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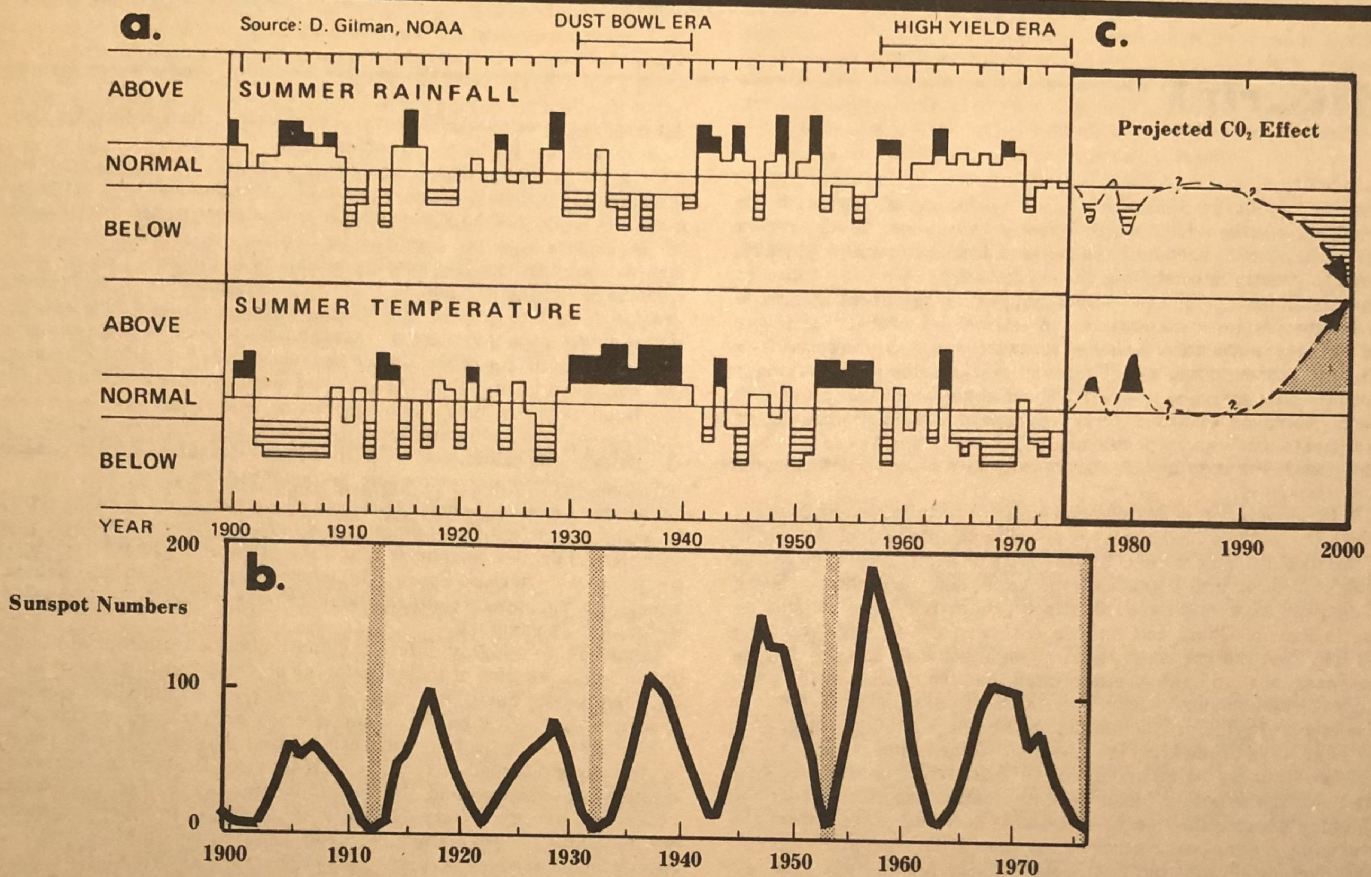
In 2025, the family of Mr. Barbat donated an original set of all issues to Dr. Marc Hudson, and agreed that these could be digitised and placed online as a resource for anyone who wants to understand how long we've known about the carbon dioxide and global warming problem.

CO₂ Newsletter

Volume 2, number 1

Oct. - Nov. 1980

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



Hottest summers result in lowest summer rainfall in the five 'Wheat Belt' states

A consistent relationship between high summer average temperature and low rainfall over a 75-year period is shown by chart (a) for the five major wheat producing states, Oklahoma, Kansas, Nebraska, South Dakota, and North Dakota.

Graph (b), showing cyclical variations of the sunspot numbers, illustrates the coincidence observed by Walter Orr Roberts between the occurrence of drought in the high plains and the occurrence of every-other sunspot minimum, that is, every 20-23 years.

In March 1974 Roberts had stated in an interview in *U.S. News & World Report*, "If a drought doesn't come within two more years or possibly three, then I'll feel that the cycle has been broken for some reason." Because of his forecasting accuracy, the 1966-1967 drought has been facetiously called 'The Walter Orr Roberts Memorial Drought'. Lowell Ponte in *The Cooling* (1976) reports that Roberts predicted the then-existing midwest drought would last until 1981, which suggests that the summer 1980 heat wave and drought do not yet signify any climate change. The 1980 heat wave and drought began for most of the affected area in late spring, thereby stunting crops later than wheat (corn, soybeans, cotton) except in North Dakota.

The long, severe dustbowl drought (the Great Drought) lasted through the 1930s and coincided generally with peak warmth in the Northern Hemisphere. The Great Drought is generally considered to

be synonymous with the Great Depression. Economists have been unable to establish any purely politico-economic reasons for that depression having lasted as long as it did and being so severe. The Great Drought came after a worldwide depression had begun, but the U.S. and its main trading partners continued to suffer from the Depression through the 1930s, while other countries recovered earlier.

The Great Drought ended with the start of a major cooling trend. The Northern Hemisphere mean annual temperatures of the 'high yield era' (1957-1974) were about 0.3° less than the dustbowl era.

Projections of cyclic global temperatures with an added CO₂-greenhouse effect (at 2° to 3° C global temperature rise for a CO₂ doubling) give an expectation of global temperatures warmer than the dustbowl era before 2000 (c). Good analogies are not available to predict what climatic effect a continued CO₂ increase and further global warming might produce eventually, other than past global warmings have generally been accompanied by a widening and slight poleward shift of the semi-tropical arid belts.

Chart (a) is from 'Climate Change to the Year 2000', a Survey of Expert Opinion, published February 1978 by the National Defense University, Washington, D.C.

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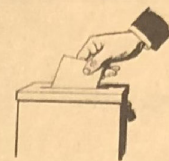
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"The first principle of freedom is freedom of choice, which many have on their lips but few in their understanding."

—Dante Alighieri



Editorial

Whether the divisiveness of the previous decade will end with the November 4 elections in the U.S. remains to be seen. Some express hope the 'me' decade is ending and the 'we' decade is beginning, which would help greatly in combating the CO₂ problem.

