PREPARED BY THE CENTER FOR CLIMATE INTEGRITY
SEPTEMBER 2019

Documentary Evidence

of oil and gas companies' knowledge of their products' role in causing climate change and their subsequent deception campaign

CENTER FOR CLIMATE INTEGRITY

TABLE OF CONTENTS

INTRODUCTION

Assembled by the Center for Climate Integrity, this collection of 36 documents provides an overview of the oil industry's 50-year knowledge of climate change, their role in causing it, the enormity of its impacts, and their subsequent denial and deception campaign that continues to this day. CCI is grateful for the diligent work of independent researchers, scholars, investigators, journalists, and non-profits who uncovered these documents.

Part One, beginning in 1963, provides documentary evidence, including public reports and internal company and trade association documents, showing that the oil industry had a deep understanding of the science of global warming and their product's role in causing it more than five decades ago. This knowledge extended from the effect of CO_2 on the Earth's climate and the clear link between fossil fuel combustion and increasing CO_2 levels, to the "potentially catastrophic" impacts that global warming would have for "at least a substantial fraction of the earth's population." In fact, scientists at Exxon's New Jersey Research and Engineering Division were among the leading climate change experts of the era. As the documents reveal, Exxon's climate modelers predicted today's global temperatures with an astonishing degree of accuracy. Exxon's expertise in climate science in these early years is remarkable, and quite unsettling when one considers the massive denial campaign the company would go on to mastermind in subsequent decades.

Exxon touts its support of the Paris Agreement while at the same time boasting to investors that it will increase oil and gas production 25% by 2030.

Oil industry experts were not alone in their understanding of the impacts of fossil fuel combustion on the global climate system. But there is a critical distinction between the way that industry and other scientists responded to this knowledge. While government researchers sounded ever-louder alarm bells (although too often clouded in scientific caveats that were easily abused by the industry), Exxon and the oil industry did exactly the opposite. They created and spearheaded the most successful social influence campaign in American history, building a climate denial, deception, and propaganda machine so persuasive that the United State remains to this day the only industrialized nation on Earth that fails to fully accept climate science.

Part Two, beginning in 1988 and extending to the present, contains documents that lay bare this deception campaign. Built on techniques perfected by tobacco and other industries, climate denial emerged as a highly sophisticated, well-funded, decades-long strategy to manufacture doubt and undermine climate science in the minds of the public, Congress, and the media. The campaign was manifest in many ways but is perhaps most distinguished by the blatant and knowing duplicity of the companies directing it. Exxon and others spent tens of millions funding denier groups to promote sham theories they had long since internally evaluated and debunked. Worse, the companies were safeguarding drilling rigs and pipelines from climate impacts as they simultaneously worked to stall any action on a problem that they characterized as "too uncertain" to justify significant government investments or policy change. As early as the 1970's, Exxon, Shell and others filed patent applications for oil rigs that could withstand rising seas and stronger storms, and Arctic drilling equipment that would be most useful in a warming (and melting) world.

Even now, when oil companies have been forced to accept climate science, they continue to deceive the public and undermine action. Exxon touts its support of the Paris Agreement while at the same time boasting to investors that it will increase oil and gas production 25 percent by 2030, a scenario that would be game-over for the climate. Shell was heralded in the media for its recent report on pathways to net-zero emissions, yet the fine print of the same report contains a disclaimer that they currently have "no plans" to pursue these paths. ConocoPhillips has declared renewable energy a priority while at the same time reporting to the Securities and Exchange Commission that fossil fuels remain their sole and exclusive focus.

This collection will be updated periodically as new documents come to light.

PART ONE

Prior Knowledge

CHAPTER ONE

Consensus that Fossil Fuels Cause Global Warming
1963—1974

Scientific understanding of the effects of carbon dioxide on the global climate system dates back to 1896 with the publication of *On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground* by Swedish physicist and Nobel Laurate Svante Arrhenius.

By the 1960's, the scientific community firmly understood that CO_2 emitted by burning fossil fuels would intensify the greenhouse effect and cause global warming. Exxon and other oil giants recognized the potential impact on their industry and invested significant resources into cutting-edge research on the causes and consequences of global warming. In the mid-1970's, Exxon scientists predicted the exact atmospheric CO_2 levels that would occur in the year 2000, and began, along with Shell, Texaco, and Chevron, to prepare and adapt their holdings and operations for a warmer world.

"This generation has altered the composition of the atmosphere on a global scale through... a steady increase in carbon dioxide from the burning of fossil fuels."

President Lyndon B. Johnson, 1965

Document 1 is a 1963 report by the Conservation Foundation summarizing the conclusions of a scientific conference held on the Implications of Rising Carbon Dioxide Content of the Atmosphere. The report, which explicitly links the burning of fossil fuels to global warming, warns of melting ice caps, inundated coasts, and the "annihilation" of "many life forms…both on land and sea" in equatorial regions. The 1966 edition of the venerable World Book Encyclopedia, **Document 2**, references the Conservation Foundation's conclusions—leaving no ambiguity as to the scientific understanding of global warming in the mid-1960's.

Just two weeks after his inauguration in 1965, President Johnson gave a speech to Congress in which he warned, "This generation has altered the composition of the atmosphere on a global scale through radioactive material and a steady increase in carbon dioxide from the burning of fossil fuels." His administration then commissioned a study on the issue, which was cited by Frank Ikard, president of the American Petroleum Institute (API), in his 1965 speech at the trade association's annual meeting, **Document 3**. In his speech, Ikard notes "One of the most important predictions of the report is that carbon dioxide is being added to the earth's atmosphere by the burning of coal, oil, and natural gas at such a rate that by the year 2000 the heat balance will be so modified as possibly to cause marked changes in climate beyond local or even national efforts."

The oil industry, keenly aware of the potential ramifications, began to conduct their own research and produce world-class reports. In 1968, API commissioned a report by the Stanford Research Institute, **Document 4**, which warns that doubling the pre-industrial atmospheric concentration of CO_2 would bring about 3°C of warming and that, "there seems to be no doubt that the potential damage to our environment could be severe…the prospects for the future must be of serious concern." Once again, the industry was clearly well aware that CO_2 from the combustion of their products would play a significant role in global warming.

Oil companies did not simply sit on these predictions but began to prepare their own facilities for a warmer world. **Document 5** is a collection of patents filed by Exxon, Chevron, and Texaco in 1973 and 1974 for equipment and methods that would help them to operate in areas of the Arctic that were previously unreachable because of polar ice sheets.

1963 Conservation Foundation,

Implications of Rising Carbon Dioxide Content of the Atmosphere

IMPLICATIONS

of

RISING CARBON DIOXIDE CONTENT OF THE ATMOSPHERE

A statement of trends and implications of carbon dioxide research reviewed at a conference of scientists . . . .

Sponsored
by
THE CONSERVATION FOUNDATION
30 East 40th Street
New York 16, N. Y.

FOREWORD

On March 12, 1963, The Conservation Foundation assembled a conference of scholars to discuss the problem of rising carbon dioxide content of the atmosphere. The conferees were ecologists, chemists, physicists and others with particular experience and interest in the problem. The structure of the conference was formulated with the help of Professor G. Evelyn Hutchinson who serves on the Foundation's advisory council. Unfortunately, illness prevented Professor Hutchinson from attending the conference and participating in the discussions.

It is known that the carbon dioxide situation, as it has been observed within the last century, is one which might have considerable biological, geographical and economic consequences within the not too distant future. What is important is that with the rise of carbon dioxide, by way of exhaust gases from engines and other sources, there is a rise in the temperature of the atmosphere and oceans. It is estimated that a doubling of the carbon dioxide content of the atmosphere would produce an average atmospheric temperature rise of 3.8 degrees Fahrenheit. This could be enough to bring about an immense flooding of the lower portions of the world's land surface, resulting from increased melting of glaciers. So far, the increase of carbon dioxide has been of the order of 10 percent, and the oceans are already experiencing some rise of temperature.

A principal purpose of the meeting was to discuss the subject with a view to clarifying the minds of a small interdisciplinary group and crystallizing some ideas for future scientific research. It is hoped that the publication of this summary of conference discussions may contribute to further examination of the carbon dioxide situation. The subject should be one of considerable concern and controversy.

This paper is a statement of the consensus of the conference. It was prepared by Noel Eichhorn of The Foundation's research staff. Although the conclusions were those reached by the conferees as a group, the wording of this paper cannot be attributed to any conferee, but is the responsibility of The Conservation Foundation.

PARTICIPANTS IN THE CONFERENCE

F. FRASER DARLING	CHAIRMAN - Vice President, The Conservation Foundation, New York, New York
EDWARD S. DEEVEY........	Department of Biology, Yale University, New Haven, Connecticut
ERIK ERIKSSON.............	International Meteorological Institute, Stockholm, Sweden
CHARLES D. KEELING	Scripps Institution of Oceanography, La Jolla, California
GILBERT N. PLASS	Aeronutronic Division of Ford Motor Company, Newport Beach, California
LIONEL WALFORD..........	Atlantic Marine Laboratory, U.S. Fish & Wildlife Service, Highlands, New Jersey
WILLIAM A. GARNETT......	Photographer - Napa, California

OBSERVERS:

SAMUEL H. ORDWAY, JR....	President, The Conservation Foundation, New York, New York
GEORGE E. BREWER, JR....	Vice President, The Conservation Foundation, New York, New York
WALLACE D. BOWMAN......	Executive Assistant, The Conservation Foundation, New York, New York
NOEL D. EICHHORN	Associate, The Conservation Foundation, New York, New York
JOHN P. MILTON	Associate, The Conservation Foundation, New York, New York

INTRODUCTION and SUMMARY

Carbon dioxide is not a pollutant in the ordinary sense. It is colorless and odorless. It has no immediate nasty effects. Even the largest amount likely to accumulate in the atmosphere, if the entire reserve of fossil fuels were burned, would not be detrimental to the existence of life; in fact, plant life would be more luxuriant. It is an inevitable product of combustion and cannot be filtered out or precipitated out. Ordinary pollutants are washed out of the atmosphere after a month or so; carbon dioxide will continue to accumulate as long as fossil fuels continue to be burned at present rates.

There is a lack of exact knowledge of the carbon cycle which is part of the general lack of quantitative knowledge of the biogeochemistry of the earth. The increasing funds available for general research and the improving coordination of research effort should help to reduce the uncertainties about the implications of the rise in atmospheric carbon dioxide.

It seems quite certain that a continuing rise in the amount of atmospheric carbon dioxide is likely to be accompanied by a significant warming of the surface of the earth which by melting the polar ice caps would raise sea level and by warming the oceans would change considerably the distributions of marine species including commercial fisheries.

The biogeochemical system of the surface of the earth is, in general, very stable and has persisted with little change over geologically long periods of time. However, the buffering mechanisms which have been adequate in the past seem unlikely to be able to compensate fully for changes of the magnitude of those now being effected by man.

The effects of a rise in atmospheric carbon dioxide are world-wide. They are significant not to us but to the generations to follow. The consumption of fossil fuel has increased to such a pitch within the last half century that the total atmospheric consequences are matters of concern for the planet as a whole. CONC Although there is the possibility of capturing the CO_2 formed by the burning of fossil fuels and storing it in the form of carbonates, relief is most likely through the development of new sources of power.

I

THE CARBON DIOXIDE SYSTEM

The carbon dioxide (CO_2) in the atmosphere is in constant exchange with the oceans and the biosphere. The amount of CO_2 in the atmosphere is being increased by the burning of fossil fuels; in addition a very small amount is added by volcanic activity. Carbon is removed from the biosphere and indirectly from the atmosphere and oceans by the accumulation of organic remains in sedimentary deposits and from the oceans by the precipitation of carbonate minerals. Carbon is removed from the biosphere by forest fires and by the cultivation of virgin soils and is added to the biosphere by such things as the production of new forest.

Of all the changes in the distribution of CO_2 only those concerning the atmosphere have been studied in any detail. In addition to the average yearly increase in CO_2 in the atmosphere of 0.7 ppm there is a clearly defined seasonal variation of 2.0 ppm in the northern hemisphere between 45°N and 90°N with a winter maximum and a summer minimum. This seasonal variation decreases with increasing altitude and is related to the seasonal changes in the transpiration rates of terrestrial plants. The southern hemisphere with less land and a far smaller terrestrial mass shows almost no seasonal variation. There is also a poleward flux of CO_2 of 5.0 ppm per year which is presumed to be balanced by an equatorward flux of CO_2 in the oceans.

If all the CO_2 added to the atmosphere by the burning of fossil fuels were retained by the atmosphere, the CO_2 content of the atmosphere would be increasing at a rate of 1.6 ppm per year. Studies of the distribution of radioactive carbon have shown that in fact an amount of CO_2 equal to about half of this "new" carbon from fossil fuels is retained in the atmosphere each year. This agrees very closely with the observed rate of increase of 0.7 ppm. The CO_2 content of the atmosphere in 1890 was 290 ppm, or 25 ppm less than the current figure. This again is about half of the amount known to have been produced by the burning of fossil fuels since 1890. It is assumed that the "new" CO_2 not retained by the atmosphere has been absorbed by the oceans, although no measurements have been made which demonstrate this. It should be realized that the man-caused changes when considered on a yearly basis are of smaller magnitude than naturally occurring variations and are, therefore, very difficult to distinguish.

The oceans contain 60 times as much CO_2 as does the atmosphere and would seem capable of absorbing most of any CO_2 which might be added to the atmosphere, however, thousands of years will be necessary for the system to return to equilibrium if CO_2 continues to be added at present rates. There are, as well, physical and chemical limitations to the amount of CO_2 which would be absorbed by the oceans and were a new equilibrium to be reached, the atmosphere would have a greater percentage of the total CO_2 than it does at the present time. The oceans are considered to be divided into a mixed layer at the surface (which is about 1/60 of the total volume and which contains an amount of CO_2 very nearly equal to that contained in the atmosphere) and the deep sea. (For some purposes it is convenient to consider, as well, an intermediate layer.) The deep sea is assumed to be absorbing about the same amount of the "new" CO_2 as is being retained by the atmosphere but the mechanism by which this CO_2 might be transferred to the deep sea is not known. The deep sea is considered to have an excess of CO_2 (over the value it should have at equilibrium) of around 10 percent which is maintained by the settling of organic remains. The deep sea, in addition, has a greater potential for storing CO_2 than the mixed layer because of its lower temperature (a circulation effect due to the presence of polar ice caps). Knowledge is limited by the difficulty of measuring the amount of CO_2 in the oceans, at least on a scale grand enough to provide a world-wide balance sheet.

The role and importance of the biosphere is less well understood than that of the atmosphere or the oceans. It has been postulated that the marine biota is quite stable in size and is probably nearly unaffected by the current increase in CO_2; however, there is considerable disagreement about this. The terrestrial biota, on the other hand, must be of considerable importance. Productivity of plants is known to be higher in a CO_2 rich atmosphere. Presumably forest productivity is rising with the increase in atmospheric CO_2. This could have the effect of reducing the amount of CO_2 by locking it up in tree trunks. On the other hand, a decrease in the terrestrial biomass, due to the cutting of forests and the cultivation of virgin land, would add CO_2 to the atmosphere and at the same time destroy one of the mechanisms by which CO_2 is removed from the atmosphere.

II

STABILITY

The CO_2 system is no exception to the general rule that any large natural system which has persisted for a long time is a very stable one. Even rather large changes in temperature or large additions of CO_2 (from fossil fuels) are compensated for with little immediately noticeable change. A warming of the oceans would increase atmospheric CO_2 at a rate of about 5.8 percent for a one degree rise in temperature, but the largest change which might be anticipated within a reasonable range of temperature is about 50 percent. A reduction in the volume of the oceans of the order of that during the maximum extent of Pleistocene glaciation might increase atmospheric CO_2 by about 10 percent but this would be partly compensated for by the lower temperature of the sea. Associated with higher temperature and the accompanying higher absolute humidity would be increased cloudiness which would probably have the effect of reducing the amount of any increase in temperature.

The burning of fossil fuel which adds CO_2 to the atmosphere also adds enough sulphur dioxide so that one third of all atmospheric sulphur (and one quarter of the total sulphur in oceans and atmosphere together) is now man-made. Sulphur dioxide eventually becomes sulphuric acid in the oceans; it is quite possible that the resulting change in alkalinity is enough to enable the surface layer to absorb about 0.5 ppm per year of the atmospheric CO_2, or approximately one third of the yearly addition of CO_2 to the system. This, of course, depends upon the sulphuric acid being retained in the surface layer. Sulphur is also an important fertilizer of the biosphere and the increase in atmospheric sulphur might cause an increase in biologic activity which would further reduce atmospheric CO_2.

Another check is the increase in biologic productivity which accompanies a rise in atmospheric CO_2. An increase in the amount of carbon in the terrestrial biomass would remove carbon from the atmosphere. (If the mixed layer of the oceans is actually taking up 0.5 ppm of CO_2 from the atmosphere each year, then the increase in atmospheric CO_2 could be due to destruction of part of the biosphere.) A considerable part of the addition to the biomass would be wood in trees, and this carbon would, in effect, be unavailable for quite a long time. However, the ratio between carbon in the terrestrial biomass and carbon in the atmosphere is not likely to change much; and, therefore, the biosphere can absorb only a part of any CO_2 added to the atmosphere. If CO_2 is fertilizing the terrestrial plants we should be able to see larger seasonal oscillations in the atmospheric CO_2.

A further possibility of a biologic check is the increased rate of accumulation of organic remains in oceanic sediments which might accompany an increase in marine biological productivity and which would remove CO_2 from the biosphere.

In general, many of the changes in the CO_2 system that have been investigated are believed to be compensated for, at least in part, by some other change (often triggered by the initial change which was being studied). Even though the checks and balances are numerous there are not enough data available to evaluate them with certainty. The present liberation of such large amounts of fossil carbon in such a short time is unique in the history of the earth and there is no guarantee that past buffering mechanisms are really adequate. It is not a cause for complacency that nature seems to have a lot of checks and that these checks seem thus far to be controlling any artificial imbalances. There may be processes presently going on which are due to man's activities and which will eventually be alarming.

Sulfer
Sulphur

(C)

III

THE INCREASE OF CARBON DIOXIDE AND ITS EFFECTS

Three of the minor constituents of the atmosphere - carbon dioxide, water vapor and ozone - are very important in the heat balance of the earth because they absorb radiation in a critical part of the spectrum. Any large change in the amounts of these in the atmosphere (even though the overall composition of the atmosphere remains nearly the same) will affect the surface temperature of the earth. An increase in CO_2 is particularly effective since the warming it causes increases as well the amount of water vapor. A doubling of the atmospheric CO_2 is calculated to increase the average surface temperature by 3.8°C. under clear sky conditions and about 2°C. under conditions of average cloudiness. (These estimates can be questioned; however, they are unlikely to be wrong by a factor of more than two or three.)

MAN'S F.F.

The recent systematic atmospheric analyses for CO_2 which began during the International Geophysical Year show consistent increases each year for all parts of the earth. The current rate of increase averages 0.7 ppm per year or about 0.2 percent. The combustion of fossil fuels at current rates adds the equivalent of 1.6 ppm of CO_2 to the atmosphere each year and must therefore be considered to be contributing to the net increase. However, there may be other large sources of CO_2 which are not so easy to distinguish and which are masked by the increase due to the burning of fossil fuels.

If all known reserves of fossil fuel were used within the next 500 years, a very reasonable assumption, and if the CO_2 system reaches $CaCO_3$ equilibrium (reducing atmospheric CO_2 to a minimum - a condition not likely to be reached for several thousand years) then the CO_2 content of the atmosphere would be four times what it is at present and the average surface temperature of the earth would have risen by 7°C. (The possible change if $CaCO_3$ equilibrium is not reached is 12.2°C.) A change even half this great would be more than sufficient to cause vast changes in the climates of the earth; the polar ice caps would almost surely melt, inundating many densely settled coastal areas, including the cities of New York and London. If the temperature of the equatorial regions were to rise by this amount many life forms would be annihilated both on land and in the sea. The average temperature of the oceans, now maintained at 4°C by the ice caps, would rise by at least 15 or 20 centigrade degrees, largely wiping out the world's present commercial fisheries. There has been a well documented warming of oceans of the northern hemisphere (about 2°C in the North Atlantic) during the twentieth century, the period of rapidly growing use of fossil fuels, but the temperature rise is too large to be attributed entirely to the concurrent 10 percent rise in atmospheric CO_2. How much the rise in CO_2 may have contributed is not known (or even whether there has been any temperature rise in the Tropics or in the southern hemisphere). In any case, the changes in marine life in the North Atlantic which accompanied the temperature change have been very noticeable. The abundance and distribution of a number of important commercial fish species have shifted northwards. These include cod, mackerel, lobster, menhaden, whiting and yellowtail flounder. The green crab has spread far enough north to cause a serious diminution of the soft clam which it feeds upon. The moths and butterflies of England have changed so drastically that descriptions of ranges and habitats done at the end of the nineteenth century are now invalid.

IV

BIOLOGICAL PRODUCTIVITY

Quantitative knowledge of the biosphere is critical to an understanding of the implications of the increase in atmospheric CO_2. Lack of this knowledge forces assumptions to be made with little besides theory to back them up. Vegetation is a buffer of very considerable magnitude in the CO_2 system. It absorbs and liberates CO_2 at rates which are comparable to the exchange between the atmosphere and upper oceans. Organisms are probably geochemical factors of the same orders of magnitude as the physical chemical factors involved in the exchange of CO_2 in the water and air.

Laboratory experiments have shown that biological productivity increases with a rise in atmospheric CO_2 and also increases with a rise in temperature. Extrapolation from these to the earth's biosphere is not presently possible, because of the lack of world-wide systematic, synoptic measures of productivity.

There is no adequate body of historical data for estimating the size of the earth's biomass; and, therefore, no basis for knowing whether it is increasing or decreasing. Total yearly photosynthesis may use an amount of CO_2 equal to approximately one quarter of the total atmospheric CO_2. At the present time marine biological productivity has been estimated to be about equal to terrestrial biological productivity; tentatively, about 6.7×10^{10} tons of carbon per year for the sea and 7.3×10^{10} tons per year for the land. However, estimates of oceanic productivity are based on very skimpy data. Many researchers have assumed that the marine biomass is nearly stable in size and that other nutrients than CO_2, such as phosphate, may be more important factors in productivity; however, there is little evidence in support of this and the subject is one of considerable controversy.

The marine biota is almost a closed system with very rapid turnover. Production is limited by the tendency of all plankton to sink, carrying with it the nutrient necessary to build up the biomass. (Phosphate removed from the land by erosion should be enriching the sea off river mouths, but the effects of this are often reduced by turbidity.)

The terrestrial biomass should be increasing in size because of the increase in temperature and in atmospheric CO_2. However, it is more likely decreasing due to the activities of man. Forests the world over are being utilized to a greater extent than ever before. In some cases, such as the United States, production of new forest is approximately equal to the destruction of old, but for the whole world, or even just the North

LAND PLANT

American continent, forests are being cut faster than they grow. To be effective in controlling the rise in CO_2, plants would have to be accumulating organic carbon at the same rate that we are burning fossil carbon.

The increase in land in agriculture which is accompanying the increase in the world's population is almost surely decreasing the total terrestrial biomass. Terrestrial biological productivity is most probably concentrated in the tropical forests which are known to be decreasing markedly. The tropical forests has developed to such a complexity and stratification that the degree of efficiency in photosynthesis is far beyond what any single plant could achieve. The tropical forest is one of the great reserves for making the earth habitable. Its removal and the attempt to grow a mono-crop result in impoverishment. We lose not so much soil, in a tropical forest there is often no soil at all, but the structure of the community in doing the job of photosynthesis -- CO_2 consumption and oxygen regeneration.

PROBLEMS AND NEEDS

The most alarming thing about the increase of CO_2 is how little is actually known about it. Part of this lack is the general absence of detailed knowledge about the surface of the earth and the changes taking place there. We should know what is happening to the physical environment both as a result of man's activity and of natural causes. There has been very little consideration of the biological consequences of man's manipulation of the environment or of the biological changes which result from climatic change. For example, the distributions of most marine organisms, including many species of commercial importance, are not known. There is evidence that the warming in the northern hemisphere during the twentieth century has drastically changed the ranges of many fish, but these changes have been little studied or catalogued.

The Continuation of the CO_2 Monitoring Program

It might be argued that there is little immediate danger in a rise in CO_2, that the world can afford to sit back for a few decades to see what happens; measurement of CO_2 could be abandoned for a while because sufficient information could be obtained from a comparison of present values with those 25 or 30 years from now. However, careful measurements have been made for a period of less than ten years in only three places in the world. (CO_2 has been measured in other places for short periods.) This is too short a time to be sure that there are not occasional sudden changes of much greater magnitude than any observed so far. Our knowledge is not advanced enough to be sure that there is no immediate cause for alarm. (In addition, many things could be learned about the relationships among atmosphere, hydrosphere and biosphere.)

The question was asked: Who is to make the measurements and at how many places should measurements be made? The U. S. Weather Bureau, which has maintained the CO_2 station in Hawaii, and has provided a man to do some of the routine work at the Scripps Institution, has limited funds for research and seems to feel its money might be better spent in other areas (artificial earth satellites). The director of the program at the Scripps Institution in San Diego has been working on this one problem for seven years and cannot be expected to continue much longer, even though adequate funds seem assured. The third study group at the Institute of Meteorology at the University of Stockholm may not have enough money to go on.

It would probably be sufficient to have one permanent station. The present station high on Mauna Loa in Hawaii, which has been in operation since 1958, would be ideal because it is isolated and therefore well insulated from local effects. There would be value in occasional testing at other locations which could then be compared to the record from Hawaii. The new Institute for Atmospheric Research in Colorado might be persuaded to include CO_2 measurements among its activities. It does not seem to be worthwhile to have the World Meteorological Organization add CO_2 to its list of things to measure at the present time; however, if it becomes necessary, it should be easy to develop a procedure which could be followed at a large number of stations.

There is a real need for more comprehensive data on the composition of the atmosphere, including the medically and physiologically important components. The Office of Meteorologic Research of the U. S. Weather Bureau should continue its studies in atmospheric chemistry even if it is no longer able to afford a continuing program of CO_2 measurements.

There are important parts of the CO_2 problem which will continue to be studied. Most oceanographic institutions will continue to have CO_2 determinations in sea water made as a routine part of their work. There is considerable interest now in the radiation flux of the earth and in the general circulation of the atmosphere and active research in these fields should continue for a long time.

There is a need for a watchdog. The effects of the continuing rise in atmospheric CO_2 while not now alarming are likely to become so if the rise continues. A committee of the National Academy of Sciences, National Research Council, might be charged with exploring the problem of the changing components of the atmosphere.

Arousing public interest in the effects of the increase in atmospheric CO_2 is as much a problem as the lack of adequate data. Without the support of informed public opinion funds for research will not be available. Even a limited monitoring program has value as a constant demonstration that the amount of CO_2 in the atmosphere is continuing to rise.

<u>The lack of quantitative knowledge of the biosphere.</u>

An exact knowledge of the role of the biosphere in the CO_2 system is now impossible because of lack of knowledge of the biosphere itself. The distributions of marine species, even commercial species, have been very poorly studied and the warming of the northern hemisphere during the present century has altered the distribution of some which had been studied. Oceanographers have tended to ignore the continental shelf areas and concentrate their activities in deep water, but there is evidence that the shallow waters are the most productive biologically.

One of the problems is that the gathering of biological data is essentially boring and very few of the people who work with such data are willing to go to sea to collect it. As a result, a great deal of marine biological data is supplied by other sorts of scientist, such as chemists, who occasionally bring things home to the biologist. There is too much specialization of interest to expect someone else to gather adequate data.

There is real lack of knowledge of the distributional nutrients in the oceans. Even in the North Sea very little work has been done to link productivity with oceanic circulation. However, even where detailed data on nutrients are available, the necessary supporting biological data often are not. (The Scripps Institution has a considerable amount of data on nutrients which has never been analyzed; the data for the North Sea have not been published.)

There is a lack of knowledge about the terrestrial biota as well. The quantitative importance of man's activities on its size is not known. No technique for estimating either total biomass, land or sea, or total biological productivity has ever been developed. While local studies are very useful in determining what must be measured, they cannot be added up to give world totals. It may be that measurements of variations in atmospheric and oceanic CO_2 will prove to be a good tool for determining changes in biological activity.

Systematic synoptic observations of the physical and biological attributes of the different environments are essential to document changes and to make realistic estimates of productivity. We must study, particularly, the distribution in time and space of marine species. We must collect isotope data, especially carbon-14, from the biosphere and the hydrosphere and the atmosphere to learn more of the role of the biosphere in the circulation of CO_2. (Atomic bomb produced carbon-14 is actually an aid in this.) Essential, too, is the study of such seemingly minor details as the turnover rate of the sea, the rate of accumulation of organic material in sediments, the distribution and effects of turbidity in the sea, and the study of such neglected organisms as seaweeds, cocco-lithophores, and dinoflagellates, which are extremely important in the metabolism of the marine biosphere.

Standardization and coordination of data gathering.

A common scientific problem is the difficulty of correlating data which have been gathered by different people for different purposes. This is particularly critical in study of subjects such as the role of CO_2, which require the application of many disciplines. Standardized systems of measurement are essential if optimum use is to be made of the world's many, and expensive, research facilities. While some kinds of speculative data gathering are not entirely amenable to standardization since results are often prejudiced to some extent by the means by which they were obtained, there should, at least, be agreement on aims. Scientists tend to measure the parameters that they know how to measure. Often, in the past, the parameter measured was the parameter which was convenient to measure and the equipment used had been designed for some other purpose. A part of this problem is the disinclination of scientists to be told what to do.

International scientific meetings accomplish a good bit of standardization and coordination. They also help to make possible the use of military and commercial equipment for scientific purposes. However, they are of doubtful use when only a few people are interested in a problem. The loss of research time necessary to attend meetings a long way from home discourages many scientists from participating and many who do participate are called on to do so much homework that they become, in effect, professional committee members. Fortunately, in the case of CO_2 the Institute of Meteorology of the University of Stockholm and the Scripps Institution have cooperated very closely and no international organization has been necessary. However, an attempt to broaden the study to include many other countries would require a more formal organization.

CO_2 measurement is not easy to assign because there must be both interest and competence. This is, in fact, a common problem in all scientific work. Data gatherers are scarce. There is little prestige involved in collecting samples. What is needed is a corps of technically trained men to carry on the unromantic part of research work who can feel that what they are doing is good and noble. Even finding money for research is not as difficult as finding people competent and willing to gather data and process it for the use of someone else. It is important that data collecting be limited to an amount which can be digested. Much of the initial processing should be done at the site and be done very quickly if much of the information is not to be lost.

A corollary to this is the need for stability in research programs. Getting started is often a lengthy and expensive process which is wasted if a program is discontinued too soon. The routine collection of the various data required for monitoring the increase of CO_2 content of the atmosphere and hydrosphere and then measuring its climatic and biological effects would have to be continued for years before significant patterns could emerge. While all of this routine work would certainly be carried on by technicians, scientists would have to design the sampling programs and continually keep in close enough touch with their execution to detect unreasonable errors and to know when and where revisions in the design were in order and to interpret the data as patterns began to emerge.

The study of the interrelationships of air, oceans and life is now at the point where even casual analysis is likely to trigger a whole new set of ideas. The increasing use of radioactive isotopes as tracers and indicators in the past twenty years has led to study of distributions of other isotopes and has opened a way for far more exact determinations of exchange rates between atmosphere and ocean or between atmosphere and biosphere. As an example, pre-war estimates of the rate at which CO_2 was exchanged between air and ocean surface varied by factors of up to 10,000; there is no longer any real disagreement.

The new technique and the vast increase in research funds in recent years have provided the beginnings of a large collection of systematic observations which is still mostly unprocessed and unpublished. Many of the questions raised by the discovery that atmospheric CO_2 is increasing in amount will be answered when the analyses of these existing data and the new data which should be accumulated in the next few years have been completed, but new questions are sure to be raised by these answers.

Science, technology and environment

Air pollution in the ordinary sense does not include the CO_2 rise in the atmosphere (although CO_2 can be used as an indicator of pollution). Man-made haze is world-wide in distribution. Cities in the United States have begun to realize that their problem is their neighbor's problem, and the other way 'round, but they still have not seemed to realize that more cars make the haze thicker or that monitoring devices should be between cities and not downtown. To a great many people no smoke still means no work and hard times. Pollution is now a political and social problem far more than it is a scientific one. (In fact, visible air pollution is a valuable tool for the meteorologist interested in studying circulation.)

Fossil fuel residues in the atmosphere in the form of such things as carcinogenic hydro-carbons are becoming more and more serious, but these can be removed (or prevented from reaching the open air.) CO_2 might be trapped and stored as carbonate but the expense would probably be prohibitive. It is almost inevitable that as long as we continue to rely heavily on fossil fuels for our increasing power needs, atmospheric CO_2 will continue to rise and the earth will be changed, more than likely for the worse.

In terms of the health of the planet there are no underdeveloped countries, only an increasing number of overdeveloped ones. Environmental damage is being done by modern technology at an increasing rate with no predictions of environmental consequences. Artificial photosynthesis has been proposed as a solution to the world's food problem. This could lead to a large reduction in "unnecessary" plant cover and an accelerated rise in atmospheric CO_2.

The fact that there may be a problem is beginning to be understood. Technical conferences, such as those held this year by the American Society of Civil Engineers and the New York Academy of Medicine, are considering environmental effects, but still only the short range effects.

The potentially dangerous increase of CO_2, due to the burning of fossil fuels, is only one example of the failure to consider the consequences of industrialization and economic development. Mankind is not helped by any technique which leads to short range benefits but long range dangers. Overdevelopment and concommitant overpopulation in many areas of the world have made the problem not one of increasing productivity but one of preventing further decreases.

Man's ability to change the environment has increased greatly in the last sixty years and is likely to continue to increase for some time to come. Even now it is almost impossible to predict all of the consequences of man's activities. It is possible, however, to predict that there will be problems without being specific about it. It is very important to alert more people, more scientists and more scholars in the social sciences as well as the pragmatical sciences, to the need for planning and the realization that there is an obligation to provide for the future as well as the present.

1966 World Book Encyclopedia Yearbook,
Special Report on Pollution

THE 1966 WORLD BOOK YEAR BOOK

REVIEWING EVENTS OF 1965

An Annual Supplement to
THE WORLD BOOK ENCYCLOPEDIA

FIELD ENTERPRISES EDUCATIONAL CORPORATION, PUBLISHERS
Merchandise Mart Plaza, Chicago, Illinois 60654
CHICAGO · LONDON · ROME · STOCKHOLM · SYDNEY · TORONTO

Polluted America

BY BROOKS ATKINSON

Pennsylvania Dept. of Health

A Pulitzer Prize-Winning Critic and Lifelong Naturalist Looks at the Land He Loves and Issues a Stern Warning to All Americans That They Are Endangering Their National Heritage

When the English pioneers settled in Jamestown and Plymouth in the early 17th century, none of them imagined that in the 20th century Americans would poison their environment. No one could then foresee a time when Americans would pollute the air, the water, and the land as if our natural resources were inexhaustible and worthless.

But that is what we are doing, and we can destroy our civilization this way. No species can exhaust its resources and endure. Nature elimi-

YEAR BOOK photo by Wes Kemp

The author: *Brooks Atkinson, foreground above, was long a foreign correspondent and drama critic of* The New York Times. *Atkinson has written many books and is a Fellow of The American Academy of Arts and Sciences.*

nates the species that overtax their environment. Highly developed nations like ours invite reprisals from nature.

The three and one-half centuries during which the original immigrants and their descendants have prospered in America are only a minute fragment of the life span of the continent. For millions of years, there has been organic life on the land. Between 35,000 and 40,000 years have passed since the first Asiatic tribes crossed over into what is now Alaska and made use of the rivers, forests, prairies, and minerals.

To the earliest immigrants from England and other European countries, America seemed fabulous. No one knew where this vast land ended. The early settlers took everything for granted. Everything seemed to have been waiting for centuries for the use of free men who could casually mine and plunder the land without exhausting it and who felt they could progressively consume the capital of land and stream that the centuries had so lavishly provided. Regarding trees as weeds, the pioneers destroyed them and burned them in heaps to make arable land. Suddenly released from the restraints of life in Europe, they hacked at everything that stood in their way.

By 1910, much of the forest was gone. The beavers and fur seals were nearly exterminated. Vast herds of buffalo were reduced to the few that were protected (a million buffaloes were killed every year from 1872 to 1875). The last of 5,000,000,000 passenger pigeons was in a zoo in Cincinnati. Now as we look back on those early centuries, when so much that was politically good was accomplished, we are stunned by the speed and the callousness of the destruction. But man is the Giant Predator—that "pervasive and destructive vertebrate," as William Vogt, the ecologist, once called him.

After ravaging the land and slaughtering its wildlife, the American is now going even further: he is pouring untreated sewage and industrial wastes into lakes and rivers. He is defiling the skies with smoke and exhaust gases. He is contaminating the land with pesticides. The United States Department of Health, Education, and Welfare, which is deeply involved in all these problems, has said, "We are running out of safe, clean, usable water, partly because we are dumping so much of our refuse into our main water sources—our streams. So, too, we appear to be running out of clean air in many of our more populous and industrialized areas, and for similar reasons."

Conservation Vital

Land, water, and air are limited resources. Although our population has increased from 31,000,000 to 195,000,000 in 100 years, the supply of land, water, and air has remained the same. The increase in population automatically puts increased pressure on our resources. But we use them as if they were waste products, to which we contribute the additional wastes of home and industry. Unless we change our whole concept of the environment, and unless we conserve our natural resources and use them intelligently, we cannot pass our civilization on to future generations. Only when a nation accepts responsibility for its natural resources can the momentum toward destruction be retarded.

During the 19th century, the great adventure of settling the prairies, building cities and industries, laying the transcontinental railroad tracks, and constructing beautiful ships gratified and paralyzed the American imagination. The myth of inexhaustible abundance was still the folklore of the land. Yet, even in that distant time, a Yankee named George C. Whipple made a statement that we would do well to heed now. Speaking for the first Board of Health of the state of Massachusetts, he declared: "We believe that all citizens have an inherent right to the enjoyment of pure and uncontaminated air and water and soil; that this right should be regarded as belonging to the whole community; and that no one should be allowed to trespass upon it by his carelessness or his avarice or even his ignorance." This statement is even more pertinent now than when it was made.

A Danger to Health

Pollution of the environment endangers the health of the population from a wide variety of sources. No one had thought very much about air until the last two decades. Most of us were brought up to think that if we opened the window at night, we would be invigorated by fresh air. But it is no longer fresh in most of the settled parts of the continent. It is so polluted from the combustion of coal and oil (known as "fossil fuels") that clean air has become an increasingly serious problem for about 60 per cent of the population.

Looking out of the 19th story window of my New York City apartment as I write this article, I have just counted 11 smoking chimneys. One is belching thick, black smoke that billows above a loft building. Another emits a blue haze that sweeps across the rooftops for several blocks. Two of the four soaring stacks of a power plant emit streams of brown smoke that drift into the upper atmosphere. A flake of oily ash blows through a crack below the window I have left partly open and smudges the paper on which I am writing. The 11 smoking chimneys I see are, of course, only a minute fraction of all the chimneys that are contemptuously tossing waste into the New York air. Moreover, massive and more destructive waste is coming from the exhaust pipes of automobiles—carbon monoxide, sulfur compounds, and nitrogen oxides.

Wherever there are cities, there is air pollution that affects our health. A long cloud of polluted air hangs in the sky all the way from Washington, D.C., to Boston in the eastern United States. In the West, Los Angeles, which lies in a basin surrounded by mountains, has had a long and increasingly alarming experience with smog. (Strictly speaking, the word "smog" means a combination of smoke and fog, but it is commonly used to describe the haze that air pollution creates.) The geographical location of Los Angeles prevents the "ventilation" needed to disperse the polluted air. The city has been variously referred to as a "bay of smokes" and a "gas chamber."

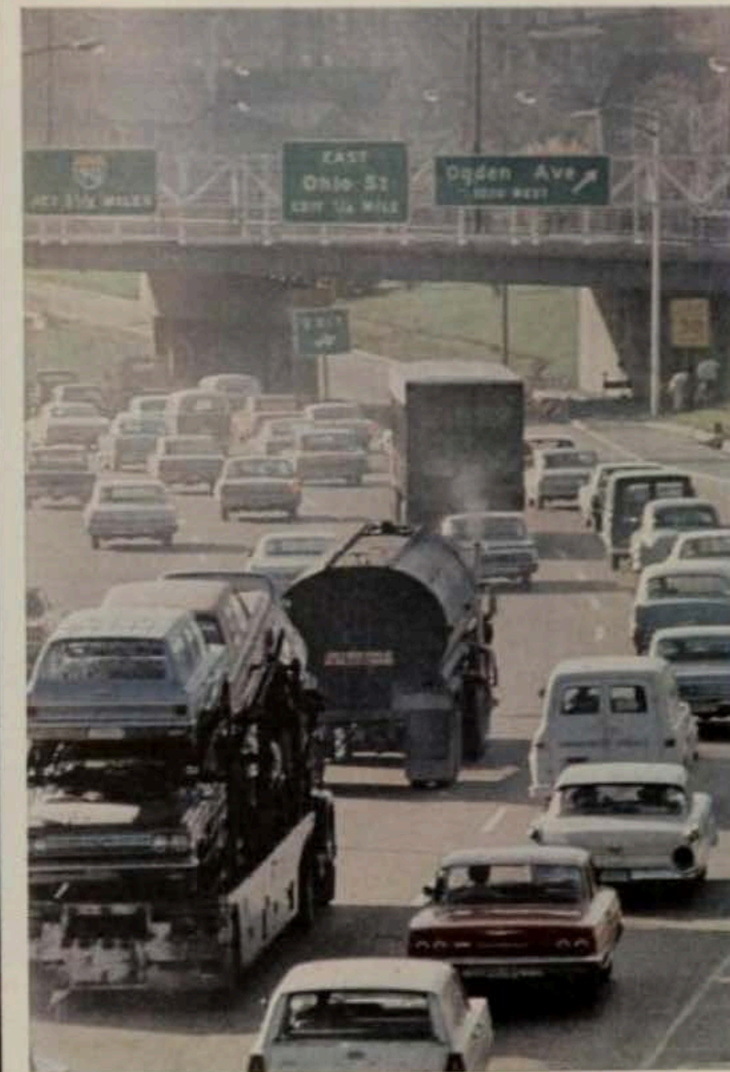
Since 1930, Los Angeles commissions have tried to diminish, if not eliminate, smog by prohibiting the burning of trash in household incinerators, and by compelling oil refineries and industrial plants to install devices for controlling the emission of waste products into the

YEAR BOOK photo by Howard Sochurek

A jet airliner coming in for a landing in New York City is cloaked in smog that shrouds the towering skyline. A cloud of polluted air hovers in the sky all the way from Washington, D.C., to Boston

air. But the smog has increased. Although the smog in Los Angeles is the most notorious in the United States, similar situations exist in many cities. Vivid examples of air pollution can be seen in the inferno of smoking stacks between Gary, Ind., and Chicago, Ill., or along the New Jersey Turnpike where a complex of plants discharge smoke and gases that blow across New York City when the wind is from the west.

