theoretically have 500 operating reactors without exceeding Levine's stringent safety goal, and the U.S. could have 5000 reactors before nuclear risks equaled one percent of the total of all man-caused risks.

Typical U.S. coal-electric plants reportedly offer a greater cancer hazard than present nuclear-electric plants. EPA-520/7-79-006 shows that existing coal plants are each expected to cause 0.0004-1.5 fatal cancers per year and new coal plants 0.0001-0.02 per year. The best new coal plant matches the low 0.0001 fatal cancers per year which that EPA report attributes to each U.S. nuclear plant.

Attempts by Herbert Inhaber to compare the overall safety of solar and wind systems with nuclear safety have resorted to using standard industrial statistics which would appear to fit these young technologies. If installation and maintenance require people to work on ladders or rooftops—as is often the case—the available statistics show a very high incidence of accidents in such situations. Hence, until more pertinent data become available, nuclear energy may be generally considered to have a large safety margin over these alternative technologies, right or wrong.

Proliferation. Reliable and efficient atomic bombs require plutonium-239 at least 90% pure and preferably purer. This 'military grade' material is present in spent fuel from conventional nuclear power plants only if the fuel has been used 70 days or less before reprocessing. Normally, commercial reactors have their first refueling after more than a year of operation for economy's sake, and at that time other isotopes have increased so that plutonium-239 comprises only 80% of the total plutonium (see graph), and cannot be enriched to 90% for all practical purposes. One explosive has been tested by the U.S. military with 80% plutonium-239, but it reportedly gave nowhere near the optimum yield due to uncontrollable premature detonation.



Comparative plutonium isotope production in irradiated reactor fuel.
(From letter to NN from W. Chubb)

No one proposes not safeguarding plutonium from spent reactor fuel, but the attractiveness of such material to countries for weapons is apparently very low. Nuclear engineer Tobias Burnett has attempted to put into perspective the attractiveness of 80% plutonium to terrorists, by noting that such material may be less dangerous in the hands of terrorists than the common fertilizer, ammonium nitrate (at 20 cents per pound), mixed into highly explosive form in a common cement mixer.

U.S. Representative Mike McCormack has noted (U.S. News & World Report, August 18, 1980) that no one in the world has yet exploded a *weapon* from such low grade plutonium. McCormack also noted that there are about 3 dozen countries in the world today that could make nuclear weapons if they chose to do so—and they could do it in about four years and at 5 to 10 percent of the cost of a nuclear power plant.

Countries which truly do not intend to utilize their nuclear generating industry to manufacture weapons normally submit to safeguards imposed by the International Atomic Energy Agency. As IAEA Safeguards Director, H. Grümm, has pointed out, the safeguards currently cost $50 million per year, which is about the same as the cost of a single, not very large, military airplane.

Thus the proliferation problem may not be so closely tied to peaceful nuclear energy that this major non-fossil energy source need be abandoned.

Disposal of Radioactive Wastes. Disposal of high level wastes from spent nuclear fuel in deep, geologically stable formations is not considered a difficult or uncertain task by technical experts. Fuel elements become unusable when they become contaminated with too high a concentration of fission products, and must be replaced even though they still have much fissionable material remaining.

The fissile plutonium in spent fuel has a high commercial value if it can be recycled as reactor fuel, which makes the plutonium in spent fuel worth about 6 times as much as gold on a weight basis. Therefore, reprocessing removes as much plutonium as can be practically separated out. Much of the controversy over the safeness of long-term disposal of nuclear wastes has to do with the proposed burial of *unreprocessed* fuel which still contains large amounts of plutonium. The nuclear industry considers such a practice to be very wasteful of an energy resource, and such disposal would entail much longer custodial care for future generations.

Wastes from reprocessed fuel, that is with most of the plutonium and uranium removed, must be isolated from the biosphere only a few hundred years in order for radioactive decay to proceed to the point where the wastes would not remain a significant health hazard. As Bernard L. Cohen has pointed out, after 600 years, a person would have to ingest about half a pound of the vitrified wastes to incur a 50% chance of contracting a fatal cancer. Such vitrification can be in the form of borosilicate glass (Pyrex).

Isolation of radioactive wastes from the biosphere for several hundred years is not considered to be a difficult challenge. Probably the most effective isolation consists of deep-ocean drilling of holes into which containers of vitrified waste would be lowered before sealing off the top of the hole. The 1976 Flowers Report of the U.K. Royal Commission on Environmental Pollution had reported the cost per such hole drilled to 1500 m in a depth of water up to 4000 m to be about $1.7 million per hole. An estimated total installation of 1200 GWe of nuclear capacity for the whole world by the year 2000 was reported to require only about 20 new holes per year.

Higher disposal costs would be incurred as disposal holes—or shafts and tunnels, as proposed in the U.S.—become more elaborate. However, the apportioned cost per unit of nuclear-electric energy is still small.

Countermeasures to halt the CO_2 buildup might be further underway if the majority vote of the public would be allowed to decide on the unhampered use of nuclear energy. Polls taken in the U.S. have consistently shown that a majority of the people favor nuclear energy. The people of Switzerland have voted in favor of allowing the use of nuclear energy. The people of Sweden were allowed to vote only on *how long* to keep nuclear energy, and a strong majority favored the longest term available on the ballot. The people of Austria had voted against nuclear energy by a very slim margin, but polls show today that a sizeable majority would favor nuclear energy if they were allowed to have another election. Overall, polls generally show that many nations of the world may be receptive to the nuclear option.

—W. N. B.