Potential impacts of the CO₂ buildup appear to represent by far the largest, most serious, man-caused environmental problem that the world will face in the not-too-distant future. Because the threat of famines from climate change and of mass migrations due both to hunger and to potential sea level rise will impact almost everybody, the CO₂ problem should be expected to bring together opposing factions on environmental and energy problems. Any delay in closing ranks to halt the CO₂ buildup is seen by some knowledgeable workers as leading to more human grief.

With the population of developing countries doubling every 20 years and with the world's food reserves actually shrinking at a disturbing rate, the threat to agricultural productivity posed by a continuing CO₂ buildup translates into potential large scale, long term famine. Some climatologists have speculated that food productivity may actually increase in Russia, China and Canada with global warming. Warming would lengthen the growing season at high latitudes and possibly increase monsoonal and sub-Arctic rainfall, but the continental interior portions of these countries may simultaneously dry up. Moreover, the decline in world grain production just in the last year (due in large part to the heat wave in the U.S.) is equivalent to the entire wheat production of two Canadas, as an article in the *Wall Street Journal* recently pointed out. If the political leaders of any nation choose to ignore the CO₂ buildup because they perceive benefits accruing to them from global warming, a distressing surprise may await their people.

What factors allowed the CO₂ problem to be ignored over the last decade when most other environmental problems received much attention and massive funding? And what factors led to the present de facto moratorium on nuclear reactor orders in the U.S. when this appears to be the only feasible large-scale substitute for fossil energy available for some time? Some answers might be:

Firstly, the earth was then experiencing a cooling trend that began in the 1940s. Also, quantification of the CO₂-greenhouse effect and the effect of dust and smoke were being contested, and some workers strongly asserted that deforestation was possibly as great a villain as fossil-fuel combustion, which would imply that a CO₂ perturbation would not be expected to last long after the CO₂ outpourings ended.

Secondly, the environmental 'crusade' was largely directed against the business community, which had embraced nuclear fission for its perceived economic and environmental benefits. Environmental discussions often became sociopolitical monologues. Formal scientific training and disciplined scientific investigation were not always regarded as necessary basis for technical expertise. Environmental priorities tended to be ranked more by immediate visibility, symbolism, or emotional response rather than measurable impacts on people's lives. Anti-civil acts were supposed to represent the suppressed will of the public, even if the acts were contrary to the public's will as expressed by election results.

Most indicators now show that the post-1940 cooling trend was a cyclical swing which ended 'on schedule' and that this bottoming out occurred about 0.2°C higher than the last such bottoming out of global temperatures in 1880-90.

The general consensus now seems to be that deforestation is nowhere near as great a source of CO₂ as fossil fuel combustion at present

if it is a net source at all. The general expectation, then, is for a CO₂ perturbation to last for many centuries.

From more than a decade of intensive studies and model analyses, the thermal sensitivity of the earth to CO₂ doubling had been narrowed generally to about 2° to 3° warming. In recent months, new participants in the debates proposed a sensitivity of about one-tenth that. It is difficult to imagine how 19th century scientists as Fourier, Tyndall, Angström, and Arrhenius could have been so cognizant of the atmosphere's greenhouse effect if a CO₂ doubling would cause only 0.26°C average global surface warming. Even if true, such warming would reproduce temperatures of the 1930s, a warmth level which is credited with causing widespread drought in the U.S. and southern Eurasia. To halt the CO₂ buildup before such a doubling occurs is seen as requiring a very rapid conversion to non-fossil energy sources starting now. The current debate over the 0.26° figure might be resolved if the heretofore unpublished supporting material would be published for all to see.

Possibly a different choice of descriptive terms in many cases would help unify the scientific community and permit clearer communications with the public. If atmospheric heat absorption would be referred to as the 'hothouse' effect, as Fourier introduced it, rather than 'greenhouse' effect, any misunderstandings about impacts on agricultural productivity might be avoided.

'Adapting' to a highly different climate may be inappropriate to apply to future victims of malnutrition or storm-driven high tides of an elevated ocean. 'Sacrificed' may be appropriate if immediate countermeasures to the CO₂ buildup could actually prevent such problems.

The 'cost' of instituting countermeasures may not refer to excess overall expenditures but to initial investments. In some cases, merely terminating subsidies and eliminating income tax credits, tax exempt bonds, and energy-investment tax credits for CO₂-producing systems and reducing the regulatory cost and punitive restraints on nuclear energy would produce savings to the public while allowing fossil energy to be phased out as a natural industrial phenomenon, just as wood energy was supplanted by fossil fuels.

A bright side of the scientific-political scene is provided by the newly started evaluation of the policy-related issues of the CO₂ problem under the Office of Science and Technology Policy (OSTP), as organized by William Nierenberg, director of Scripps Institution of Oceanography. At long last, a systematic analysis of the policy options and tradeoffs has been started, including the options of deferral and inaction. Ironically, the birth of this study derives from the Synfuels Act, which also provides massive subsidies for the most CO₂-productive energy system available.

What is still lacking is a specific plan to show how the energy-substitution scenarios of F. Niehaus and David Rose could be translated into reality in order to halt the CO₂ buildup at optional ceiling values. These are the only CO₂-limiting scenarios advanced so far which do not call for a virtual cessation of energy use worldwide. It would be beneficial to have for comparison specific scenarios which call for large-scale reduction of energy use, showing who is expected to give up what. Also, a specific scenario of the supplanting of fossil fuels with energy sources other than nuclear (wind, solar, hydroelectric) would be helpful to the public. People could see just what substitutions and cutbacks would be required to them specifically. The people of the world should then be allowed to select the preferred course of action or adaption without intimidation, coercion, or obfuscation.

With a more unified scientific effort, with CO₂-limiting scenarios clearly set out in comparison with any other possible courses, and with a better means of passing this knowledge to the public, we might soon progress toward practical solutions.

Some problems of the carbon cycle

A facet of the carbon cycle which has received comparatively little attention so far is estimating the changes in carbon inventories in root systems of plants of the subsoil or below plow depth. Currently above-ground inventories of carbon in the terrestrial biota are becoming more accurate as more regions of the world are methodically sampled and as more historic records are compiled. Estimates of the changes of carbon in shallow soils are also becoming less subjective as more direct measurements are made.

However, very few accurate observations seem to be available for estimating annual and monthly carbon storage in deeper root systems and the carbon retention rate after plants have died or have been harvested. Conceivably the monthly additions to carbon storage in root systems differ sufficiently from above-ground carbon storage to help explain the phase difference between annual fluctuations in atmospheric CO₂ concentrations and net hemispheric metabolism observed in the above-ground terrestrial biota. Subsoil roots might even offer a place for an overlooked carbon pool as the 'missing sink' of carbon, that is the carbon budget gap between most ocean-atmosphere-biota models which suggest biotic growth between what most ocean-atmosphere-biota models suggest, a slightly increasing biota or no net change, and what some biologists assert, a shrinking biota due to deforestation, and inventories which consider a shrinking biota due to deforestation.

The difficulty in making an accurate inventory of root systems is, of course, due to the inaccessibility. Often deep excavations must be dug with painstaking care to expose and measure the root system of a single plant or tree. Studies made in such excavations in the Great Plains region by J.E. Weaver (1968) have shown that the roots of grasses (including maize) commonly reach a depth twice the above-ground

height, and that the roots of trees and small non-grasslike herbs may reach 6 m in depth.