Pollution of the air is estimated to cost the nation between \$11,000,000,000 and \$20,000,000,000 a year in damage to property, houses, furnishings, and clothing. It contains caustic elements that rot building stones and eat holes in metal roofs. Among its eccentric minor effects, it damages the pipes of church organs. In New York City, the sheep-



YEAR BOOK photo by Don Stebbing

Exhaust fumes from motor vehicles, above, *are a major source of air pollution. Open burning of garbage and trash,* below, *also discharges pollutants into the atmosphere of many communities.*

Pennsylvania Department of Health

skin valves that let air into the pipes deteriorate rapidly. A valve that would last 20 or 30 years in a clean atmosphere lasts only above five years in New York City.

This is the air we breathe. Where the air is dirty, there is evidence which suggests that the incidence of respiratory diseases, ranging from chronic bronchitis to cancer, increases. Among older people, there is evidence that air pollution accelerates diseases that include hardening of the arteries, heart trouble, asthma, and emphysema.

The Threat of Air Pollution

Under extreme circumstances, multiple deaths have occurred during periods when temperature inversions intensified pollution. A temperature inversion occurs when a layer of warm air lies above a layer of cooler air and acts as a lid that prevents the rising and dispersion of ground pollution. There are a number of classic instances of deaths during temperature inversions. In five days in 1930, for example, 60 people died during a temperature inversion in the heavily industrialized Meuse Valley in Belgium. They had breathed excessive amounts of sulfur and hydrocarbons. In 1948, a temperature inversion in Donora, Pa., that lasted four days produced an accumulation of fumes from steel, acid, and zinc plants. Forty-three per cent of the population became ill. Twenty persons died.

In 1952, a London fog filled the ground level of the atmosphere with sulfur dioxide and additional contaminants. There were about 4,000 deaths. In 1953, between 65 and 250 New Yorkers may have died from air pollution when a stagnant weather system captured a high concentration of toxic elements that entered the lungs. In two weeks in the winter of 1963, air pollution was reported as a major factor in 647 more deaths than normal in New York City.

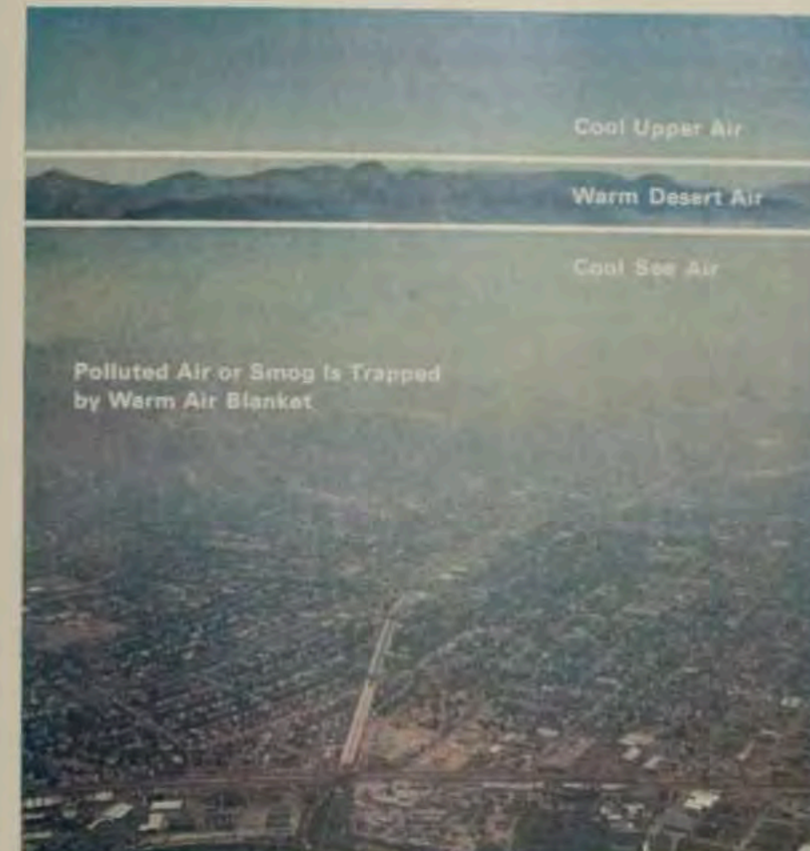
Air pollution poses another threat; one that is almost unbelievable.

Major Sources of Air Pollution

The three largest U.S. cities are all plagued by air pollution, but the major sources of it vary, relatively, to a marked degree. Chicago and Los Angeles use modern methods to control incineration.

YEAR BOOK diagram

When A Thermal Inversion Sets In



Edward J. Blood

Smog-bound Los Angeles, above, has been called a "bay of smokes" and a "gas chamber," as pollutants are frequently trapped by thermal inversions. In such cases, cool air from the ocean stagnates beneath a blanket of warm desert air, preventing normal dispersion. When the warm air is finally blown away, the ground air is able to escape, and the smog disperses.

It can change the physical nature of the planet. Exhaust gases from the burning of fossil fuels increase the carbon dioxide content of the air, which, in turn, increases the temperature of the atmosphere. Unlike some other pollutants, carbon dioxide cannot be washed out of the air. The temperature increase affects life in the oceans. During the 20th century, "there has been a well documented warming of the oceans in the Northern Hemisphere," says a report by the Conservation Foundation. "The changes in marine life of the North Atlantic have been very noticeable. . . . The abundance and distribution of a number of commercial fish have shifted northward."

But this is only a minor result. If the carbon dioxide content of the atmosphere were doubled, the average temperature of the earth would rise 3.8° F. The glaciers in the north would then begin to melt, and the level of the oceans would rise and inundate coastal cities. "It is almost inevitable that as long as we continue to rely heavily on fossil fuels for our increasing power needs, the atmospheric carbon dioxide will continue to rise, and the earth will be changed, more than likely for the worse," the foundation concludes. It is also possible that high-flying jet aircraft may help to increase the atmospheric temperature by spreading a layer of haze through the atmosphere in the form of ice crystals that will not melt. In the United States, there are more than 1,000 jet planes continuously in the air. They, too, burn fossil fuels and leave residues in the atmosphere.

Those of us who remember the anxiety over fallout from nuclear fission a few years ago may have some difficulty in accepting the idea that nuclear energy used for industrial purposes is on the whole cleaner than the energy derived from burning fossil fuels and is, therefore, more desirable. Nuclear energy, as such, is not an air pollutant, but it has one tremendous disadvantage: it produces large quantities of radioactive waste—"radioactive garbage"—that cannot be carelessly flung into the air or water, or onto the land, but must be disposed of with extreme caution.

As long as we require energy to drive cars, manufacture goods, and heat houses, there is no easy solution to the problem of air pollution. The simple process of being alive creates wastes and contaminants. Nature itself contaminates the air with volcanic eruptions, forest fires, and dust storms. Absolute purity is absolutely impossible, but this does not justify massive contamination of the air over cities in the United States which are being increasingly polluted by man with toxic wastes dangerous to the health of all.

Our Natural Glory Degraded

Since rivers and lakes occupy an exalted place in the natural glory of the United States, it is depressing that we are degrading them. We treat water as if it were "a discarded piece of trash," in the angry phrase of an Alabama state conservationist. The history of America is intertwined with its rivers. This is one of the grandest facts about America. The voyages of De Soto, Marquette, Joliet, and La Salle on the Mississippi are an example of this. In 1608, a year before Henry Hudson explored the river now named for him, Captain John Smith expressed himself as astonished by the abundance and the quality of the fish in the Potomac estuary. In 1804, Lewis and Clark began their epochal penetration of the new continent by ascending the Missouri, which, like the Hudson and Potomac, is now heavily polluted. Audubon drifted down the Ohio, and Thoreau rowed up the Merrimack—both of them polluted rivers now.

Our love of America derives to an important degree from the lore of its rivers. Their names have a mystical resonance—Bitterroot, Chattahoochee, Colorado, Columbia, Green, Monongahela, Penobscot, Raccoon, Rogue, St. Johns, Snake, Susquehanna, Yellowstone. There is something almost hypnotizing about all bodies of water. People are drawn to them and gaze at them as if under some spell. As Herman Melville, the author of *Moby Dick*, put it: "They must get just as nigh the water as they can without falling into it."

People also have a less admirable trait on the shores of rivers and lakes. They use water as a dump. They throw things into it. They find rivers convenient places in which to get rid of junk. Probably the people who sail on the Potomac near Washington, D.C., love the river and find the sensation of being on it, or close to it, an idyllic experience. But some admirers who recently volunteered to help clean it picked out of it old automobile tires, mattresses, boxes, discarded automobile batteries, and a sewing machine. When the skipper of a small boat tried to retrieve a wrench he had dropped into the river, his magnet brought up nothing but beer cans. The bottom of the Potomac is lined with rubbish. Although human beings love rivers, they also use rivers contemptuously.

A Grave Water Problem

Municipalities and industries putrefy rivers on a massive scale. A century ago, when the population was small and industries were few, clean water did not seem to be a serious problem. It is one of our gravest problems now. In addition to the needs of our increasing population, the uses of water have increased with the installation of more bathrooms, washing machines, garbage disposal units, and lawn sprinklers. By the year 2000, our requirements for water will be about 1,000,000,000,000 gallons a day. Since the available water supply is expected to be about 650,000,000,000 gallons a day, it is readily apparent that most of the water will have to be used at least twice. If it is used more than once, treatment methods will have to be more efficient than are the methods in common practice today. Sewage treatment plants that remove 80 per cent of the contaminants from water are currently regarded as good. Seventy per cent is as much as many modern plants remove.

Despite the size of the problem and the attention paid to it by government officials and responsible citizens, a lot of today's sewage is not treated at all. "It is an astonishing fact," says the United States Department of Health, Education, and Welfare, "that of the 11,420 U.S. communities with sewers, 2,139 still dump their sewage raw into local streams and watersheds."

One-third of New York City's sewage (500,000,000 gallons a day) flows raw into the Hudson and East rivers. The sewage from Detroit passes through a primary cycle of sewage treatment but not a secondary cycle. It pollutes the Detroit River so heavily that the federal government is demanding an improved treatment plant that will cost the city $100,000,000. Although Chicago treats its sewage in modern plants, the surplus effluent that is finally discharged into the Chicago Sanitary and Ship Canal contains wastes equivalent to the untreated sewage of 1,000,000 people and contains solid wastes, suspended in solution, amounting to 1,800 tons a day. Lake Michigan is an "industrial cesspool," in the phrase of U.S. Senator Gaylord Nelson of Wisconsin. Along its shoreline, it receives wastes from Illinois, Indiana, and Wisconsin cities and industrial plants. Some experts doubt that this portion of Lake Michigan can ever be cleaned. During the summer of 1965, one quarter of Lake Erie was so heavily polluted by adjacent

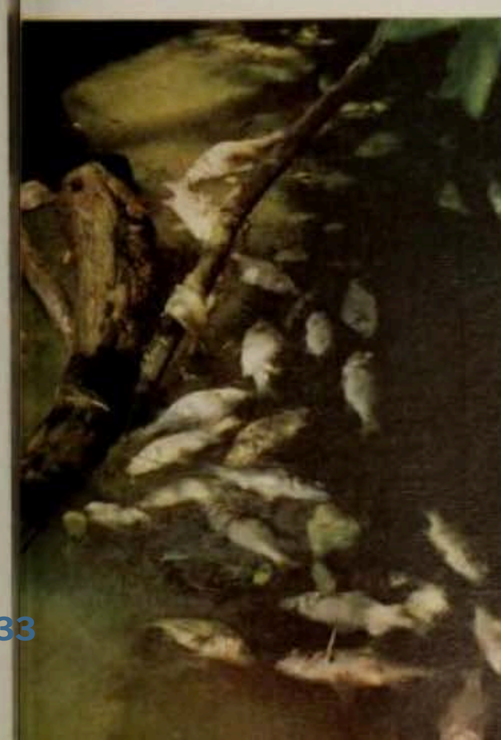
U.S. Department of Health, Education, and Welfare

Discharge from a paper mill flows into Lake Erie and covers several acres of the water's surface. The lake has been described as the worst case of large-scale pollution that has ever been known. One observer has said that it is "dying."

cities and farms that its oxygen supply was virtually depleted. Lacking oxygen, fish were unable to breed and feed. "A dying lake," someone called it. Someone else has described it as the worst case of pollution on a large scale that has ever been known.

This heavy contamination is not a transient problem. At the present rate of construction, treatment plants will not keep pace with the expanding population. By 1970, the total discharge of wastes will be considerably greater than today. In 1963, it was estimated that the treatment projects then needed would cost $2,200,000,000—a sum that startles people concerned with the problem.

Water pollution consists of organic wastes from domestic sewage and industrial plants, plant nutrients that breed algae and water weeds,



U.S. Department of Health, Education, and Welfare

Municipalities and industries putrefy rivers on a massive scale, as shown by waste material flowing from a steel mill, above. *The lovely Potomac,* left, *is so polluted even the fish die.*

oil, acids, chemicals, alkalies, dyes, detergents, pesticides, and sediments. It also consists of radioactive residues from the mining of radioactive ores, nuclear testing, and intrusions of salt water. Heated water discharged from power plants is also a pollutant. Pollution kills fish on a colossal scale. Since polluted water can and does cause typhoid, dysentery, and hepatitis, clean water is not just a matter of aesthetics. It is also a matter of public health. Shellfish can transmit many diseases. The condemnation of shellfish because of contamination from sewage can also be extremely costly. When the oyster beds at the mouth of the Mobile River were condemned in 1960, the loss of income to the industry was estimated at $4,880,000 a year according to the Alabama Conservation Department.

The debasement of our rivers is an appalling sight. Take the "lordly Hudson," or the "great river of the mountains," as it has been called. Because of its romantic beauty, it has been traditionally compared to the Rhine. The comparison, unfortunately, has another aspect. The Rhine, too, is grossly polluted. Beginning as fresh water from the Alps, it picks up chemicals, potash, minerals, and oil as it flows through Germany. When it emerges in The Netherlands, visibility in the water is limited to 16 inches.

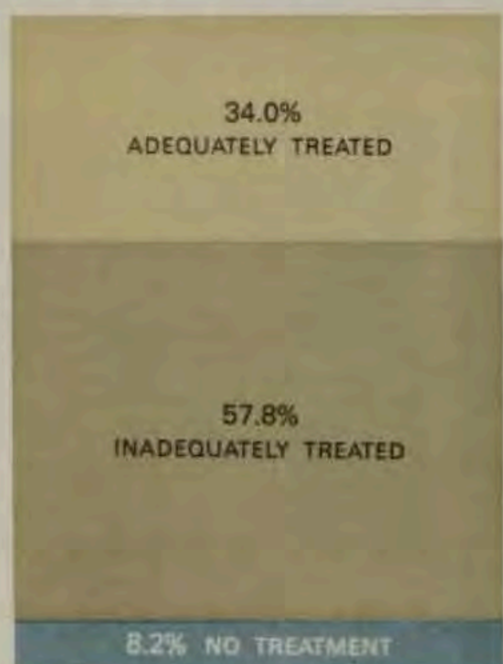
The Hudson is much the same. At Troy, it picks up sewage, pesticides, oil, and other pollutants from cities and farming areas along the Mohawk River. (One stream that empties into the Mohawk is said to be so full of oil and grease that its water cannot be used to fight fires.) From Albany south to New York City, the lordly Hudson is a long sewer. It is a little less polluted at the middle section near Poughkeepsie, but heavily polluted in the north and south sections where municipal and industrial waste is large. Even the middle section is so contaminated that it cannot be used for drinking or for swimming without heavy chlorination. It was a joyous river a hundred years ago. Unfortunately, it is a filthy river now.

In the spring of 1965, I rode up the river from New York City to Glens Falls and back again in a helicopter with a director of the New York State Regional Development Office. From a helicopter, the configuration of the Hudson is a natural masterpiece—broad bays of open water shining in the sun, the dramatic stone wall of the Palisades, the narrow trench of the Highlands, the noble mound of Storm King across the river from the steep pitch of Breakneck Ridge, the green hills, the smooth croplands, the charming islands. No wonder Henry Hudson admired it. When he was there, the bays contained whales and bred shellfish, and the river was full of sturgeon. Sturgeon still abounded in the 19th century and were known as "Albany beef" because of their food value. It has been said that men first settled along the Hudson, not because of its navigability, but because of the abundance of fish that could be found there.

A helicopter journey today, however, discloses the negative aspects of this glorious waterway. It is a sewer and a dump. One sees oily scum, garbage dumps, sewage outlets that stain the water along the shore, long, ragged plumes of smoke from industrial plants, white and yellow waste fluids pouring out of factories and spilling into the river, decaying piers, capsized barges, abandoned buildings without roofs or windows. Each generation leaves its rubbish along the Hudson River to infect and corrupt the future. Given time, the Hudson will be a wasteland.

On the west shore across from Poughkeepsie, a large, rambling boathouse in a gay design is slowly crumbling. It is a relic of the days when boating on the river, swimming in it, and picnicking beside it were common forms of pleasure. The river is sparingly used for pleasure now. The water is green or brown and opaque in many places. It has a disagreeable odor. Much that takes place along the Hudson tends to degrade it. It has degenerated into a commercial waterway, used largely by tankers that discharge oil at the many tank colonies on the shore. The festive Hudson River Day liners with their great American flags, their streams of fluttering pennants and their holiday travelers no longer ply the upper reaches of the Hudson. Civilization has corrupted this great river.

Home Sewage Disposal



Thousands of communities still dump raw human waste into rivers and waterways. Of all sewage discharged from American homes, only 34 per cent is adequately treated.

YEAR BOOK diagram from U.S. Public Health Service estimates and Chemical Week

The Plight of the Potomac

The history of the Potomac is similar. In the early 19th century, in the warm months of the year, John Quincy Adams, a gloomy Yankee, used to begin his day as President of the United States by walking from the White House to the Potomac, laying his clothes on the bank, and swimming in the water. Few things during the rest of his day seemed so clean and tonic. Modern Presidents have to swim in the White House pool which is filled with filtered and chlorinated water. The Potomac estuary in the District of Columbia is contaminated with the residue from sewage plants, sediment from upriver, sludge, trash, litter, logs, and other forms of debris from a modern city. Someday, swimming may be pleasant and safe in the Potomac if people now concerned about the river can persuade others to share their hopes. But the dirty water is far from inviting today.

In view of the history of the Potomac, and the loveliness of the parks on both shores, the filthiness of the water is particularly discouraging. George Washington, in a mood of pardonable pride, called the Potomac "the finest river in the world." When he was farming in the Mt. Vernon region, it was certainly different than today. Now 2,000,000 people live around the estuary. In 1985, there will be 3,000,000; in 2010, 5,000,000. Contemplating the rapid expansion of the future, Gordon E. McCallum of the United States Public Health Service says: "Our job will never end." It will be virtually impossible to keep ahead of the problem. If John Quincy Adams dipped into the Potomac every morning now, he would require medical attention. The water of the lovely river that washes our beautiful capital city is not clear, not blue, but "soupy green," as one of its custodians describes it. Although the Potomac estuary may look romantic, its contamination is real.

We Can Meet The Challenge

By J. I. Bregman and Sergei Lenormand

If no sizable effort is made to reduce and control the massive contamination of our vital resources, the nation's health, wealth, and beauty will continue to erode at an even more catastrophic rate than in the past. Although the situation is critical, it is not hopeless. Effective methods are available to deal with the problem.

The major sources of air pollution can be attacked in five basic ways:

- A relatively simple approach, already adopted in some communities, is the elimination of all open burning of garbage, leaves, trash, refuse, and junk. At a modest cost, such wastes can be collected and disposed of in modern municipal incinerators that emit far less exhaust gas than does open burning. Often garbage and trash can also be used for land fill.
- Because sulfur dioxide is one of the most noxious and damaging of the air pollutants, all heating and industrial plants can be required by municipal ordinances or state laws to burn only fuels containing a low sulfur content. If this is not possible, ways can be provided for removing or dispersing the resulting gas.
- New combustion equipment can be designed to burn fuel efficiently.
- Filtering devices can be installed to collect soot, ash, and other solid particles discharged by heating systems and industrial plants.
- Pollution caused by automobiles can be minimized by installing devices, or redesigning engines, to reduce exhaust gases. California has already passed a law requiring exhaust reduction systems on all automobiles sold in the state beginning in 1966.

Methods for eliminating the major portion of pollutants from water have been known for many years. Techniques such as filtration, aeration, settlement (in which solids are allowed to sink to the bottom of polluted water), and dilution (in which polluted water is cleansed by mixture with fresh water) can be used for primary treatment.

Chemical methods, such as chlorination, can be employed for secondary treatment. When applied to both municipal sewage and industrial wastes, a combination of these techniques can eliminate almost all objectionable materials. Most communities already have some kind of water treatment facility, but in many instances, such facilities are inadequate.

An urgent need exists for the construction of separate storm and sanitary sewerage systems. The two systems should not be combined as they so often are at present. In the first place, storm run-off does not require treatment. It can drain directly into a waterway. More important, when combined with sewage in one system, storm run-off frequently overloads treatment plant facilities. This causes much of the sewage to flow directly into nearby waterways.

To use the water available to us in the most efficient manner possible, we must conserve as much as we can. Already, in some industrial operations, water is treated in the plant and reused, cleansed, and reused many times before finally being evacuated. Hopefully, this practice will become much more widespread in years ahead.

The reduction of water and air contamination is clearly a problem that is more political and financial than technical. Some 32 states and Puerto Rico had approved some air pollution laws by 1963. Of these, however, only 15 actually carried any enforcement authority. Among the states that now have control programs, the average expenditure is only about four cents per capita per year—less money than schoolchildren spend for candy or ice cream in a single week.

To a large extent, the problem consists of overcoming fears of federal intervention and resistance to appropriating sufficient funds for the control of the major sources of pollution.

The first federal air pollution control program of any consequence was established in 1955, with the passage of Public Law 155. This act provided for government research, as well as for grants and contracts to research organizations and universities.

In 1963, a major implementation of this act came with the enactment of Public Law 88-206, popularly known as the Clean Air Act. The act laid the foundation for interstate agreements, and the establishment of a commission with legal authority to curtail or prevent one state from polluting another. It also made substantial funds available to develop control agencies on state, county, and municipal levels. In addition, the federal government for the first time was able to take legal action when it could prove an interstate health hazard existed.

Another big step forward was the passage late in 1965 of a law giving the federal government authority to establish emission standards for motor vehicle exhausts. This means that by 1968, all new automobiles will probably be equipped with devices to control exhaust fumes.

Federal jurisdiction over water pollution advanced appreciably in 1965 when President Lyndon B. Johnson signed a bill that requires the states to establish clean water standards by 1967. Thereafter, the federal government will have the power to set standards for states that have not done so.

Residents of New York state have already given evidence that they intend to solve their own problems without pressure from the federal government. In November, they overwhelmingly approved a proposition authorizing the state to raise $1,000,000,000 through a bond issue to assist the financing of sewage treatment and other anti-pollution facilities throughout New York.

The issue of state versus federal jurisdiction—either with regard to water or air pollution—is not really the crux of the matter. The crucial issue relates to individual concern and commitment. Are we willing, for example, to spend as much to combat pollution as we spend on smoking?

The funds essential to this massive task in the coming decade may be more sizable than those needed for almost any other government program. The expense, however, may be no more than the approximately $50,000,000,000 spent for tobacco during the past 10 years, and certainly less than the roughly $100,000,000,000 expenditure for alcohol during the same period. Moreover, the longer we wait to mobilize against pollution, the more it will eventually cost. The total clean-up bill substantially increases each day we delay making a total effort to restore our environment and maintain the integrity of our natural resources.

While we may not be able to eliminate it, we have the means to control pollution. It is now imperative that we get on with the task.

General pollution of the environment will continue until the public puts a stop to it. Municipalities will economize on the treatment of sewage until the citizens assume the responsibility themselves. Industries will continue to dump their wastes into the air or the water until citizens make a public issue of it.

In this, as in all aspects of life, we need an ethic. In the legal sense, people can own land, but they do not own it in the moral sense. They are custodians of a land that each generation passes on to the next. In *A Sand County Almanac*, an inspired and pioneering book published in 1949, the late Aldo Leopold defined the land ethic: "A land ethic changes the role of *Homo sapiens* from conqueror of the land community to plain member and citizen of it. It implies respect for his fellow members and also respect for the community as such." Our natural resources are not adversaries to be conquered, nor raw products to be squandered. They are rich and wonderful parts of our inheritance. They are to be loved, respected, and wisely administered by all of us.

Since human beings have minds, they do have certain advantages over what we call dumb animals. We can reason from facts. We can save life by obeying abstract knowledge and doing some of the things that do not come easily. But in the last analysis, we are mammals. We flourish or fall, live or die, by the same natural laws that govern the wild creatures of the earth, as well as the grains in the meadow and the roses beside the house. As a nation, we acquired a beautiful land three and one-half centuries ago. We have created a civilization that is in many ways as beautiful as the land because its sovereign principle is freedom of the body, mind, and soul.

But freedom can degenerate into anarchy. Having been carelessly used, the land has lost its original grandeur and exultance. "The air we breathe, our water, our soil, and wildlife are being blighted by poisons and chemicals which are the by-products of technology and industry," President Lyndon B. Johnson said in 1965 in his "Message on the Natural Beauty of Our Country."

We are wasting and poisoning the shining green land that Americans have loved since the day they first saw it.

See also Section Two, *Water for a Thirsty World;* Section Three, WATER AND FLOOD CONTROL.

YEAR BOOK photo by Don Stebbing

"In three and one-half centuries of expansion and an increasing productivity," author Brooks Atkinson recently remarked, "Americans have had to exchange the old myth of unlimited abundance for the sobering reality of a polluted continent. We think of ourselves as intelligent beings, and in many respects we are. But we have also behaved irresponsibly, as if each generation owned the total environment and could carelessly dispose of it without any obligation whatever to the next."

1965 speech by American Petroleum Institute (API)
President, Frank Ikard,
Meeting the Challenges of 1966

American Petroleum Institute

PROCEEDINGS
1965

NOTE—Statements contained herein, although prepared for use in publications of the American Petroleum Institute, represent the expressed opinion of the author.

TABLE OF CONTENTS

PROCEEDINGS OF THE AMERICAN PETROLEUM INSTITUTE, 1965

SECTION I—GENERAL

SECTION II—MARKETING

General Committee—Minutes and Reports, available from the API Division of Marketing at no charge, contains, in addition to the minutes of the midyear meeting, complete papers which are listed in this Table of Contents under "General Committee" (except the first paper).
Minutes of other committee meetings, as well as complete papers of those abstracted herein and listed in this Table of Contents under each of the other committee headings, are also available on request from the Division of Marketing.

MEETING THE CHALLENGES OF 1966 †

FRANK N. IKARD*

Welcome to the 45th Annual Meeting of the American Petroleum Institute.

As always, it is good to see so many in attendance. These meetings of ours provide a yearly opportunity to reflect on past performance, assess current problems, and formulate future programs. But they mean much more than that. They offer concrete evidence of the need for industry people to explore these matters not separately, but together; to advance our best thinking not in private isolation, but in open convention.

It is commonplace and almost trite to observe that the challenges we face together, in noncompetitive areas, grow in number, size, and complexity year by year. But perhaps it's worth observing that as they do, they tend to involve more segments of our industry and more people in our industry more deeply than in the past.

The year 1965 has been no exception. A broad stream of activities has called for an unusual degree of leadership by the Board of Directors, particularly by Chairman J. Ed. Warren. Chairmen in the past have observed that the first year of their term tended to be the more active year, with the second affording some time for reflection and forward planning. I doubt if Ed *found* time for that—he had to *make* it—on top of an extraordinarily active schedule.

The year 1965 has also been a year in which we've heavily depended on the help of the thousands of volunteers throughout the industry. I wish to thank them at this time for their extensive participation, and the entire API staff joins me in this expression of appreciation. We hope their enthusiasm will inspire many more to take part in industry affairs in the coming year.

Federal and State Legislative Activity

In observing that this has been a most active year, particularly in government relations, I have in mind the readings of a fairly reliable thermometer—federal and state legislative activity. The record shows that in the first session of the 89th Congress, just completed, more than 14,000 bills were introduced. This is almost as many as were introduced in *both* sessions of the 88th Congress. So the thermometer tells us that federal legislative activity is running at double speed. Going right along with the trend, the number of bills of interest to our industry was also up. In 1965, our industry kept a close watch on no fewer than 200 pieces of proposed federal legislation.

State governments were also very legislative-minded, with about 100,000 bills introduced. Of these, about 4,000 would have affected our industry in some way and required close study.

It takes no crystal ball to see that our involvement in government matters will intensify in the year ahead.

The industry is well-positioned to meet the challenges and opportunities of 1966. The issues that concerned us in 1965—air and water conservation, oceanography, taxes, wage and hour legislation, and highway sign legislation—to name just a very few—alerted industry people to the need for doing their homework. Many more people in our industry had to learn more about some unfamiliar subjects. And many more of us learned not only *why* it was important to make the industry's voice heard and its opinions felt, but also *how* to do it. As a result of the experiences of 1965, then, we can face the issues of 1966 with a feeling that we are at least better prepared.

A swift review—of just a few of the upcoming issues—suggests the variety of challenges 1966 will hold out to us. As Mr. Dunlop said, I think it is really opportunity.

Government Fact-Gathering

First, consider the area of government fact-gathering.

A year ago at this time, I commented on the government interagency group that is studying government facts and figures. Shortly afterward, the study group criticized the present industry fact-gathering as being inadequate, particularly in the areas of reserves, productive capacity, wells drilled, transportation and deliverability, and expenditures and revenues.

We believed a year ago—and we believe now—that any facts and figures the industry is asked to provide ought to be relevant to national needs—not just a display of federal curiosity. Figures we are asked to provide ought to be obtainable without placing an undue physical or financial burden on the industry. And if the figures we do provide are to be used as the basis for framing new policies, they ought to be *firm* figures—not just informed guesses, as in the case of indicated or ultimate reserves.

Industry itself has recognized the need for more complete data. Our response to this recognized need, and to the findings of the government study group, has been constructive. Task groups, under the chairmanship of Mr. Gunness, will be developing improved fact-gathering in three areas—reserves and productive capacity, drilling statistics, and the economics of exploration and drilling.

These, of course, are just the initial steps in the general overhaul of our fact-gathering services. Much remains to be done in 1966 and beyond. But you can be sure that our positive action in this area lends weight

---

* President, American Petroleum Institute, New York, N.Y.

† Presented at a general session during the 45th Annual Meeting of the American Petroleum Inst., in the Conrad Hilton Hotel, Chicago, Ill., Nov. 8, 1965; presiding, J. Ed. Warren, chairman, API Board of Directors.

to our opinions in the whole area of government fact-gathering.

Oil and Gas Taxation

Another issue worth comment at this time—one that especially underscores the need for wider participation in industry affairs—is that of percentage depletion.

The historic 27½-percent depletion rate has been maintained for decades, despite many challenges, for several important reasons. First, the wisdom of the provision and the established rate have been self-evident. Time and time again, Congress has correctly traced the continued discovery of new petroleum and the continued expansion of reserves to the historic and appropriate tax treatment of the industry. But equally important is the fact that the industry people have supported percentage depletion with a united voice. And because we spoke in a single voice, our position was clearly understood.

Now it appears that percentage depletion will once again go under a microscope—partly, at least, in the study of the balance of payments question.

Any policy—even a good policy—ought to be subject to periodic review. But it is one thing to review a policy to see if it is working; it is quite another to suggest that it has to be tinkered with or dismantled to see if it is working.

Land Law Review

Another area that will demand our wider interest and attention involves the work of the Public Land Law Review Commission. This commission was drawn up by Congress to review all laws dealing with public lands. Its duties come into important focus when you consider that one-third of the land area of the United States falls within the purview of these laws.

There are indications that this will be no routine examination. It could well develop into a thorough-going review of policies relating to domestic and foreign development of oil and gas. Chairman Wayne Aspinall says that his commission will be following the course of tariffs, quotas, proposed international commodity agreements, and the development of petrochemical complexes. Along with it will be further study of depletion provisions.

The industry is assisting in the work of that commission through representation by several of its outstanding members. But many more people in our industry will ultimately become involved. The findings and announcements of the commission will trigger lively discussion and debate. Industry people at all levels must be prepared to take part. Many more of us will have to become practitioners of public affairs—articulators of the industry's point of view.

Now, the three issues I've touched on—government fact-finding, oil and gas taxation, and land law review—were selected primarily for illustrative purposes—to show why more participation in industry affairs will be necessary in 1966. But none of them ranks in immediacy with the final issue I want to discuss. It will, without question, overshadow all others in the demands it will make on us. I refer, of course, to air and water conservation.

Air and Water Conservation

The fact that our industry will continue to be confronted with problems of air and water conservation for many years to come is demonstrated by the massive report of the Environmental Pollution Panel of the President's Science Advisory Committee, which was presented to President Johnson over the weekend.

This report unquestionably will fan emotions, raise fears, and bring demands for action. The substance of the report is that there is still time to save the world's peoples from the catastrophic consequence of pollution, but time is running out.

One of the most important predictions of the report is that carbon dioxide is being added to the earth's atmosphere by the burning of coal, oil, and natural gas at such a rate that by the year 2000 the heat balance will be so modified as possibly to cause marked changes in climate beyond local or even national efforts. The report further states, and I quote: ". . . the pollution from internal combustion engines is so serious, and is growing so fast, that an alternative nonpolluting means of powering automobiles, buses, and trucks is likely to become a national necessity."

The report, however, does conclude that urban air pollution, while having some unfavorable effects, has not reached the stage where the damage is as great as that associated with cigarette smoking. Furthermore, it does not find that present levels of pollution in air, water, soils, and living organisms are such as to be a demonstrated cause of disease or death in people; but it is fearful of the future. As a safeguard, it would attempt to assert the right of man to freedom from pollution and to deny the right of anyone to pollute air, land, or water.

There are more than 100 recommendations in this sweeping report, and I commend it to your study. Implementation of even some of them will keep local, state, and federal legislative bodies, as well as the petroleum and other industries, at work for generations.

The scope of our involvement is suggested, once again, by the thermometer of legislative activity this past year. On the federal level, hearings and committee meetings relating to air and water conservation were held almost continuously. The results, of course, are the Water Quality Act of 1965 and an important amendment to the Clean Air Act of 1963.

Turning to the state level, more than 350 bills dealing with air and water conservation were considered by 41 state legislatures. One hundred and seventy-five of these related to air pollution control, and 190 were related to water pollution control. As for the results of all this, 30 air pollution bills passed in 18 states, and 35 water bills in 19 states.

The signs of heavier industry involvement next year are unmistakable. The Water Quality Act, for example, provides that states are to set water quality criteria by

June of 1967—criteria that must be acceptable to the Department of Health, Education, and Welfare (HEW). If an individual state fails to act, the department will set water criteria in its stead.

As for the Clean Air Act amendment, the new provision gives HEW the authority to set standards for exhaust emissions from new motor vehicles. And it provides for increased federal air pollution research, including a study of automotive hydrocarbon emissions from the carburetor and fuel tank. There will also be further studies on ways to cut down sulfur oxide emissions resulting from the burning of residual oil and coal.

Obviously, a large and necessary job lies ahead for this nation. Our industry must give its fullest cooperation in this national effort to improve our air and water resources. At the same time, we must also do what we can to put a good cause on a rational track.

Industry cooperation is not made easier by the emotionalism with which the matter is now charged—an emotionalism we can expect to see intensified. Some writers, politicians, and even research people have found that strong words on pollution are a short way and a certain route to attention.

We *must* not permit the job ahead of us in air and water conservation—either its size or its complexity—to become obscured by rash statements and fanciful notions. Clear water and clear air will only come about through clear thinking.

Our position was put forward in a letter to the President last January, in response to his comments about air and water conservation in his State of the Union message. We pointed out that past experience in this field indicates the waste of money and time that can be involved in false starts. And we firmly stated our belief that well-meaning programs can founder where they are based on supposition unsupported by scientific knowledge; developed through inadequate research.

We pointed out to the President—and it is worth reminding ourselves here today—that our industry's concern for water quality is sincere and long standing. Thirty-seven years ago, at a time when many local governments scarcely gave thought to water purity, the industry formed the API Committee on Disposal of Refinery Wastes. The industry can take a great deal of pride, too, in its solid support of this effort all during the 1930's—when there were perhaps more pressing economic problems.

Nor is industry concern with clean air a recent matter, provoked by headlines of the moment. We have been sponsoring research and publishing our findings for more than 10 years—starting long before the national spotlight was thrown on this problem.

I thought you would be interested in the results of some recent studies that indicate the extent of our industry's commitment in air and water conservation.

API sponsorship of basic research over the years has involved substantial sums. This basic research has been carried on in some 20 different university laboratories and research institutions. It has ranged from studies of the effect of pollutants on crustaceans to studies on the composition of diesel exhaust. In continuation of these efforts, further research—principally to establish needed factual information on matters of current interest in the area of air conservation—is right now under consideration within the API Board of Directors.

The API research effort is, of course, only a small part of industry spending. A study of expenditures by companies for *water* conservation is not completed, but we *do* have figures on *air* conservation. They show that in the past 10 years, companies have spent more than $210 million on air conservation research and new and improved control facilities. For 1966, these companies have earmarked more than $41 million for these purposes—almost double the average annual rate of the previous 10 years.

Expenditures by individual companies on water conservation have lead to achievements worth talking about. A typical example is the East Coast refinery with a water treatment system so efficient that an oyster bed thrives just below the point where treated waters are released. Or the inland refinery—again typical—with a water reclaim system so efficient that it has greatly reduced its requirements from city water mains and recently won compliments from water officials. Or the California refinery that uses schools of small fish to check the quality of effluent in its refinery ponds.

Such achievements have not been spectacular in the newspaper headline sense. None have been crash programs to seek one-shot solutions. Rather, they have proceeded in a calm, sensible, programmed way and have made—and will continue to make—a real and lasting contribution to air and water conservation.

One recent industry effort has seen the development of a procedure to avert potentially harmful air pollution episodes. Any city could use it. When alerted by a monitoring system and weather forecast to a threatened buildup of pollutants, the community would take control steps to reduce emissions. These steps might include temporary fuel switching, changing of plant operations, and cutting down on incineration and open burning.

In short, we have an achievable, economical solution to a real pollution problem.

Our overall record in air and water conservation is good—a record of which we can be proud. But in 1966 it can serve a larger purpose than merely giving us a chance to point with pride. These past and present efforts, and our record of concern over many years, merit the deep attention of anyone seriously interested in conserving air and water. Industry people with expertise in these areas—and many more of them now exist than in the past—must make their expertise available.

Conclusion

In conclusion, then, the challenges of 1966 will be many and varied. They call, first of all, for even wider and more active participation by all of us. Those among us who have been reluctant to take part in these matters must be urged toward a more active role.

But, of course, we need more than just added participation—more voices added to the chorus. Success in any program depends also upon unity. Certainly we benefit from diversity of opinion and individuality of viewpoint. But our industry is best understood, and its needs are more readily appreciated, when it can strike a single note. Our industry thrives today because it has identified those areas that could help, or impede, its progress; and when it has responded, it has done so in a clear voice, easily understood.

So, we look toward 1966 as a year of great challenge and opportunity. It can also be a year of achievement if we have broad participation and strong support, which I know we will have, in these areas of common concern.

1968 SRI report to API,

Sources, Abundance, and Fate of Gaseous Atmospheric Pollutants

STANFORD RESEARCH INSTITUTE

MENLO PARK, CALIFORNIA

[redacted]

Final Report

February 1968

SOURCES, ABUNDANCE, AND FATE OF GASEOUS ATMOSPHERIC POLLUTANTS

Prepared for:

AMERICAN PETROLEUM INSTITUTE
1271 AVENUE OF THE AMERICAS
NEW YORK, N.Y. 10020

ATTN: MR. W. A. BURHOUSE
ASSISTANT DIRECTOR

By: E. ROBINSON AND R. C. ROBBINS

SRI Project PR-6755

Approved: N. K. HIESTER, DIRECTOR
CHEMICAL DEVELOPMENT AND ENGINEERING DIVISION

18 μ. As such CO_2 prevents the loss of considerable heat energy from the earth and radiates it back to the lower atmosphere, the so-called "greenhouse" effect. Thus the major changes which are speculated about as possibly resulting from a change in atmospheric CO_2 are related to a change in the earth's temperature.

The latest data available for estimating CO_2 temperature effects are those of Moller (1963). From Möller's data a CO_2 increase of 25% would result in an increase in temperature at the earth's surface of between 1.1 and 7°F, depending on the assumption made regarding the likely humidity changes accompanying this temperature change. If the amount of water vapor in the atmosphere remained unchanged, the smaller increase would occur, but if the relative humidity were to remain constant then the larger calculated increase would prevail. If, instead of a 25% increase, the CO_2 content were to double, the expected change would be about three times this figure. For atmospheric calculations, Möller's model is still a relatively simple one and has not included all of the possible major interactions occurring in the atmosphere. For this reason it is likely that Möller's calculations overestimate the effects on temperature of an increase in CO_2. More comprehensive models are under development and should be available shortly.

If the earth's temperature increases significantly, a number of events might be expected to occur, including the melting of the Antarctic ice cap, a rise in sea levels, warming of the oceans, and an increase in photosynthesis. The first two items are of course related since the increase in sea level would be mainly due to the added water from the ice cap. Estimates of the possible rate at which the Antarctic ice cap might melt have been made. If the poleward heat flux were increased 10%, the ice cap could disappear in about 4000 years. A shorter time, about 400 years, is estimated if it is considered that half the energy associated with a 2% increase in radiation were used to melt the polar ice cap. A 2% increase might result from a 25% increase in CO_2 by the year 2000.

With regard to sea level changes, if 1000 years were required to melt the Antarctic ice cap, the resulting 400 foot rise in sea level would occur at a rate of 4 feet per 10 years. This is 100 times greater than presently observed changes.

Changes in ocean temperature would change the distribution of fish and cause a retreat in the polar sea ice. This has happened in recent time on a very limited scale.

Changes in CO_2 might also bring about increased photosynthesis in areas where CO_2 might be a limiting factor in present growth patterns. Where temperature has been a limiting factor to growth and development, an increase in biological activity might be expected.

Although there are other possible sources for the additional CO_2 now being observed in the atmosphere, none seems to fit the presently observed situation as well as the fossil fuel emanation theory.

C. Summary of Carbon Dioxide in the Atmosphere

In summary, Revelle makes the point that man is now engaged in a vast geophysical experiment with his environment, the earth. Significant temperature changes are almost certain to occur by the year 2000 and these could bring about climatic changes.

Since Revelle's report, McCormick and Ludwig (1966) have studied the possible world-wide change of atmospheric fine particles. An increase in fine particulate material will have the effect of increasing the reflectivity of the earth's atmosphere and reducing the amount of radiation received from the sun. Thus this effect would be the opposite of that caused by an increase in CO_2. The argument has been made that the large-scale cooling trend observed in the northern hemisphere since about 1955 is due to the disturbance of the radiation balance by fine particles and that this effect has already reversed any warming trend due to CO_2.

It is clear that we are unsure as to what our long-lived pollutants are doing to our environment; however, there seems to be no doubt that the potential damage to our environment could be severe. Whether one chooses the CO_2 warming theory as described in detail by Revelle and others or the newer cooling prospect indicated by McCormick and Ludwig, the prospect for the future must be of serious concern.

It seems ironic that in our view of air pollution technology we take such a serious concern with small-scale events such as the photochemical reactions of trace concentrations of hydrocarbons, the effect on vegetation of a fraction of a part per million of SO_2, when the abundant pollutants which we generally ignore because they have little local effect, CO_2 and submicron particles, may be the cause of serious world-wide environmental changes.

the ambient atmosphere should be carefully checked, but probably the most important feature as far as atmospheric chemistry is concerned is to determine the source of the nitrate in the atmosphere. The source, on the basis of our analysis of the atmospheric nitrogen cycle, seems to be by the oxidation of NH_3. The oxidation mechanism for atmospheric NH_3 is unknown. This is a very difficult problem which has been evaded or ignored for several years. If NH_3 cannot be shown to be the source of the nitrate, then it will be necessary to find a sufficient natural source of NO or NO_2 to provide the nitrate.

In the area of atmospheric organic gases the almost complete absence of information on all the possible components except CH_4 should be remedied. Proven analytical techniques are available for such studies. While there may be some doubt in the cases of SO_2, H_2S, and other compounds that available techniques are sufficiently sensitive for use in the ambient atmosphere, this is not the case for the low molecular weight organics. Here, gas chromatography is presently capable of detecting the trace levels of many atmospheric organics present in the fractional part-per-billion range. Although the ambient concentrations are known, methane is in the same category as CO in that there is a major need to determine the sink or scavenging mechanism. At present this can only be guessed at.

Past and present studies of CO_2 are detailed and seem to explain adequately the present state of CO_2 in the atmosphere. What is lacking, however, is an application of these atmospheric CO_2 data to air pollution technology and work toward systems in which CO_2 emissions would be brought under control.

Another point which has been made in our discussion is that N_2O, CO, CH_4, and CO_2 have essentially the same atmospheric residence times because, we believe, vegetation plays a major role in the scavenging cycle for each of the materials. This postulate should obviously be carefully checked by

1974 Exxon, Chevron, and Texaco patents for arctic equipment

United States Patent [19]

Devine

[11] **3,727,571**

[45] **Apr. 17, 1973**

[54] **ICEBREAKING CARGO VESSEL**

[75] Inventor: **Walter B. Devine,** Houston, Tex.

[73] Assignee: **Esso Research and Engineering Company,** Linden, N.J.

[22] Filed: **July 7, 1971**

[21] Appl. No.: **160,385**

[52] **U.S. Cl.** **114/41**
[51] **Int. Cl.** **B63b 35/08**
[58] **Field of Search** ....
114/40–42

[56] **References Cited**

UNITED STATES PATENTS

499,296 6/1893 Kruisbrink.............................114/42

FOREIGN PATENTS OR APPLICATIONS

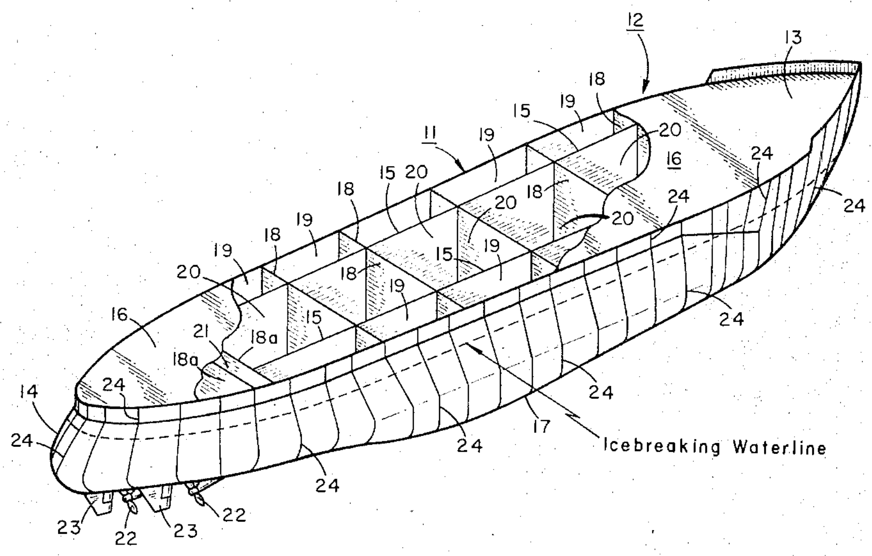
54,173 6/1935 Norway.................................114/40

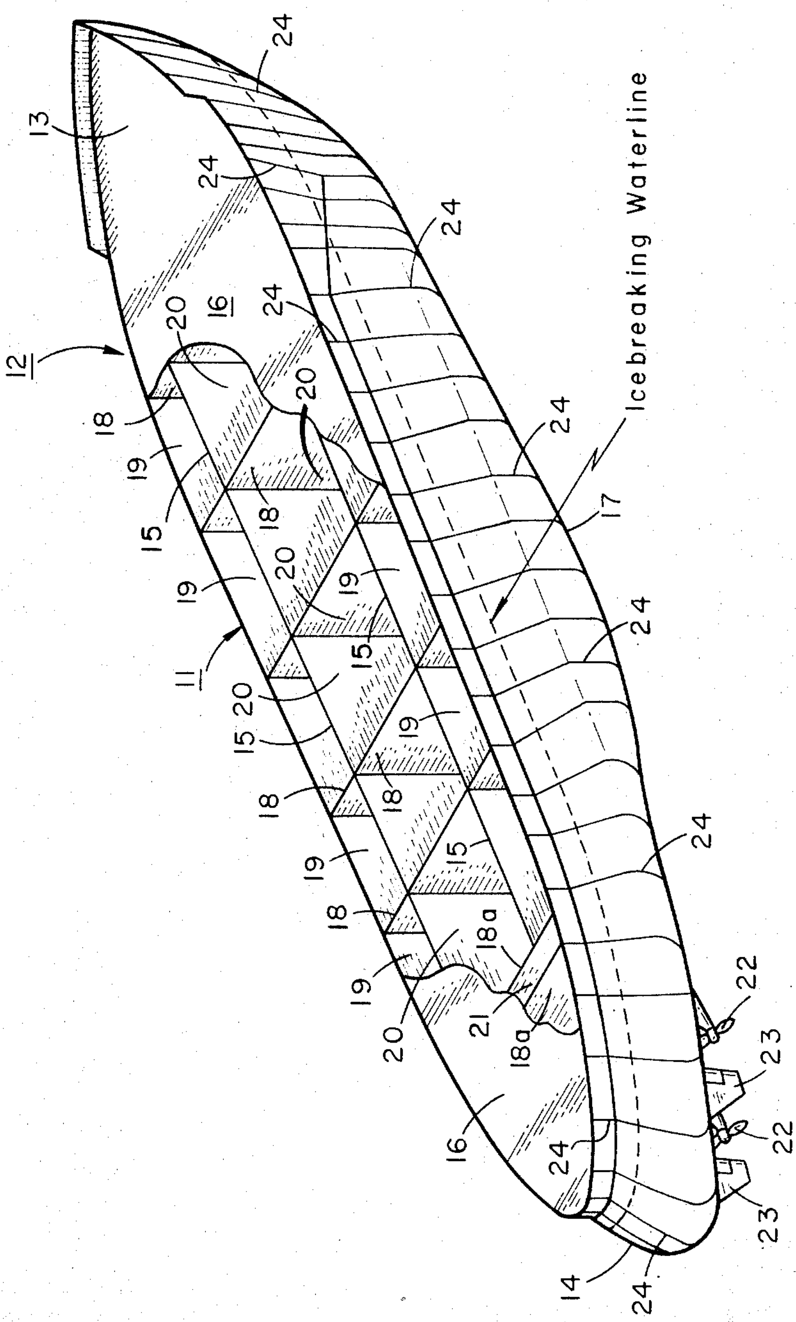
Primary Examiner—Trygve M. Blix
Attorney—Thomas B. McCulloch et al.

[57] **ABSTRACT**

A hull shape for an icebreaking cargo vessel, such as a tank ship, is provided which provides for lower ice breaking resistance, greater displacement in ice, and greater rudder and screw protection against ice when proceeding astern in ice laden or ice covered waters than conventional icebreaking vessels. The hull shape is such that a down breaking bow and a maximum ice-water line beam is provided forward of the midpoint of the hull while aft of the midpoint the ice-water line beam is smaller than that forward, the hull beam below the maximum ice-water line beam being greater than the ice-water line beam in the aft part of the hull. Vertical sections through the hull forward of the mid point slope downwardly and inwardly while aft the vertical sections slope downwardly and outwardly.

7 Claims, 1 Drawing Figure





INVENTOR.
WALTER B. DEVINE,
BY
[signature]
ATTORNEY.

ICEBREAKING CARGO VESSEL

CROSS-REFERENCE TO RELATED APPLICATIONS

This application contains subject matter related to Ser. No. 46,649 filed June 16, 1970 for Peter M. Kimon, Ser. No. 48,326 filed June 22, 1970 for Peter M. Kimon and Charles L. Crane, Jr. and Ser. No. 100,171 filed Dec. 21, 1970 for William O. Gray.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is directed to an ice breaking cargo vessel. More particularly the invention is concerned with an ice breaking tank ship where the tanks are mainly located in the cargo area. In its more specific aspects, the invention is concerned with an ice breaking tank ship having a hull of particular configuration which provides greater maneuverability, greater displacement, and greater rudder and screw protection from ice when proceeding astern.

2. Description of the Prior Art

It has been heretofore known to provide a tanker ship with a hull of particular configuration for use in ice such as the S. S. Manhattan which made an experimental voyage through the Northwest Passage to Prudhoe Bay on the north slope of Alaska. The S. S. Manhattan, however, was a converted conventional tanker fitted with a special bow and other equipment since it was not built originally for voyage through the Northwest Passage.

It has also been known to provide ice breaking ships of various hull configurations to break ice to form a passage for other vessels of a conventional design. However, it has not been known heretofore to provide a cargo vessel with a specially designed hull for ice breaking and built to carry maximum cargo for its displacement. Nor has it been known to construct tank ships of this nature.

The present invention is therefore quite important, new, useful and unobvious since it allows building of cargo vessels which may be used in arctic waters and which serve also as an ice breaker for itself.

The following listed U.S. patents were considered with respect to the present invention:

15,472	1,445,839	3,016,865
17,472	1,500,000	3,075,489
63,577	1,591,748	3,125,977
151,774	1,726,882	3,130,701
499,296	1,859,139	3,191,572
593,664	1,875,629	3,286,674
743,171	2,322,790	3,289,623
812,656	2,364,845	3,331,347
857,766	2,374,845	3,335,686
857,776	2,517,978	3,352,270
993,440	2,663,276	3,382,678
1,121,006	2,669,961	3,410,241
1,195,857	2,754,791	3,416,216
1,254,892	2,764,954	3,435,796
1,398,246	3,009,434	

SUMMARY OF THE INVENTION

The present invention may be briefly described and summarized as involving a marine vessel for use in Arctic operations having a hull of specific configuration in which the hull has a down breaking ice bow with the maximum ice-water line beam well forward of the mid point of the hull. The ice-water line beam aft of the maximum beam tapers inward and forms or develops a smaller beam aft of the vessel's midpoint. The hull of the vessel below the ice-water line approaches a maximum beam aft of the maximum ice-water line beam and this maximum hull beam is maintained well into the after part of the vessel and the hull beam is greater than the ice-water line beam. Vertical sections through the hull from forward to aft are such that forward, the hull slopes downwardly and inwardly and aft, the hull slopes downwardly and outwardly.

DESCRIPTION OF THE DRAWING

The present invention will be further illustrated by the single FIGURE which is a perspective showing of a preferred embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENT RELATIVE TO THE DRAWING

Referring now to the drawing numeral **11** designates the hull of vessel **12** having a fore peak **13** and a stern **14**, longitudinal bulkheads **15** which may be parallel or at an angle to the main deck **16** and the bottom **17** and transverse bulkheads **18** which are parallel to each other. All bulkheads extend from the main deck **16** vertically to the bottom **17**. The bulkheads **15** and **18** form wing tanks **19** and center tanks **20**.

A pump room, cofferdam or fuel oil tank **21** formed of bulkheads **18a** separates the tanks **19** and **20** from an engine room in the stern part of the vessel **12**.

It is to be noted that the hull **11** is flaired outwardly at the maximum ice-water line beam in the forward part of the vessel and the hull slopes downwardly and inwardly while in the aft sections the hull flairs downwardly and outwardly providing a greater beam and consequently adds displacement.

The vessel may have two or more screws **22** (only two are shown) and rudders **23**. The screws **22** and rudders **23** are located such that they are well below the stern overhang which protects them from ice. The lines **24** shown on the hull **11** illustrate vertical sections taken through the vessel **12** from stem to stern and illustrates vividly the features of the present invention.

The engine room may be provided with steam, oil, or nuclear powered propulsion means not shown and also the main deck may be provided with living quarters, a bridge and one or more stacks leading upwardly from the propulsion means and engine room to carry off gases, vapors, smoke, and the like.

In the present invention the vessel breaks ice in a downward fashion as the vessel moves ahead. Since the body of the vessel aft of a maximum beam becomes narrower on the ice-water line vicinity but remains at a maximum beam below the ice breaking water line thereby relieves ice friction and allows room in the broken ice path for the stern to swing giving the vessel greater maneuverability while still maintaining high displacement for given water line dimensions. Ice is also moved away from the rudders and screws when the vessel moves astern.

Thus the combined effects of the invention are the provision of (i) a down breaking bow with a down and inward slope at the maximum beam, (ii) a path in the ice significantly wider than the stern to reduce ice friction and provide room for the broken ice to use as the maximum beam passes, (iii) a wider ice broken path to maneuver the stern for turning the vessel about in heavy ice. A significant slope on the sides of the hull as shown in the drawing assists in breaking the ice and also moving it away from the rudders and screws when moving ahead as well as astern.

The nature and objects of the present invention having been fully described and illustrated and the best mode and embodiments contemplated set forth,

what I wish to claim as new and useful and secure by Letters Patent is:

1. An ice breaking vessel having a hull, bow and stern in which:

the bow is down breaking and has a maximum ice-water line beam forward of the midpoint of the hull;

the ice-water line of the hull aft of the maximum beam having a smaller beam aft of the hull's midpoint;

the maximum beam on the ice-water line slopes downwardly and inwardly;

the hull below the ice-water line having a maximum beam aft of the maximum ice-water line beam, which is maintained in the aft part of the vessel, where the maximum hull beam is greater than the ice-water line beam;

vertical sections through the hull from forward to aft being such that from forward to aft the hull slopes downwardly and inwardly and the hull in the aft sections including the stern slope downwardly and outwardly;

whereby the vessel has greater maneuverability, greater displacement, greater icebreaking facility, and is provided with greater rudder and screw protection against ice when proceeding astern in ice laden or covered waters than conventional ice breaking vessels.

2. A vessel in accordance with claim 1 in which the stern overhangs propulsion means and steering means.

3. A vessel in accordance with claim 1 in the propulsion means is a plurality of screws.

4. A vessel in accordance with claim 1 in which the hull interior has a cargo area comprising a plurality of tanks.

5. A vessel in accordance with claim 4 in which the plurality of tanks are formed by longitudinally and transverse spaced apart bulk heads extending vertically from a main deck of the vessel to the bottom of the hull.

6. A vessel in accordance with claim 4 in which means are provided for separating the tanks from the stern.

7. A vessel in accordance with claim 6 in which the separation means comprises a pump room, cofferdam or fuel oil tank.

* * * * *

United States Patent [19]

Devine

[11] 3,745,960
[45] July 17, 1973

[54] **TANKER VESSEL**

[75] Inventor: **Walter B. Devine,** Houston, Tex.

[73] Assignee: **Esso Research and Engineering Company,** Linden, N.J.

[22] Filed: **May 6, 1971**

[21] Appl. No.: **140,803**

[52] **U.S. Cl.** .... **114/74 R,** 114/78
[51] **Int. Cl.** **B63b 25/08**
[58] **Field of Search** .... 114/74 R, 74 A, 72, 114/73, 76, 78, 116, 65 R

[56] **References Cited**

UNITED STATES PATENTS

3,356,600	12/1967	Field et al.	114/74 R X
3,247,822	4/1966	Laskey et al.	114/74 R
R19,374	11/1934	Butterworth	114/74 R UX
3,399,645	9/1968	Dahan	114/74 R

FOREIGN PATENTS OR APPLICATIONS

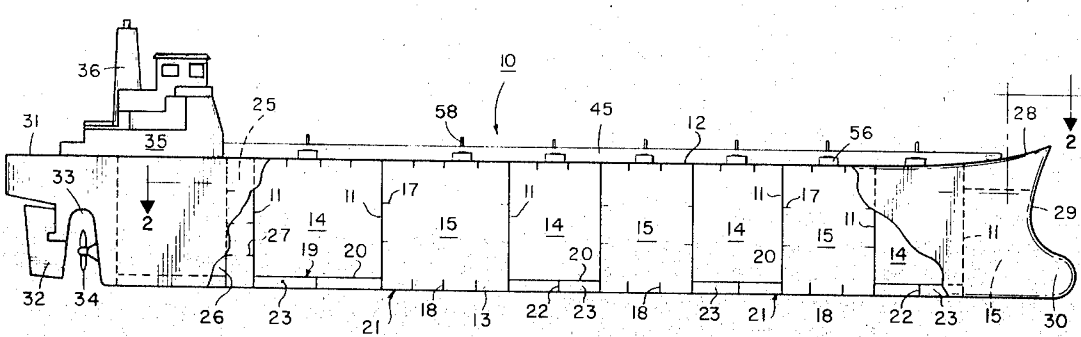
1,311,097	10/1962	France	114/74 R
1,004,760	9/1965	Great Britain	114/74 R

Primary Examiner—Milton Buchler
Assistant Examiner—E. R. Kazenske
Attorney—Thomas B. McCulloch, Melvin F. Fincke, John S. Schneider and Sylvester W. Brock, Jr.

[57] **ABSTRACT**

A tanker vessel for carrying liquid material is provided with a cargo area provided with a plurality of spaced apart longitudinal bulkheads and a plurality of parallel transverse bulkheads vertically extending from the main deck of the vessel to the vessel shell, said bulkheads forming a plurality of wing tanks, first central tanks, selected of the first central tanks having a double bottom, divided by a vertical bulkhead into two tanks. The double bottom carries liquid water ballast only, the first selected central tanks carry water ballast or other liquid products, and the remaining tanks carry liquid products. The first selected central tanks are free of bulkhead stiffeners which are provided on the longitudinal and transverse bulkheads.

6 Claims, 3 Drawing Figures



PATENTED JUL 17 1973

3,745,960

SHEET 1 OF 2

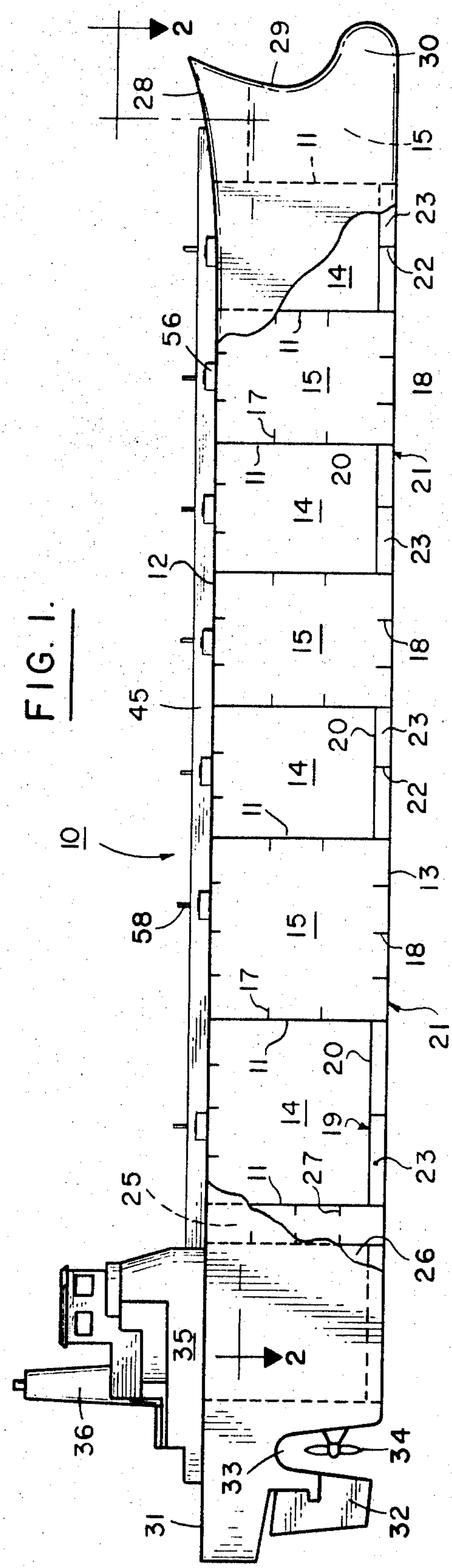


FIG. 1.

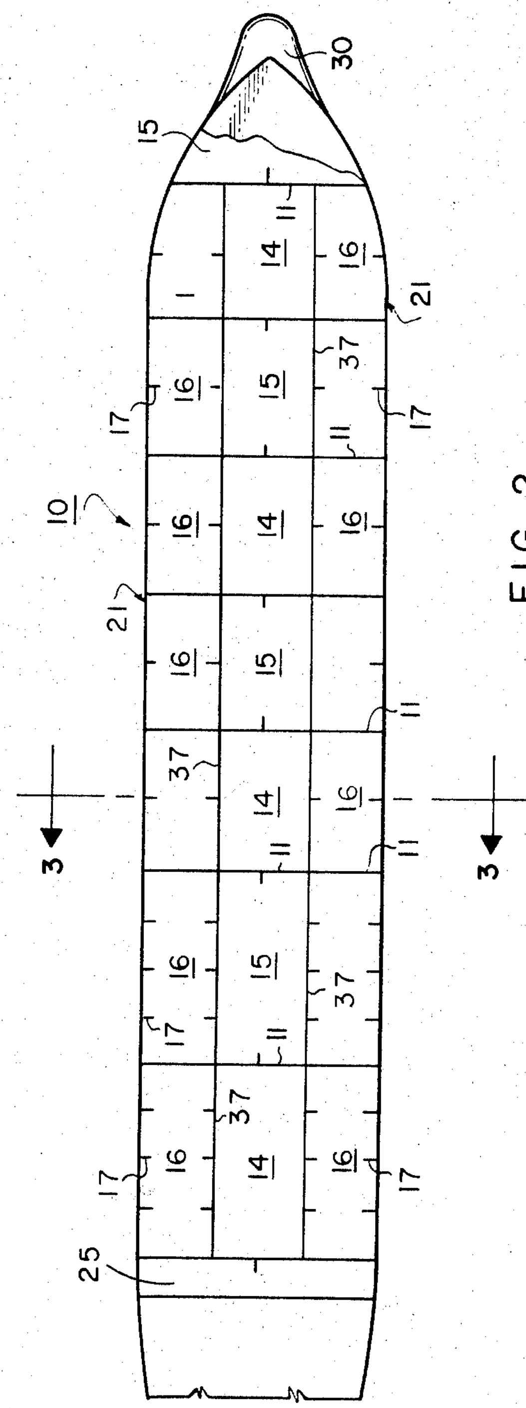


FIG. 2.

INVENTOR.

WALTER B. DEVINE,

BY

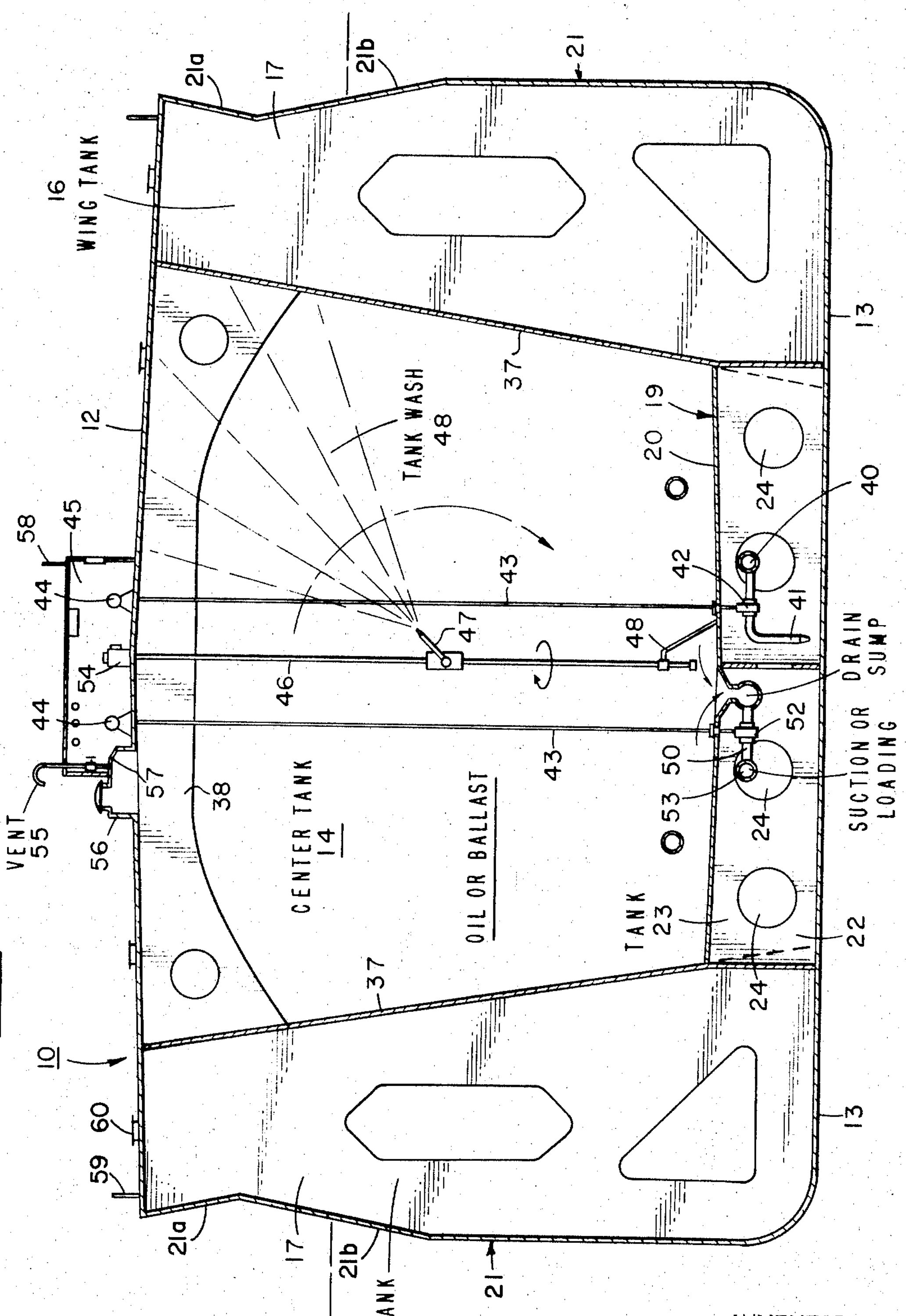
ATTORNEY.

PATENTED JUL 17 1973

3,745,960

SHEET 2 OF 2

FIG. 3.



INVENTOR.
WALTER B. DEVINE,
BY
ATTORNEY.

TANKER VESSEL

CROSS-REFERENCE TO RELATED APPLICATION

This application contains common subject matter to an application entitled "TANK VESSEL" filed May 5, 1971 for Walter B. Devine, Ser. No. 139,430.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is directed to tanker ships particularly marine vessels which are suitable for use in the arctic. More particularly the invention is concerned with a tanker vessel having a particular arrangement of bulkheads and tanks. In its more specific aspects the invention is directed to an arctic tank ship which has an arrangement of tanks wherein there is a minimum of metal exposed to corrosive fluids and in which the strength of the vessel is unimpaired.

2. Description of the Prior Art

It is known to employ longitudinal and transverse bulkheads in tank ships. It is also disclosed in the patent literature that the corrosivity of certain products such as gasoline and the like may be overcome by using a combination of layers of steel of diverse electrochemical potential in tank ships. It is also known to provide tunnels under the tanks of a tank ship to carry pipelines and the like. The prior art teaches the provision of ballast bags in tank ships to avoid contamination with liquefied cargo. Various water ballast configurations have been devised and/or proposed to achieve various tank configurations other than that obtained with intersecting longitudinal and transverse bulkheads. All of these proposals and prior teachings are still open to various objections in providing tank ships wherein the tanks and the ships are constructed in an expensive manner and the problems which are encountered in the arctic where special strength is needed are not solved. It is, therefore, novel and unobvious to provide tanker vessels or ships for arctic usage in accordance with the present invention which are sufficiently strong that navigation in ice covered waters may be achieved.

The following listed U.S. patents were considered in connection with this invention:

U.S. Pat. No. 2,237,321
U.S. Pat. No. 2,428,050
U.S. Pat. No. 2,979,009
U.S. Pat. No. 3,247,822
U.S. Pat. No. 3,364,893
U.S. Pat. No. 3,385,251

SUMMARY OF THE INVENTION

The present invention may be briefly described and summarized as a tanker vessel for arctic and the like use wherein versatile center tanks for arctic tankers are provided wherein said tanks are so constructed and arranged as to carry cargo on one leg of a journey and ballast water on the return leg of such journey. By virtue of positioning bulkhead stiffeners outside selected center tanks and by virtue of fitting said selected tanks with double bottoms, the amount of steel exposed to the different corrosive effects of salt water and oil is significantly reduced. Furthermore, the tanks are easy to clean since the stiffeners are exteriorly positioned and therefore do not interfere with the flow of liquid through the suction ports. The double bottoms serve not only as tanks but also reinforcement for the selected center tanks which are substantially free of internal stiffeners or trusses.

BRIEF DESCRIPTION OF THE DRAWING

The present invention will be described further by reference to the drawing in which:

FIG. 1 is an inboard profile of the tanker ships of the present invention;

FIG. 2 is a sectional view of the main bulkhead arrangement taken along the line 2—2 of FIG. 1; and

FIG. 3 is a cross-sectional view of the tanker vessel taken along the line 3—3 of FIG. 2, showing the inner construction of the wing tanks and selected center tanks as well as the bottom tanks under the selected tanks.

DESCRIPTION OF THE PREFERRED EMBODIMENT WITH RESPECT TO THE DRAWING

Referring now to the drawing and particularly to FIGS. 1 and 2, number 10 designates a tanker vessel such as a marine vessel designed for use in the arctic and like environments. The vessel 10 is provided with a plurality of transverse vertical bulkheads 11 which extend from the main deck 12 to the bottom shell 13. Selected of the bulkheads 11 form selected tanks 14 which are substantially free of internal trusses or stiffeners, and the internal structure, excepting the bulkheads, is not subject to corrosion. The selected tanks 14 may alternate between tanks 15 which are provided with bulkhead stiffeners 17 and beams 18. The bulkheads 37 and 11 with shell 21 form wing tanks 16 along the starboard and port sides of vessel 10.

The selected tanks 14 have double bottoms 19 formed of members 20 and shell 21 of the vessel 10. The double bottoms 19 have internal plates 22 which support the inner bottom 20 and forms inner bottom tank 23 underneath the tanks 14. Plates 22 are provided with openings 24 therethrough for fluid communication in tank 23 and also to allow passage of conduits as shown in FIG. 3. A pump room 25 is defined by one of the transverse bulkheads 11 and a bulkhead 26 and is provided with internal stiffening means 27 which suitably may be trusses. The bulkhead 26 and the bulkhead 27 form an engine room for the motive power for the ship which may be a diesel engine, a steam engine, or nuclear power means, and the like.

The outside shell of the first of the tanks 15 which is used for ballast defines a fore peak 28, a prow 29 having a bulbous bow 30. The stern of the vessel or fantail 31 is provided with a steering means 32 and a tunnel 33 in which is located one or more propulsion means such as screws 34. On the main deck 13 is arranged the bridge and living quarters 35 through which protrudes a stack 36 leading from the engine room to carry off steam, smoke, other vapors, gases, and the like.

In FIG. 2 it will be seen that longitudinal bulkheads 37 intersect the transverse bulkheads 11 and form with the shell and the transverse bulk-heads the several tanks described with respect to FIG. 1.

Referring now to FIG. 3 which is a cross section of the tank ship of the present invention, it will be noted that the tank 14 is strengthened by upper beam 38, inner bottom 20, shell 21, and the internal vertical plate 22 supporting the inner bottom 20 and by using bulkheads 37 referred to in FIG. 2. The wing bulkheads 37 are preferably angled to provide maximum tank capacity for the combination oil/ballast tanks 14 for a minimum steel weight and the upper part of it may form an angle greater than 90° with the main deck 13, while the lower portion of the wing bulkhead 37 may form an angle of 90° with the bottom shell or an angle greater than 90° with the bottom shell as indicated by the dotted lines.

Referring again to FIG. 3, it will be noted that the bottom 20 of tank 14 slopes slightly from each bulkhead 37 toward the center of the vessel where there is provided a drain sump. Connected into the sump is a line 50 which also connects into longitudinally running line 53 and is controlled by a valve 52. A reach rod 43 operably connects valve 52 to a valve control means 44 enclosed in a covered access means 45 on the deck 12.

Extending downwardly into tank 14 from a control means 54 in covered access means 45 is a conduit 46 which is provided with at least one nozzle means 47; line 46 is closed on its lower end adjacent floor 20 and connects to floor 20 by a support means 48 which also acts as an electrical ground. One or more conduits such as 46 may be provided in each tank 14 and may also be adapted to rotate if desired. During tank washing operations, liquids are drawn off by way of the sump, line 50 and line 53, the combination of which also provides means for loading or unloading of the tank 14. Tank vents 55 lead from oil hatches 56 which are provided with viewing ports 57 within the covered access means 45.

Tanks 23 and 15 are also provided with means to load and unload liquids, such as line 41 which connects in a longitudinal line 40 and is controlled by valve 42. Valve 42 is also connected by a reach rod to a control means 44 in covered access means 45. Although not illustrated, wing tanks 16 are also provided with means for loading or unloading liquids. Tank vents 55 lead from oil hatches 56 which are provided with viewing ports 57 in the covered access means 45.

The top of the covered access means 45 is provided with guard rail 58, while the main deck 13 is also provided with guard rails 59. The wing tanks 16 are also provided with Butterworth hatches 60 through which well known Butterworth cleaning means may be inserted and employed to clean the tanks 16 as required.

As also shown in FIG. 3, there is an upper vertical portion 21*a* of the sides of shell 21 which slopes outwardly above a connecting vertical portion 21*b* which slopes inwardly.

It will be seen from the foregoing description taken with the drawing that unobvious and useful results are obtained in that tanks are provided which are substantially free of inner structural means providing minimum exposure of metal to corrosive liquids such as sea water used as ballast and crude petroleum fractions thereof and other corrosive liquids which may be carried by tanker ship.

The present invention is, therefore, quite desirable, unobvious and useful and presents advantages over the prior art.

The nature and objects of the present invention having been completely described and illustrated, what I wish to claim as new and useful and secure by Letters Patent is:

1. A tanker vessel having a shell, main deck, and cargo area for carrying liquid material which comprises:
   a. a plurality of spaced apart longitudinal bulkheads and a plurality of spaced apart parallel transverse bulkheads in said cargo area intersecting said longitudinal bulkheads, said bulkheads extending from the main deck to the vessel shell and forming a plurality of wing tanks and central tanks;
   b. said longitudinal bulkheads forming an angle greater than 90° at least with the main deck;
   c. selected of said central tanks having double bottoms with internal structural stiffening means below the selected central tanks;
   d. bulkhead stiffeners arranged only on the outside of said longitudinal and transverse bulkheads forming said wing tanks and said selected central tanks; and
   e. an upper vertical portion of the sides of said shell sloping outwardly above a connecting vertical portion of the sides which slopes inwardly.

2. A tanker vessel in accordance with claim 1 in which the selected first central tanks are provided with fixed vertical washing means depending from the main deck.

3. A tanker vessel in accordance with claim 1 in which the selected tanks are provided with rotatable vertical washing means depending from the main deck.

4. A tanker vessel in accordance with claim 3 in which the double bottom of each central tank provided with washing means is composed of an inner and outer bottom, the inner double bottom sloping toward the center of the vessel and the outer double bottom being formed by the vessel shell.

5. A tanker vessel in accordance with claim 4 in which each of the inner double bottoms is provided with a ballast line and an oil line for filling and draining the selected central tanks.

6. A tanker vessel is accordance with claim 1 in which the selected first central tanks alternate with other first central tanks having bulkhead stiffeners.

* * * * *

United States Patent [19]

Mott et al.

[11] **3,793,840**

[45] **Feb. 26, 1974**

[54] **MOBILE, ARCTIC DRILLING AND PRODUCTION PLATFORM**

[75] Inventors: **George E. Mott,** Metairie; **James P. Wilbourn,** New Orleans, both of La.

[73] Assignee: **Texaco Inc.,** New York, N.Y.

[22] Filed: **Oct. 18, 1971**

[21] Appl. No.: **189,972**

[52] **U.S. Cl.** **61/46.5**
[51] **Int. Cl.** **E02b 17/00**
[58] **Field of Search** .... 61/46.5, 46; 114/.5 T

[56] **References Cited**

UNITED STATES PATENTS

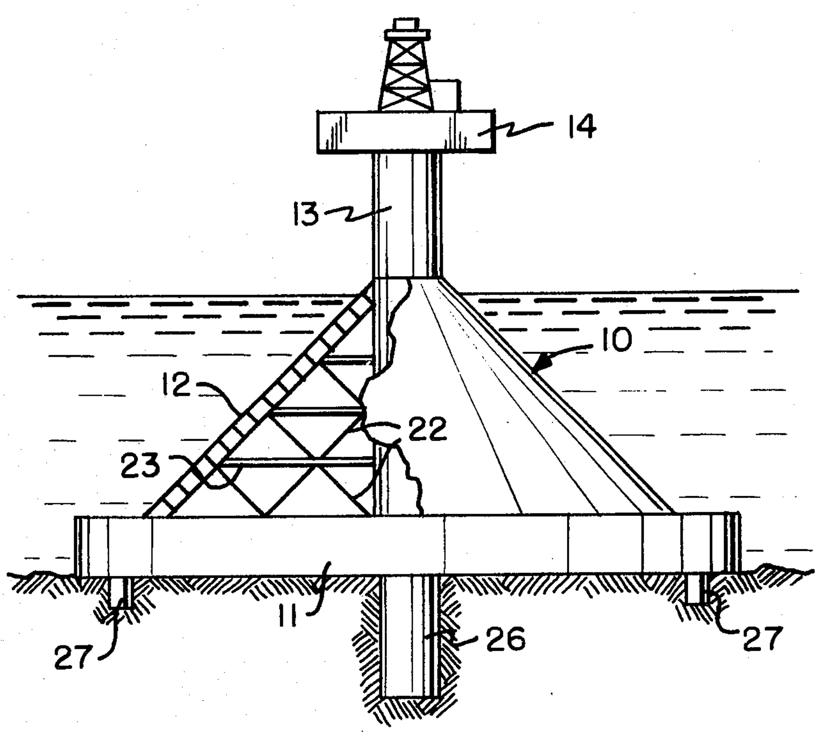
2,574,140	11/1951	Boschen	61/46.5
3,486,343	12/1969	Gibson et al.	61/46.5
2,622,404	12/1952	Rice	61/46.5
3,408,821	11/1968	Redshaw	61/46.5
3,645,104	2/1972	Hogan	61/46.5
2,661,600	12/1953	Hopkins	61/46.5
3,165,898	1/1965	Elliott	61/46.5

Primary Examiner—Jacob Shapiro
Attorney, Agent, or Firm—Thomas H. Whaley; Carl G. Ries

[57] **ABSTRACT**

The invention relates to a marine platform adapted to be removably positioned at an offshore body of water, the surface of which is periodically subjected to sheet ice and floating ice masses. The platform includes a controllably buoyant foundation-like base at its lower end, which normally rests on the ocean floor. A shell-like body extends upwardly from said base and is defined on its external surface by a progressively decreasing cross sectional area from the body lower end, to a point adjacent the upper end. A work deck disposed at, and operably carried at the body upper end includes equipment necessary to function at said offshore site. A caisson extending uprightly through the platform is partially embedded into the substratum beneath the platform, firmly anchoring the latter and protecting wells during and after a drilling operation.