If carbon is retained in sub-soil root systems for a significant length of time after cropping, repeated annual cropping may result in relatively large accumulations of carbon out of sight. The carbon sequestered in dead roots of harvested virgin forests may — when added to the mature regrowth — be found to equal or exceed the total carbon in the original stand.

Also receiving relatively little attention presently is the problem of estimating changes in oceanic uptake of CO₂ for some future climate. Using radioactive tracers created by above-ground nuclear explosions, oceanographers are able to determine the local rates of mixing or water downflow which would apply also to waters which have become saturated with CO₂ at the surface. When completed, these studies will provide valuable information on the rate of oceanic uptake under present climatic conditions, but are probably not representative of a different climate. Several studies suggest that average global wind energy will decrease with a CO₂-induced global warming, so that the CO₂ mixing rate and oceanic uptake rate may decrease.

The magnitude of such a decrease might be estimable from geologic studies of earlier warm periods. A study of anoxic marine environments in the geologic past by G.J. Demaison and G.T. Moore (1978, 1980) has found that 'oceanic anoxic events' (when oxygen uptake by ocean waters was minimal worldwide) have occurred at 'major global climatic warmups' and at major oceanic transgressions of the land surface. Presently open-ocean anoxic layers occur only on a reduced scale far from the same deep, oxygenated polar water sources where substantial amounts of CO₂ are now being captured and carried into deep waters. This implies that CO₂ is being taken up much faster now than during past global warmups.

Excerpts from recent reports

From 'Background and Purpose Statement for the Carbon Dioxide Workshop', St. Petersburg, Florida, October 30-31, 1980, by G.M. Woodwell, Gordon J. MacDonald, Roger Revelle, and Charles David Keeling:

"... To date, most of the reports or debates on the CO₂-climate issue have focused on the scientific and technical uncertainties surrounding the issue and on establishing research plans to resolve these uncertainties. . .

"By comparison with these scientific efforts, lesser emphasis has been placed on considering the policy implication of CO₂-climate change, and in particular, on evaluating alternative policy options. Two major reports which have addressed these issues are:

"- A report to the Council on Environmental Quality (CEQ) entitled 'The Carbon Dioxide Problem: Implications for Policy in the Management of Energy and Other Resources' (July 1979)

"- A report commissioned by OSTP from the NAS ad hoc Study Panel on Economic and Social Aspects of Carbon Dioxide Increase (April 18, 1980).

"While both of these policy-oriented reports identified a number of interesting policy implications of increased CO₂ levels, they differed substantially in their conclusions. For example, the report to CEQ recommended that rather than waiting for proof of CO₂-induced climate change, policy measures to control emissions of CO₂ should be developed now. The report to OSTP, on the other hand, concluded that while there are currently too many scientific uncertainties about the CO₂-climate relationship to explore questions of policy, 'we believe we can learn faster than the problem can develop'. Furthermore, both study groups were composed primarily of scientists and academics, rather than actual policy makers.

"... the primary purpose of the workshop is to bring together leading scientists and policy-makers to assess whether, and if so, when, public policy measures should be adopted to either prevent or adapt to CO₂-induced changes in global climate. . . . Specifically, the workshop discussions will focus on two major policy-related questions:

"1. Are the potential consequences of increased atmospheric CO₂ levels significant enough to warrant development of public policy responses either now or in the future?

"2. What is the nature of the relationship between scientific CO₂-climate endeavor and the development of public policy? For example, what are the possible tradeoffs between taking certain actions now, based on very limited information, versus delaying a decade or more in hopes of having better information on which to act? . . .

"The following list of key policy-related issues is provided to stimulate and guide the workshop participants' discussions of these issues . . .

"1. What, if any, are the major uncertainties that must be resolved before policy choices are made?

"- Are these uncertainties likely to be resolved in the next ten years? For example, how likely is it that current research programs will provide conclusive evidence of CO₂-induced climate change in this ten to twenty year time frame?

"- Does scientific evidence today warrant development of any policies?

"2. How much lead time is required to develop and implement policy measures in response to potential CO₂-induced climate change?

"- What effect might delay have in terms of precluding, limiting, or reducing the feasibility of various policy options? In expanding them?

"- If preventative actions are required, when should they be taken? How long might it take to formulate and implement them? How long before results will occur?

"- How long might it take to develop and adopt coordinated international policies to prevent CO₂-induced climate change? To adapt to such change?

"3. What changes in energy, air quality, land use, and foreign policies might be considered to prevent CO₂-induced climate changes?

"- How effective might they be?

- Which actions can be taken unilaterally? Which require the cooperation of other nations?

"- What are the relative advantages and disadvantages of these actions? Which nations and/or sectors of the public will experience these advantages and disadvantages?

"- How much and what types of information are required to justify taking preventative actions? When is this information expected to be available?

"- How likely is it that preventative measures will be adopted soon? In a decade?

"4. What actions might be taken to adapt to the consequences of CO₂-induced climate change?

"- Which nations will be most able to take these actions?

"- What compensatory measures might be considered (e.g., increase food aid to countries that lose agricultural productivity)?

"- What are the socio-economic and other tradeoffs between preventative and adaptive actions?

"5. What international mechanisms are available for either preventing or adapting to CO₂-induced changes in climate?

"- What precedents exist for international action? Have such actions been successful?

"- What are the chances of success in seeking international cooperation on measures to prevent CO₂-induced climate change? On adaptive/compensatory measures?"

From In Science, "No Advances Without Risks", Interview With Phillip Handler, President of the National Academy of Sciences, U.S. News & World Report, Sept. 15, 1980:

"Q Should the public be allowed to help decide what projects are pursued or not pursued?

"A Generally no, if what you mean is basic scientific research. . . .

"Most members of the public usually don't know enough about any given complicated matter to make meaningful informal judgments. And that includes scientists and engineers who work in unrelated areas. . . .

"We're going to have very large technological decisions to make in the next 10 or 20 years, such as the future of coal or how much total energy we may have—particularly in the light of what the effect of releasing more carbon dioxide will be. I don't think John Doe will ever have enough information to justify technological public policymaking by public referenda.

"To make intelligent decisions about science-based technology, we will have to rely on analyses and advice from institutions that the polity trusts. We need to find knowledgeable wise men in a manner equivalent to the Founding Fathers of this country or the original idea of the Electoral College, a group who could deal with the subject at hand while enjoying the trust of their fellow citizens.

"In modern form, that means institutions that can be relied on to analyze the great technical problems and then make clear to the larger society what our options may be. Then all of us can debate those options and communicate with those whom we elect to serve as decision makers on our behalf. . . ."

From 'Comment from Europe', by Simon Rippon, Nuclear News, October 1980:

"... In view of (Germany's Chancellor Helmut) Schmidt's unequivocal support for nuclear development, voiced at last year's European Nuclear Society conference in Hamburg . . . one might have expected an equally positive declaration on this occasion, but he was constrained by the precarious situation within his . . . party to stick to the line narrowly agreed upon at the party conference, held at the end of 1979; this line calls for first priority for German coal and 'limited' development of nuclear energy. Schmidt did say that in ten years, the world will start to realize that coal is too valuable to be burned, and he expressed considerable concern about the long-term effects of carbon dioxide in the atmosphere as a result of combustion of fossil fuels."