5 Claims, 4 Drawing Figures



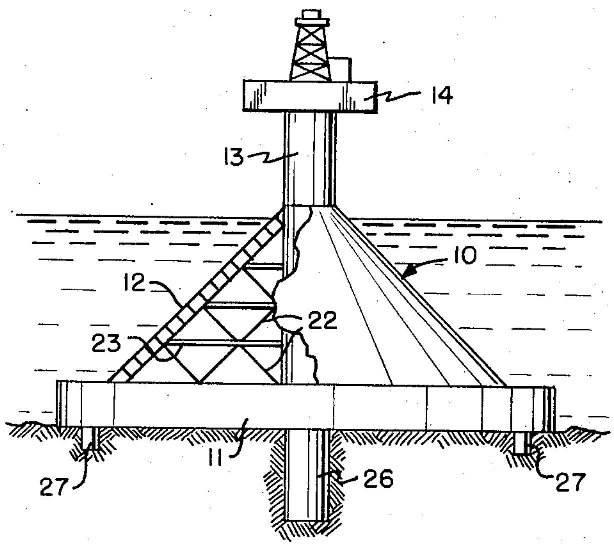


FIG. 1

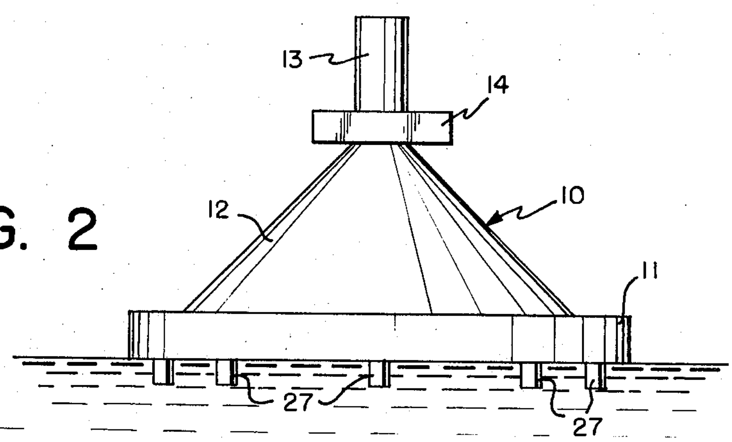


FIG. 2

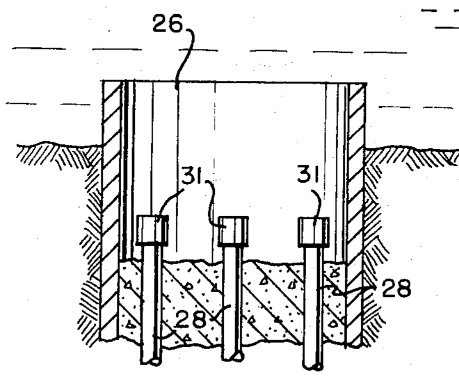


FIG. 4

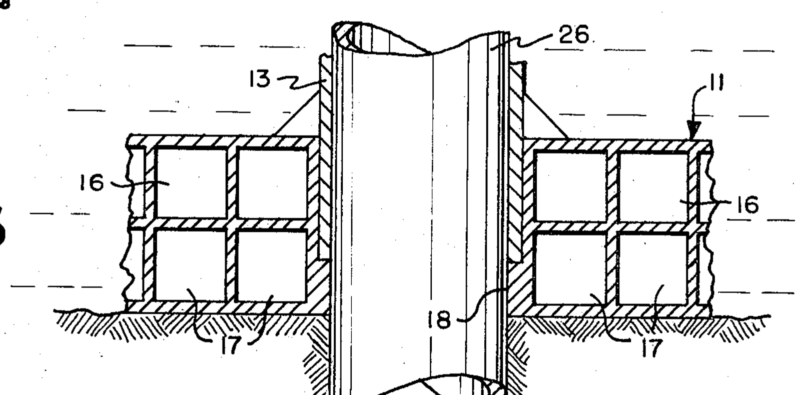


FIG. 3

MOBILE, ARCTIC DRILLING AND PRODUCTION PLATFORM

BACKGROUND OF THE INVENTION

A marine platform of the type presently disclosed can serve many purposes and be utilized by a number of industries. In the specific instance of the petroleum industry, the platform is generally positioned in an offshore body of water to drill into and explore the substratum for the possibility of producing crude oil and gas. Normally, in water depths up to several hundred feet such marine platforms are fixed to the drilling site by piles of similar retaining means.

In the instance of such marine platforms built for use in Arctic tideland waters, the problem of rigid positioning of the unit is compounded by the presence of floating ice during certain periods of, and smetimes for the entire year. More specifically, it is known that for most of the year, the presence of large ice floes as well as moving sheet ice, virtually prohibit the use of any sort of conventional fixed platform.

On the other hand in more protected areas such as Alaska's Cook Inlet, the problem of sheet ice which moves with the tide can be met to a degree by incorporating into the platform specific features to overcome the conditions prompted by the presence of the moving ice.

One method found to be suitable for opposing the lateral thrust of a moving ice mass, whether in the form of floes or an entire ice field, is by fabricating a platform with sufficient mass and with an adequate degree of stability to physically resist the displacing forces exerted on the structure. Such platforms however as a rule are of a relatively permanent nature in that once they are installed at a particular site they are not amenable to be subsequently readily removed or to be reused in different water depths. Thus, if the site proves to be nonproductive, the use of an expensive nonsalvageable platform would result in excessive operating expense.

In addition to the stated problems of initially drilling wells in ice infested waters, the subsequently drilled wells and well head equipment are further jeopardized by heavy ice floes. Ice floes are known to reach to the ocean floor and be of such a magnitude as to scour and dig out the latter. This results in the subjecting to bending, breaking off or otherwise damaging, any sea floor equipment installed in such an environment. Even though the said equipment be buried to a desired depth beneath the ocean floor, it may still be susceptible to physical damage when extraordinary size icebergs or the like are in the area.

It is therefore economical and desirable to utilize a fixed type platform for offshore drilling under ice conditions, and yet provide such a platform that is mobile and can be reused in different water depths if it is determined that a particular area is nonproductive. This problem is suitably countered and overcome by the present marine apparatus. Said structure comprises in effect a platform adapted for drilling, producing or exploratory work in an offshore body of water in which moving ice is prevalent.

The platform is provided with a relatively widespread foundation-like base to afford a firm footing. Further, it is made salvageable such that the platform can be removed from a particular spot and subsequently reset at an alternate drilling or producing location. The platform embodies a downwardly extending heavy walled caisson through which the respective wells are drilled. Said caisson is of sufficient strength and rigidity to resist installation forces and to protect the wells during the drilling operation. When the platform is removed, the caisson may be left in place and thus serves as a well protector. The platform is physically contoured along its exterior particularly along the level at which ice would be concentrated, such as to expose a minimum area thereof to contact with moving ice.

DESCRIPTION OF THE DRAWINGS

FIG. **1** is a vertical elevation in partial cross section of the instant marine structure shown submerged and anchored at an underwater site.

FIG. **2** is similar to FIG. **1** illustrating the platform when buoyed to a floating position.

FIG. **3** is a segmentary view in cross section showing a portion of the structure shown in FIG. **1.**

FIG. **4** is an enlarged segmentary view showing a well head installation subsequent to removal of the anchoring caisson.

Referring to FIG. **1**, a platform **10** of the type contemplated is shown installed at the floor of an offshore body of water. Base **11** comprises in general a circular, octagonal or other multisided barge-like unit disposed at the lower end of the platform, which member ordinarily assumes a horizontal disposition. Base **11** supports an upstanding, conically shaped shell or body **12** having a contoured external surface which connects a relatively broad lower section to a relatively constricted narrow portion at the upper end. Body **12** is further provided with an upwardly extending column **13** along which an equipment deck **14** is operably received. Thus, when the platform is submerged at a working site, deck **14** can be raised or lowered to a desired height beyond the water's surface. Further, when the platform is installed at a drilling site, either the upper end of said shell **12** or column **13** is disposed adjacent to the water's surface whereby to meet, break up and deflect moving ice at the water's surface.

Base member **11** comprises in effect a barge-like vessel formed of a plurality of closed, individually controlled tanks. By regulation of the buoyancy of the respective tanks, the attitude and disposition of the base can be readily regulated between the ocean floor and the water's surface. Base **11** is preferably formed with welded steel or reinforced concrete sections of sufficient strength and so reinforced, as to resist external forces and pressures expected in the depths of water where the platform would normally be positioned. The respective compartments such as **16** and **17** within base **11** are individually separated by discretely placed bulkheads and panels. Thus, selective adjustment of the buoyancy of said compartments results in the platform being raised or lowered to a desired depth or positioned at a desired attitude.

While not presently shown, each compartment **16** and **17** is connected with a buoyancy system regulated from the water's surface and adapted to urge a fluid medium such as water or drilling mud through the respective compartments as required. Said system of course includes means for regulating the flow of said fluids to achieve the purpose of raising or adjusting the level of the barge.

An opening 18 extends transversely and centrally of barge 11, communicating the upper and lower surfaces thereof in a generally vertical disposition.

Elongated, conically shaped shell 12 is disposed with its center axis normal to base 11, extending into and being rigidly connected to the latter. Column 13 also connects to and extends axially through conical shell 12 and base 11. The respective members are thus secured one to the other in a manner to form a rigid, upright structure. The relationship between said members not only assembles the respective parts into a unitary component, but transfers or applies sheer stress and overturning loads applied to column shell exterior, to the widespread base 11. A suitable fastening means between base 11 and shell 12 may be provided by fabricating the shell 12 of reinforced concrete whereby to achieve a satisfactory bonded engagement between the body peripheral lower edge, and the base.

Base 11 is further provided with means to assure its fixed positioning at a desired offshore working site. Thus, said base includes not only center transverse opening 18, but optionally may include openings adapted to receive a plurality of relatively short spud piles 27 which can be driven through the base to engage or be embedded into the substratum after the platform comes to rest on the latter.

The lower edge of conical shell 12 is secured to base 11 and maintains the shell in a substantially upright disposition. One embodiment of said shell comprises a hollow, heavy walled unit formed of reinforced concrete, steel, or a combination of said materials. Preferably, the shell is made in the form of a geometrically conical member characterized by an outer wall surface having a horizontal cross section which decreases as the distance from base 11 increases.

The primary function of conical shell or body 12 is to provide a relatively widespread footing for the platform in conjunction with base 11. Further, said body is provided with a sloping outer contour or surface to best encounter moving sheet ice whereby to deflect the latter upwardly, causing it to break into smaller pieces due to induced bending stresses. While not presently shown in detail, compartments built into the interior of shell 12 are vented to the atmosphere to better control the internal and external pressures while the platform is being submerged.

Elongated, cylindrical column 13 extends coaxially of shell 12 from the point adjacent to base 11 to which it is fastened, to a point beyond the shell 12 upper end. Thus column 13 projects upwardly for a substantial distance beyond the shell upper end when platform 10 is resting on the floor of an offshore drilling site. The primary function of said column is to operably support work deck 14 during the transportation of the platform as well as to provide a means of elevating the work deck 14 a desired distance beyond the water's surface during actual drilling operations.

Column 13 thus comprises an elongated cylindical member formed of relatively heavy walled steel or reinforced concrete. The column lower end is received in receptacle means forming opening 18 in base 11 and is fastened to the latter by cementing, welding, or other appropriate means. The upper end of shell 12 is further fastened to the outer wall of column 13 to fixedly join the entire assembly into a unitary structure. Intermediate support means such as struts, braces 22 and 23 or bulkheads are further disposed within body 12 and radiate outwardly from the column wall to reinforce both the shell and the column, and to permit ballasting of the conical shell 12 as needed.

Toward facilitating movement of deck 14 longitudinally along the column 13 exterior, either to the upper or lower position, the column can be provided with the necessary slots, indentations, protrusions or the like. Said means facilitate gripping of the column wall by a plurality of climbing jacks and claps carried within deck 14. Such jacks are clamps known in the art and are frequently utilized on mobile offshore structures for regulating the disposition of retractable legs carried on the marine platform or structure.

Subsequent to platform 10 being submerged at a desired offshore location, a caisson 26, which has previously been secured inside column 13 and extends longitudinally thereof, is released and jetted into the sea bottom. Base 11 is thus firmly embedded in the substratum beneath the platform quickly and easily without the use of either piles or anchor. A sufficient embedment of said caisson 26 will assist platform 10 in absorbing and transmitting to the ocean bottom, lateral forces imposed on the structure, thus further insuring against the possibility of lateral displacement of the platform.

As shown in FIG. 3, caisson 26 extends preferably in a downward direction through the center of the platform to achieve the desired anchoring function. Further, in connection with a drilling or producing operation, and as shown in FIG. 4, when it is deemed feasible to move the platform, column 13 is free to slide along the embedded portion of caisson 26 as the platform is raised by ballasting.

In such position, the lower remaining end of the caisson serves as a protector or enclosure for both wells and well head equipment at the floor of the drilling site.

In the event that icebergs of other relatively deep ice masses tend to scour the floor of the ocean in the vicinity of submerged wells 28, the protruding portion of caisson 26 will form a barrier about said wells. Should caisson 26 nonetheless be contacted by a floating iceberg in a manner to bend or deform the caisson walls, the internal wells 28 would still be protected due to their position within the caisson which will tend to bend rather than fracture as they are displaced by the ice mass.

Caisson 26 is initially assembled with platform 10 during fabrication of the latter. Thus, it can be floated to the drill site by the buoyant platform. It is appreciated that since caisson 26 will be lowered or driven into the substratum, it will be necessary to add additional caisson sections if the platform is moved to other locations. A number of caisson sections would thus be carried, ancillary to the platform placing operation.

As shown in FIG. 3, when in the installed position, the lower end of caisson 26 is disposed contiguous with walls of the column 13 extending through the shell lower surface. If it is desired to permanently place a platform at a desired location, means may also be provided for cementing or otherwise rigidly fastening the shell 12 upper and lower ends to the casing to rigidize the disposition thereof and to avoid movement in response to pressure exerted against the platform.

As shown in FIG. 1, subsequent to the platform being anchored into position, deck 14 is elevated along column 13 outer surface, beyond the water's surface a predetermined height to facilitate drilling operation and to maintain deck carried equipment beyond the reach of the anticipated waves and ice.

As shown in FIG. **4,** wells **28** may be completed with subsea well heads **31** or extended to the deck elevation for conventional surface cntrols, or may be capped for future use. In the latter event, such equipment may be embedded below the surface of the substratum as a form of protection. In such instance, the remaining, protruding portion of caisson **26** will serve to enclose said well head and equipment until such time as the wells are connected to the surface for producing petroleum fluids.

Subsequent to said drilling operation as noted, platform **10** is separated from caisson **26** by ballasting the latter to raise it a predetermined distance beyond the ocean floor. The platform will then slide upwardly along caisson **26** in an orderly, controlled manner. Thereafter, by controlled flotation of the base **11** and venting of body **12,** the platform can be entirely raised from its position and refloated to an alternate working site.

I claim:

1. A marine platform adapted to be removably positioned at an offshore body of water, the latter being in an environment subject to floating ice, which platform includes;

a submergible base including buoyancy means incorporated therein for controllably regulating the disposition of said base between the floating position at the water's surface, and a resting position at the floor of said body of water, said base having means forming a vertical transverse opening therethrough, a guide column having upper and lower ends, the latter being fixed to and extending upwardly from said base in alignment with said vertical transverse opening, the column upper end being of sufficient length to extend beyond the water's surface when said base is positioned at said floor,

a caisson disposed internally of and contiguous with said guide column, extending longitudinally thereof and having the lower end embedded into the substrate beneath said platform whereby to anchor the latter during a drilling operation, and to subsequently permit upward guided movement of said platform along the caisson when the platform is raised from a submerged position,

an elongated shell characterized by a generally conical external surface, having the broad end connected to said base and having the upper constricted end in engagement with said guide column adjacent the upper end thereof, and

a deck operably carried on said guide column upper end being longitudinally movable therealong for positioning a desired distance beyond the water's surface.

2. A marine platform as defined in claim **1,** including a caisson operably received in said guide column and longitudinally movable through the latter whereby to permit lowering of said caisson downwardly through said base to permit embedment thereof into the floor of said body of water.

3. In an apparatus as defined in claim **2,** wherein said guide column is of substantially uniform diameter and slidable along said caisson outer surface to guide the latter during lowering thereof into the substrate.

4. In an apparatus as defined in claim **1,** wherein said conical shell is of sufficient height to position at least a portion thereof beyond the water's surface when said base is resting at said floor.

5. In a marine platform as defined in claim **1,** wherein said caisson extends upwardly along said guide column to position with the upper end thereof adjacent to and beneath the water's surface.

* * * * *

United States Patent [19]
Hudson et al.

[11] **3,831,385**
[45] **Aug. 27, 1974**

[54] **ARCTIC OFFSHORE PLATFORM**

[75] Inventors: **Thomas A. Hudson,** Balboa Island; **Gordon E. Strickland, Jr.,** Yorba Linda, both of Calif.

[73] Assignee: **Chevron Research Company,** San Francisco, Calif.

[22] Filed: **June 26, 1972**

[21] Appl. No.: **266,084**

[52] **U.S. Cl.** **61/46.5,** 61/1, 114/40, 165/47

[51] **Int. Cl.** **E02b 15/02,** F24j 1/00

[58] **Field of Search** .... 61/46, 46.5; 114/40, 41, 114/42, 5 D; 165/47; 166/.5; 9/8 P

[56] **References Cited**

UNITED STATES PATENTS

993,440	5/1911	Duplessis	114/41
3,632,172	1/1972	Robinson et al.	114/42 X
3,749,162	7/1973	Anders	166/5
3,759,046	9/1973	Anders	61/46.5

OTHER PUBLICATIONS

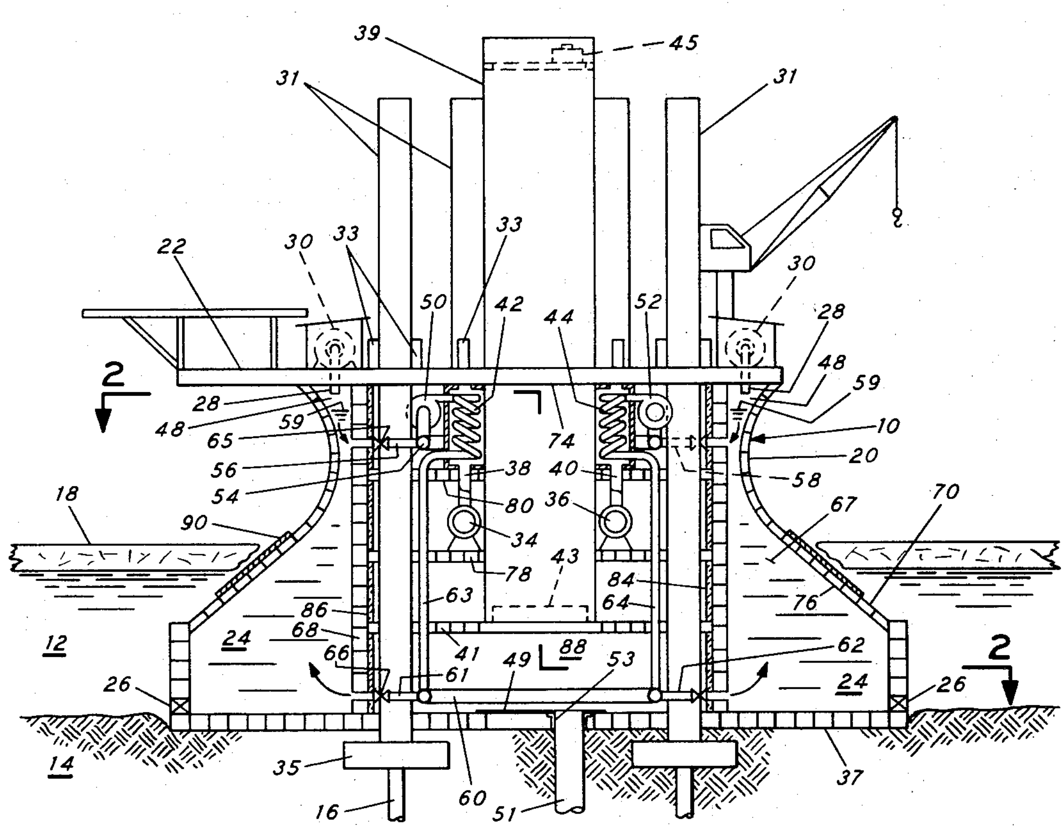
The Oil and Gas Journal of Sept. 14, 1970 pages 60–61.

Primary Examiner—Jacob Shapiro
Attorney, Agent, or Firm—Ralph L. Freeland, Jr.; Charles J. Gibeau

[57] **ABSTRACT**

A method and apparatus for reducing ice forces on a marine structure erected in a body of water which becomes frozen through natural weather conditions. The structure has a wall of heat transmitting material forming its perimetrical surface in the zone where natural ice will freeze onto or impinge against the structure. Enclosed chambers are built within the structure and in heat transmitting relationship with the outer wall and heat is applied to the chambers to heat and maintain the outer wall at a temperature above the melting point of the natural ice occurring in the water around it. In a preferred embodiment the marine structure is formed with a heated wall which slopes upwardly and inwardly in the area of ice contact to provide a ramp-like surface upon which a sheet of ice will be forced with reduced friction as it moves against the structure. Thus an edge of the sheet of ice will be prevented from adhering to the structure and will be lifted above its normal position on the water surface as the ice moves against the structure, causing the sheet to be bent and fractured, reducing the force imposed by it on the structure.

15 Claims, 4 Drawing Figures



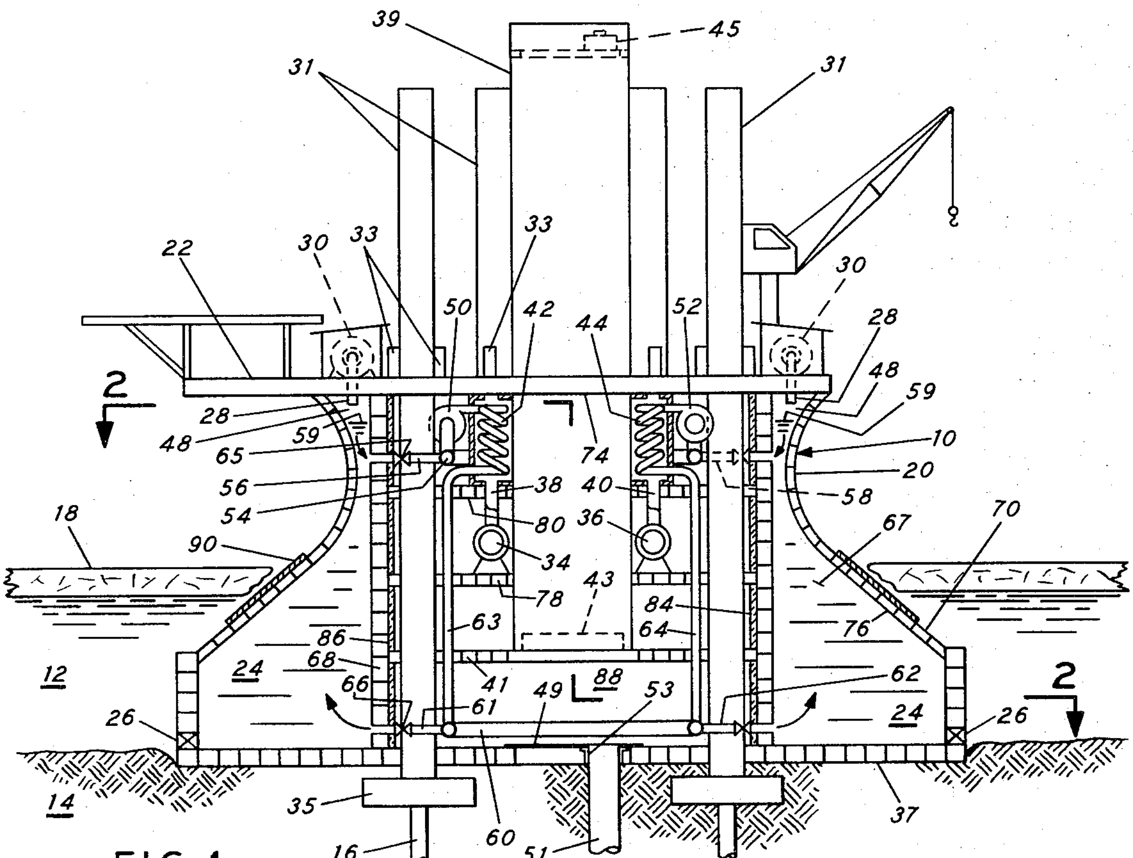

39
45
31
31
33
33
22
30
30
50
42
44
52
28
28
48
48
59
59
10
65
74
20
56
38
40
58
54
80
36
67
18
90
34
70
43
78
84
76
63
64
86
68
62
24
24
12
66
41
88
49
53
61
26
26
2
2
14
35
37
16
60
51

FIG. 1

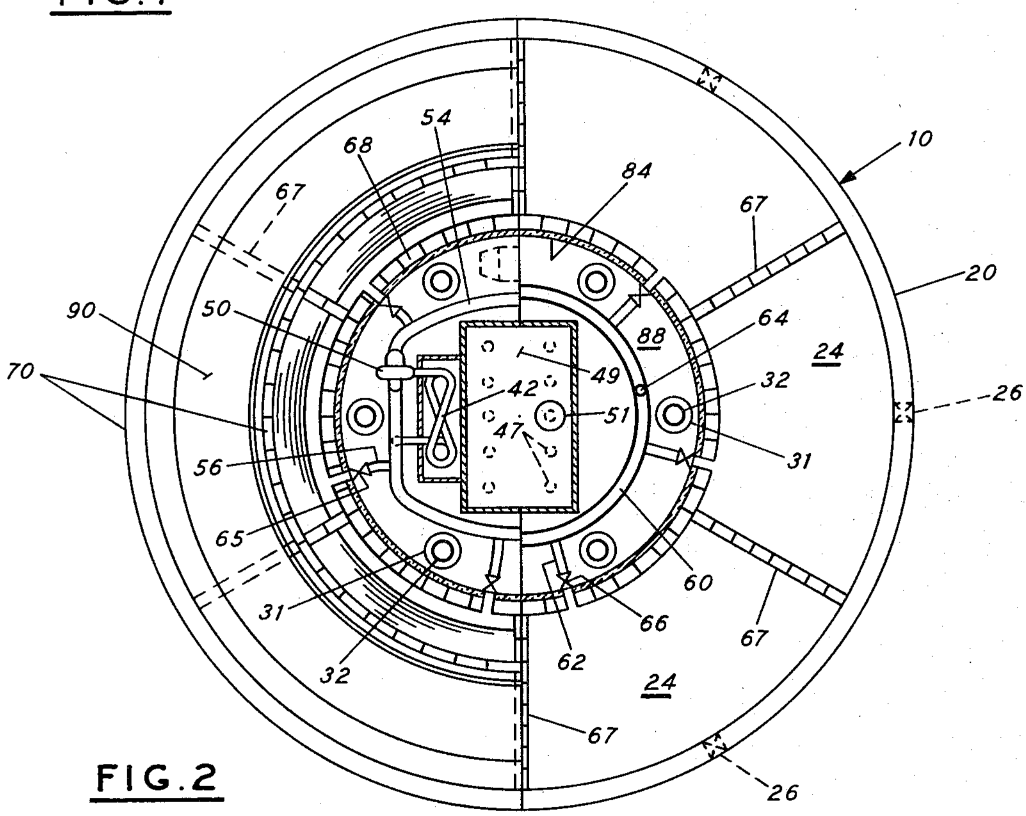

54
10
68
84
67
67
20
90
50
64
88
24
70
49
32
26
42
51
47
31
56
65
60
31
66
67
32
62
24
67
26

FIG. 2

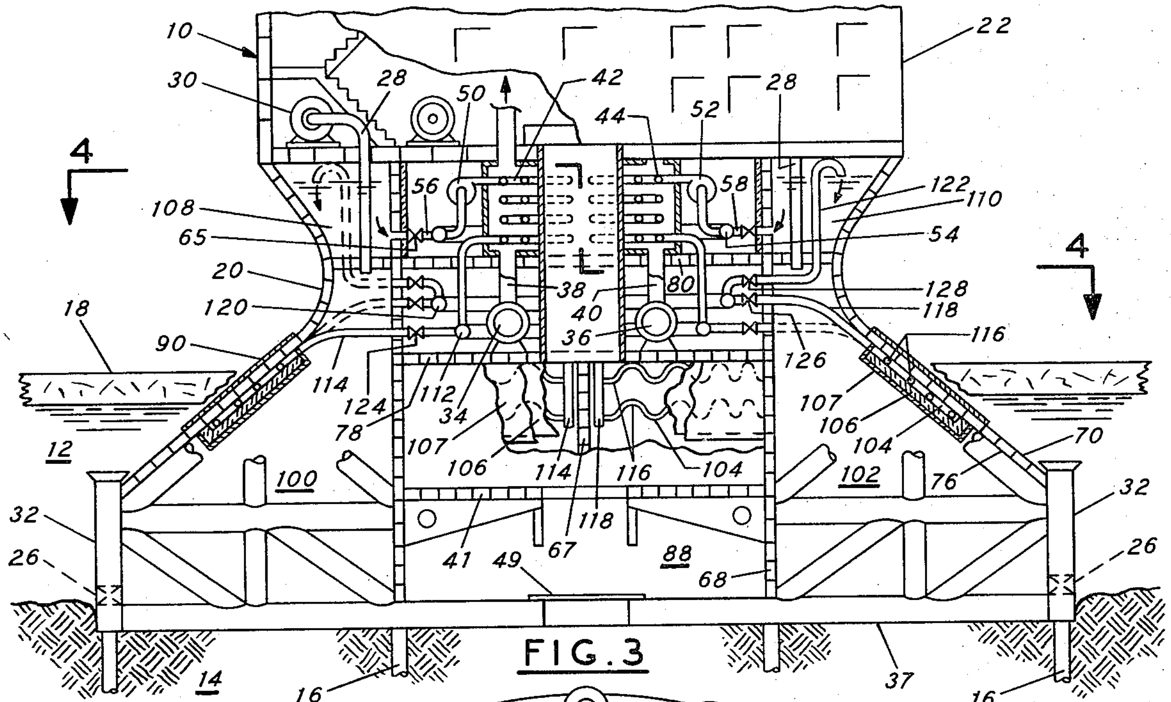

10
22
30
28
50
42
44
52
28
4
56
58
122
110
108
65
54
4
20
38
80
128
18
120
40
118
36
116
90
126
114
124
112
107
34
106
78
104
70
12
107
106
114
116
104
100
102
76
32
32
118
26
26
41
49
67
88
68
14
16
37
16

FIG. 3

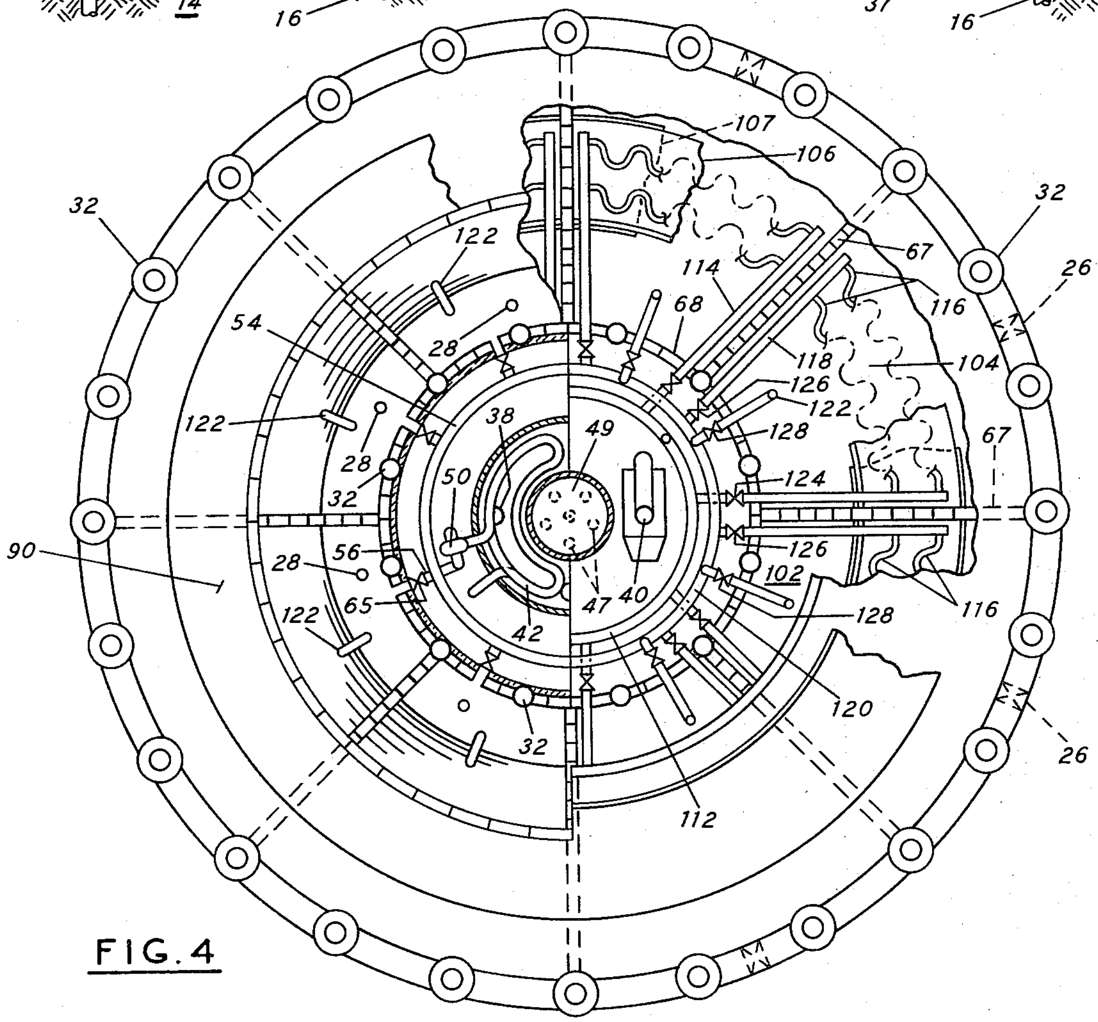

107
106
32
32
122
67
26
114
68
116
54
28
118
104
126
122
122
38
49
128
28
50
124
67
32
90
56
126
28
102
65
47
40
128
122
42
116
120
32
26
112

FIG. 4

ARCTIC OFFSHORE PLATFORM

BACKGROUND OF THE INVENTION

This invention relates to a marine structure for installation in waters upon which thick sheets of ice are formed during the winter season. In arctic and antarctic waters the winter ice normally may reach thicknesses of 6 to 10 feet or more and rafting, pressure ridges, and other accumulations may cause the thickness of the ice in places to be several times the thickness of the original sheet. The ice sheets are of vast area and although normally they may move relatively slowly with wind and water currents, the mass of ice in movement can cause very high forces on a stationary structure in its path. Such ice may have a compressive strength in the range of about 650 to 1,000 pounds per square inch and a structure strong enough to withstand the crushing force of the ice would necessarily be very massive and correspondingly expensive to construct.

It has been proposed heretofore that rather than build a structure strong enough to withstand the total crushing force of the ice, i.e., strong enough to permit the ice to be crushed against the structure and thus enable the sheet of ice to flow around it, the structure be built with ramp-like surfaces which would cause an edge of the moving ice sheet to be forced upwardly above its normal position on the surface of the water as it came into contact with the structure, thus bending the ice sheet and placing a tensile stress in the ice. Since the ice has a flexural strength of about 85 pounds per square inch, a correspondingly relatively smaller force is placed on the structure as the ice impinging on it fails in tension.

Several forms of structures having a sloping perimetrical wall for installation in waters where they would be exposed to the forces of moving ice are illustrated in a paper by J. V. Danys entitled "Effect of Cone-Shaped Structures on Impact Forces of Ice Floes," presented to the First International Conference on Port and Ocean Engineering under Arctic Conditions held at the Technical University of Norway, Trondheim, Norway, during Aug. 13 to 30, 1971.

Another publication of interest in this respect is a paper by Ben C. Gerwick, Jr. and Ronald R. Lloyd entitled "Design and Construction Procedures for Proposed Arctic Offshore Structures," presented at the Offshore Technology Conference meeting at Houston, Texas during Apr. 1970.

In testing in a laboratory cold room scale models of offshore structures incorporating the above design principle to investigate the action upon them of sheet ice it was found that the ramp-type of surface, when moving relative to the ice sheet and in contact with it, caused appreciably less force to be imposed on the platform structure than would be the case if the platform wall presented to the ice sheet was disposed vertically to it as would be the situation if, for example, a proportionately larger diameter pile or caisson was contacted by the moving ice sheet. It was discovered, however, that this condition was true only while the ice sheet could move relative to the platform and that as explained hereinafter ordinarily much larger forces would be imposed on the marine structure before the bond between it and the ice was broken to permit such relative movement.

In the actual installation of a marine structure in arctic waters it is proposed to construct and assemble the structure in a shipyard and tow the assembled structure to the offshore site where it will be established during the time the waters are open and relatively ice-free. At this time the structure will be lowered into contact with the submerged earth and piles may be driven into the earth to hold the structure in place against the horizontal forces imposed upon it. Piles may also be used to assist supporting the vertical loads on he structure.

In the farther northern arctic waters such as the waters off of the north slope of Alaska, the open water season is relatively short, approximately six weeks, after which ice begins to form on the open waters. The ice will freeze around and onto the marine structure which has been fixed at the offshore site. This condition has been duplicated in the laboratory to determine what effect the newly frozen sheet ice would have on a scale model of a ramp-sided offshore structure as described heretofore and particularly to determine what forces would be imposed on it.

As the ice sheet built up in thickness on the surface of the water surrounding the model structure, it also froze onto the surface of the structure in contact with the water. When the ice sheet reached the required thickness for the test, it was found that a much greater force was required to start relative motion between the model and the adhering ice sheet than was required to maintain the relative motion after the adhesive bond was broken. For the conditions of the test, approximately 5 to 10 times as much force, depending on specific conditions, was imposed on the model structure by the ice sheet before the bond was broken than was imposed after this relative motion was established.

The amount of force imposed initially on the structure by the ice sheet will, of course, be dependent on the form, dimensions and characteristics of the structure and the dimensions and characteristics of the ice. But in all cases, as the problem is understood now, a much greater force will be imposed initially on the structure before the adhesive bond between it and the ice is broken than will be imposed after the bond is disrupted. Ordinarily it would be necessary under these conditions to build the structure strong enough to withstand the initial forces imposed on it by the ice sheet even though the forces imposed on it during the major portion of its useful life would not require a structure of such rugged construction. A structure built strong enough to withstand the initial ice forces would be correspondingly more expensive to build and more difficult to install than one designed to take only the load of a relatively moving ice sheet. The present invention is designed to alleviate this condition of initial high loading imposed on the offshore structure by a method and apparatus to be described hereinafter.

SUMMARY OF THE INVENTION

The invention will be described hereinafter as applied particularly to an offshore structure used primarily for drilling oil wells or as an adjunct to producing oil from subaqueous oilfields in regions of the earth where the open waters become frozen on the surface with an appreciable thickness of ice. For simplicity of description, such a structure may be designated hereinafter as an offshore drilling platform although it will be appreciated that the principles of this invention may be applied to other types of marine structures such as offshore production platforms, offshore loading and unloading stations for petroleum tankers, lighthouses, piers or other structures established in a fixed location and exposed to the forces of ice sheets which move on the surface of the water.

Pursuant to the invention a method is provided for preventing the natural ice from freezing on and adhering to the surfaces of the offshore structure exposed to the water in the zone of natural ice formation and appropriate apparatus is exemplified to accomplish this method. This method comprises a system for applying heat to the inner surface of the outer wall or shell of the structure, particularly adjacent the water line where the natural ice will tend to freeze onto or impinge against the outer surface of the shell to cause the temperature of the outer surface of the shell in the area of ice contact to be maintained above the melting point of the ice. The heating system is such that heat can be applied continuously to the shell of the platform while ice is present in the water around it, both to prevent adhesion of ice to the shell and to provide a film of water between the ice and the outer surface of the shell to assist the ice in slipping over and upon this surface when the ice contacts it, both of which features function to reduce the force imposed on the structure by the moving ice sheets.

In a preferred embodiment of the invention, an offshore drilling platform is constructed with a portion of its perimetrical outer wall or shell in the form of a frustum of a cone sloping upwardly and inwardly of the platform at an angle of approximately 45° to the horizontal. The conical surface extends from a location below the region of ice formation on the surface of the water to some distance above the level of the water surface and will function somewhat in the manner of a ramp upon which an edge of a sheet of ice will be raised above its natural level on the surface of the water as the ice moves toward the platform. Thus, the ice sheet will be flexed in the region of the platform causing the ice to fracture and break from the tensile forces resulting from the flexural stress.

Water-tight compartments, which in the preferred embodiment function as water tanks, are constructed within the platform adjacent the outer conical shell and the latter acts as a common exterior wall for both the platform structure and the water tanks. The tanks are connected to pumps for circulating water through them and through heat exchangers, which latter are in communication with the exhaust gases from the engines which generate the power for operating the machinery and other apparatus on the platform. The tanks are filled with water which is heated an amount to maintain the outer surface of the shell of the platform above the melting point of the natural ice which forms around or impinges upon it, thus preventing the ice from freezing onto and adhering to the outer surface of the platform. Preferably the water tanks are of sufficient capacity to contain enough heated water to maintain the critical area of the shell of the platform at a temperature above the melting point of the natural ice throughout a period of at least 24 hours if no additional heat is added to the water during that time. This will provide a safe period for making repairs if the source of heat for the water should fail during the critical period when the ice sheet may otherwise be in a condition to freeze onto the platform and start moving. It will be noted that if the source of heat for the water fails during the time when the ice sheet is in motion so that the intact ice sheet does not adhere to the shell, any additional load imposed on the platform by the ice will be considerably less than the force imposed on the platform by the thrust of an ice sheet which is frozen onto and adhering to the shell.

It is not intended that the invention be limited to heated water tanks placed within the shell of the platform, and other means for performing the method of this invention also will be described hereinafter or will become apparent as the description of the invention proceeds in conjunction with the accompanying drawings which form part of this specification.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic representation, partly in section and with some elements rearranged in position for clarity of disclosure, of an offshore drilling platform incorporating the features of this invention and illustrates the embodiment which employs heated water tanks to maintain the critical areas of the shell of the structure above the freezing temperature of the natural ice around it.

FIG. **2** is a schematic illustration in sectional plan view taken on the line **2—2** of FIG. **1.**

FIG. **3** is a schematic representation in elevation and partly in section of another arrangement of apparatus incorporating the features of this invention and illustrates the use of heat transfer panels to heat the critical area of the perimetrical shell of an offshore structure above the melting point of the natural ice surrounding it.

FIG. **4** is a schematic illustration in plan view and partly in section taken along the line **4—4** of FIG. **3,** with portions broken away to expose details of the assembly.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. **1** represents an offshore drilling platform **10** installed in a body of water **12** in engagement with the underwater bottom **14** to which it is secured temporarily by piles **16.** The platform is designed particularly for installation in arctic waters upon which thick sheets of ice **18** will seasonably be formed. The platform has a lower support portion **20** which extends into the water and forms a base which supports a deck portion **22** above the surface of the water. The lower portion of the platform is exposed to the water and ice forces incident to its environment and is the portion of the platform of principal interest to the present invention. The upper portion of the platform may contain several levels of decks and may be enclosed and heated to provide a reasonably comfortable working environment and protection for men and equipment from the winter weather during which the temperature may drop to the range of −60° F. Without adequate heating facilities in the working areas the operation of the arctic drilling platform would become virtually impossible during a major portion of the year.

Since it is both expensive and difficult to construct and install a drilling platform in arctic waters, it is desirable to provide a platform which is capable of drilling a number of wells from the same location. For example, the drilling platform illustrated in FIG. **1** may be designed to drill **10** or more wells from the same platform site to a depth of approximately 16,000 feet and accordingly is made large enough to accommodate the machinery and equipment necessary for this purpose. By way of illustration only, a platform of this capacity for installation in 40 feet of water may have a bottom diameter of approximately 180 feet and a diameter at the water line of approximately 120 feet. The base portion may have a height of 85 feet and support above it decks and other appurtenant equipment including a drilling derrick reaching to an elevation of approximately 160 feet above the floor of the sea.