From 'Carbon Dioxide Warming and Coastline Flooding: Physical Factors and Climatic Impact', by Stephen H. Schneider and Robert S. Chen, Annual Review of Energy, 1980:

"... Changes in agricultural productivity, water supply, and energy demand are examples of . . . impacts which, although difficult to quantify, may well be the most likely and significant consequences of climatic changes. . . . But we do believe that (a) plausible physical arguments can be given to support the possibility of a deglaciation from CO₂-induced warming and (b) it could well take decades of research to narrow considerably the wide range of uncertainties inherent in present estimates of the magnitude and timing of these three potential physical changes—approximately the time frame in which the climate system will 'perform the experiment' of proving many of these estimates too high or too low. . . .

"The plausibility of a significant and rapid rise in mean sea level (should the surface temperature at the poles increase) is based on the possibility that a huge mass of glacial ice, the West-Antarctic Ice Sheet (WIS), could collapse into the surrounding oceans. . . . The principal contention is that the ice sheet is now unstable, as evidenced by a concave surface profile, decreasing glacial extent (i.e., a retreating ground line), extensive basal melting, and the overall thinning of the interior ice (T. Hughes 1973, 1975, 1977). These conditions could lead to a 'surge' of the ice streams, in which the glacial ice advances at a relatively high velocity (perhaps 110 m per day or more according to Hollin (1960)). Such a surge, augmented by powerful calving processes, could then result in the rapid disintegration of the interior of the ice sheet. . . .

"However, Budd & McInnes (1973) imply that the drainage basins would surge independently from each other in the absence of a common initiation, as indicated by the bedrock elevations and ice flowlines for Antarctica (T. Hughes 1980, in press) . . . It does seem likely . . . that if a surge were to begin, most of the WIS ice now above sea level would enter the ocean (ibid.) Additional ice might flow out through outlet glaciers across the mountains from East Antarctica. . . .

"Only general limits can be placed on the likely timing of a WIS disintegration. Hollin (1969, 1972) discusses a catastrophic collapse that might occur in a week and examines the possibility of sedimentary evidence of waves or tsunamis which might accompany such a rapid event. The Laurentide Ice Sheet is thought by some to have undergone a collapse of its Hudson Bay ice dome by calving processes in 200 years or less (R. Bryson et al 1969; J. Andrews et al 1972; J. Ives et al 1975), based on relative dates derived from carbon-14 analysis. Thomas et al (1979) have recently derived estimates for the retreat times of grounding lines of ice streams in the Ross Ice Shelf region, obtaining values of 50-200 which depend critically on the bottom topography and presence of ice rises. They also suggest that the destruction of the ice shelves might not begin for several centuries due to an assumed slow thermal response of the ocean; however, this seems inconsistent with estimates of the sensitivity of sea surface temperatures to the CO₂-perturbed radiation balance and the recently reported active circulation and melting between the Ross Ice Shelf (A. Gilmour 1979; S. Jacobs et al 1979; R. Michel et al 1979) . . . In summary, although many uncertainties remain, a WIS disintegration could begin within a few years of an Antarctic warming and could take between a few decades and a few centuries to proceed significantly toward completion. . . .

"The geographic changes due to a sea level rise of approximately 5 m have been analyzed for the United States using . . . topographic maps . . . the effects of tides, storm surges, coastal erosion, and land subsidence have been ignored. . . .

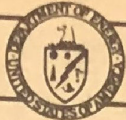
"... as much as one fourth of Florida may be submerged by a 4.6 m local rise and one third by a 7.6 m rise, including all but four of its cities of over 25,000 people (in 1970) in the latter case. Louisiana would be subject to inundation of comparable magnitude. New Orleans is of particular note since much of the city is already several feet below sea level, protected only by extensive levees. Large portions of the Texas coast, including the cities of Galveston, Corpus Christi, Beaumont, and Port Arthur, already very susceptible to hurricane flooding because of flat terrain, would be inundated permanently. In the mid-Atlantic region a 25-ft rise would submerge Savannah, Georgia; Charleston, South Carolina; four out of eight Virginia cities with populations over 100,000 (in 1970); one fourth of Delaware; and portions of Washington D.C., including much of the Smithsonian Institution. One could launch a boat from the west steps of the United States Capitol should such a flooding occur, and row to the White House South Lawn. . . . Along the north Atlantic Coast, although only small land areas are involved compared with the previous regions, well-developed coastal lowlands in several major cities such as New York City, Atlantic City, and Boston (including most of the Massachusetts Institute of Technology and Harvard University) would be inundated by a 15- to 25-ft rise in local mean sea level. . . .

"The geographic analysis . . . can be combined with demographic and property value data from United States censuses . . . to yield quantitative estimate of the impacts of the hypothesized sea level rise. By assuming that population, income, and wealth are distributed evenly within a county, initial estimates of the numbers of people displaced and the immobile wealth destroyed can be obtained. . . . For a 15-ft rise, over 11 million people (about 6% of the 1970 continental United States population) plus some 110 billion 1971 dollars in non-removable, taxable property value (about 6% of the total) are affected; for the 25-ft case, these values increase to about 16 million people (8%) and 150 billion 1971 dollars (8%). Since an estimated one third of the United States property is not taxed. . . . these figures can be increased by 50%, yielding 160 and 220 billion 1971 dollars of the 15- and 25-ft cases, respectively (or about 4% and 6% of the 1971 Net National Wealth). On a regional scale, the impacts are yet more severe: some 40% of Florida's population and about half of both its income and immobile wealth . . . are affected in the 15-ft case and an additional 10-15% of each in the 25-ft case. (In 1980 dollars these estimates are probably several times too low.)

"... we have not made any attempt to estimate secondary economic effects, which may at the least equal direct losses (H. Cochran et al 1974), nor actual replacement costs after a major economic perturbation of this kind. We have ignored potential environmental consequences for wetlands, inland ecosystems. . . .

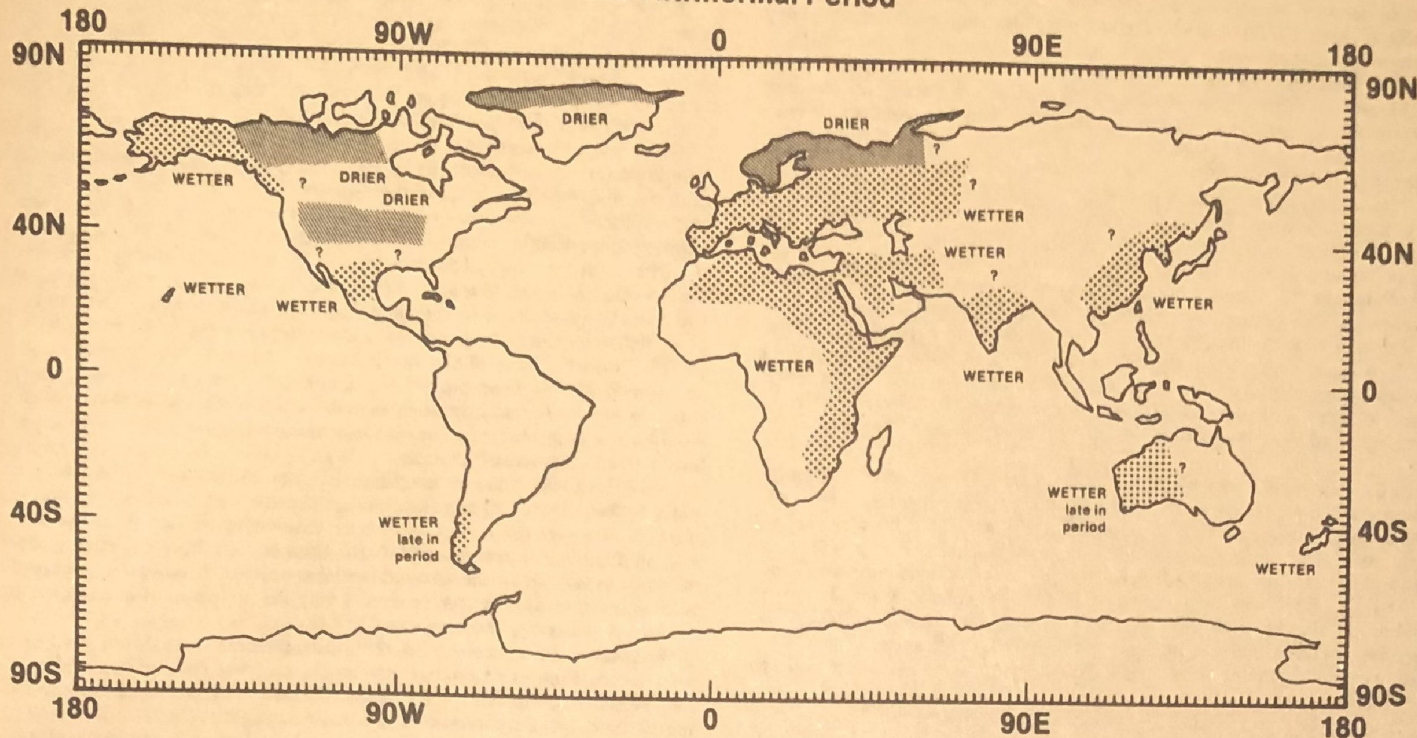
"... we generalize our estimate of the real property costs to the United States of a 7.6 m sea level rise (about one quarter of 1 trillion 1971 US dollars) to the rest of the world. For the sake of this example, we assume the total world value (in 1971 dollars) of inundated areas to be 2.5×10^{12} , ten times greater than estimated US losses. Furthermore, we assume that losses from such flooding occur in 150 years. What then is it 'worth' to us today to invest in measures to prevent such a 2.5×10^{12} catastrophe in 150 years?

"... assuming . . . that we discount the future at a yearly rate of 7% per year . . . a 2.5×10^{12} inundation cost in 150 years is worth only



Source: Kellogg, 1978

The Altithermal Period



about \$75,000,000, a sum considerably less than the economic value of fossil fuel-related industries or the potential agricultural income from deforested lands. . . . All of this assumes, of course, that discounting the future at 7% per year is a 'politically rational' policy.

"If the inundation were to occur in only 20 years, though, it would be worth \$6 X 10¹¹, a loss sufficiently serious to warrant dramatic, immediate policy actions. . . .

"Regardless of the 'correct' discount (or, some would argue, value) rate we should use to evaluate the worth of the future, one thing remains clear: discounting at high rates further diminishes the likelihood that this generation will invest heavily to hedge against potential CO₂-induced losses in the future. . . .

"in the case of the potential climatic consequences of CO₂ increases, several policy options can be listed, progressing from the most passive (i.e. do nothing), up to very active countermeasures that involve complex international regulations—or even climate control schemes. . . .

"1. DO NOTHING DIFFERENT Those either (a) unaware of the issues, (b) perplexed thoroughly by the uncertainties, or (c) special interests most likely to be adversely affected by some policy are the most likely to favor this inactive policy. . . .

"2. STUDY (OR MONITOR) MORE Few who are aware of the potential for global climatic change from CO₂-generating activities wholly dismiss the policy aspect of the problem as premature. . . . (We scientists who so frequently suggest this option, in part because of our professional commitment to increased knowledge, must be especially careful to justify our advice, as funding agencies are well aware of our special interest in research.) . . . [T]his policy is favored at the highest levels of government in the United States. . . .

" . . . infrastructural inertia implies that once a decision to curb CO₂ emissions were made, it would likely be decades before the trend of increasing CO₂ concentrations could be reversed. Thus one cannot delay a decision to curtail CO₂ emissions (or other such active policies) by some 10 years while experts study, without some risk! That risk, of course, is that the future will be committed to a larger dose of CO₂ and its impacts if such a decision is delayed, relative to the impacts that would be felt if the decision to cut CO₂ emissions were made now. . . .

"3. BUILD RESILIENCE . . . that is, active efforts are pursued to minimize the vulnerability of various economic or political sectors of society to climatic changes. . . .

"REDUCE THE CO₂ INSULT . . .

"[W]e believe it is not premature to begin to consider steps to minimize our vulnerability both to CO₂-induced climatic changes and to any future shifts away from fossil fuels. . . ."

From 'Effects of Carbon Dioxide Buildup in the Atmosphere', Hearing before the Committee on Energy and Natural Resources, United States Senate, April 3, 1980:

"Senator (Dale) BUMPERS. . . The fact that there has been no political response to the testimony we have had here for at least 3 years, the last 3 years, about the potential for dramatic climatic effect upon the earth by the buildup of CO₂, (the point that the whole problem is such a long term problem) is well taken.

"Congress has not responded and we are getting some conflicting information too. People who have testified have not been . . . precise and definitive. . . .

"For example, 'Science magazine' on March 28 estimated that the average Earth temperature rise from doubling the world's atmospheric CO₂ is about 26 hundredths of one degree Celsius, which is about 1 tenth of the value generally estimated.

"Dr. (Gordon) MACDONALD (Chief Scientist of MITRE Corporation). Could I comment on that point?

"Senator BUMPERS. Yes.

"Dr. MACDONALD. I have looked in detail at that paper. It is a very strange paper.

"Senator BUMPERS. Shall I throw it away?

"Dr. MACDONALD. Yes. The final result is the product of two numbers. One is described very badly. The other is described as a result of the search under preparation. One can reconstruct the reasoning and do the proper calculations, and would have to multiply the second number by a factor of six, the first number by a factor of two to get the proper description, so that number is off by a factor of about 12.

"Dr. (William) KELLOGG (Senior Scientist, National Center for Atmospheric Research): I quite agree with what Dr. MacDonald has said. The conclusion is based on a calculation at the surface at a point. It does not apply to the global carbon dioxide question as it stands.

"Dr. MACDONALD. That is correct."