A drilling platform of the above-noted dimensions will weigh several thousand tons before it receives any of the machinery and equipment necessary for the drilling operation. The weight of the platform will increase proportionately as it is designed to withstand greater natural forces and since the weight of the structure reflects its cost, the cost will increase proportionately as the weight increases. The present invention is directed toward a procedure for reducing the forces imposed on the base portion by natural ice formations, thus permitting less structural material to be incorporated in it and correspondingly reducing its mass as well as reducing its cost.

For a drilling platform of the size and drilling capacity referred to, power generators adequate to produce approximately 3,300 horsepower will be supplied to operate the rotary table, drawworks, mud pumps and the other equipment and appurtenances necessary for the drilling operation. In accordance with one exemplary embodiment of this invention the waste heat from the power generating source is used to heat the shell of the platform above the melting point of the natural ice surrounding it in the manner and for the purpose to be described in more detail hereinafter. If, for example, the power source selected is a turbine engine and three 1,100 hp gas turbines are used for the power necessary to operate the drilling platform, more than 32,000,000 BTU/hr. waste heat from the turbines will be available for heating the shell of the support structure. This amount of heat is amply adequate to maintain a shell of the dimensions noted above continuously at a temperature above the melting point of the natural ice formed in the water in contact with it.

The structure illustrated in FIG. **1** represents a drilling platform which is towed to the drilling site in a completely assembled and equipped condition and which requires no additional construction at the site except for lowering it into engagement with the sea bottom and, when necessary, securing it with piles. Ballast tanks **24** (FIGS. **1** and **2**) are built into the base portion **20** as an integral part of it to ballast the platform when being towed and to enable it to be lowered through the water into contact with the sea bottom. The ballast tanks are each provided with appropriate sea cocks **26** which can be manipulated remotely from aboard the platform by means not shown but which can be provided for within the skill of the art and each ballast tank has connected to it a respective blowdown pipe **28** which receives air under pressure from a compressor **30.** The sea cocks can be opened to admit water into the ballast tanks or, alternatively, pressurized air can be introduced into the tanks to expel water from the tanks through the sea cocks.

When the platform is under tow, enough water is admitted to the ballast tanks to give it a draft of about 8 to 10 feet and the ballast tanks have sufficient volume to provide adequate buoyant space above the ballast water to give the platform stability in its towing condition. The ballast tanks may of course be trimmed as necessary to compensate for any uneven distribution of weight in the platform.

The drilling platform represented by FIG. **1** is constructed to be readily established with full operating capability at a selected drilling site and with the ability to be removed from one site and established at another in operating condition without delay. To assist this mobility it is desirable that the platform be constructed to be stabilized at an offshore location with a minimum of secondary construction operations, such as the driving of piles, being required to secure it in position against the forces it will be exposed to.

The platform is constructed with a plurality of leg members **31** which are mounted to be moved vertically relative to the body of the platform by corresponding jacking arrangements **33.** The legs have expanded foot portions **35** and contain internal guides **32** (FIG. **2**) for the piles **16.** When the platform assembly reaches a drilling site, and while it still is floating, the leg members are lowered into engagement with the sea bottom. While the jacks are engaged with their respective legs the sea cocks **26** are opened to admit additional water to the ballast tanks **24** increasing the weight of the platform enough to give it negative buoyancy. The footings **35** are designed to control the penetration of the legs into the sea bottom as the weight of the platform increases.

The jacks **33** are now operated to lower the platform along the legs in a leveled controlled condition until the bottom **37** of the platform is seated on the sea floor. The ballast tanks may now be flooded an additional amount, adding sufficient weight to the platform for it to resist being displaced by natural forces.

In locations where the platform will be exposed to adverse conditions such as the thrust of sheet ice, the piles **16** may be driven into the submerged earth to hold the platform securely in position against horizontal loads imposed on it. It is an object of this invention to provide means for reducing considerably the force which otherwise would be imposed on a stationary platform by an ice sheet moving against it, thus enabling a structure to be assembled which is more adaptable to the conditions of use described heretofore.

When the platform is to be moved to another location the piles **16,** if such piles have been used, are cut below the footings **35** or otherwise detached from the platform. The compressors **30** are operated to expel water from the ballast tanks until a condition of buoyancy of the assembly is reached which will permit it to be elevated off bottom along the legs **31** under controlled conditions. Preferable during this operation, sufficient water will be kept in the ballast tanks to give the platform some negative buoyancy and it will be lifted along the legs by the operation of and under control of the jacks **33.** The platform is raised to its floating position, the ballast is adjusted, and the assembly is towed to its new location where it is again set on bottom as described heretofore.

FIG. **1** represents the drilling platform installed at the drilling site and equipped for the drilling operation. The derrick, indicated at **39,** is enclosed for protection from the weather and extends into the body of the structure to a deck **41** which contains a support **43** for the rotary table. The derrick has a crown block **45** which can be shifted to be aligned vertically with each of the several positions **47,** FIG. **2,** on bottom plate **49** through which separate wells may be drilled. The rotary table, not shown, likewise is constructed to be moved into alignment selectively with each of the positions **47.** When a well is being drilled a casing **51** is set in the well bore and sealed with a watertight connection **53** to the plate **49.** If the platform is to be moved to another location, the casing will be detached from the platform and a watertight cover will be secured over the corresponding opening.

As previously indicated, gas turbines may be used as the primary source of power for the platform. Two of the power generating gas turbines **34** and **36** are illustrated schematically in form and position in FIG. **1.** The exhaust from each turbine is led through a respective conduit **38** and **40** to heat exchangers as represented by the coils **42** and **44.** It is within the concept of this invention to provide a bank of heat exchangers which will be in communication with the exhaust ducts of all the power turbines or to provide separate heat exchangers associated with each respective power turbine. However, it is important that there be some redundancy in this portion of the apparatus to provide adequate operating heat exchanger capacity if some portion of the power generating or heat exchanger apparatus must be closed down for maintenance or repair.

In this illustrative embodiment of the invention, after the drilling platform is established in operating condition the ballast tanks **24** are substantially filled with a heat transfer liquid. Atmospheric space **48** is left at the top of the tanks to function as a surge chamber and to provide for expansion of the liquid. Otherwise the ballast tanks may be connected to auxiliary surge tanks, not shown, for this purpose.

The heat transfer fluid may be sea water to which an appropriate corrosion inhibitor has been added to protect the steel surfaces in contact with it. Desirably an antifreeze component is added to the water to prevent it from freezing solid within the ballast tanks and to cause it to remain pumpable if the water is not heated during a period when the shell of the support structure is reduced below the freezing point. Where fresh water is available in sufficient quantity, the ballast tanks may be purged of any salt water they contain and filled with fresh water to which is added a corrosion inhibitor, an antifreeze component and an algicide to make up a compounded heat transfer fluid.

Antifreeze components available for this purpose would be, for example, soluble salts, such as sodium chloride and calcium chloride, an alcohol such as methanol, or a glycol such as ethylene glycol, or a glycerol, or any of several other antifreeze substances which are well known, any of which may be added to the water in the ballast tanks in a sufficient amount to prevent the water from freezing to a nonpumpable condition throughout a predetermined temperature range at a time when heat is not being applied to the water. A corrosion inhibitor is selected to be compatible and effective with the chosen antifreeze component.

The heat exchangers **42** and **44** are connected by appropriate pumps, as **50** and **52,** respectively, to a common manifold **54** from which respective conduits, as **56** and **58,** communicate with the top portion of each individual tank **24** below the level **59** of the water contained in it. The lower portion of each tank is in communication with a common manifold **60** through respective lower conduits, as **61** and **62.** The heat exchangers **42** and **44** are connected to manifold **60,** as by respective conduits **63** and **64** and the pumps operate to draw cooler water from the top portion of the tanks and pump it through the heat exchangers and thence into the bottom manifold **60** from which it is directed into the bottom portion of the tanks **24.** Although a single pump may be used for circulating the heat transfer fluid through the tanks **24,** it is advisable to have at least a second pump connected in the system, either as an operating component or as standby, to insure the continued operation of the system if one of the units should fail to function. Appropriate valves placed in the upper and lower conduits such as, respectively, valve **65** in conduit **56** and valve **66** in conduit **61** provide a means for controlling the flow of heat transfer fluid through an individual tank independently of the flow through adjoining tanks and also provide a means for isolating an individual tank from the heat transfer fluid circulating system as may be necessary for repair or maintenance.

The ballast tanks for a platform of the dimensions described heretofore are designed to hold in excess of a total of 20,000 barrels of water. The heat transfer fluid circulating system is designed to circulate fluid through these tanks at the rate of approximately 800 gallons per minute when the platform is in normal operation and 32,000,000 BTU/hr. will be available from the power generating turbines to heat this fluid. When the fluid in the ballast tanks is heated sufficiently to maintain the outer surface of the support structure shell at approximately 33° F, there will be enough heat stored in the water in the ballast tanks to keep the shell above the freezing point of the ambient water for a period of 24 hours, thus providing a safe period for repairs, or for securing the wells and abandoning the platform if the power generating system on it should fail under conditions which imperil the safety of the platform.

The platform shown in FIGS. **1** and **2** indicates, by way of example, six ballast tanks **24.** However this is not a critical number and more or fewer tanks may be appropriate for particular platforms. The tanks illustrated are separated by radially disposed watertight walls or bulkheads **67** and are closed on their radially inwardly sides by a cylindrical wall or bulkhead **68.** The radially outer wall of the tanks is the perimetrical wall or shell **70** of the lower portion **20** of the platform.

FIG. **1** also indicates the ballast tanks as extending from the watertight bottom **37** of the platform up to the bottom deck **74** of the upper portion **22** with the heat transfer fluid in the ballast tanks in direct heat transfer contact with the inner surface **76** of outer wall **70** throughout substantially all of this region. However, for some platforms, it will be sufficient to provide tanks for the heat exchange fluid which, although of adequate capacity, are of less volume than those indicated in the drawings. Such smaller tanks will be distributed around the inner surface **76** of the wall **70** and be constructed to expose the inner surface to contact with the heat exchange fluid throughout the area where natural ice could freeze to the shell, extending for a distance above and below the surface level of the ambient water, to maintain this zone of the shell above the melting temperature of the natural ice in contact with it. By this construction a weighted dry ballast may be used which requires less space than water ballast and thus provides additional dry working area within the platform.

In the illustrated embodiment the cylindrical bulkhead **68** defines working space at the core of the platform and appropriate decks, as **41, 78** and **80** are provided to support men and machinery. Although this space will be heated to a comfortable working temperature which normally may be above the temperature of the fluid in the tanks **24,** there is nevertheless provided a layer of insulation **84** placed against the radially inner surface **86** of bulkhead **68** to reduce heat loss from these tanks if the temperature of the core area **88** should be below that of the tanks.

Preferably a wear plate **90** is secured to the outer surface of the shell in the zone on the platform of ice contact to strengthen this area and to receive the impact and abrasive action of the ice sheet bearing against the support structure.

FIGS. **3** and **4** represent an alternative arrangement of apparatus embodying the present invention and indicate also a modified form of platform to which it is applied. The same numerals as used previously will be used again where applicable in relation to FIGS. **3** and **4** to designate corresponding elements.

In this modification the lower support portion **20** and the upper deck portion **22** may be constructed as separate units which will be assembled together at the offshore site. The support portion has pile guides **32** built into it around its periphery as well as through its central section to receive a corresponding number of piles **16.**

The support portion of the platform is towed to a chosen offshore location and sunk into contact with the sea bottom by increasing the ballast weight. Piles **16** are then inserted through the pile guides **32** and driven into the submerged earth. The support section is leveled and the piles are grouted to the pile guides to hold the platform securely in position against the horizontal and vertical loads imposed on it. Subsequently, the upper deck portion **22** is lightered to the location and assembled on the stabilized lower portion.

In this modification, as in the platform illustrated in FIG. **1,** a watertight bulkhead **68** surrounds the central area **88** of the platform and defines the inner wall of compartments **100** and **102** which may be used as ballast tanks for trimming the platform under tow and for sinking it at the well site in the manner described heretofore. However, rather than filling the compartments with the heat transfer fluid to keep the shell of the support section above the freezing point of the ambient water, panels of coils of tubing are fitted to the inner surface of the shell in heat transfer relationship and the panels are manifolded together to receive the heat transfer fluid from heat exchangers which are exposed to the exhaust gases of the power generating turbines for the platform in a manner similar to that described heretofore. In this modification of the invention after the drilling platform has been secured to the underwater bottom, the water may be displaced from the individual compartments which are then loaded with sufficient dry weighting material to compensate for whatever residual buoyancy the assembled platform may have. This procedure reduces the corrosion problem of the interior surfaces of the compartments caused by water contained in the tankage and also provides additional dry working or storage space within the confines of the platform.

Referring still to FIG. **3,** the heating panels **104** are placed against the interior surface **76** of the shell **70** in heat transferring relationship throughout the area which will be in contact with the ice sheet **18** formed on the surface of the ambient water and preferably will extend for some distance above and below the thickness of the sheet to assure that this area of the shell will be elevated in temperature above the melting point of the surrounding ice. A wear plate **90** is secured to the outer surface of the shell in this area for the purpose described heretofore. The panels of heating coils are covered on their inward surfaces with a layer of insulating material **106,** such, for example, as a foamed urethane to confine the heat from the panels to the shell of the platform in this area. Preferably the insulating material is in turn covered by a cover **107** secured in a watertight manner to the surface **76** to prevent water in the ballast tanks from contacting the heating panels and the insulation.

In operation a heat transfer fluid of the type described heretofore flows from surge tanks, as **108** and **110** into a manifold **54** from which it is taken by pumps **50** and **52.** The pumps deliver the fluid to heat exchangers **42** and **44** which receive heat from the exhaust gases of the platform power generating engines **34** and **36** through ducts **38** and **40.** The fluid flows from the heat exchangers to a manifold **112** and from the manifold respective conduits **114** conduct the fluid to the heat transfer panels **104.** The fluid is pumped through the tubing **116** of the panels and thence flows through respective conduits **118** into a manifold **120** from which it is conducted by piping **122** to the respective surge tanks as **108** and **110.**

Appropriate valving is placed in the system to provide for the control of the fluid circulation to any one of the panel sections or to any surge tank and to enable these portions of the apparatus to be taken out of the operating system for maintenance or repair. Thus, respective valves **124** are placed in the conduits **114** from the manifold **112** to the corresponding sections of the heat transfer panels **104** and respective valves **126** are placed in the conduits **118** carrying the return fluid from the heat transfer panels to the manifold **120.** In like manner, each section of the surge tankage can be isolated independently of the others by a respective valve **128** placed in the piping **122** which leads from the manifold **120** to the surge chamber and by a corresponding respective valve **65** in the conduits, as **56** and **58,** from the individual surge chamber, as **108** and **110,** to the manifold **54.**

Since in the modification illustrated in FIG. **3** the heat for the shell **70** of the support section of the platform is concentrated in the zone of ice formation in the surrounding water, less total heat will be required to maintain this portion of the shell above the melting point of the natural ice than was used for the modification of the invention described in relation to FIG. **1** and less heat generating capacity will be required for this purpose.

It is within the concept of this invention that, under some conditions of ambient weather and the platform configuration, the shell of the platform in the zone thereon of ice formation can be heated above the melting point of the ice by diverting the exhaust gaseous fluids from the power generating engines through appropriate ducting into heat transferring contact with the inner surface of the shell to function as the heat transfer fluid. Also, it is within the concept of this invention to provide sufficient power generating means aboard the platform to generate power for panels of electrical heating elements arranged in a manner similar to that described with reference to the heat transfer panels illustrated in FIGS. **3** and **4**.

If it is desired to keep the platform on location after the drilling operations are completed, when it no longer is necessary to generate the amount of power required for drilling, auxiliary sources of power may be used directly to supply the heat necessary to prevent ice from adhering to it. Thus, a steam boiler may be used which is designed primarily to supply the heat transfer fluid for the ballast tanks **24** or for the heating panels **104**, or the heat may be supplied by a power source external to the platform, as by connecting panels **104** of electrical heating elements to a source of electrical power generated apart from the platform.

The inventive concept is directed to the method and appropriate apparatus for reducing the forces imposed by natural ice on an offshore platform. For platforms of the dimensions recited in the specification by way of example, the force imposed on such a platform by the movement of a sheet of ice 8 feet thick frozen on and adhering to its steel shell will be approximately 10,000,000 to 20,000,000 pounds total. When the shell is heated above the melting point of the ice and the adhesion is broken, the force of the ice sheet upon the platform will be reduced in the order of five to ten times for a total force of approximately 2,000,000 pounds.

A preferred embodiment of this invention and a modification of it have been described herein. However, it is apparent that other modifications may be made to the exemplary arrangement of apparatus disclosed herein without departing from the inventive concept and it is intended that the invention include all of the modifications and equivalents within the scope of the appended claims.

What is claimed is:

1. A method for reducing ice forces on a marine structure established in a fixed condition in a body of water which becomes frozen through ambient natural conditions, comprising:

forming an enclosed chamber in said marine structure at a position on said structure at which an exterior surface of a wall portion of said chamber will be in contact with said water and in an area on said structure of potential contact with ice caused by natural freezing of said water,

disposing said exterior surface of said wall portion at an angle inclined to the surface of said water to form a sloping ramp-like surface to receive and elevate above its natural level an edge portion of a sheet of ice as said sheet of ice moves into contact with said surface,

placing a controllable source of heat in communication with the interior of said chamber,

heating the interior of said chamber an amount at least sufficient to cause the temperature of said exterior surface to be above the melting point of natural ice formed in said water adjacent said structure,

and controlling the heat of said interior to maintain said temperature of said exterior surface above said melting point as said ambient conditions at the location of said structure changes,

thereby preventing said ice from freezing onto and adhering to said exterior surface thus reducing the force exerted on said fixed structure by a relative movement of said ice which is in contact with said exterior surface and assisting the ice in slipping over and upon said surface as said movement of said sheet of ice is continued.

2. The method in accordance with claim **1** wherein said interior of said chamber is heated by a heat transfer fluid at a temperature above the melting point of said ice,

and wherein said heat transfer fluid is heated and circulated through the said interior of said chamber at a controlled rate sufficient to cause said temperature of said exterior wall to be maintained above the melting point of said ice.

3. The method in accordance with claim **2** wherein said heat transfer fluid is a liquid which is heated by heat generated from a source on said marine structure and is circulated through a heating means therefor and through said chamber by a circulating pump mounted on said marine structure.

4. The method in accordance with claim **2** wherein said heat transfer fluid is heated by the waste heat exhausted from an engine employed to generate power to operate the machinery and equipment associated with said marine structure.

5. The method in accordance with claim **2** wherein said heat transfer fluid is a mixture comprising water, an antifreeze component and a component to inhibit corrosion of the walls of said interior of said chamber.

6. A method for preventing ice from adhering to a selected surface of a marine structure established in a fixed condition at a location in a body of water which becomes frozen through ambient natural conditions, comprising

forming an outer wall for said structure at a position which will be in contact with said water in a zone of natural freezing of said water,

disposing said outer wall at an angle to the surface of said water to form a sloping wall at least throughout the region of said zone,

constructing said sloping wall to receive an edge portion of a sheet of ice which moves against said wall,

said wall being formed of a material which transmits heat and having an interior surface exposed within said structure and an exterior surface in contact with said water,

heating said interior surface of said wall by means of a source of heat generated on said structure,

and controlling said heat to maintain said exterior surface of said wall above the melting point of ice formed naturally in said water adjacent said structure as the weather conditions at the location of said structure changes to provide a film of water between said wall and said ice in contact with said wall portion,

said film of water providing a means for reducing the force imposed on said structure by said ice as said ice moves upon said structure in engagement with said wall.

7. A method for reducing the force imposed on a marine structure established in a relatively fixed location by the movement against it of a sheet of ice present in the water adjacent the said structure, comprising

constructing said structure with an outer surface which is sloped inwardly and upwardly of said structure in the area of potential contact with an ice sheet present in said water, heating said surface to a temperature above the melting point of said ice to prevent said ice from freezing on and adhering to said surface,

maintaining said surface at a temperature above the melting point of said ice continuously during the time a sheet of ice exceeding a predetermined minimum thickness is present in the water adjacent said structure to maintain a film of water between said surface and said ice,

constructing said heated surface to function as a ramp to cause a portion of a sheet of ice which moves against said structure to be lifted and bent from its normal position on said water,

said film of water providing a means for reducing the force imposed on said structure by said ice as said ice moves relative to and against said structure and in engagement with said surface,

selecting an angle of slope of said surface of an amount to cause said portion of said sheet to be bent sufficiently to fail in bending and to fracture said ice as it moves against said structure,

thereby reducing the force imposed on said structure by a sheet of ice moving relative to and in contact with said surface to an amount less than that imposed by the movement of an unfractured sheet of ice which is frozen onto said surface.

8. A marine structure constructed to be maintained in a fixed position in a body of water which becomes frozen through natural conditions, comprising

a support portion of said structure,

said support portion extending into a body of water and supporting a work platform above the surface of said water,

a perimetrical wall of said support portion in contact with said water and extending from below the surface of said water to above said surface,

said wall constructed to be disposed at an angle inclined to said surface of said water to provide a ramp-like surface to receive a sheet of ice moving relative to and in contact with said structure,

at least one circumferentially disposed chamber within said support structure with said perimetrical wall forming the outer wall of said chamber,

means for circulating a heat transfer fluid through said chamber,

and means on said structure for heating the circulating said heat transfer fluid an amount sufficient to maintain the temperature of said perimetrical wall above the melting temperature of natural ice occurring in said body of water adjacent said wall.

9. A marine structure in accordance with claim **8,** including

engines on said structure for providing motive power for the operation of equipment on said structure,

exhaust gases produced by the operation of said engines,

heat exchanger means on said structure,

means for directing said exhaust gases to said heat exchanger means, and

means for circulating said heat transfer fluid through said heat exchanger means to provide said heating of said heat transfer fluid.

10. A marine structure in accordance with claim **9** wherein said heat transfer fluid is a mixture comprising water and an antifreeze component.

11. Means for reducing the effect of ice forces on a structure established and maintained in a fixed position in an open sea environment, which sea becomes frozen at the surface through natural conditions, comprising

a marine structure positioned in an open sea environment in fixed relationship to the bottom of the sea,

a perimetrical wall on said structure,

a selected area of said wall being formed of a material which readily transmits heat,

an outer surface of said selected area of wall positioned to be in contact with the ice of said sea, and disposed at an inclined angle to the surface of said water in a position to receive and support an edge portion of a sheet of ice which continuously moves into contact with said selected area and to elevate said edge portion above its natural level an amount to cause said sheet of ice to fracture continuously adjacent said structure,

an inner surface of said selected area of wall,

means for excluding said sea from contact with said inner surface,

said selected area of wall extending upwardly from below the surface of said sea to above said surface at least throughout a zone of natural freezing of said water,

a source of heat on said structure, and

means for applying heat from said source to said inner surface of said selected area of wall in an amount to maintain the temperature of the said outer surface in the region of said zone above the melting point of said ice in contact with said structure to provide a film of water between said ice and said area of said wall thereby to reduce the force transmitted from the continuously moving said ice to said structure.

12. Means for reducing the effect of ice forces in accordance with claim **11** in which the said selected area of said perimetrical wall is sloped upwardly and inwardly of said structure at an angle of approximately 45° to the horizontal to provide a ramp-like surface to receive and elevate above its natural level on said sea a portion of a sheet of ice which moves against said structure, thereby to cause said sheet of ice to bend and break adjacent said wall.

13. An offshore drilling platform for use in a body of water which becomes frozen through natural conditions, comprising

a supporting base portion constructed to be installed in a relatively fixed position in a body of water,

platform decks supported by said portion above the surface of said water,

a circumferential wall on said base portion with at least a portion of said wall being made watertight and with a frustoconical form converging upwardly of said drilling platform and extending from a location below the surface of said water to a location above said surface,

ballast compartments within said base portion and adjoining said portion of said wall in heat transmitting relationship,

said base portion constructed with sufficient buoyant capacity to maintain said drilling platform in a floating condition to permit said platform to be towed through said water,

means for admitting ballast into said ballast compartments to decrease said buoyant capacity an amount to cause said drilling platform to be lowered into contact with the underwater bottom, means for displacing ballast from said ballast compartments,

means for circulating a heat transfer fluid through said ballast compartments,

means for heating said fluid an amount sufficient to increase the temperature of said portion of said body of water adjacent said drilling platform and in contact with said portion of said wall.

14. An offshore drilling platform in accordance with claim **13** including

a power generating engine on said platform,

waste heat produced by said engine,

and means for heating said heat transfer fluid with said waste heat.

15. An offshore work platform for use in a body of water upon which ice is formed through natural conditions, comprising,

a base portion positioned in a body of water,

means securing said base portion to the underwater bottom,

a deck portion supported by said base portion above the surface of said water,

a wall section on said base portion and extending from below said surface of said water to above said surface,

said wall section formed converging upwardly and inwardly of said platform at least in the region of contact of said surface of said water with said wall section and constructed to receive and elevate above its natural level a portion of a sheet of ice which moves on said body of water into contact with said wall section,

a watertight compartment enclosed within said wall section approximately in horizontal alignment with said region,

heating means within said compartment and in heat transfer relationship with said wall section,

and means on said platform for operating said heating means to heat said wall section in said region above the melting point of ice formed in said water and in contact with said wall section thereby to form a lubricating film of water in the area of contact between said sheet of ice and said wall section.

* * * * *

PO-1050
(5/69)

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,831,385 Dated August 27, 1974

Inventor(s) Thomas A. Hudson and Gordon E. Strickland, Jr.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2, line 10, "he structure" should read --the structure--.

Column 15, line 13, "said heat" should read --said circulating heat--.

Signed and sealed this 12th day of November 1974.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

United States Patent [19]

Bhula

[11] **4,427,320**

[45] **Jan. 24, 1984**

[54] **ARCTIC OFFSHORE PLATFORM**

[75] Inventor: **Dilipkumar N. Bhula,** Houston, Tex.

[73] Assignee: **Shell Oil Company,** Houston, Tex.

[21] Appl. No.: **350,458**

[22] Filed: **Feb. 19, 1982**

[51] **Int. Cl.**[3] **E02B 17/00**

[52] **U.S. Cl.** **405/211;** 405/217

[58] **Field of Search** 405/61, 195, 211, 217

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,215,952 8/1980 Baardsen 405/211
4,252,471 2/1981 Straub 405/211
4,335,980 6/1982 DePriester 405/217

FOREIGN PATENT DOCUMENTS

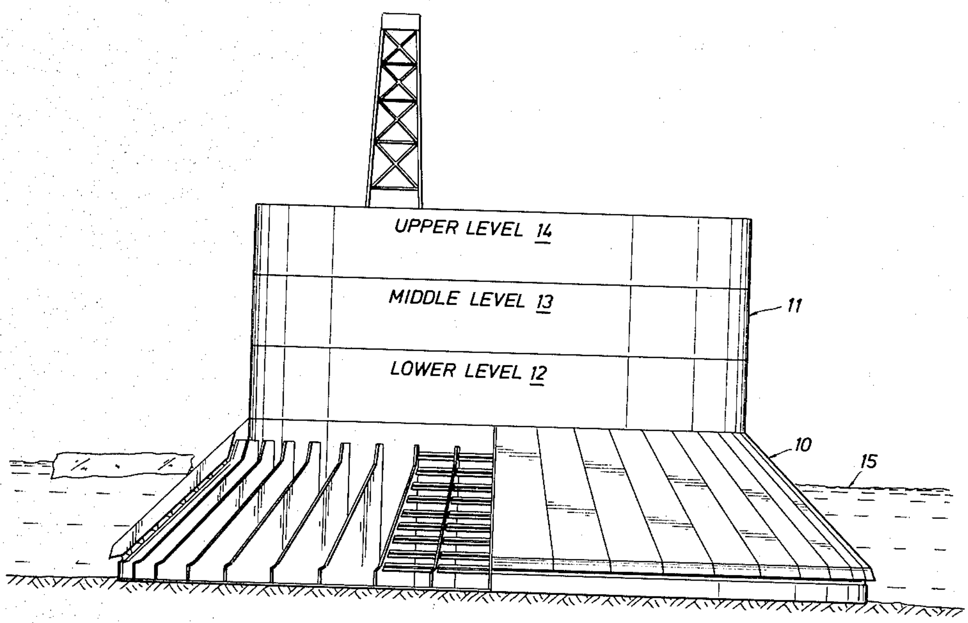
1081483 7/1980 Canada 405/211

Primary Examiner—David H. Corbin

[57] **ABSTRACT**

An offshore structure for use in drilling and producing wells in arctic regions having a conical shaped lower portion that extends above the surface of the water and a cylindrical upper section. The conical portion is provided with a controlled stiffness outer surface for withstanding the loads produced by ice striking the structure. The stiffness properties of the outer shell and flexible members are designed to distribute the load and avoid high local loads on the inner parts of the structure.

6 Claims, 6 Drawing Figures



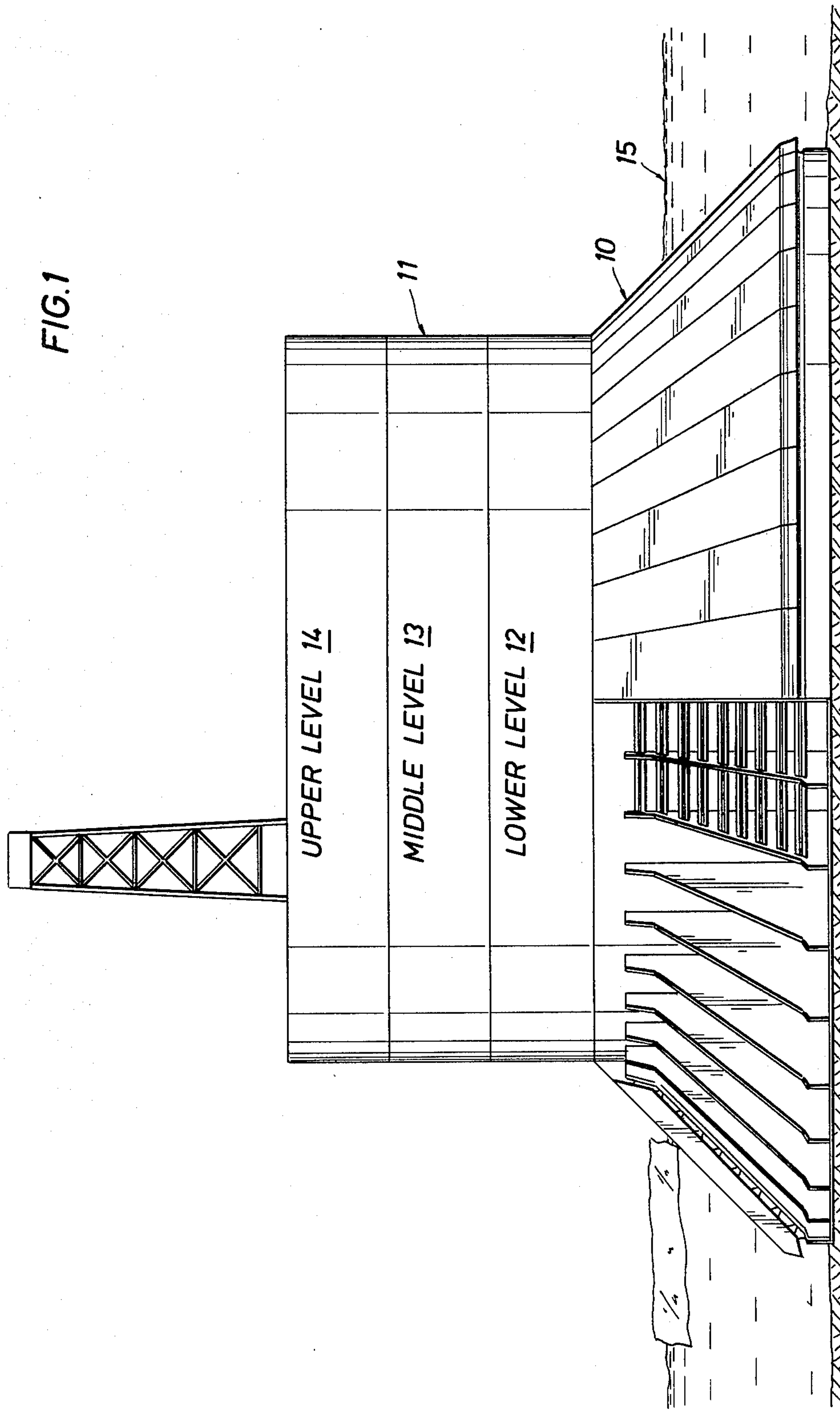


FIG. 1

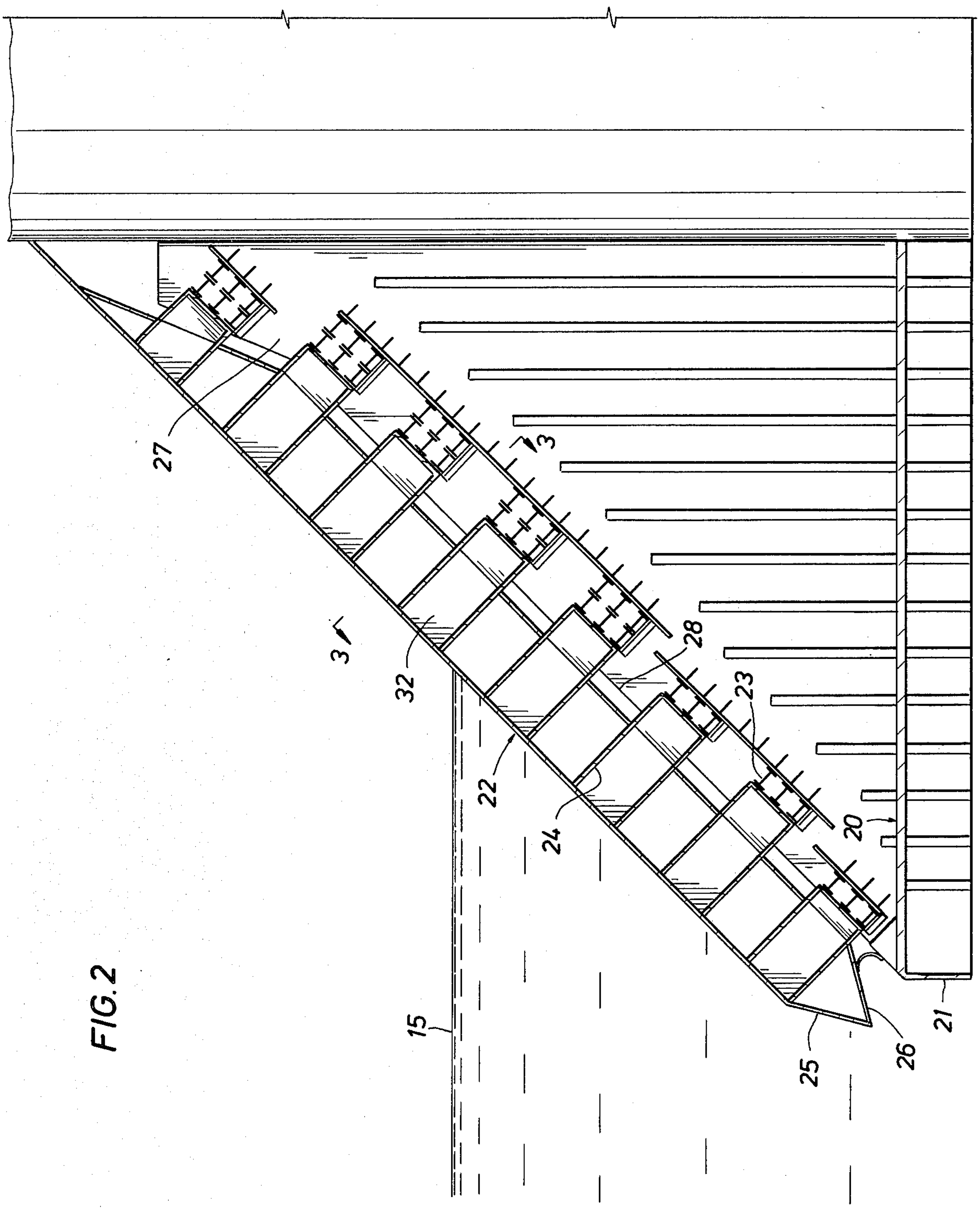


FIG. 2

FIG. 3

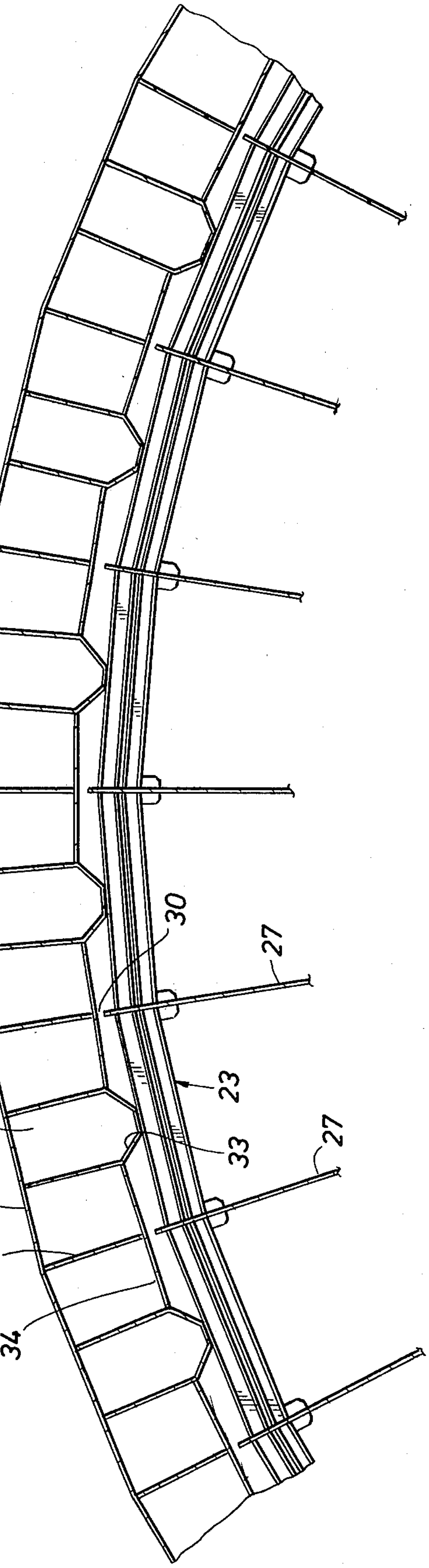
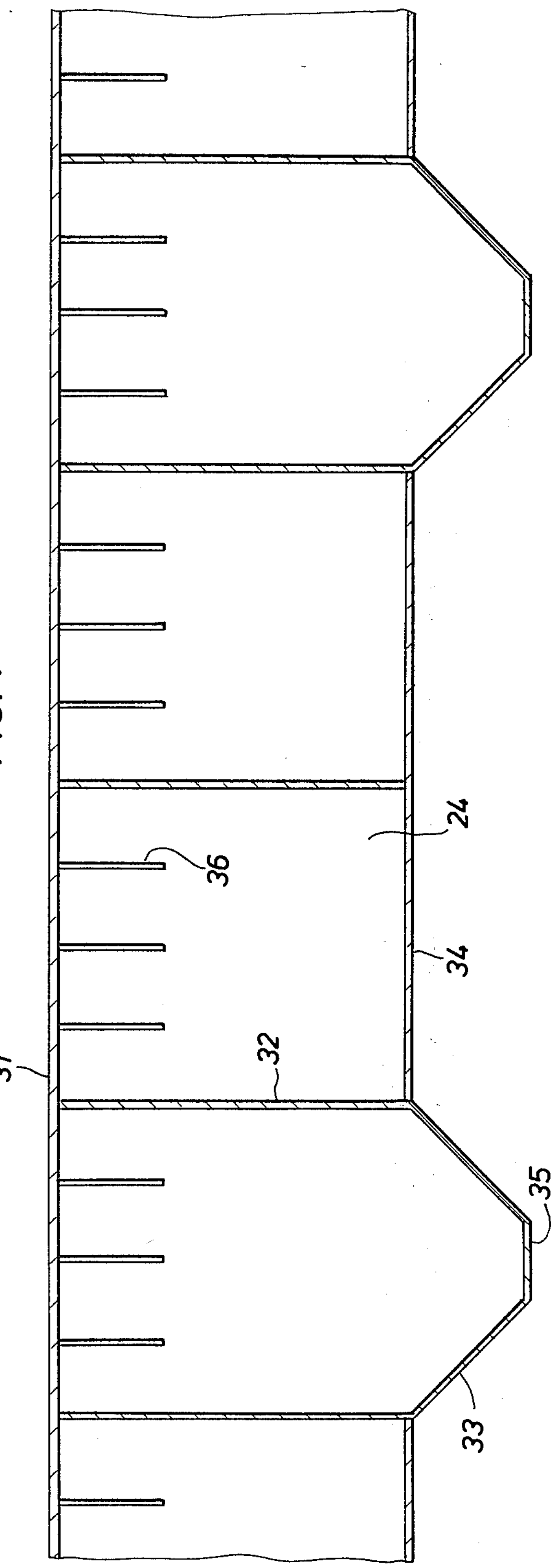


FIG. 4



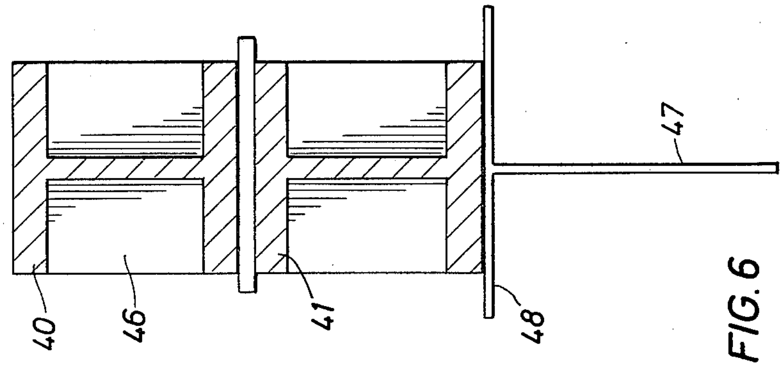


FIG. 6

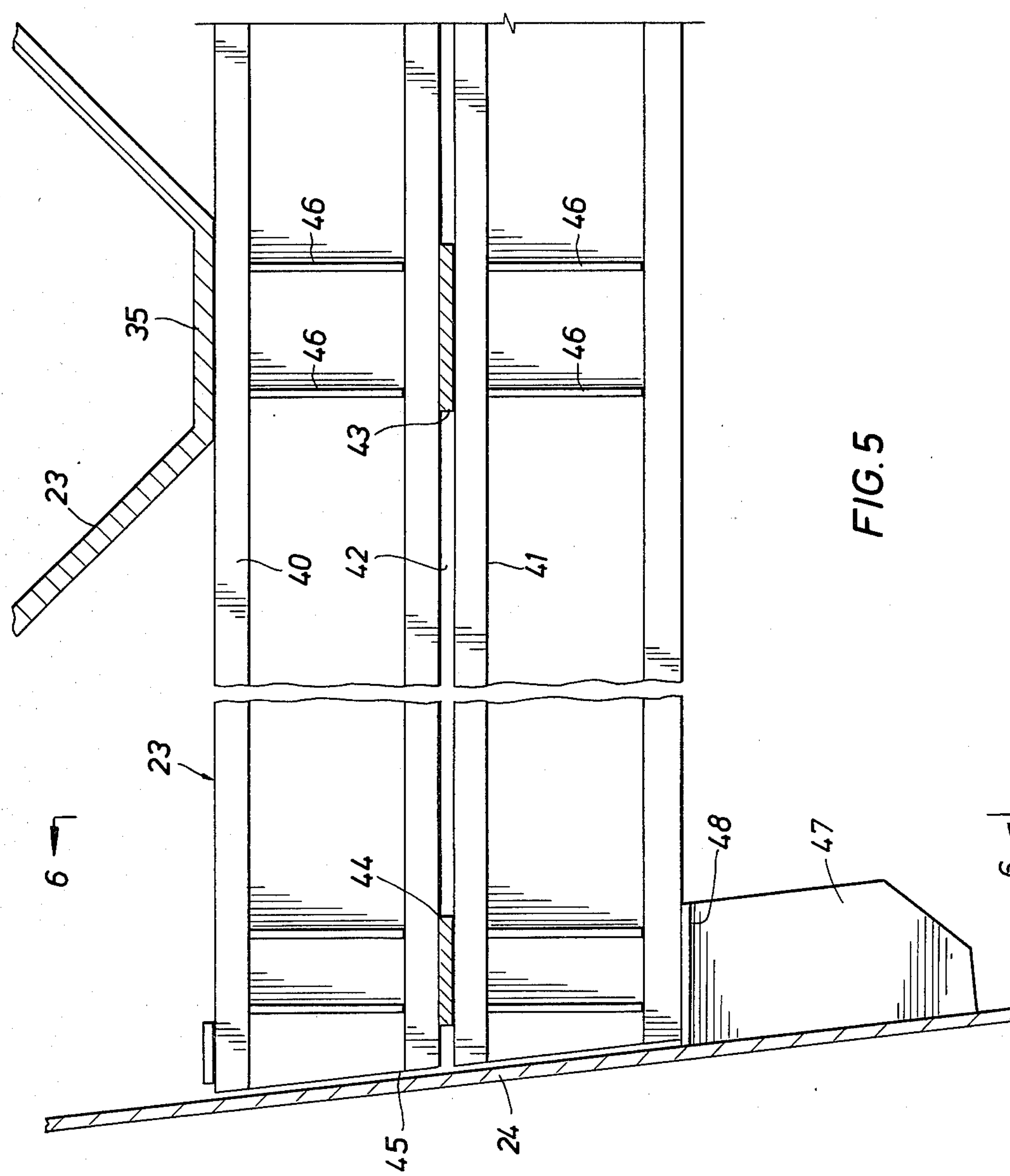


FIG. 5

ARCTIC OFFSHORE PLATFORM

BACKGROUND OF THE INVENTION

The present invention relates to offshore structures and particularly structures for conducting drilling and producing operations in the Arctic regions. More particularly, the structure is particularly adapted for conducting operations in the shallow waters of the Beaufort Sea. As is well known, the Beaufort Sea at particular times of the year contains large movements of relatively thick sea ice and offshore drilling structures must withstand this movement. In the past, it has been suggested that any offshore structures based in the shallow waters of the Beaufort Sea have a conical base section to force the moving ice upward, causing it to break due to the tension forces imposed upon the ice. This will cause the large ice features to break into smaller pieces which then can pass safely around the offshore structure.

While the use of conical-shaped bottom sections obviously solves the problem of breaking the large moving ice sheets into smaller sections, the problem still remains of how to provide an outer skin for the conical section that can withstand the loads imposed by the moving ice sheets. One solution suggested by the prior art is described in U.S. Pat No. 4,215,952 where a resilient material is disposed between the wear surface of the conical base section and the support portion thereof. The use of the resilient section is intended to reduce loads imposed upon the structure by the large ice floes. While this is a possible solution, it requires the use of relatively flexible outer surfaces on the conical base in order that the load can be transmitted to the resilient material positioned between the support structure and the outer surface. The key design problem is to avoid excessive concentration of load on the supporting bulkheads.

BRIEF DESCRIPTION OF THE INVENTION

The present invention solves the above problems by spreading the load over a larger area before it is transferred to the bulkheads. This is achieved by using a stiff conical outer shell which is supported by a system of beams spanning between radial bulkheads. When the ice load is applied to the stiff outer shell it, in turn, transfers the load to the supporting beams. Since these beams are more compliant than the outer shell they will deflect, permitting the shell to move inward and transfer the load to adjacent sets of beams.

The upper end of the conical outer shell is attached to a cylindrical upper shell which houses three decks which contains the drilling and production equipment.

The entire structure may be constructed in a less hostile environment, towed to location under its own buoyancy, and installed on location by water ballasting. It will resist ice and wave loads by a gravity foundation using a system of steel skirts to transfer the loads into the foundation soil.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is more easily understood from the following description when taken in conjunction with the attached drawings in which:

FIG. **1** is a schematic elevation view of the base section of the invention attached to a circular production platform.

FIG. **2** is a vertical section of the conical base section.

FIG. **3** is a horizontal section taken along line **3**—**3** of FIG. **2**.

FIG. **4** is a portion of FIG. **3** drawn to an enlarged scale.

FIG. **5** is a horizontal section of the flexible beam structure.

FIG. **6** is a section taken along line **6**—**6** of FIG. **5**.

DESCRIPTION OF PREFERRED EMBODIMENTS

The structure of the present invention is designed to resist loads due to first year and multiyear ice sheets and ridges, rubble piles and dynamic impacts from storms accompanied by ice invasions. The overall form of the structure comprises a frustum of a cone for the lower portion with a base diameter, for example, of 350 feet. The base portion has a cone angle of typically 45 degrees and is joined to a cylindrical upper section. The upper section contains the drilling and production equipment and facilities.

The conical portion of the structure consist of a system of radial and circumferential bulkheads supported by a continuous base plate. The ice and wave loads are borne by a stiff outer shell comprising an orthotropic structural system consisting of radial and meridional webs and top and bottom flanges. The outer shell transfers the loads to a bulkhead system through an indirect load path created by supporting the outer shell on a system of flexible beams which span the space between the radial bulkheads. The stiffness properties of the outer shell and flexible beams are selected to distribute the load over a number of bulkheads instead of a single bulkhead. This avoids the imposition of high local loads on individual bulkheads as is the case with previous designs.

Referring now to FIG. **1**, there is shown an elevation view of the conical base section **10** coupled to a cylindrical upper section **11** that may be either a drilling or production facility. The upper section is provided with three levels; **12**, **13** and **14**. which can contain drilling supplies, the drilling equipment, production equipment and living quarters for the drilling or production personnel. The base section is provided with sufficient height so that the upper portion of the truncated conical section extends above the normal water line **15**. The extension should be sufficient so that moving ice will ride up the conical section and break due to tension stress before it impacts on the upper section **11**.

Referring to FIG. **2**, there is shown a partial vertical section of the conical base member shown in FIG. **1**. The conical base member includes a base plate **20** which is attached to a skirt **21** which extends down into the ocean bottom to assist in anchoring the conical base in position. Normally, the conical base will be ballasted or flooded so that the weight of the conical base, plus the sea water, will cause it to sink and rest on the ocean floor with the skirt **21** penetrating the ocean floor. The base **20** may be constructed of a stiffened plate system. The outer skin **22** of the conical base is actually composed of two spaced-apart plate members having a series of circumferential stiffening webs **24** and meridional webs **32**. The actual construction of the outer surface will be described in detail with relation to FIGS. **3** and **4**. The space between the outer and inner plates at the lower end of the outer surface is closed by two continuous plate members **25** and **26**. The composite outer shell is spaced from the outer ends of the radial bulkheads **27** so that it is free to move within this restricted distance as the supporting beams flex. The flexible beam systems **23** are positioned between the radial bulkheads **27** as particularly shown in FIGS. **5** and **6**. As shown, the flexible beam system adjacent the water line is provided with a double set of beams since this is the area which is subject to the greatest load by the moving ice.

Referring now to FIGS. **3** and **4**, there is shown the detailed construction of the outer shell and the flexible supporting beams of the conical member. In particular, the outer surface **22** of the base member consists of an outer skin **31** and an inner skin **34** which are spaced apart. The inner and outer skins are held apart by the horizontal or circumferential webs **24** shown in FIG. **2** and a series of meridional webs **32**. The combination of the meridional and the circular webs form a cellular or egg crate type structure for the outer shell.

It should be noted that the outer shell is spaced a distance **30** from the ends of the radial bulkheads **27** and supported at the mid-span of the flexible beam system **23** by parallelogram shaped load transfer boxes **33**. As shown in FIG. **4**, the load transfer box **33** terminates in a flat flange section **35** which contacts the individual beam members. In addition to the meriodional webs **32**, a series of secondary stiffening webs **36** are positioned between each of the meridional webs.

Referring now to FIGS. **5** and **6** there is shown the details of the flexible beam system used for supporting the outer shell of the conical base. In particular, each flexible beam member of the system adjacent the water line comprises two I-beams **40** and **41** which are spaced apart a short distance **42** by spacing members **43** and **44** positioned at the center and the ends of the beams respectively. The spacing members allow the beams to transmit the load from the outer shell to the radial bulkheads while maintaining their ability to flex with respect to each other without shear transfer. To increase their flexibility the ends of the I-beams have a slight clearance **45** at each end adjacent the radial bulkheads. The end of the innermost beam is supported by a T-section having an end **48** attached to the beams and a web **47** attached to the radial bulkheads. The flanges of the I-beams are reinforced by web members **46** adjacent the center and the ends respectively, to ensure that the load-bearing portions of the beam and the flanges do not buckle or collapse. As best seen in FIG. **5**, the flat section **35** of the parallelogram shaped box of the outer shell bears against the outermost flange of the I-beam **40**. Thus, the load from the outer shell is transmitted over a narrow area of the beam which permits the beam to slightly flex to absorb the load imposed on the outer shell. Since the beams are not connected at their ends to the radial bulkheads but only supported by the T-sections, the beams can readily flex, absorbing the load from the outer shell. The flexibility of the conical base and limited contact points between the outer shell and supporting structure also prevents excessive loads as a result of temperature fluctuation. Also, an insulating layer can be placed on the inside surface of the outer shell of the conical base and upper cylindrical section to provide thermal insulation.

In a typical base structure designed for a load of 25,000 kips and a maximum contact pressure of 1600 psi, the base structure would have a diameter of approximately 350 feet with a height of roughly 70 feet for operating in water depths of 30 to 60 feet. The upper cylindrical drilling platform is 210 feet in diameter with a height of 90 feet. The outer shell of the conical section includes two-inch outer and two-inch inner plate walls with two-inch meridional webs with one-inch plate radial bulkheads. The radial bulkheads were placed on 9-degree centers while the flexible beam system composed of I-beams having a flange width of approximately 1.5 feet and a thickness of 2.75 inches with a 12-inch high web. The total weight of steel in the structure is approximately 40,000 tons which would provide the reserve buoyancy of approximately 50,000 tons while towing the base structure in an upright position.

The above described conical base structure provides a flexure of approximately two inches when the outer surface of the conical base is subjected to its maximum load of 26,000 kips. In order to withstand greater loads, it may be necessary to increase the diameter of the conical base and increase the thickness or strength of some of the members. While increasing the diameter and the thickness of the members, it should be borne in mind that one should still maintain the flexible beam system.

What is claimed is:

1. An offshore structure for use in arctic water containing moving ice masses comprising:

a frustum base section and a circular upper section, said base section having sufficient height to extend above the surface of the water;

the skin of said frustum section having a controlled stiffness cellular structure formed by an outer plate member and an inner plate member, said outer and inner plate members being separated by a series of radial and meridional webs fastened to said plates to form a cellular structure; and

a flexible beam structure, said beam structure being formed by a series of circumferential beams supported by a series of radial bulkheads projecting upward from the bottom of said frustum, said skin being attached to said flexible beam structure intermediate said radial bulkheads.

2. A frusto-conical base member for use in an offshore structure for conducting operations in arctic waters having moving ice, said base member comprising:

a solid circular bottom;

an outer skin for said base, said outer skin being formed by a solid outer plate and a solid inner plate, said inner and outer plates having a general conical shape and radially spaced, a plurality of meridional web members positioned between said inner and outer plates and fasten thereto to maintain the spacing between said plates;

a plurality of radial bulkheads attached to said bottom and terminating short of said outer skin; and

a plurality of horizontal flexible beams, said beams being secured between said radial bulkheads to form a series of vertically spaced substantially circular beams, said beams supporting said outer skin at points intermediate said bulkheads.

3. The base member of claim **2** wherein in addition to said meridional members a series of circumferential webs are positioned between said inner and outer plates and fastened thereto.

4. The base member of claim **3** and in addition secondary stiffening webs, said webs being attached to the outer shell and positioned between said meridional members.

5. The base of claim **4** wherein said inner plate is provided with a series of load transfer boxes that project inwardly from said inner plate, said load transfer boxes having a flat surface that contacts said beams at approximately the center thereof.

6. The base member of claim **5** wherein said box has a parallelogram cross section.

* * * * *

Predicting a Global Catastrophe
1977—1982

As the oil industry continued to study the processes and potential effects of global warming, their predictions grew increasingly accurate and their concerns increasingly dire. On at least three separate occasions, oil industry scientists and executives were warned of the potentially "catastrophic" impacts of global warming resulting from the use of their products. These stark warnings would ultimately go unheeded by the industry.

In 1977, Exxon scientist James Black gave a presentation, **Document 6**, to the Exxon Corporation Management Committee. Black predicts a 1-3° C global temperature increase by 2050 based on reasonable CO_2 emissions expectations and warns of a 5-10 year window to gather the necessary information and act.

Document 7, an internal Exxon memorandum from 1979, shows how the industry's understanding of climate change and modeling continued to advance: the severity of climate change could now be directly linked to the amount of CO_2 released. This report also included an appendix listing some very worrisome ecological impacts of increased CO_2 levels in the atmosphere. But perhaps most significantly, the memo introduced the idea that climate change might limit the company's ability to sell its product.

> **"At a 3% per annum growth rate of CO_2, a 2.5°C rise brings world economic growth to a halt in about 2025"**
>
> *American Petroleum Institute, 1979*

In 1979, API and industry scientists from Exxon, Texaco, SOHIO, and others began the "CO_2 and Climate Task Force" to monitor and share climate research. **Document 8** features minutes from a 1980 meeting where representatives were briefed on "The CO_2 Problem." The meeting's presentation described the "scientific consensus on the potential for large future climatic response to increased CO_2 levels" and predicted global temperature increases of 2.5°C by 2038, and then 5°C by 2067, leading to "major economic consequences" and "globally catastrophic events." The presentation concludes, "At a 3% per annum growth rate of CO_2, a 2.5°C rise brings world economic growth to a halt in about 2025."

By the early 1980's, researchers and executives were grappling with a growing understanding of the severity of the risk. In a brief memo from 1981, **Document 9**, Exxon research manager Rodger Cohen warns that calling climate change impacts "of a magnitude well short of catastrophic" in 2030 would be "too reassuring" and that it was "distinctly possible that the CPD [corporate planning department] scenario will likely produce effects which will indeed be catastrophic (at least for a substantial fraction of the earth's population)."

In 1982, Exxon's Environmental Affairs program manager M. B. Glaser circulated an internal briefing on *The CO2 "Greenhouse" Effect*, **Document 10**, which he warned was not to be distributed externally. The briefing reviews the scientific understanding of climate change and warns, "In addition to the effects of climate on global agriculture, there are some potentially catastrophic events that must be considered. For example, if the Antarctic ice sheet which is anchored on land should melt, then this could cause a rise in sea level on the order of 5 meters. Such a rise would cause flooding on much of the U.S. East Coast, including the State of Florida and Washington, D.C."

1977 presentation by Exxon scientist James Black,
The Greenhouse Effect

EXXON RESEARCH AND ENGINEERING COMPANY
P.O. BOX 51, LINDEN, N.J. 07036

PRODUCTS RESEARCH DIVISION
J.F. BLACK
Scientific Advisor

June 6, 1978

The Greenhouse Effect

Ref. No: 78PR 461

Mr. F. G. Turpin, Vice President
Exxon Research and Engineering Co.
Petroleum Staff
P. O. Box 101
Florham Park, NJ 07932

Dear Frank:

The review of the Greenhouse Effect which I presented to the Exxon Corporation Management Committee last July used only vu-graphs, without a prepared text. Last month, I had the opportunity to present an updated version of this talk to PERCC. The attached text was dictated shortly afterward to satisfy requests for a written version of the talk from people who had not heard the presentation last July. Also attached is a summary.

Sincerely,

Jim

J. F. BLACK

JFB/mbh
Attachments: Summary
Text
Vugraphs

CC: Messrs. N. Alpert
W. M. Cooper, Jr.
E. E. David
E. J. Gornowski
R. L. Hirsch
F. A. L. Holloway
P. J. Lucchesi
L. E. Swabb, Jr.

THE GREENHOUSE EFFECT

J. F. Black, Products Research Division
Exxon Research and Engineering Co.

SUMMARY

The earth's atmosphere presently contains about 330 ppm of CO_2. This gas does not absorb an appreciable amount of the incoming solar energy but it can absorb and return part of the infrared radiation which the earth radiates toward space. CO_2, therefore, contributes to warming the lower atmosphere by what has been called the "Greenhouse Effect."

The CO_2 content of the atmosphere has been monitored since 1957 at two locations, the Mauna Loa Observatory, Hawaii and the South Pole. These and other shorter studies show that CO_2 is increasing. If the increase is attributed to the combustion of fossil fuels, it can be calculated that the CO_2 content of the atmosphere has already been raised by about 10 to 15% and that slightly more than half of the CO_2 released by fossil fuel combustion is remaining in the atmosphere. Assuming that the percentage of the CO_2 remaining in the atmosphere will stay at 53% as fossil fuel consumption increases, one recent study predicts that in 2075 A.D., CO_2 concentration will peak at a level about twice what could be considered normal. This prediction assumes that fossil fuel consumption will grow at a rate of 2% per year until 2025 A.D. after which it will follow a symetrical decrease. This growth curve is close to that predicted by Exxon's Corporate Planning Department.

Mathematical models for predicting the climatic effect of a CO_2 increase have not progressed to the point at which all the feedback interactions which can be important to the outcome can be included. What is considered the best presently available climate model for treating the Greenhouse Effect predicts that a doubling of the CO_2 concentration in the atmosphere would produce a mean temperature increase of about 2°C to 3°C over most of the earth. The model also predicts that the temperature increase near the poles may be two to three times this value.

The CO_2 increase measured to date is not capable of producing an effect large enough to be distinguished from normal climate variations. As an example of normal variations, studies of meteorological and historical records in England indicate that the mean temperature has varied over a range of about ±0.7°C in the past 1000 years. A study of past climates suggests that if the earth does become warmer, more rainfall should result. But an increase as large as 2°C would probably also affect the distribution of the rainfall. A possible result might be a shift of both the desert and the fertile areas of the globe toward higher latitudes. Some countries would benefit but others could have their agricultural output reduced or destroyed. The picture is too unclear to predict which countries might be affected favorably or unfavorably.

It seems likely that any general temperature increase would be accentuated in the polar regions, possibly as much as two- or three-fold as mentioned above. Any large temperature increase at high latitudes would be associated with a reduction in snow cover and a melting of the floating ice-pack. Present thinking suggests that there would be little or no melting of the polar ice-caps in response to warmer temperatures on a time scale over which the Greenhouse Effect is predicted to apply.

A number of assumptions and uncertainties are involved in the predictions of the Greenhouse Effect. The first is the assumption that the observed CO_2 increase can be attributed entirely to fossil fuel combustion. At present, meteorologists have no direct evidence that the incremental CO_2 in the atmosphere comes from fossil carbon. The increase could be at least partly due to changes in the natural balance. There is considerable uncertainty regarding what controls the exchange of atmospheric CO_2 with the oceans and with carbonaceous materials on the continents.

Models which predict the climatic effects of a CO_2 increase are in a primitive stage of development. The atmosphere is a very complicated system, particularly on a global scale. In existing models, important interactions are neglected, either because they are not completely understood or because their proper mathematical treatment is too cumbersome. Substantial efforts are being expended to improve existing models. But there is no guarantee that better knowledge will lessen rather than augment the severity of the predictions.

The Greenhouse Effect has been the subject of a number of international scientific conferences during the past two years. These meetings have identified the information needed to definitely establish the source and ultimate significance of the CO_2 increase in the atmosphere. Present thinking holds that man has a time window of five to ten years before the need for hard decisions regarding changes in energy strategies might become critical. The DOE is presently seeking Congressional support for a research program which will produce the necessary information in the required time. This program is described.

THE GREENHOUSE EFFECT

By

J. F. BLACK

Transcript of a Talk
Delivered Before the PERCC Meeting
May 18, 1978

The Greenhouse Effect refers to a warming of the earth's atmosphere due to an increase in the concentration of carbon dioxide. As a background for the discussion today, the first vugraph outlines the basis for the Greenhouse Effect.

The earth receives energy in the form of both visible and ultraviolet radiation from the sun. Some of this radiation is reflected back into space, some is absorbed by the atmosphere but most is absorbed at the earth's surface. The earth in turns reemits energy in the form of infrared radiation toward space. Carbon dioxide and other atmospheric constituents absorb part of the infrared radiation. This absorbed energy warms the atmosphere. Therefore, higher carbon dioxide concentrations result in a more rapid absorption of the outgoing infrared radiation and warmer temperatures near the earth's surface. In my talk today I am planning to discuss:

I. The Source and Projected Magnitude of the CO_2 Increase in the Atmosphere

II. The Global Temperature Increase Which Can Be Expected From Higher CO_2 Concentrations

III. The Potential Problems Arising From a Global Temperature Increase

IV. Research Needed to Establish the Validity and Significance of Projected Increases of CO_2 in the Atmosphere.

My information is derived from following recent literature in this area and from talks with some of the leading research people in the field.

I. <u>The Source and Projected Magnitude of the CO_2 Increase in the Atmosphere</u>

Since 1958, CO_2 has been monitored at a number of remote sites which are free from local inputs (Vugraph 2). These are Point Barrow, Alaska; some Swedish aircraft flights; Mauna Loa, Hawaii; American Samoa and the South Pole. The carbon dioxide concentration has been found to be increasing rather uniformly at all locations with the South Pole measurements rather lagging those in the Northern Hemisphere.

Atmospheric scientists generally attribute this growth in CO_2 to the combustion of fossil fuel. A principal reason for this is that fossil fuel combustion is the only readily identifiable source which is (1) growing at the same rate, (2) large enough to account for the observed increases, and (3) capable of affecting the Northern Hemisphere first. If this assumption regarding the origin of carbon dioxide is true, it can be calculated that a little over 50% of the CO_2 entering the atmosphere is remaining there and the rest is being absorbed in surface sinks on the continents or in the ocean. Extrapolating backwards in time to follow the history of fossil fuel combustion, it can be estimated that since 1850 the concentration of this gas in the atmosphere has increased by about 13%. This increase amounts to about 75 billion metric tons of carbon dioxide.

It is also possible to extrapolate into the future. One of the most commonly quoted extrapolations is that of the Oak Ridge National Laboratory which was published in 1976[1]. This study produced two scenarios for the growth of fossil fuel consumption (Vugraph 3). Prior to 1973, fossil fuel use had been growing exponentially at about 4.3% per year. The scenario for most rapid growth assumed that this growth rate would continue, modified by a depletion factor which reduced the exponent in proportion to the amount of fossil fuel which remained unburned. Their second and more conservative assumption presumed that fossil fuel utilization would grow with a 2% growth rate out to 2025 A.D. followed by a symetrical decrease. This latter scenario is close to that developed independently by the Coordination and Planning Department of the Exxon Corporation.

Vugraph 4 presents the predicted atmospheric carbon dioxide levels which would result from each of these scenarios. The vertical axis in this vugraph presents the atmospheric carbon dioxide concentration relative to that which was calculated to have existed in 1850, prior to the combustion of appreciable amounts of fossil fuel. It can be seen that the scenario based upon very rapid growth predicts that by 2075 the atmospheric carbon dioxide concentration will be about 4 to 5 times that which existed prior to the industrial revolution. Moreover, at that time, the carbon dioxide concentration will still be increasing. The more conservative assumption, shown in the lower curve, predicts that carbon dioxide concentrations will level out about a century from now at a value which is about twice that in existence in 1850 and then would decline at a very slow rate.

Although carbon dioxide increase is predominantly attributed to fossil fuel combustion, most scientists agree that more research is needed to definitely establish this relationship. The possibility that the increasing carbon dioxide in the atmosphere is due to a change in the natural balance has not yet been eliminated. In fact, a look at the magnitude of the natural interchanges, as shown in Vugraph 5, shows that this possibility should be taken seriously.

The data in Vugraph 5 are taken from a Scientific Workshop on Atmospheric CO_2 sponsored by the World Meteorological Organization in December 1976. The vugraph shows the fluxes of CO_2 into and out of the atmosphere in units of billions of metric tons of carbon per year. It can be seen that fossil fuels are estimated to contribute five billion tons of carbon per year to the atmosphere and that about half of this is reabsorbed by the oceans or by the biosphere. The conclusion that fossil fuel combustion represents the sole source of incremental carbon dioxide involves assuming not only that the contributions from the biosphere and from the oceans are not changing but also that these two sources are continuing to absorb exactly the same amount as they are emitting. The World Meteorological Organization recognized the need to validate these assumptions, particularly in view of the fact that the rate of carbon dioxide increase represents less than 2% of the rate at which the atmosphere is exchanging carbon dioxide with the biosphere and the oceans.

The biologists have been claiming that deforestation and associated biogenic effects on the continents represent an important input of carbon dioxide to the atmosphere. Vugraph 6 summarizes the results from recent papers by a number of biologists on the contribution of the biosphere to the growth of CO_2 in the atmosphere relative to the contribution of fossil fuel combustion. Their estimates for this ratio are presented in the first column. In April of 1977, Adams[2] estimated that the ratio of the weight of carbon from net wood burned to the weight of carbon from fossil fuel burned in this century has been at least 0.1 and may have approached 1.0. The following month, Bolin[3] claimed that the increase in carbon dioxide due to the expansion of forestry and agriculture was at least half that due to fossil fuel combustion. In August of 1977, the National Academy of Sciences issued a report[4] which attributed the Greenhouse Effect to fossil fuel combustion and which received a considerable amount of sensational publicity. This has produced a rash of papers by the biologists to support their position. In January of this year, Woodwell[5] and a number of other authors from academic and oceanographic centers published a paper claiming that the terrestrial biomass appears to be a net source of carbon dioxide for the atmosphere which is possibly greater than that due to fossil fuel combustion. The following week, Stuiver[6] published results based upon C^{13}/C^{12} ratios which reported that the net release of carbon dioxide from the biosphere in the century prior to 1950 was twice as great as that from fossil fuel combustion. Even if it is assumed that the biospheric release stopped in 1950, the contribution of the biosphere up to the present time would still be 1.2 that from fossil fuel. The last four articles which I have quoted were all published in Science. In the present month, Wilson[7] published an article in Nature which supports the claim that deforestation has produced at least half as much carbon dioxide in the atmosphere as can be attributed to fossil fuel.

Now, you will remember that earlier in this talk it was pointed out that if the increase in carbon dioxide in the atmosphere is due to fossil fuel combustion, about 50% of the CO_2 being released remains in the atmosphere and the rest is absorbed in either the oceans or the continents. If there have been substantial releases of carbon dioxide in addition to that which can be attributed to fossil fuels, the natural sinks for carbon dioxide must be larger and more efficient than previously estimated. This would reduce the levels to which carbon dioxide has been projected to increase. This possibility is vehemently denied by the oceanographers, who claim that the oceans cannot possibly absorb much more carbon dioxide. However, it is my impression that the science of oceanography has not as yet reached a state of development which can justify such a positive claim.

The current status of scientific opinion regarding the carbon cycle is summarized in Vugraph 7. First, current scientific opinion overwhelmingly favors attributing atmospheric carbon dioxide increase to fossil fuel combustion. However, most scientists feel that more research is needed to support an unqualified conclusion. Finally, some scientists, particularly the biologists, claim that part or all of the CO_2 increase arises from the destruction of forests and other land biota.

II. <u>The Global Temperature Increase Which Can Be Expected From Higher CO_2 Concentrations</u>

Predictions on the significances of increases in atmospheric CO_2 must be based upon climate modeling. Modeling climatic effects is currently handicapped by an inability to handle all the complicated interactions which are important to predicting the climate. Some of these are shown in Vugraph 8.

One interaction which has not has yet been included with any degree of sophistication in climate models is the effect of cloudiness. Clouds can reflect incoming visible and ultraviolet radiation back into space with greater efficiency than would occur at the ground. On the other hand, at their bottom surface they absorb outgoing radiation and the cloud tops also emit infrared radiation, depending upon the temperature (that is altitude) at which the top is located. The effect of a cloud will therefore depend upon its size, its shape, and the altitude at which it is located.

Another uncertainty which has not, as yet, been handled in any great detail is the atmosphere - ocean circulation - sea surface temperature interaction. How should the heat capacity of the oceans be handled in view of the turbulence at the surface and to what depths are the oceans involved in interacting with the atmosphere? These are important questions because the entire heat content of the atmosphere is equal to the heat content of just the first three meters of the oceans. A third uncertainty in modeling is the interaction between the seasons and long-term climate trends. In present models, the changes which are predicted for increasing carbon dioxide concentrations are calculated with respect to a constant climate, that is a perpetual spring or summer season. It is quite possible that this assumption is inadequate. For example, the best accepted explanation for the on-set of the ice ages is that orbital and other changes result in the earth entering a period in which summers are cooler and winters are warmer than normal. Thus, this produces more precipitation and faster glacier growth during the winter and less melting during the summer.

Finally, a serious question has been raised as to whether climate is really predictable. This possibility was raised by Lorenz[8] in 1970. He drew an analogy to mathematical modeling. Many mathematical models of complicated phenomena are based upon a large number of non-linear equations with a variety of complex feedback interactions. If the mathematician is fortunate, when a model of this type is run on the computer, it will converge and give him a definite answer. Such a model is called transitive. On the other hand, when a complicated model is tested, it is not at all unusual to find that the solution will not converge but will oscillate back and forth without producing a stable answer. Such a model is called intransitive. There is also an intermediate condition. Occasionally, a model is found to converge initially upon a definite answer but after a short period to jump off this solution and settle down upon another one. After a second indefinite period, it will jump up and converge again upon a third solution and so on producing a number of apparent solutions in a random manner. Such a model is called almost transitive (or almost intransitive). Lorenz pointed out that the climate is a system which is the result of a large number of non-linear energy inputs between which there are many complicated feedback interactions. He therefore suggested that the climate may be a natural example of an almost transitive system which does not have a stable solution. It will settle down into an apparently stable condition but then after a random period will jump over to another apparent stability, etc.

It is not certain, however, that such a pessimistic outlook is justified and it has not stopped the development of many models of the Greenhouse Effect and other climate phenomena. The simplest of these are the one-dimensional models in which the input at the earth's surface is averaged over the globe and detailed calculations are carried out to predict vertical variations. Such models do not require much computer time and can include detailed treatment of vertical phenomena such as radiative transfer. They suffer, however, from the fact that the influence of latitudinal variations is completely ignored.

The next more complicated models are so-called zonally averaged models in which various latitude regions are treated separately in a two-dimensional manner. These take more computer time but are still short enough to permit considerable sophistication in the calculations. They still suffer, however, from an incomplete treatment of latitudinal interactions. In spite of this, many modelers feel that they are the most valuable type of model upon which to work.

The most complicated models are the so-called general circulation models which are three-dimensional in character. These take very long times to compute and the ratio of real to machine time can be as low as 10 to 1. A great deal of the computer time is spent in moving large masses of air around the globe and recalculating the snyoptic profiles every 10 to 15 minutes. Their advantage is that latitudinal effects are completely included but the sophistication with which vertical effects can be treated is limited due to the time and expense associated with running the model.

One of the best general circulation models of the Greenhouse Effect, and the one which is most frequently quoted, is that developed by Manabe and Wetherald[9]. Their predictions for the climatic effect of a doubling of CO_2 are presented in Vugraph 9. This vugraph predicts that a doubling of the atmospheric CO_2 concentration would produce a temperature rise at lower altitudes and a temperature decrease above twenty kilometers. At the surface the temperature rise would be about 2 to 3°C from the equator up to about 60° latitude, with a much greater increase predicted for the poles. The larger increase at the poles results from two effects. First, vertical mixing at the poles is reduced due to a natural decrease in the height of the inversion layer in these regions. Second, the model contains a temperature - ice and snow cover - reflectivity interaction by which increases in atmospheric temperature melt the snow and ice cover and reduce the amount of heat reflected back into space.

Simplifications incorporated in this model include fixed cloudiness, a "swamp" ocean which has zero heat capacity, and idealized treatment of the topography. The model also contains a simplified treatment of the infrared radiation transfer in the atmosphere. In a separate calculation, Manabe[10] calculated that the use of a more sophisticated treatment, developed by Rodgers and Walshaw[11], would reduce the indicated temperature increases at the surface by about 0.5°C. In the light of this and other models, it is generally accepted by climatologists that a doubling of the carbon dioxide concentration in the atmosphere would produce from 1.5°C-3.0°C warming at the earth's surface in the lower and mid-latitudes with about 2 to 3 times greater effect at the poles.

The next natural question is the significance of such a temperature rise compared to the magnitude of the natural temperature changes which have been observed to occur in the past. A comparison with respect to historical temperature changes since 1850, according to Kellogg[12], is presented in Vugraph 10. In this figure, the observed mean Northern Hemisphere temperature is plotted as the solid line. It can be seen that this has varied less than ±1°C over the last century. The extrapolations past 1977 result from the application of Manabe and Wetherald's model[9] with the assumption that the carbon dioxide levels will double by 2050 A.D. The lower dashed line in the figure represents an estimate of what the recent temperature trends would have been if the CO_2 increase had not occurred.

The significance of a temperature increase of the magnitude predicted by Manabe and Wetherald with respect to the long term record of climate is presented in Vugraph 11 which was prepared by Mitchell[13]. This figure shows that the expected temperature increase would be large even compared to the temperatures at the time of the last interglacial. As this temperature increase decayed, however, it would represent an amelioration of an expected natural cooling trend.

III. The Potential Problems Arising from a Global Temperature Increase

The implications arising from Manabe and Wetherald's predictions for the temperature effects resulting from a doubling of carbon dioxide concentrations in the atmosphere are outlined in Vugraph 12. It appears fairly certain that if the high increases they predict in the polar regions do occur, the permanent snow cover and floating sea ice will be reduced or possibly eliminated. This will have a negligible effect on sea level, however, since the snow cover does not represent an appreciable amount of water and the floating ice is already in equilibrium with the sea.

There will probably be no effect on the polar ice sheets. These are three in number. The Greenland ice sheet in the Northern Hemisphere represents an amount of water equivalent to a five meter rise in sea level. If the floating sea ice is removed, the Greenland ice cap would be surrounded by water. This might produce increased precipitation and actually result in the growth of this ice sheet.

The world's largest ice sheet is the East Antarctic sheet which contains water equivalent to a rise of 70 meters in the world's oceans. It is estimated that the temperature effects produced by doubling the atmospheric CO_2 concentration would not affect this very large glacier and that it too might increase in size.

The area on which most uncertainty exists is with respect to the West Antarctic ice sheet. The water in this glacier is equivalent to about a seven meter rise in the world's oceans. The West Antarctic ice sheet extends out over the ocean floor. Warmer oceans might result in an intrusion of the ocean waters underneath this ice sheet and a decrease in its size might occur. If this happens, an oceanic rise of some fraction of the maximum amount (7 meters) might take place.

With a warmer climate around the world, it seems fairly certain that precipitation would increase. On a global basis, this should result in a lengthening of the growing season. Growing seasons are estimated to increase about ten days for each 1°C rise in temperature.

The changing precipitation patterns, however, would benefit some areas and would harm others. It is not possible, on the basis of present information, to predict just where these effects would occur. As a first estimate, one might say that the climatic zones in the world would move northward. The effect of this on the agriculture of the U.S. and Russia is indicated in Vugraph 13.

The broadening of the equatorial regions might result in a northward migration of the desert areas in the United States. Our present corn and wheat belts would also move northward and migrate into Canada. It can be seen that Russia, which is indicated by the crossed hatched area, lies considerably farther north than does the United States. The very dark areas indicate the agricultural regions of Russia. If climatic zones migrate northward, the Russians have plenty of room to adopt to the change. Even those nations which are favored, however, would be damaged for a while since their agricultural and industrial patterns have been established on the bais of the present climate.

IV. Research Needed to Establish the Validity and Significance of Projected Increases of CO_2 in the Atmosphere

The Greenhouse Effect has been attracting a large amount of scientific attention. Some of the more important recent meetings on this subject are presented in Vugraph 14. The World Meteorological Organization held a scientific workshop on atmospheric CO_2 in Washington, DC, in December 1976. ERDA held a workshop on the Environmental Effect of CO_2 from Fossil Fuel Combustion at Miami in March of 1977. This meeting was organized by their Advisory Committee for research on the Greenhouse Effect, the Chairman of which is Dr. Alvin Weinberg. DOE's present research effort on the Greenhouse Effect is a direct result of this workshop and I will be saying more about their program later. SCOPE (Standing Committee on the Planetary Environment), a West European organization, held a workshop on the world carbon budget in March of 1977 in Hamburg, Germany. The most recent major meeting was that organized in Luxenburg, Austria, this past February by IIASA (International Institute for Applied Systems Analysis) for the World Meteorological Organization, the U.N. Committee on the Environment and SCOPE.

The conclusions from this last meeting summarize the present world scientific opinion with respect to the Greenhouse Effect. The IIASA meeting was organized into three working groups. Some of the more significant recommendations of these working groups are presented in Vugraph 15.

The working group on the carbon cycle concluded that scientific confidence in models of that cycle is considerably less than it was ten years ago. What is necessary to instill greater confidence is to provide a better understanding of the flux from the biosphere as reported by the biologists. The working group also recommended that more information be obtained on the interchange of CO_2 into the ocean and how it is transported to greater depths.

The second working group, on the climatic impact of a doubling of CO_2, reached conclusions close to those which have been summarized in the present talk. They felt that a doubling of atmospheric carbon dioxide would produce a 2-3 degree centigrade increase in temperature depending upon the influence of clouds.

The third working group was concerned with the impact of the Greenhouse Effect on energy strategies. They recommended that man can afford a 5-10 yr. time window to establish the validity and significance of the Greenhouse Effect. They said that it is premature to limit the use of fossil fuels at present but that their use should not be encouraged. This group went on to recommend more research and greater effort on the development of energy sources which would not result in CO_2 release.

The DOE has initiated a major research program on the Greenhouse Effect under the leadership of David Slade. Detailed recommendations for this effort have been prepared by an Advisory Committee. These recommendations would have the DOE research program concentrate principally upon obtaining better information regarding the carbon cycle while research on climatic effects, including climate modeling, would be left up NOAA. Six programs for research on the carbon cycle are being recommended for immediate funding. These are presented in order of priority in Vugraph 16.

This immediate program would cost \$1.56 $\overline{MM}$ in the first year and would soon grow to about \$10 $\overline{MM}$ per year. The program to receive highest priority, is obtaining a better estimate of fossil fuel CO_2 output. This would involve a worldwide study of how fossil fuel combustion might be expected to increase and what would limit this increase in both the under-developed and developed countries. The second project relates to the use of carbon isotopes to obtain a better estimate of the input of carbon dioxide from the biosphere. It is hoped that C^{13}/C^{12} ratios as well as C^{14}/C^{12} ratios can be used for this purpose.

The third project is to obtain a direct assessment of the biosphere input by observing the growth or depletion of vegetated areas around the world from the Landstat satellites. High resolution radar and aerial photography will probably be required in some instances to identify vegetation types. The global vegetation map provided by these methods would be used to identify sample areas for 1) further analysis using photographs of higher resolution and 2) ground validation of vegetation and soil type to define the relationship between image characteristics and desired ground information. Two hundred to a thousand such areas would be identified and would be resurveyed at 2 to 5 year intervals in a program which would be expected to be able to detect a 2% change in the vegetation. This is an expensive program and would require about \$3 $\overline{MM}$ per year when it is running in full force.

The fourth project is to expand and improve the carbon dioxide monitoring network. This would involve adding 10 to 15 additional monitoring stations at suitably remote areas and expanding the instrumentation at all stations so that it could determine carbon isotope ratios.

The fifth project is to obtain better information on the transfer of carbon dioxide from surface waters into the deeper ocean. This would involve not only studies of CO_2 but also of tracers such as tritium, helium-3 and radiocarbon. This would require research with oceanographic ships and, when completely under way, would cost about $5 MM/year. The last of the high priority programs for immediate funding is to obtain better information on the buffering of CO_2 absorption in the ocean.

After the initial programs are under way, the Advisory Committee is recommending that an additional effort involving seven more programs be established. These are listed, in order of priority, in Vugraph 17. The entire program would cost $1.26 MM in the planning phase and would rise to $5 MM/year when under way.

The first item in this program, and the seventh in the overall priority list, is to determine whether shallow water carbonates are dissolving because of CO_2 levels. The second item would be to obtain a better estimate of the response of the biota as a sink for additional carbon dioxide. The third in this program is to develop better models for the carbon cycle. Although modeling is an extremely important undertaking, it is placed ninth on the overall list because information from the earlier programs is needed for better model development.

Item number ten recommends a study and a better definition of the rate of carbon dioxide exchange across the interface between the air and the ocean. The next project would be to study the flux of organic carbon into and within the sea. Item number twelve is to develop improved carbon dioxide measurement techniques, while the final item on this list is to study the dissolution of deep sea calcium carbonate as a final sink for atmospheric carbon dioxide.