From 'Assessing the Response of Biotic Resources to Climatic Change from High and Low Releases of CO₂', by Jerry S. Olson, DoE CDERAP (Annapolis Workshop of April 2-6, 1979), published October 1980:

" . . . In my judgment, rising CO₂ is more likely than not to lead to . . . shifts of climatic pattern. A second issue then is whether climatic shifts—which are credible under more than one assumption about fuels

and carbon cycling — could have impacts that would change the further carbon release seems more likely to me now than net storage — to create a positive feedback which aggravates the original excess instead of helping to correct it. . . .

"The models do suggest that changes in the earth's carbon cycle and in CO₂ concentrations could be far beyond those required to have a very high probability of significantly changing the climate — in spite of modifying factors noted below. . . Both the 'managed' and 'unmanaged' parts of the biosphere could contribute significantly to runaway feedback of CO₂ release of respiration (including decomposition of dead organic residues) and fires release more CO₂ than the increases in organic production which follow from the new environmental regime.

"The extent, intensity, and uncertainties about the effects of increases in CO₂ therefore call for caution regarding the future policies on coal and other fossil fuels (Rotty and Weinberg, 1977). Coal use may have to expand temporarily to replace some uses of oil and natural gas. However, Niehaus (1976) and other analysts are prudent in cautioning about scenarios which assume protracted expansion of fossil fuel use.

"Our much lower limiting scenario, which assumes a decrease in global CO₂ release within 50 years (Baes et al., 1976), would call for profound human adjustments if this scenario should prove necessary or even possible. Man will presumably seek an intermediate course between very high and very low bounds on the limits for future releases of CO₂.

"If technological and agricultural releases of CO₂ continue their rapid increases, the occurrence of a sevenfold increase followed by a slow decrease in atmospheric CO₂ is suggested by several different carbon cycle models. Under these conditions, experts anticipate a warming trend of several degrees C *despite the presence of various causes for cooling*. . . . Such cooling influences would apparently be either much smaller or slower than the warming caused by increased CO₂. The warming trend might also be accompanied by less effective or less reliable precipitation over wide areas, even though some other areas may get wetter. . . .

"It is too late to forestall the prospect for higher future concentrations of atmospheric CO₂. Clear increases are already being monitored all around the world. . . . Therefore, minimizing the future excess CO₂ might conceivably become the first objective of a concerted effort to preserve humanity's options for energy and natural resources. Maximizing biological production could become objective two for global management of the biosphere. However, if the biosphere is to help significantly as a mode of 'waste disposal' of excess CO₂ that will continue to be released while fossil fuels last, a high rate of income will have to be coupled with notably increased storage of the carbon fixed by plants in order to delay release back to CO₂.

"Even under optimum conditions, the capacity of forests and soils may not be nearly sufficient to store the CO₂ released from the burning of fossil fuels at rates commonly extrapolated from past trends. . . .

"Clearing of forest lands for agricultural use has already taken most of the best land. Further clearing — of more or less wild marginal lands — may soon pass points of diminishing economic return. . . . Intensive agriculture for the purpose of higher net assimilation rates, higher leaf area index, and efficient conversion of net primary production to more usable products per unit area may, for a while, even add to the growing commitment of fossil energy in agriculture. . . .

". . . increased temperature would not necessarily increase the (biomass) production rate unless there were sufficient extra moisture to compensate for enhanced evaporation. Even then, respiration may increase faster than photosynthesis in locally adapted genetic types

and certain heterotrophic respiration will increase. Unless there were species or varieties already available to take advantage of a different response on NPP (photosynthesis minus respiration) to temperature, it is quite possible that total and usable production will decrease with rising temperature. . . .

"Effect of carbon dioxide on climate may already be present, but may be submerged in variations related to the preceding factors or in random fluctuations ('noise'). However, almost any of the carbon models discussed above will eventually have CO₂ increases so large that the mean warming can be expected to equal and then considerably exceed all the cooling factors put together. . . .

"Warming automatically increases evapotranspiration and thus demands enhanced water supply, if the water balance formerly achieved under cool conditions is to be maintained. Budyko's (1977) analysis of past climatic change shows how mid-continental warming has often been accompanied by drying and also by an enhancement of the fluctuations in moisture supply that are typical of continental climate. If these did result, however, 'dust-bowl' droughts could significantly increase the risks to agriculture in the semiarid regions. Wheat may have to be shifted to parts of the maritime climate belts where rainfall increased. Even more complex changes might occur as storm tracks shift (Blasing and Lofgren, in press). It seems improbable that many areas would get enough increase in rain to make up for the above-mentioned losses from evapotranspiration. . . .

"By A.D. 2025, it seems credible that the shifts of climatic pattern could be broad enough to cause changes in the water balance of whole states and geographic regions. Many categories of fuel development (i.e., oil shale and western coal) might then be held back because of unreliable surface and underground water supplies. Thus, agriculture and public use of limited water reserves may put an upward boundary on the U.S.A.'s part of the releasing of CO₂. . . .

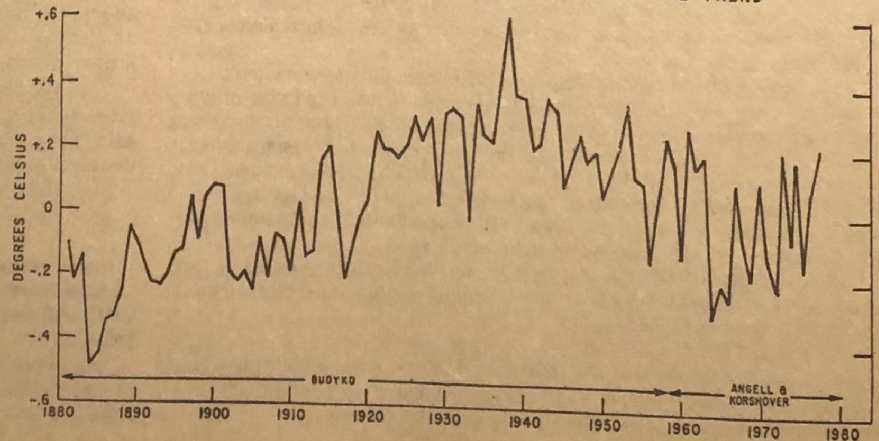
"In areas outside the tropics (23° latitude), warming would result in more comfortable winters, but also would increase risks of heat exhaustion, heat stroke, heat stress and debilitation of people with chronic illnesses during heat waves in the hotter summers, thereby increasing rates of premature death in some areas. In urban settings, irritability, aggression and intolerance of crowding are likely to increase under the anticipated warmer conditions. These physiological and emotional problems could be redressed by emigration poleward in an attempt to stay with accustomed climates and/or by expanded air conditioning. However, the latter would add summer demand for fuel consumption, and could thus hasten the rise of the high CO₂ scenario projected for the early 21st century. . . .

"Failure of wild species to complete their life cycles (for many physical and biological reasons) would be followed by life zone shifts in some cases, with species tracking the movement of climate to new geographic belts. 'Weedy' species might thrive where balances of competition have been upset. Some native plant and animal populations would start the long course toward extinction. Usable resources might be upset because of pest and disease problems aggravated by the loss of former climatic and biological controls. . . .

"Long before the rise of sea level from melting glaciers becomes obvious to society, we expect there would be noticeable changes of inland water levels because these levels are far more sensitive to either a wetter or a drier regional hydrological balance. . . . Net warming and evaporation would probably mean a net lowering of many inland waters, with navigational and sewage disposal problems, such as those experienced by Chicago during the last natural low fluctuations of Lakes Michigan and Huron (1964). . . .

Update of Northern Hemisphere surface temperatures through 1978, as prepared by James K. Angell, Air Resources Laboratory, NOAA. In order to be compatible with the analysis of Budyko, the data represent the region 20°N to North Pole.

NORTHERN HEMISPHERE MEAN ANNUAL TEMPERATURE TREND



(Revised 1980)

(A) 20 percent reduction of Greenland's glacial volume might take 2000 years according to an unpublished analysis by B. Stauffer of the Physics Department of the University of Berne, for a sustained warming of only 3°. However, if the models are right in suggesting warming in high latitudes (even if the world average is 3° at sea level), Stauffer's analysis suggests less than 200 years at the higher temperature would suffice to attain the same reduction. . . . Whether or not Stauffer's analysis is confirmed in detail, the point is that it well illustrates the general idea of physical impacts which are difficult if not impossible to reverse once the process has passed a critical state. . . .

... the losses through property damage will not be as gradual as the creep of mean sea level. Damage will be felt suddenly over wide areas during coastal storms which will reach meters above the rising mean sea level and cause billions of dollars of damage in a few hours. . . . Bolin's (1975) map reminds us that the world's seaports, many of the largest cities, much of the richest farm land and a large fraction of Earth's population are located within reach (50 to 70 m altitude) of glacial melt-water, should a sudden warming trigger major melting of the Antarctic glacier over a longer period of centuries. . . .

Even if we become certain that dustbowl climates will become worse or that a significant fraction of Florida will be submerged, who is to decide that these risks outweigh the profit from using Wyoming's coal quickly or from expanding Quebec's agriculture far northward? Internationally, how would submergence of much of the Netherlands be weighed against the benefits of having synthetic fuels available at rates equal to or greater than the current rates of use of natural gas and petroleum for a few generations after the latter energy sources are nearly gone?

"One conventional moral principle is that humanity should forego those gambles that are so great and so sudden that they outweigh natural disasters which can be deplored and then patched up by charity or by 'technological fixes'. If the benefits of continued fossil fuel expansion are perceived as so overwhelming that they warrant taking comparable risks, then a minimal obligation would seem to include planning to cope with the uncertainties and with the worst possible set of outcomes, however disagreeably and sceptically the required analyses may be received in bureaucratic and legislative circles. . . .

"Contingency plans should already be scrutinizing the impact of drastic shifts in policy on fossil fuel and other energy sources and uses. . . ."

From 'Environmental Effects on the Oceans Cyrosphere, and Ocean Biota', Report of Panel I, October 1980, Workshop On Environmental and Societal Consequences of a Possible CO₂-Induced Climate Change, held at Annapolis MD April 2-6, 1979 (DoE Carbon Dioxide Effects Research and Assessments Program):

"... The consensus of Panel I is that a scientifically defensible case can be made that this possibility (of disintegration of parts of the Antarctic ice sheet) should be taken seriously, though there is not immediate cause for alarm, and if it were to occur there would be decades of warning. . . . At issue are certain portions in West Antarctica and possibly East Antarctica which are resting on bedrock below sea level, and are apparently vulnerable under certain conditions to slumping into the oceans over a few decades or centuries. . . .

"It is . . . quite unlikely that a brief workshop proceeding should go beyond the generation, at best, of some new perspectives. . . .

"In the North Pacific Ocean, where no deep overturning now occurs, one effect would be to diminish the nutrient supply within the euphotic zone. Nutrients might accumulate in the deeper waters. . . .

"The same processes might occur to a greater degree in the Southern Ocean, where the saline and nutrient-rich circum-polar waters lie near to the euphotic zone and maintain a high nutrient concentration near the sea surface all around Antarctica. . . .

"... it appears that the two most important cryospheric effects of a warming are likely to be on the Arctic sea ice because of the further effect on global climate, and on the Antarctic ice sheet, because of the further effect on sea level.

"Critical Conditions for Ice Shelves. In Antarctic today only the coasts of the northwest Antarctic Peninsula are completely lacking in ice shelves. Presumably it is significant that the absolute limit of ice shelves is closely associated with the following midsummer conditions: (a) average air temperature of 0°C, (b) summer isotherm of -1.5°C for coldest level of Antarctic surface water mass, and (c) northern limit of summer pack ice.

"Water temperature is likely to be the crucial factor, particularly over intervals of a century or less. This in turn on the persistence of summer sea ice in the Antarctic and how fast and to what level the Antarctic surface water might warm in summer after dissipation of this ice.

"The West Antarctic ice sheet at present appears well insulated against warming as the midsummer air temperature along its ice shelf front is about -5°C. Ample warning of the southward advance of a climate unfavorable to the West Antarctic ice sheet will be available from satellite monitoring of the small ice shelves immediately south of their present limit. . . .

"It is possible that rapid collapse of the West Antarctic Ice Sheet may now be under way in the Amundsen Sea Sector. In this sector, Thwaites and Pine Island Glaciers calve directly into Pine Island Bay, which is kept free from sea ice by katabatic (downward) winds blowing off the ice sheet. As a consequence of these polynia (polynia: an area of open water in sea ice), the sea surface in Pine Island Glaciers are not buttressed. Modeling results described in detail in the paper of Terry Hughes annexed to this report show that only bedrock sills or steps in the ice-stream channels of these glaciers can prevent their grounding lines from migrating irreversibly into the heart of the West Antarctic Ice Sheet. It is thus very important to determine whether such sills or steps exist. . . .

"The cold Antarctic ice cap, with its high albedo, forms a cold overlying air mass which results in a virtually permanent atmospheric high pressure area. This high pressure is more or less immune to any changes resulting from CO₂ increase, at least so long as the ice cap remains. Thus, surrounding the continent is an easterly air circulation. The accompanying Ekman drift (a wind-induced drift in the upper few tens of meters to the right of the wind direction) is toward the continent. This tends to keep any low salinity surface water and any unmelted ice close to the continent. The deeper return flow thus tends to be outward - inhibiting the incursion of deeper, warmer water. In summer the stable boundary layer formed over this cold water tends to protect it from warming by incoming air masses from lower latitudes. The continent therefore tends to hug its insulating blanket to itself, to prevent coastal warming.

"However, with a sufficient general warming, this protection must break down, so the exposed glacial ice would start to melt as summer sea ice disappears and the Ekman drift brings warmer water from the north.

"The definition of 'sufficient' is unknown. . . .

"Arctic Sea Ice. Sea ice has a large influence on the thermodynamics of both the ocean and the atmosphere, and is therefore an important component of the climate system. The high albedo of ice, and in particular of snow-covered ice, sharply reduces the absorption of solar radiation. . . . Its insulating ability inhibits ocean-to-atmosphere heat exchange, except in the area of polynias. . . .