V. Summary

A summary of my talk is presented in Vugraph 18. In the first place, there is general scientific agreement that the most likely manner in which mankind is influencing the global climate is through carbon dioxide release from the burning of fossil fuels. A doubling of carbon dioxide is estimated to be capable of increasing the average global temperature by from 1° to 3°C, with a 10°C rise predicted at the poles. More research is needed, however, to establish the validity and significance of predictions with respect to the Greenhouse Effect. It is currently estimated that mankind has a 5-10 yr. time window to obtain the necessary information. A major research effort in this area is being considered by the U.S. Department of Energy.

BIBLIOGRAPHY

1. The Global Carbon Dioxide Problem, ORNL-5194, C. F. Baes, Jr., H. E. Goeller, J. S. Olson and R. M. Rotty: Oak Ridge National Laboratory, August 1976.

2. J. A. S. Adams, M. S. M. Mantovani, and L. L. Lundell: Science, 196, 54, April 1, 1977.

3. Bert Bolin: Science, 196, 613, May 6, 1977.

4. Energy and Climate, National Academy of Sciences, Washington, DC, 1977.

5. G. M. Woodwell, R. H. Whittaker, W. A. Reiners, G. E. Likens, C. C. Delwiche and D. B. Botkin: Science, 199, 141, January 13, 1978.

6. Minze Stuiver: Science, 199, 253, January 20, 1978.

7. A. T. Wilson: Nature, 273, 40, May 4, 1978.

8. E. N. Lorenz: J. Appl. Meteorol., 9, 325, 1970

9. Syukuro Manabe and Richard T. Wetherald: J. Atmospheric Sciences, 32, 3, January 1975.

10. Syukuro Manabe: Man's Impact on Climate, W. H. Matthews, W. W. Kellogg, and G. D. Robinson, Eds, The MIT Press, 256, 1971.

11. C. D. Rodgers and C. D. Walshaw: Quart. J. Roy. Meteor. Soc., 92, 67, 1966.

12. W. W. Kellogg, Effects of Human Activities on Global Climate, Report to the Executive Committee, Panel of Experts on Climatic Change, World Meteorological Organization, Feb. 1977.

13. J. Murray Mitchell, Jr.: Environmental Data Service, NOAA, March 1977.

THE GREENHOUSE EFFECT

J. F. BLACK

TALK BEFORE

PERCC MEETING

MAY 18, 1978

BASIS FOR THE GREENHOUSE EFFECT

I. **EARTH RECEIVES VISIBLE & UV RADIATION FROM SUN**

A. Some Reflected Into Space
B. Some Absorbed By Atmosphere
C. Most Absorbed At Earth's Surface

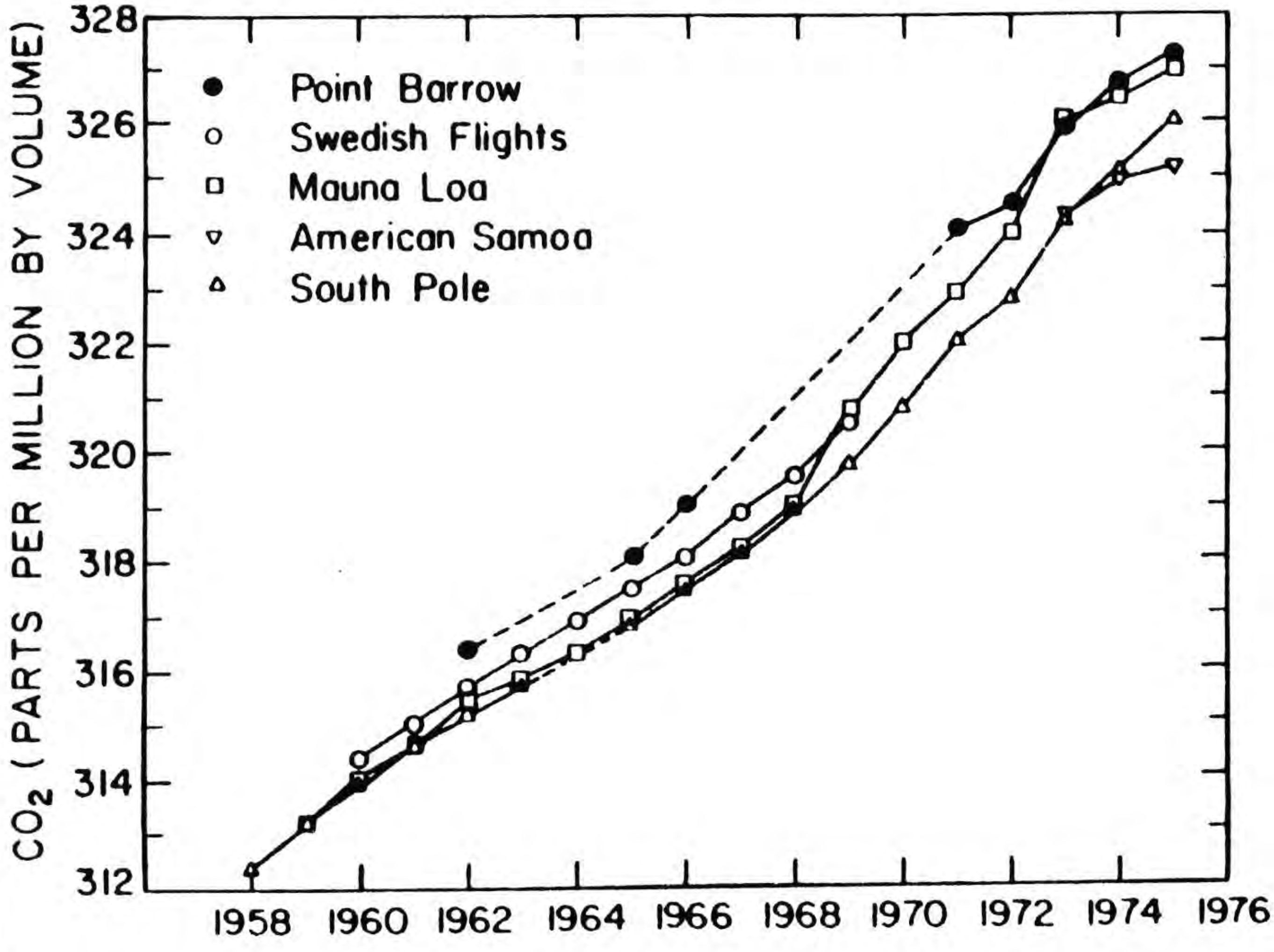
II. **EARTH EMITS INFRARED RADIATION TOWARD SPACE**

A. Carbon Dioxide And Other Atmospheric Constituents Absorb Part Of The Infrared Radiation
B. Absorbed Energy Warms The Atmosphere

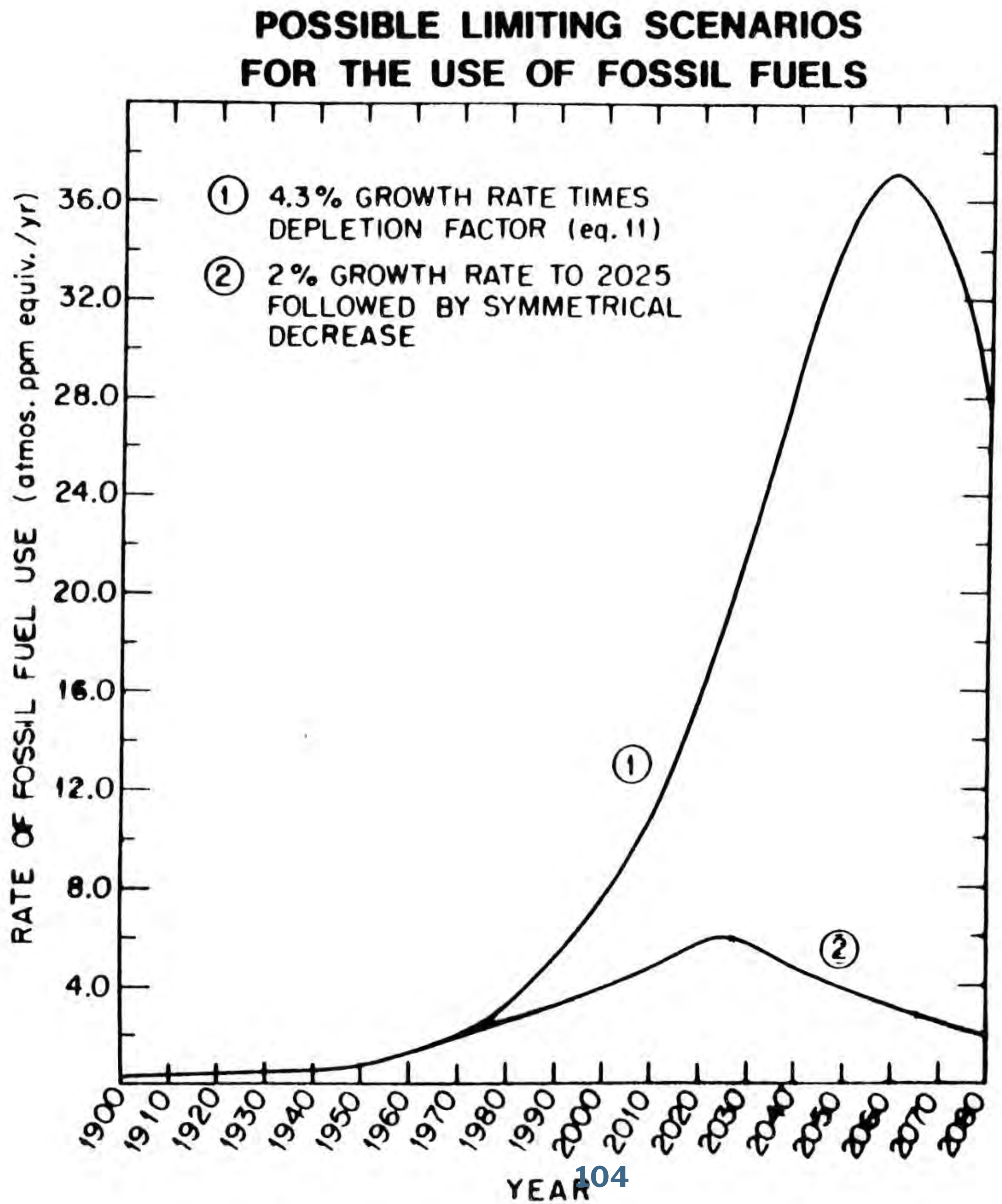
III. **THEREFORE HIGHER CO_2 CONCENTRATIONS WARM THE LOWER ATMOSPHERE**

VUGRAPH 2

CO_2 MEASURED AT REMOTE SITES



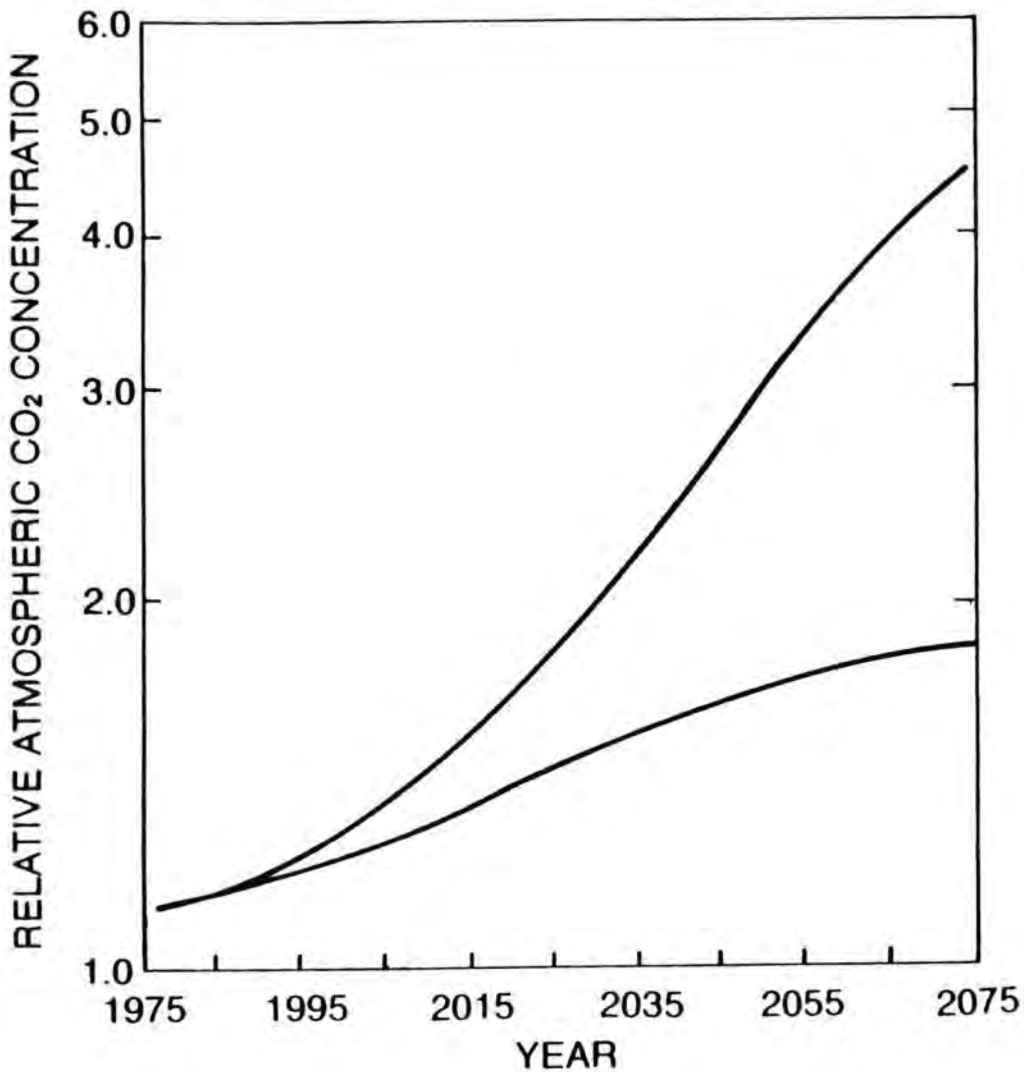
VUGRAPH 3



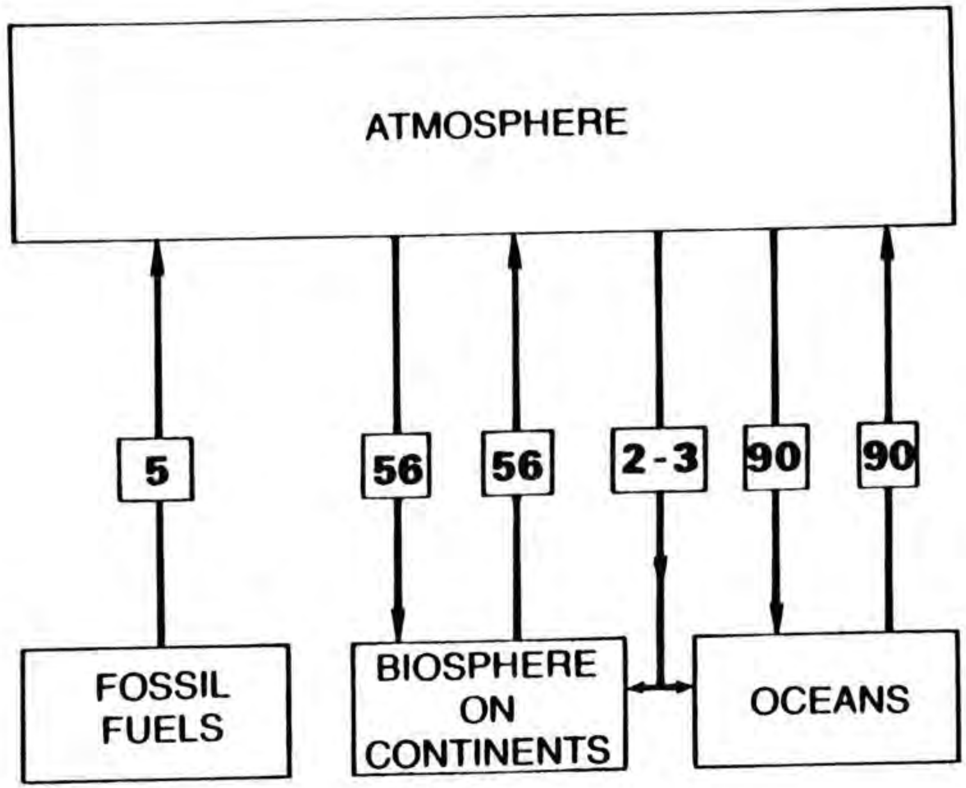
POSSIBLE LIMITING SCENARIOS
FOR THE USE OF FOSSIL FUELS
① 4.3% GROWTH RATE TIMES DEPLETION FACTOR (eq. 11)
② 2% GROWTH RATE TO 2025 FOLLOWED BY SYMMETRICAL DECREASE
RATE OF FOSSIL FUEL USE (atmos. ppm equiv./yr)
36.0
32.0
28.0
24.0
20.0
16.0
12.0
8.0
4.0
①
②
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
YEAR

VUGRAPH 4

PROJECTED ATMOSPHERIC CO_2 CONCENTRATIONS RELATIVE TO 1860



CO_2 EXCHANGE
(Billions Of Tons Of Carbon Per Year)



VUGRAPH 6

RATIO OF CO_2 DERIVED FROM BIOSPHERE VS FOSSIL FUEL

RATIO	1ST AUTHOR	JOURNAL	DATE
0.1-1.0	ADAMS	SCIENCE	4/1/77
0.5	BOLIN	SCIENCE	5/6/77
0.8-1.6 (1)	WOODWELL	SCIENCE	1/13/78
2.0 (2)	STUVIER	SCIENCE	1/19/78
0.5	WILSON	NATURE	5/4/78

(1) PRESENT RATE (2) 1850-1950

VUGRAPH 7

CURRENT STATUS OF SCIENTIFIC OPINION

I. Current Opinion Overwhelmingly Favors Attributing Atmospheric CO_2 Increase To Fossil Fuel Combustion

II. Most Scientists Feel More Research Is Needed To Support An Unqualified Conclusion

III. Some Scientists Claim That Part Or All Of The CO_2 Increase Arises From The Destruction Of Forests And Other Land Biota.

UNCERTAINTIES WHICH LIMIT CLIMATE MODELING

I. **CLOUDINESS**

A. Effect Of A Cloud Depends On Size, Shape and Position.

II. **ATMOSPHERE — OCEAN INTERACTIONS**

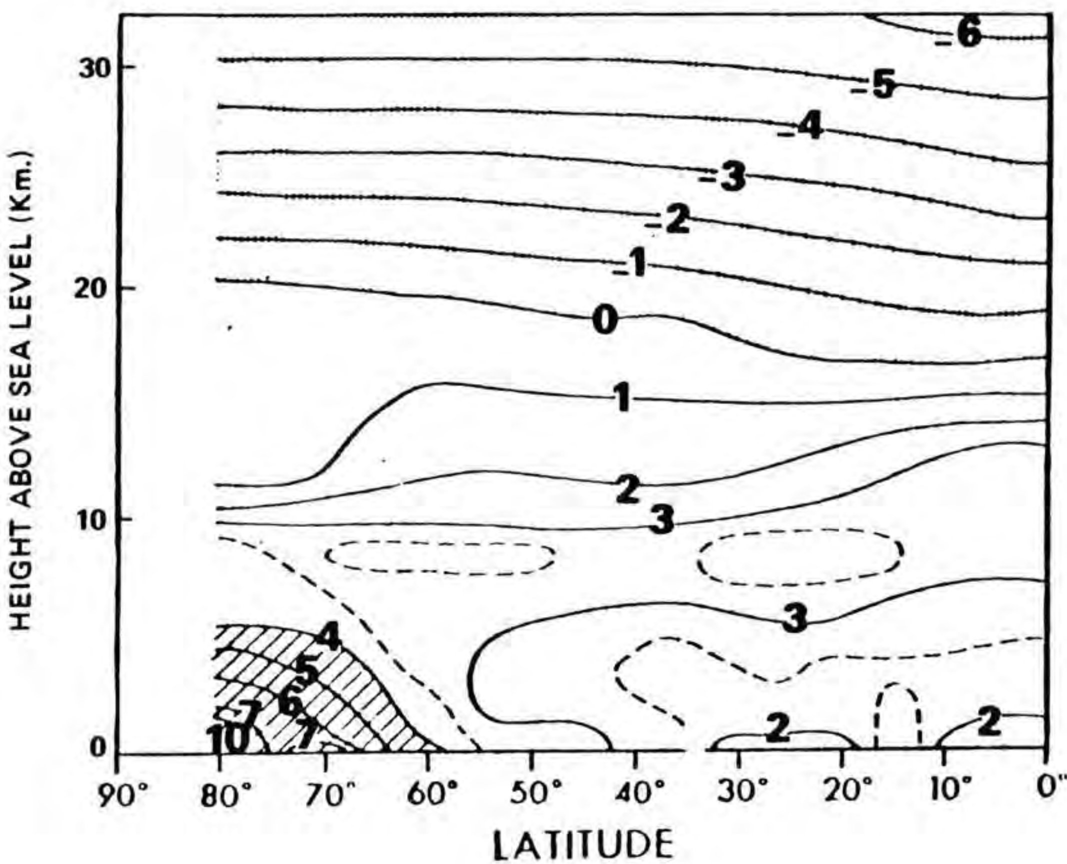
A. How Should Heat Capacity Be Handled
B. To What Depth Is The Ocean Involved

III. **THE INTERACTION BETWEEN SEASONS AND LONG TERM TRENDS**

IV. **IS CLIMATE REALLY PREDICTABLE**

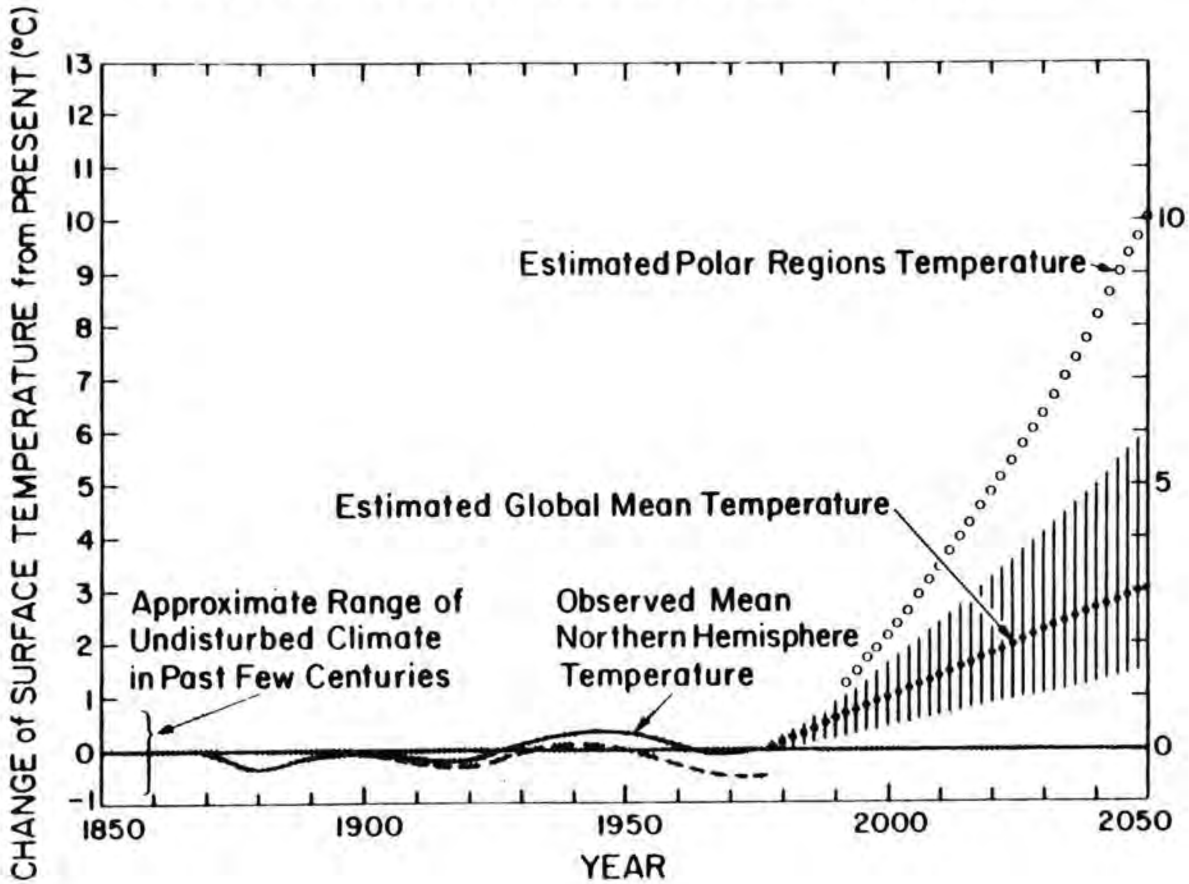
A. Could Be An "Almost Transitive " System Which Fluctuates Between Stable States.

TEMPERATURE EFFECT OF DOUBLING CO_2



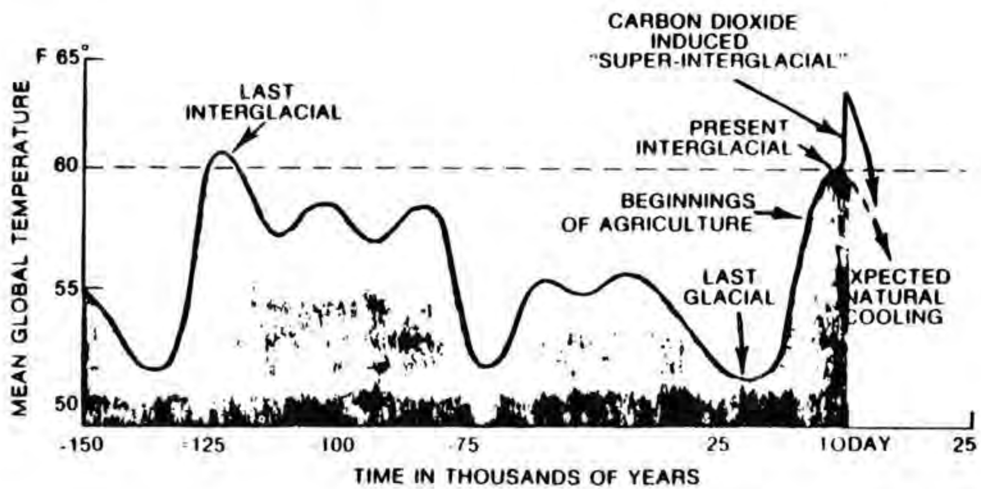
VUGRAPH 10

HOW PREDICTED ΔT
COMPARES WITH RECENT TEMPERATURES



VUGRAPH 11

EFFECT OF CO_2 ON AN INTERGLACIAL SCALE



IMPLICATION OF PREDICTED GREENHOUSE EFFECT

I. **PERMANENT SNOW COVER AND FLOATING SEA ICE WILL BE REDUCED**
   - A. Negligible Effect On Sea Level

II. **PROBABLY NO EFFECT ON POLAR ICE SHEETS**
   - A. West Antarctic Ice Sheet Most Critical

III. **LENGTH OF GROWING SEASON WOULD INCREASE**
   - A. 1°C Temperature Rise Adds 10 Days

IV. **CHANGES IN PRECIPITATION PATTERNS WILL BENEFIT SOME AREAS AND HARM OTHERS.**
   - A. Models Can Not Predict These Effects
   - B. Can Study Evidence From Climatic Optimum 4000-8000 Years Ago.


MOST OF THE USSR'S VAST
AGRICULTURAL LAND BASE
LIES LATITUDINALLY NORTH
OF THE UNITED STATES
Fairbanks
Leningrad
Kiev
Moscow
Arctic Circle
60
40
40
Minneapolis
San Francisco
Denver
Springfield
Philadelphia
Washington
SOVIET AGRICULTURAL LANDS

VUGRAPH 13

VUGRAPH 14

RECENT MEETINGS ON GREENHOUSE EFFECT

I. WORLD METEOROLOGICAL ORGANIZATION

SCIENTIFIC WORKSHOP ON ATMOSPHERIC CO_2

NOV. 28 - DEC. 3, 1976, WASHINGTON, D. C.

II. ERDA - WORKSHOP

ENVIRONMENTAL EFFECT OF CO_2 FROM FOSSIL FUEL COMBUSTION

MARCH 7-11, 1977, MIAMI BEACH, FLA.

III. SCOPE

WORKSHOP ON WORLD CARBON BUDGET

MARCH 21-26, 1977, HAMBURG, GERMANY

IV. IIASA

CARBON DIOXIDE, CLIMATE AND SOCIETY

FEB. 21-24, 1978, LAXENBURG, AUSTRIA

VUGRAPH 15

WORKING GROUP REPORTS - IIASA WORKSHOP

I. THE CARBON CYCLE

   A. CONFIDENCE IN MODELS CONSIDERABLY LESS THAN 10 YEARS AGO

   B. BIOSPHERE FLUX MUST BE ESTABLISHED

II. WHAT WILL BE CLIMATE IMPACT OF 2 X CO_2

   A. 2-3°C INCREASE DEPENDING ON HOW CLOUDS ACT

III. CO_2 QUESTION VS. ENERGY STRATEGIES

   A. MAN CAN AFFORD 5-10 YR. TIME WINDOW TO ESTABLISH WHAT MUST BE DONE.

   B. IT IS PREMATURE TO LIMIT USE OF FOSSIL FUELS BUT THEY SHOULD NOT BE ENCOURAGED.

VUGRAPH 16

ERDA PROPOSALS FOR IMMEDIATE FUNDING

($1.56 $\overline{MM}$ TO START - SOON UP TO $9.8 $\overline{MM}$/YR.)

1. BETTER ESTIMATE OF FOSSIL FUEL CO_2 OUTPUT
2. USE CARBON ISOTOPES TO GET INPUT FROM BIOSPHERE
3. DIRECT ASSESSMENT OF BIOSPHERE INPUT ($3 $\overline{MM}$)
4. EXPAND AND IMPROVE MONITORING NETWORK
5. TRANSFER OF CO_2 INTO DEEPER OCEAN ($5 $\overline{MM}$)
6. BUFFERING OF CO_2 ABSORPTION IN OCEAN

PROJECTS STARTING AFTER INITIAL PROGRAMS ARE UNDER WAY

($1.26 $\overline{MM}$ TO START - RISES TO $5.0 $\overline{MM}$/YR)

7. ARE SHALLOW WATER CARBONATES DISSOLVING
8. RESPONSE OF BIOTA TO CO_2 INCREASE
9. BETTER MODELS OF CARBON CYCLE
10. CO_2 EXCHANGE ACROSS AIR-SEA INTERFACE
11. FLUX OF ORGANIC CARBON INTO & WITHIN SEA
12. IMPROVE CO_2 MEASUREMENT TECHNIQUES
13. DISSOLUTION OF DEEP SEA $CaCO_3$ AS FINAL SINK

VUGRAPH 18

SUMMARY

I. CO_2 RELEASE MOST LIKELY SOURCE OF INADVERTENT CLIMATE MODIFICATION.

II. PREVAILING OPINION ATTRIBUTES CO_2 INCREASE TO FOSSIL FUEL COMBUSTION.

III. DOUBLING CO_2 COULD INCREASE AVERAGE GLOBAL TEMPERATURE 1°C TO 3°C BY 2050 A.D. (10°C PREDICTED AT POLES).

IV. MORE RESEARCH IS NEEDED ON MOST ASPECTS OF GREENHOUSE EFFECT

V. 5-10 YR. TIME WINDOW TO GET NECESSARY INFORMATION

VI. MAJOR RESEARCH EFFORT BEING CONSIDERED BY DOE

1979 Exxon memo,

Controlling the CO_2 Concentration in the Atmosphere

Central Files

PROPRIETARY INFORMATION

For Authorized Company Use Only

EXXON RESEARCH AND ENGINEERING COMPANY

P.O. BOX 101, FLORHAM PARK, NEW JERSEY 07932

EXXON ENGINEERING PETROLEUM DEPARTMENT
Planning Engineering Division

Cable: ENGREXXON, N.Y.

R. L. MASTRACCHIO
Manager
L. E. Hill
Senior Eng. Assoc.

October 16, 1979

Controlling Atmospheric CO_2

79PE 554

Dr. R. L. Hirsch:

The attached memorandum presents the results of a study on the potential impact of fossil fuel combustion on the CO_2 concentration in the atmosphere. This study was made by Steve Knisely, a summer employee in Planning Engineering Division.

The study considers the changes in future energy sources which would be necessary to control the atmospheric CO_2 concentration at different levels. The principle assumption for the CO_2 balance is that 50% of the CO_2 generated by fossil fuels remains in the atmosphere. This corresponds to the recent data on the increasing CO_2 concentration in the atmosphere compared to the quantity of fossil fuel combusted.

Present climatic models predict that the present trend of fossil fuel use will lead to dramatic climatic changes within the next 75 years. However, it is not obvious whether these changes would be all bad or all good. The major conclusion from this report is that, should it be deemed necessary to maintain atmospheric CO_2 levels to prevent significant climatic changes, dramatic changes in patterns of energy use would be required. World fossil fuel resources other than oil and gas could never be used to an appreciable extent.

No practical means of recovering and disposing of CO_2 emissions has yet been developed and the above conclusion assumes that recovery will not be feasible.

It must be realized that there is great uncertainty in the existing climatic models because of a poor understanding of the atmospheric/terrestrial/oceanic CO_2 balance. Much more study and research in this area is required before major changes in energy type usage could be recommended.

W. L. Ferrall

W. L. FERRALL

WLF:ceg
Attachment

c: J. F. Black
J. W. Herrmann
L. E. Hill
E. D. Hooper
F. J. Kaiser
R. L. Mastracchio
W. H. Mueller
H. Shaw
G. O. Wilhelm

CONTROLLING THE CO_2 CONCENTRATION IN THE ATMOSPHERE

The CO_2 concentration in the atmosphere has increased since the beginning of the world industrialization. It is now 15% greater than it was in 1850 and the rate of CO_2 release from anthropogenic sources appears to be doubling every 15 years. The most widely held theory is that:

- The increase is due to fossil fuel combustion
- Increasing CO_2 concentration will cause a warming of the earth's surface
- The present trend of fossil fuel consumption will cause dramatic environmental effects before the year 2050.

However, the quantitative effect is very speculative because the data base supporting it is weak. The CO_2 balance between the atmosphere, the biosphere and the oceans is very ill-defined. Also, the overall effect of increasing atmospheric CO_2 concentration on the world environment is not well understood. Finally, the relative effect of other impacts on the earth's climate, such as solar activity, volcanic action, etc. may be as great as that of CO_2.

Nevertheless, recognizing the uncertainty, there is a possibility that an atmospheric CO_2 buildup will cause adverse environmental effects in enough areas of the world to consider limiting the future use of fossil fuels as major energy sources. This report illustrates the possible future limits on fossil fuel use by examining different energy scenarios with varying rates of CO_2 emissions. Comparison of the different energy scenarios show the magnitude of the switch from fossil fuels to non-fossil fuels that might be necessary in the future. Non-fossil fuels include fission/fusion, geothermal, biomass, hydroelectric and solar power. The possible environmental changes associated with each scenario are also discussed.

CONCLUSIONS

As stated previously, predictions of the precise consequences of uncontrolled fossil fuel use cannot be made due to all of the uncertainties associated with the future energy demand and the global CO_2 balance. On the basis that CO_2 emissions must be controlled, this study examined the possible future fuel consumptions to achieve various degrees of control. Following are some observations and the principle conclusions from the study:

- The present trends of fossil fuel combustion with a coal emphasis will lead to dramatic world climate changes within the next 75 years, according to many present climatic models.

- The CO_2 buildup in the atmosphere is a worldwide problem. U.S. efforts to restrict CO_2 emission would delay for a short time but not solve the problem.

- Warming trends which would move the temperate climate northward may be beneficial for some nations (i.e., the USSR, see Figure 1) and detrimental for others. Therefore, global cooperation may be difficult to achieve.

- Removal of CO_2 from flue gases does not appear practical due to economics and lack of reasonable disposal methods.

- If it becomes necessary to limit future CO_2 emissions without practical removal/disposal methods, coal and possibly other fossil fuel resources could not be utilized to an appreciable extent.

- Even with dramatic changes in current energy resource use, it appears unlikely that an increase of 50% over the pre-industrial CO_2 level can be avoided in the next century. This would be likely to cause a slight increase in global temperatures but not a significant change in climate, ocean water level or other serious environmental efforts.

The potential problem is great and urgent. Too little is known at this time to recommend a major U.S. or worldwide change in energy type usage but it is very clear that immediate research is necessary to better model the atmosphere/terrestrial/oceanic CO_2 balance. Only with a better understanding of the balance will we know if a problem truly exists.

Existing Data and Present Models

Since the beginning of industrialization, the atmospheric carbon dioxide concentration has increased from approximately 290 ppm in 1860 to 336 ppm today. Atmospheric CO_2 concentrations have been recorded on a monthly basis by C. D. Keeling since 1958 at Mauna Loa Observatory in Hawaii (see Figure 2). Seasonal variations are clearly shown with the CO_2 concentrations lowest during the North American and Eurasian summers, due to increased photosynthetic activities. Over the last ten years, the atmospheric concentration has been increasing at an average rate of about 1.2 ppm/year.

The present consumption of fossil fuels releases more than 5 billion tons of carbon as CO_2 into the atmosphere each year. Data to date indicate that of the amount released approximately one-half is absorbed by the oceans. The other half remains in the atmosphere. There is some question as to whether the terrestrial biosphere is a sink, absorbing atmospheric CO_2, or a source of CO_2 emissions, due to man's land clearing activities. Current opinion attributes the atmospheric CO_2 increase to fossil fuels and considers the biosphere input to be negligible.

Figure 3 shows the carbon cycle with the ocean and the biosphere as sinks for approximately 50% of the fossil fuel emissions. Most models show the ocean to be a major sink while the biosphere appears to be a much smaller sink if it absorbs any CO_2 at all. It is clear from Figure 3 that the net atmospheric increase in CO_2 is quite small compared to the quantities of CO_2 exchanged between the atmosphere and the earth. This makes it very difficult to analyze the fossil fuel impact on the overall carbon cycle.

The fossil fuel resource is very large compared to the quantity of carbon in the atmosphere. Therefore, if one half of the CO_2 released by combustion of fossil fuels remains in the atmosphere, only about 20% of the recoverable fossil fuel could be used before doubling the atmospheric CO_2 content.

The concern over the increasing CO_2 levels arises because of the radiative properties of the gas in the atmosphere. CO_2 does not affect the incoming short-wave (solar) radiation to the earth but it does absorb long-wave energy reradiated from the earth. The absorption of long-wave energy by CO_2 leads to a warming of the atmosphere. This warming phenomenom is known as the "greenhouse effect."

A vast amount of speculation has been made on how increased CO_2 levels will affect atmospheric temperatures. Many models today predict that doubling the 1860 atmospheric CO_2 concentration will cause a 1^o to 5^oC global temperature increase (see Figure 4). Extrapolation of present fossil fuel trends would predict this doubling of the CO_2 concentration to occur about 2050. A temperature difference of 5^oC is equal to the difference between a glacial and an interglacial period. The temperature increases will also tend to vary with location being much higher in the polar region (see Figure 5). These temperature predictions may turn out too high or low by several fold as a result of many feedback mechanisms that may arise due to increased temperatures and have not been properly accounted for in present models.

These mechanisms include:

- A decrease in average snow and ice coverage. This is a positive feedback mechanism since it would result in a decrease of the earth's albedo (reflectivity) which would produce an added warming effect.

- Cloud Cover. This is considered the most important feedback mechanism not accounted for in present models. A change of a few percent in cloud cover could cause larger temperature changes than those caused by CO_2. Increased atmospheric temperature could cause increased evaporation from the oceans and increased cloud cover.

- Ocean and Biosphere Responses. As the CO_2 level is increased and the ambient temperature rises, the ocean may lose some of its capacity to absorb CO_2 resulting in a positive feedback. However, increased CO_2 levels could increase photosynthetic activities which would then be a negative feedback mechanism.

As evidenced by the balance shown in Figure 3, the atmospheric carbon exchange with the terrestrial biosphere and the oceans is so large that small changes due to these feedback mechanisms could drastically offset or add to the impact of fossil fuel combustion on the earth's temperature.

Appendix A gives one, but not unanimous, viewpoint of how the environment might change if the feedback mechanisms are ignored. The contribution that will ultimately be made by these feedback mechanisms is unknown at present.

Energy Scenarios for Various CO_2 Limits

Using the CO_2 atmospheric concentration data recorded to date, the correlation of these data with fossil fuel consumption and the proposed "greenhouse effect" models, this study reviews various world energy consumption scenarios to limit CO_2 atmospheric buildup. The concentration of CO_2 in the atmosphere is controlled in these studies by regulating the quantity of each type of fossil fuel used and by using non-fossil energy sources when required. The quantity of CO_2 emitted by various fuels is shown in Table 1. These factors were calculated based on the combustion energy/carbon content ratio of the fuel and the thermal efficiency of the overall conversion process where applicable. They show the high CO_2/energy ratio for coal and shale and the very high ratios for synthetic fuels from these base fossil fuels which are proposed as fuels of the future.

The total world energy demand used in these scenarios is based upon the predictions in the Exxon Fall 1977 World Energy Outlook for the high oil price case for the years 1976 to 1990. It is assumed that no changes in the sources of supply of energy could be made during this period of time. Case A, which has no restrictions on CO_2 emissions, follows the high oil price predictions until 2000.

Petroleum production and consumption is the same in each scenario. The high oil price case predictions are followed until 2000. After 2000 petroleum production continues to increase until a reserve to production ratio (R/P) equals ten to one. Production peaks at this point and then continues at a ten to one R/P ratio until supplies run out.

The consumption of coal, natural gas and non-fossil fuels (fission/fusion, geothermal, biomass, hydroelectric and solar power) vary with each scenario. Shale oil makes small contributions past the year 2000. It is not predicted to be a major future energy source due to environmental damage associated with the mining of shale oil, and also due to rather large amounts of CO_2 emitted per unit energy generated (see Table 1). If more shale oil were used, it would have the same effect on CO_2 emissions as the use of more coal. The fossil fuel resources assumed to be recoverable are tabulated in Appendix B.

A. No Limit on CO_2 Emissions

In this scenario no limitations are placed upon future fossil fuel use. The use of coal is emphasized for the rest of this century and continues on into the next century. The development and use of non-fossil fuels continue to grow but without added emphasis. Natural gas production continues at a slowly increasing rate until an R/P ratio of 7/1 is reached around 2030. Production after 2030 continues at a 7/1 ratio until reserves run out. Figure 6 shows the future energy demand for this scenario.