"The extent of sea ice is known to be quite sensitive to climatic fluctuation, and it can be said with confidence that a warmer climate would be accompanied by diminished ice cover. However, what degree of warming would be required to cause the Arctic Ocean to become ice-free each summer - freezing each winter - and what conditions might lead to continuously open Arctic are as yet uncertain. It is possible that the kind of CO₂-induced warming anticipated within the next century would lead to the first and perhaps even the second of these states.

"... A retreat of permanent ice cover . . . could lead to the development of new fisheries. The elimination of Arctic ice cover would have profound effects on the climate of all the northern land masses and probably of the entire globe. . . ."

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Toward more accurate energy accounting

At the Senate hearings of April 2, 1980, on the CO₂ problem, David Rose brought up an important point that "national energy accounts are ... all screwed up" because most such accounting fails to measure efficiencies all the way through to end-use. Rose cited an example that while electric power plant conversion may be only 35% efficient, miscalculated end-use efficiencies may show comparable non-electrified systems to use energy more efficiently, when the opposite is true. He cited conventional analyses which consider that in a diesel train '100% of the fuel is properly used' whereas 'two-thirds of the energy would be wasted in producing electric power to run the train'. But the efficiency of the whole combination of engine, generator and wheel-driving motors in a locomotive is actually less than that of a train run on an electric grid, and in addition, the diesel engine is often running when the train is not, which lowers the relative efficiency even further.

Imprecise energy accounting can lead to illogical policies that frustrate true conservation. Also, desired utility may be sacrificed unnecessarily in the name of conservation due to poor energy accounting. Carried a step further, imprecise accounting in regard to the economics of energy supply can result in consumers paying much more than necessary for their energy while being subjected to unnecessarily high levels of pollutants.

A figure often referred to in an environmental context is the growth rate of electric energy usage for a particular country. If the population is growing at 2% per year, then the first 2% of the energy growth rate goes toward maintaining a level per capita usage. Thus 3% gross energy growth amounts to 1% net growth, and 4% gross yields 2% net. Some of the growth may further be exported in the form of refined or manufactured products which should be considered as energy consumed in a different country. Thus if aluminum is exported in exchange for ores or machinery is exported in exchange for vegetables, the benefits of the energy consumption may accrue to a foreign account. Also some electric growth may result in an overall saving in energy use as electric energy replaces less efficient systems.

Because of the nature of utilities' accounting, consumers do not pay the actual cost of electricity provided by the nearest power plant but instead pay a cost that is averaged throughout the system. France has found that its nuclear electricity costs are substantially less than fossil-fuel electricity, and is considering reducing rates to people residing in the vicinity of nuclear plants. By such an accounting practice, the actual savings of nuclear would then accrue to the people who have a voice in deciding what type of generating plant they will allow to be sited near them.

The various shortages of energy supply in the U.S. that together are often referred to as the 'energy crisis' appear to have resulted from policies based on imprecise accounting. Price controls on U.S. energy producers have generally been based by the government on the first-in, first-out accounting method rather than true replacement cost. Such accounting does not allow for the effects of inflation, and consequently is considered to have caused the rapid decline in U.S. natural gas supplies from 1967 until recently as too few exploratory wells were drilled to sustain level reserves.

The great shortfall of domestic oil production with respect to U.S. demand — which allowed the OPEC nations to institute high cartel prices after Saudi Arabia nationalized its oilfields in 1973 — was foreseen by members of the U.S. oil industry. Unlimited imports of then cheap oil had been allowed (and even encouraged for utilities and refiners in the northeastern states) by the U.S. government during the Viet Nam war. A great difference in domestic and foreign oil-producing costs results from an average production of 17 barrels per well per day in the U.S. versus an average 5252 barrels per day in the Middle East (1978 figures).

The controlled price of domestic oil has been set below replacement cost since 1973, and has ranged variously from 37% to 80% of the world price, or parity. Refiners who bought domestic oil at the low controlled price were required to pay large sums ('entitlements') to refiners of higher-priced imported oil in order to spare the consumers in different regions from the large price differential. Thus most of the higher prices for gasoline went to foreign countries and the revenues which went to U.S. producers was actually less than was being spent searching for replacement supplies. Predictably, oil reserves have been steadily declining. (U.S. crude oil reserves now stand at less than 28 billion barrels, which represents little more than a 4 year supply at current use rates; this, of course, affects perceptions of national security.)

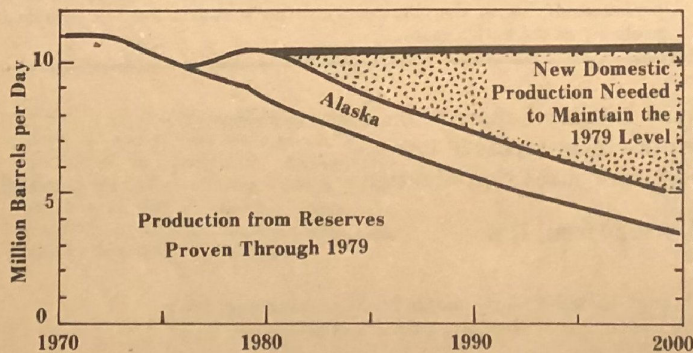
The perceived profits which led to the Windfall Profits Tax (which taxes only the sales of domestically produced oil) appears to be based essentially on oil company balance sheets which typically fail to account for 'phantom' inventory profits, under-depreciation and general inflation. Specific accounting shows that U.S. consumers may pay about 65 cents per gallon on domestically produced gasoline (in addition to other taxes) due to the Windfall Profits Tax. That is, a 70% tax rate on the difference ('windfall profit') between 32 cents per oil gallon controlled price and 85 cents per oil gallon world price yields 37 cents per gallon to the government. If all that tax is apportioned just to the gasoline fraction of the crude oil, this amounts to about 65 cents tax per gallon which the public is apparently not cognizant of.

Both oil and natural gas production are rapidly depletive. A large portion of petroleum sales revenues must be devoted continually to finding and developing new supplies or the producers would otherwise produce themselves out of business. The accompanying graphs show the expected normal decline of U.S. oil and gas production if new supplies are not found and developed by the future expenditure of vast, inestimable sums. To maintain just the same domestic oil supply rate as today would require that nearly 5.5 million barrels per day of new oil production be found and developed by 2000. The investment required to achieve 5.5 million barrels per day of synthetic oil from coal and oil shale (which releases much more CO₂ to the atmosphere per unit of energy) would be about \$275 X 10⁹ in 1980 dollars. This same amount would build about 275 1000-megawatt (electrical) nuclear reactors at today's costs if unnecessary costs of delay were eliminated. That many reactors operating 70% of the time could produce the mechanical energy equivalent to about 10 million barrels of oil per day, assuming 30% oil-conversion efficiency. (Total U.S. oil consumption is presently about 19 million barrels per day.)

Largely because of the great U.S. appetite for oil, the U.S. presently adds more CO₂ to the atmosphere than all the developing countries of the world combined.

— W.N.B.

U.S. Domestic Oil Supply 1970-2000



U.S. Natural Gas Supply to 2000