Figure 7 shows that the CO_2 buildup from this energy strategy is quite rapid. The yearly atmospheric CO_2 increase rises from 1.3 ppm in 1976 to 4.5 ppm in 2040. Noticeable temperature changes would occur around 2010 as the concentration reaches 400 ppm. Significant climatic changes occur around 2035 when the concentration approaches 500 ppm. A doubling of the pre-industrial concentration occurs around 2050. The doubling would bring about dramatic changes in the world's environment (see Appendix A). Continued use of coal as a major energy source past the year 2050 would further increase the atmospheric CO_2 level resulting in increased global temperatures and environmental upsets.

B. CO_2 Increase Limited to 510 ppm

This energy scenario is limited to a 75% increase over the pre-industrial concentration of 290 ppm. No limitations are placed on petroleum production. Natural gas production is encouraged beginning in 1990 to minimize coal combustion until non-fossil fuels are developed. Production of natural gas would increase until 2010 when an R/P ratio of 7/1 would be reached. Production would then continue at a R/P of 7/1 until supplies ran out. The development and use of nonfossil fuels are emphasized beginning the 1990's. Non-fossil fuels start to be substituted for coal in 1990's. Figure 8 shows the future energy demand by fuel for this scenario.

Figure 9 shows the atmospheric CO_2 concentration trends for this scenario. The lower graph shows the maximum yearly atmospheric CO_2 increase allowable for the 510 ppm limit. The yearly CO_2 increase peaks in 2005 when it amounts to 2.3 ppm and then steadily decreases reaching 0.2 ppm in 2100. A 0.2 ppm increment is equivalent to the direct combustion of 5.1 billion B.O.E. of coal. This would be approximately 2 to 3% of the total world energy demanded in 2100. (For more detail on the construction of Figure 9, see Appendix C.)

A comparison of the Exxon year 2000 predictions and this scenario's year 2000 requirements shows the magnitude of possible future energy source changes. The Exxon predictions call for nonfossil fuels to account for 18 billion B.O.E. in 2000. This scenario requires that 20 billion B.O.E. be supplied by non-fossil fuels by

2000. This difference of 2 billion B.O.E. is equivalent to the power supplied by 214-1000 MW nuclear power plants operating at 60% of capacity. If it were supplied by methane produced from biomass, it would be equivalent to 80,000 square miles of biomass at a yield of 50 ton/acre, heat value of 6500 Btu/dry pound and a 35% conversion efficiency to methane. Therefore even a 20% increase in non-fossil fuel use is a gigantic undertaking.

The magnitude of the change to non-fossil fuels as major energy sources is more apparent when scenarios A and B are compared in the year 2025. Scenario B requires an 85 billion B.O.E. input from non-fossil fuels in 2025. This is almost double the 45 billion B.O.E. input predicted in scenario A. This 35 billion B.O.E. difference is approximately equal to the total energy consumption for the entire world in 1970.

The environmental changes associated with this scenario wouldn't be as severe as if the CO_2 concentration were allowed to double as in scenario A. Noticeable temperature changes would occur around 2010 when the CO_2 concentration reaches 400 ppm. Significant climate changes would occur as the atmospheric concentration nears 500 ppm around 2080. Even though changes in the environment due to increased atmospheric CO concentrations are uncertain, an increase to 500 ppm would probably bring about undesirable climatic changes to many parts of the earth although other areas may be benefitted by the changes. (See Appendix A, part 1).

C. <u>CO_2 Increase Limited to 440 ppm</u>

This scenario limits future atmospheric CO_2 increases to a 50% increase over the pre-industrial concentration of 290 ppm. As in the previous case, no limitations are placed on petroleum production and increased natural gas production is encouraged. Much emphasis is placed on the development and use of non-fossil fuels. Non-fossil fuels are substituted for coal beginning in the 1990's. By 2010 they will have to account for 50% of the energy supplied worldwide. This would be an extremely difficult and costly effort if possible. In this scenario coal or shale will never become a major energy source. Figure 10 shows the future world energy demand by fuel for this scenario.

The atmospheric CO_2 concentration trends for this scenario are shown in Figure 11. To satisfy the limits of this scenario the yearly CO_2 emissions would have to peak in 1995 at 2.0 ppm, and then rapidly decrease reaching a value of 0.04 ppm in 2100. A 0.04 ppm maximum allowable increase means that unless removal/disposal methods for CO_2 emissions are available only one billion B.O.E. of coal may be directly combusted in 2100 (or 1.4 billion Barrels of Oil). This would be less than 1% of the total energy demanded by the world in 2100.

To adhere to the 440 ppm limit, non-fossil fuels will have to account for 28 billion B.O.E. in 2000 as compared to 20 billion B.O.E. in scenario B and 18 billion B.O.E. in scenario A. This difference between scenarios A and C of 10 billion B.O.E. is equivalent to over 1000, 1000 MW nuclear power plants operating at 60% of capacity. Ten billion B.O.E. is also approximately equivalent to 400,000 square miles of biomass at 35% conversion efficiency to methane. This is equivalent to almost one-half the total U.S. forest land.

By 2025 the 110 billion B.O.E. input from non-fossil fuels called for in this scenario is more than twice as much as the 45 billion B.O.E. input predicted in scenario A. This difference of 65 billion is approximately equal to the amount of energy the entire world will consume in 1980. In terms of power plants, 65 billion B.O.E. is equivalent to almost 7000, 1000 MW nuclear power plants operating at 60% of capacity.

An atmospheric CO_2 concentration of 440 ppm is assumed to be a relatively safe level for the environment. A slight global warming trend should be noticeable but not so extreme as to cause major changes. Slight changes in precipitation might also be noticeable as the atmospheric CO_2 concentration nears 400 ppm.

S. KNISELY

REFERENCES

Corporate Planning Department, Exxon Corp. (Fall, 1977). World Energy Outlook, 1977-1990.

Flower, A. R. (1978). "World Oil Production," Scientific American 238 (3), pp. 42-49.

Griffith, E. D. and Clarke, A. W. (1979). "World Coal Production," Scientific American 240 (1), pp. 38-47.

McCormick, W. T., R. B. Kalisch, and T. J. Wander (1978). "AGA Study Assesses World Natural Gas Supply," The Oil and Gas Journal. February 13, 1978, pp. 103-106.

Peterson, E. K. (1969). "Carbon Dioxide Affects Global Ecology," Environmental Science and Technology 3 (11), pp. 1162-1169.

Rotty, R. M. (1979). Uncertainties Associated with Global Effects of Atmospheric Carbon Dioxide, ORAV/IEA-79-6 (0).

Siegenthaler, U. and Oeschger, H. (1978). "Predicting Future Atmospheric Carbon Dioxide Levels," Science 199, pp. 388-395.

Shaw, Henry (1978). Attached Appendix (B) of Letter to Dr. E. E. David, Jr. on December 7, 1978.

Steinberg, M., A. S. Albanese and Vi-duong Dang (1978). "Environmental Control Technology for Carbon Dioxide," presented at 71st Annual AICHE Meeting, November 12-16, 1978, Miami, Florida.

Stuiver, M. (1978). "Atmospheric Carbon Dioxide and Carbon Reservoir Changes," Science 199, pp. 263-258.

Terra, Stan (1978). "CO_2 and Spaceship Earth," EPRI Journal July/August, 1978, pp. 22-27.

Williams, J. (1978). "Global Energy Strategies, the Implications of CO_2," Futures, August, 1978, pp. 293-302.

b1798

Table 1

CO_2 EMISSIONS

Fuel	lb CO_2 Emitted* / 1000 Btu Fuel	% of Present CO_2 Output
SNG from Coal	0.35	0
Coal Liquids	0.32	0
Methanol from Coal	0.38	0
H_2 from Coal Gasification	0.38	0
Shale Oil	0.23	0
Bituminous Coal	.21	38%
Petroleum	.15	49%
Natural Gas	.11	13%
Fission/Fusion	0	0
Biomass	0	0
Solar	0	0

* Includes conversion losses where applicable.

c1798

APPENDIX A

ECOLOGICAL CONSEQUENCES OF INCREASED CO_2 LEVELS

From:

Peterson, E.K., "Carbon Dioxide Affects Global Ecology," Environmental Science and Technology 3 (11), 1162-1169 (Nov '69).

1. Environmental effects of increasing the CO_2 levels to 500 ppm. (1.7 times 1860 level)

   - A global temperature increase of 3°F which is the equivalent of a 1°-4° southerly shift in latitude. A 4° shift is equal to the north to south height of the state of Oregon.

   - The southwest states would be hotter, probably by more than 3°F, and drier.

   - The flow of the Colorado River would diminish and the southwest water shortage would become much more acute.

   - Most of the glaciers in the North Cascades and Glacier National Park would be melted. There would be less of a winter snow pack in the Cascades, Sierras, and Rockies, necessitating a major increase in storage reservoirs.

   - Marine life would be markedly changed. Maintaining runs of salmon and steelhead and other subarctic species in the Columbia River system would become increasingly difficult.

   - The rate of plant growth in the Pacific Northwest would increase 10% due to the added CO_2, and another 10% due to increased temperatures.

2. Effects of a doubling of the 1860 CO_2 concentration. (580 ppm)

   - Global temperatures would be 9°F above 1950 levels.

   - Most areas would get more rainfall, and snow would be rare in the contiguous states, except on higher mountains.

   - Ocean levels would rise four feet.

   - The melting of the polar ice caps could cause tremendous redistribution of weight and pressure exerted on the earth's crust. This could trigger major increases in earthquakes and volcanic activity resulting in even more atmospheric CO_2 and violent storms.

   - The Arctic Ocean would be ice free for at least six months each year, causing major shifts in weather patterns in the northern hemisphere.

- The present tropics would be hotter, more humid, and less habitable, but the present temperature latitude would be warmer and more habitable.

b1798

APPENDIX B

FOSSIL FUEL RESOURCES

Oil - Assume 1.6 trillion barrels of oil potentially recoverable as of 1975 (assuming the future recovery rate to be 40%). The minimum allowable Reserve to Production (R/P) ratio is ten one.

Shale Oil - Potential of 3.0 trillion B.O.E. but assuming 1977 technology only 200 billion B.O.E. actually recoverable.

Natural Gas - Approximately 1.6 trillion B.O.E. potentially recoverable. Minimum allowable R/P = 7.1.

Coal - Potential recoverable reserves equal approximately 12 trillion B.O.E. assuming a conservative 25% recoverability.

APPENDIX C

CONSTRUCTION OF SCENARIOS B AND C
(Scenario A requires no CO_2 emissions control)

1. Scenario B

The CO_2 concentration vs. year curve in Figure 9 was generated by the following equation:

after 1970 (t = 0), then

$$*C = 292 \text{ ppm} + 219 \text{ ppm}/[1 + 5.37 \exp. (-t/24 \text{ years})]$$

where C = concentration in ppm

The curve on the lower section of Figure 9, atmospheric CO_2 increase vs. years, is generated by finding the difference in the concentrations of successive years. This curve gives the maximum yearly increases allowable to stay within the limits placed on this scenario. The amount of fossil fuel that may be consumed in any given year can then be calculated by the lower curve. For example:

In 2100 the maximum allowable CO_2 increase equals 0.2 ppm.

This is equivalent to:

$$\frac{2 \text{ ppm}}{} \times \frac{2.1 \times 10^9 \text{ ton C}}{1 \text{ ppm}} \times \frac{2000 \text{ lb}}{\text{ton}} \times \frac{44 \text{ lb } CO_2}{12 \text{ lb C}} = 3.1 \times 10^{12} \text{ lb } CO_2$$

3.1×10^{12} lb CO_2 may be released by the combustion of:

for coal: $$\frac{3.1 \times 10^{12} \text{ lb } CO_2}{} \times \frac{1000 \text{ Btu}}{.21 \text{ lb } CO_2} \times \frac{1 \text{ B.O.E.}}{5.8 \times 10^6 \text{ Btu}}$$

= 2.5 billion B.O.E. of coal

This scenario is based on the assumption that 50% of CO_2 released each year will always be absorbed by the ocean and the rest will remain in the atmosphere.

*Derived from an equation presented by U. Siegenthaler and H. Oeschger (1978) (see references).

2. Scenario C

The equation for the generation of Figure 11 is derived to be,

after 1970 (t = 0), then

$$*C = 292 \text{ ppm} + 146 \text{ ppm}/[1 + 3.37 \exp.(-t/20 \text{ years})]$$

This scenario is the same as Scenario B only with different limits.

Figure 1


MOST OF THE USSR'S VAST
AGRICULTURAL LAND BASE
LIES LATITUDINALLY NORTH
OF THE UNITED STATES
Fairbanks
Leningrad
Kiev
Moscow
Arctic Circle
60
40
40
Minneapolis
Philadelphia
Washington
San Francisco
Denver
Springfield
SOVIET AGRICULTURAL LANDS

Figure 2

CONCENTRATION OF ATMOSPHERIC CO_2 AT MAUNA LOA OBSERVATORY, HAWAII

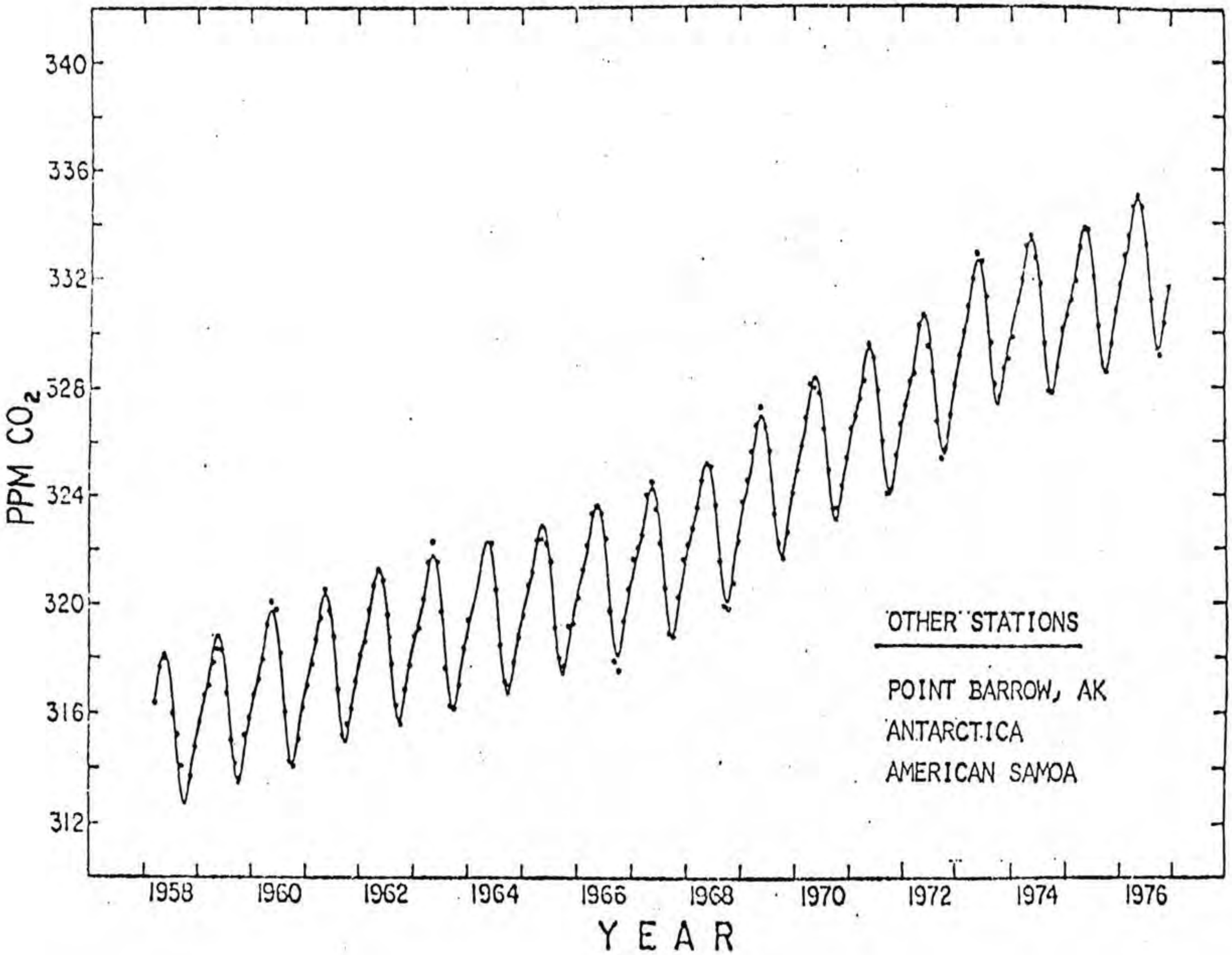


Figure 3

The Carbon Cycle

Current

Fluxes in Gt/a
Pool sizes in Gt

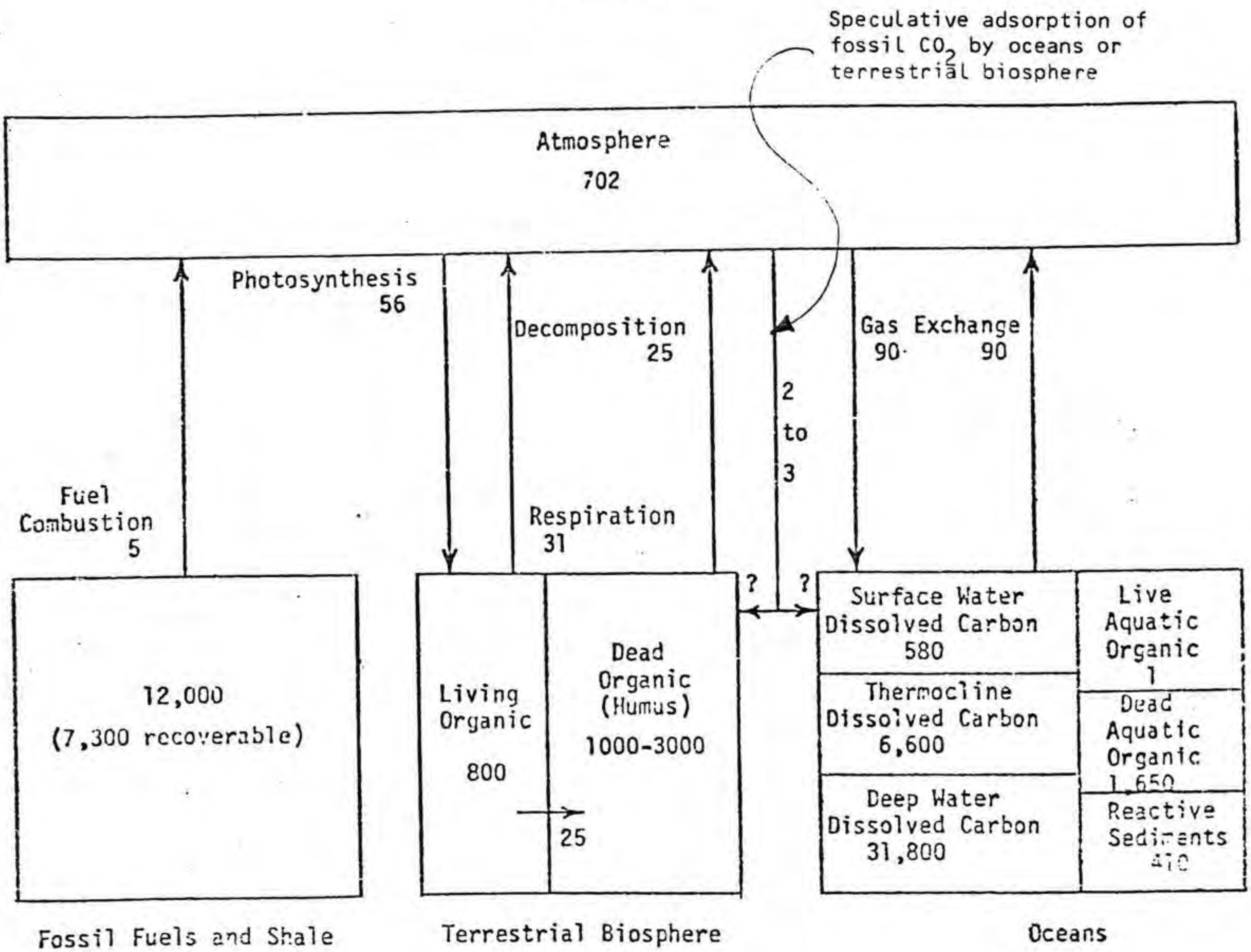


Figure 4

HOW PREDICTED ΔT COMPARES WITH RECENT TEMPERATURES

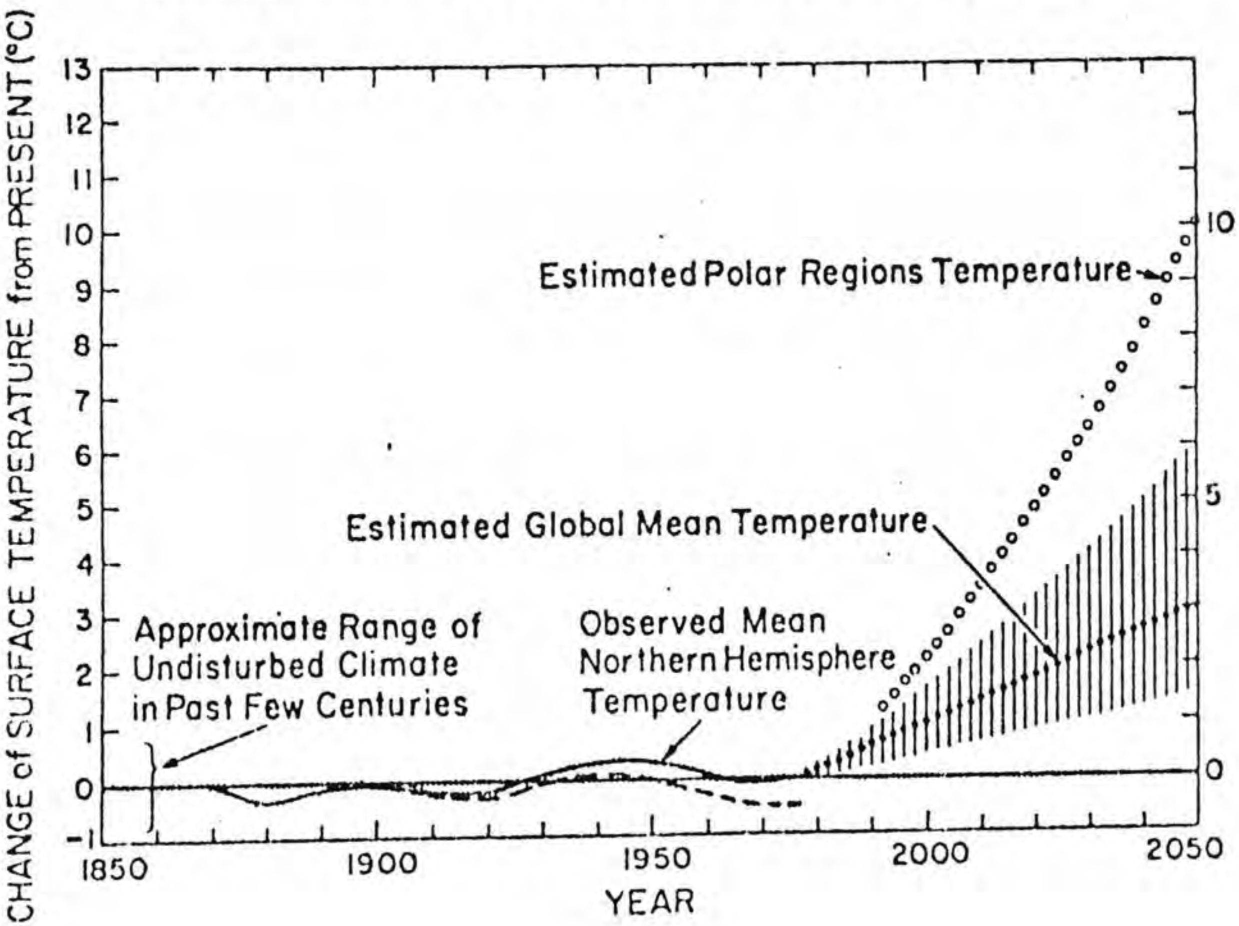


Figure 5

TEMPERATURE EFFECT OF DOUBLING CO_2

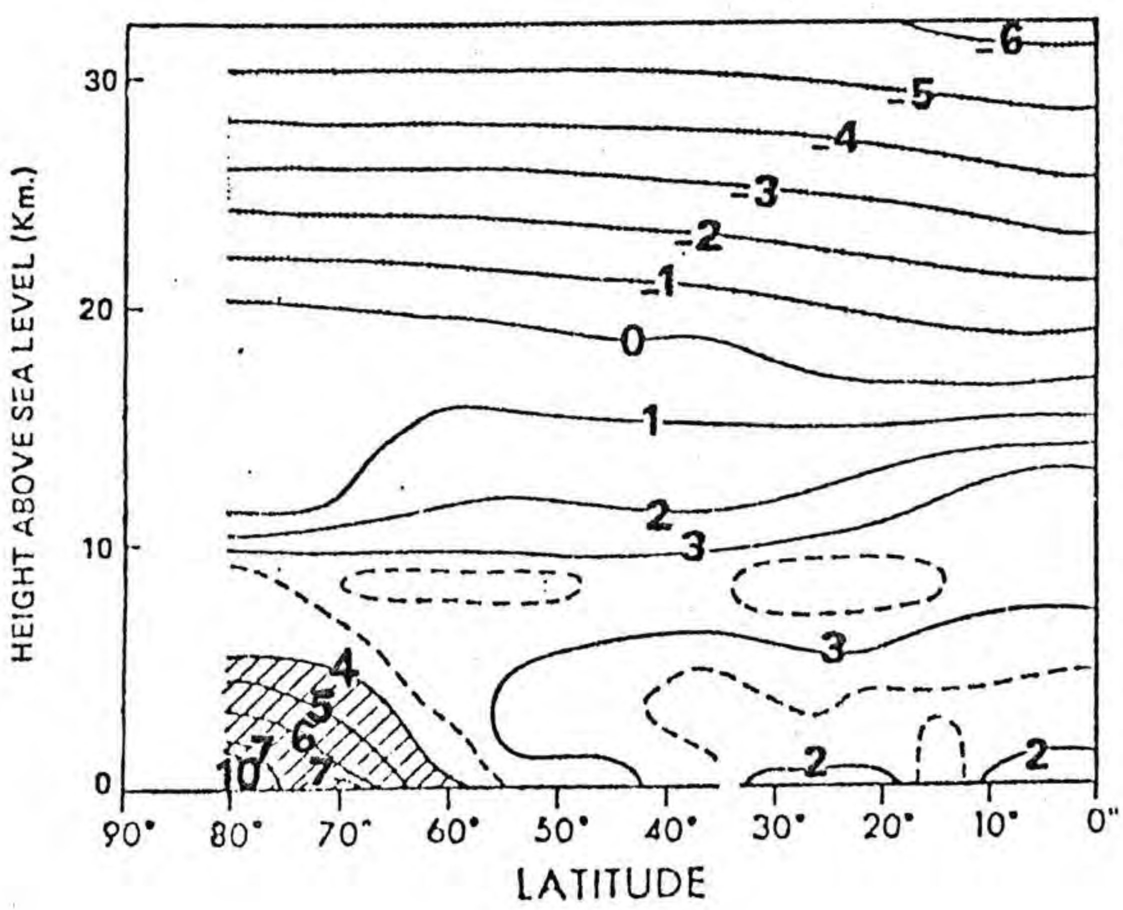


Figure 6

WORLD ENERGY DEMAND BY FUEL

UNLIMITED CO_2 INCREASE
(COAL EMPHASIS)

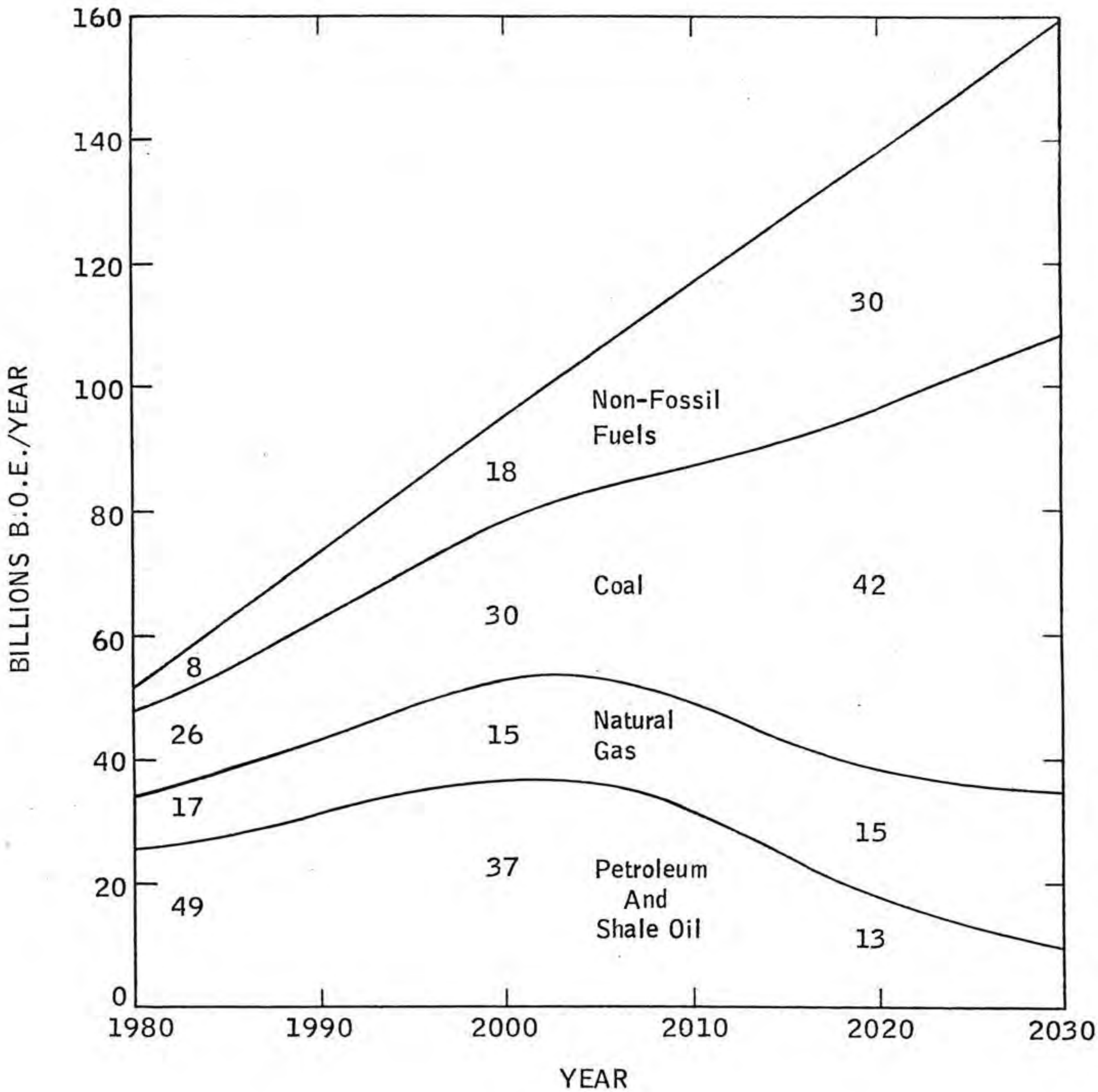


Figure 7

CO_2 IN ATMOSPHERE

RATE OF CO_2 BUILDUP

UNLIMITED INCREASE

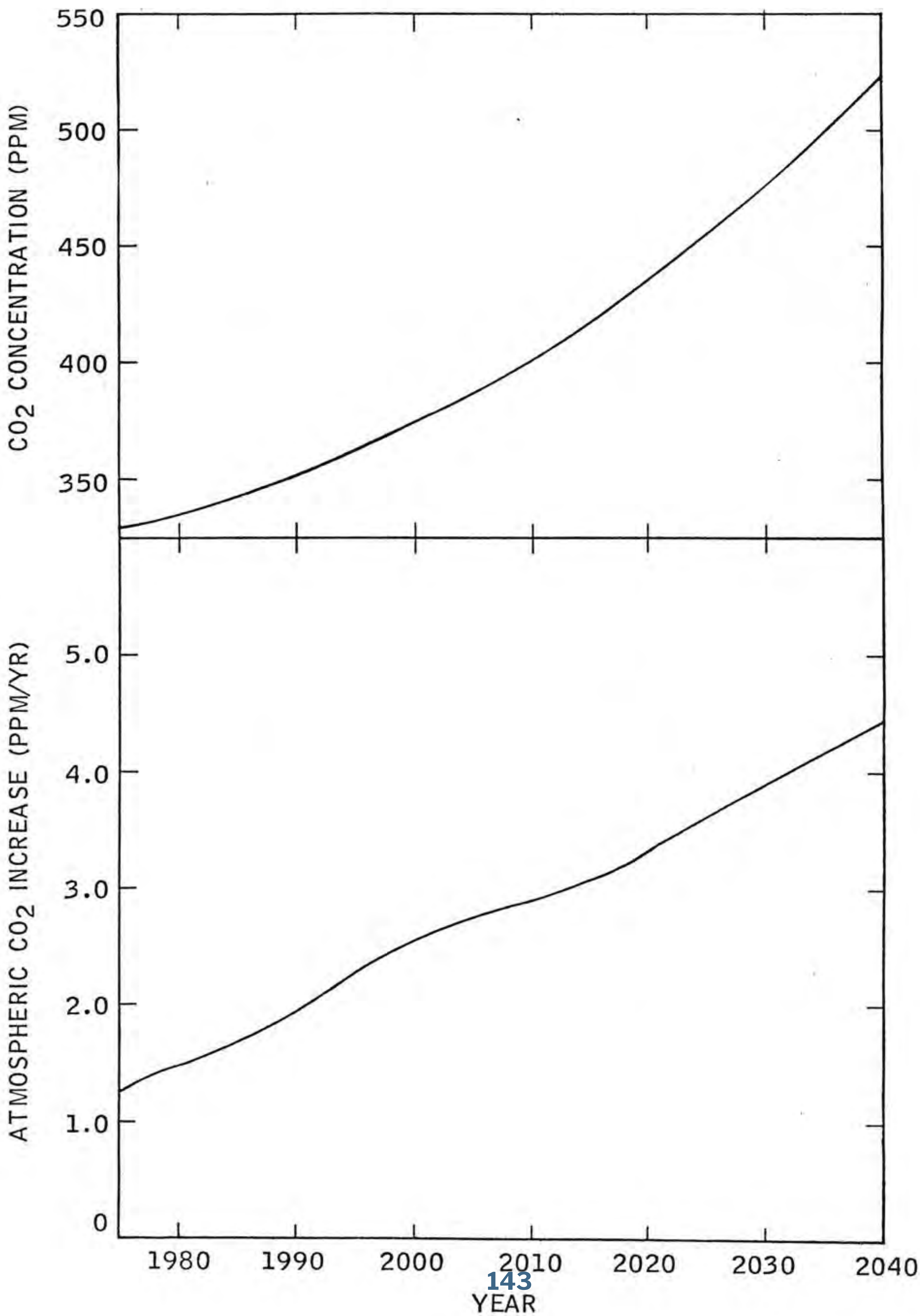


Figure 8

WORLD ENDERGY DEMAND BY FUEL
LIMITED TO A 75% CO_2 INCREASE

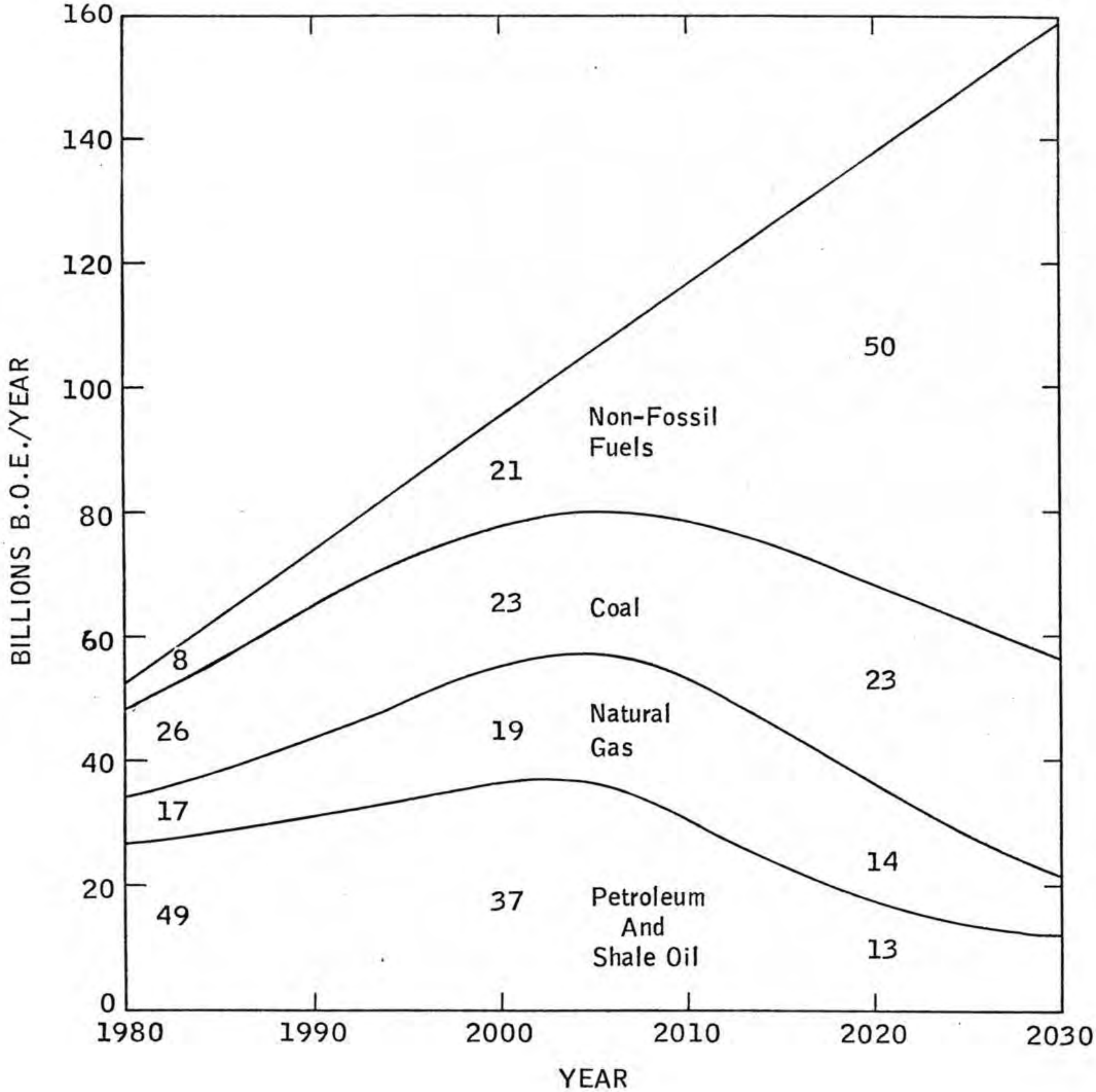


Figure 9

CO_2 IN ATMOSPHERE

RATE OF CO_2 BUILDUP
LIMITED TO 75% INCREASE

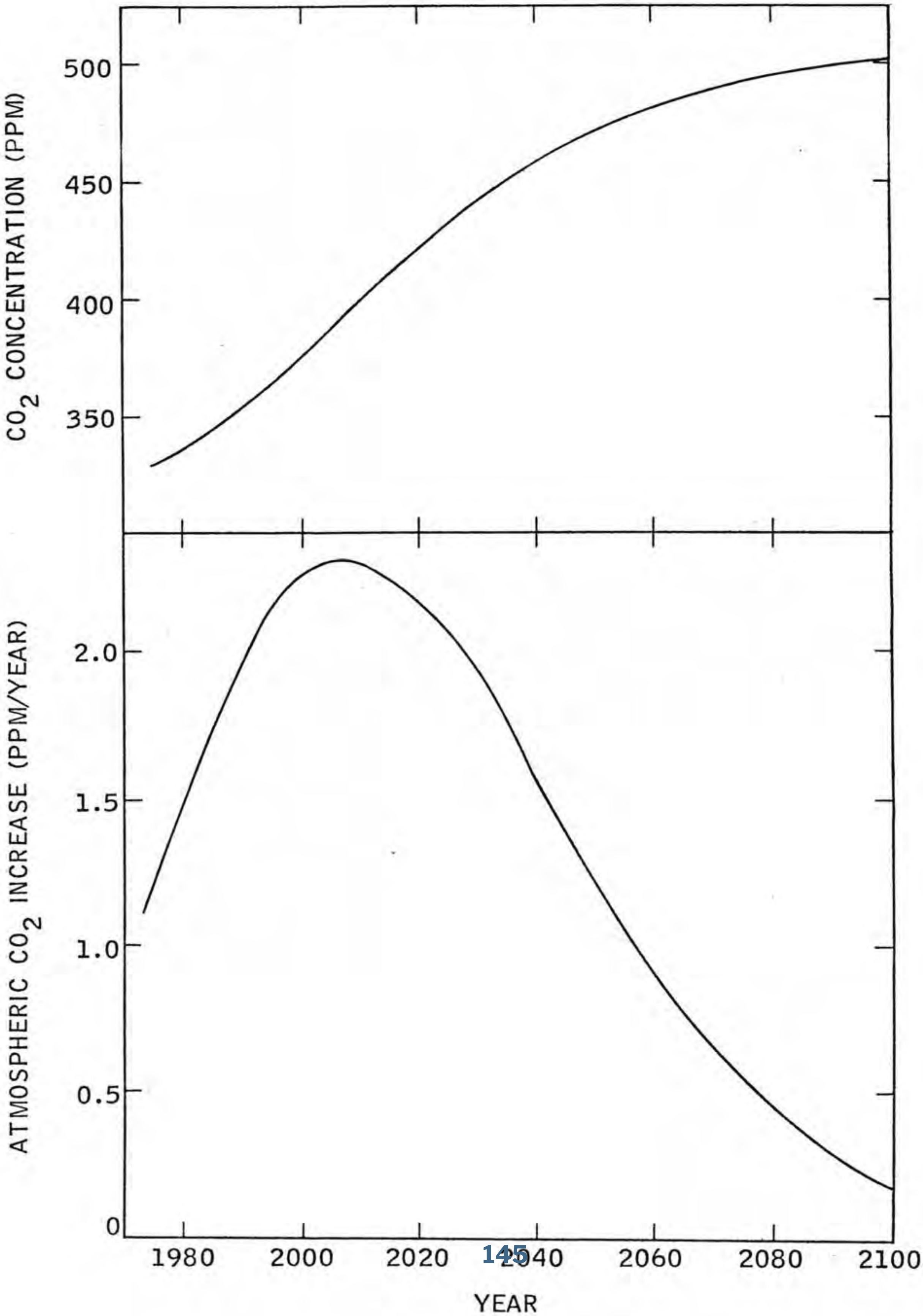
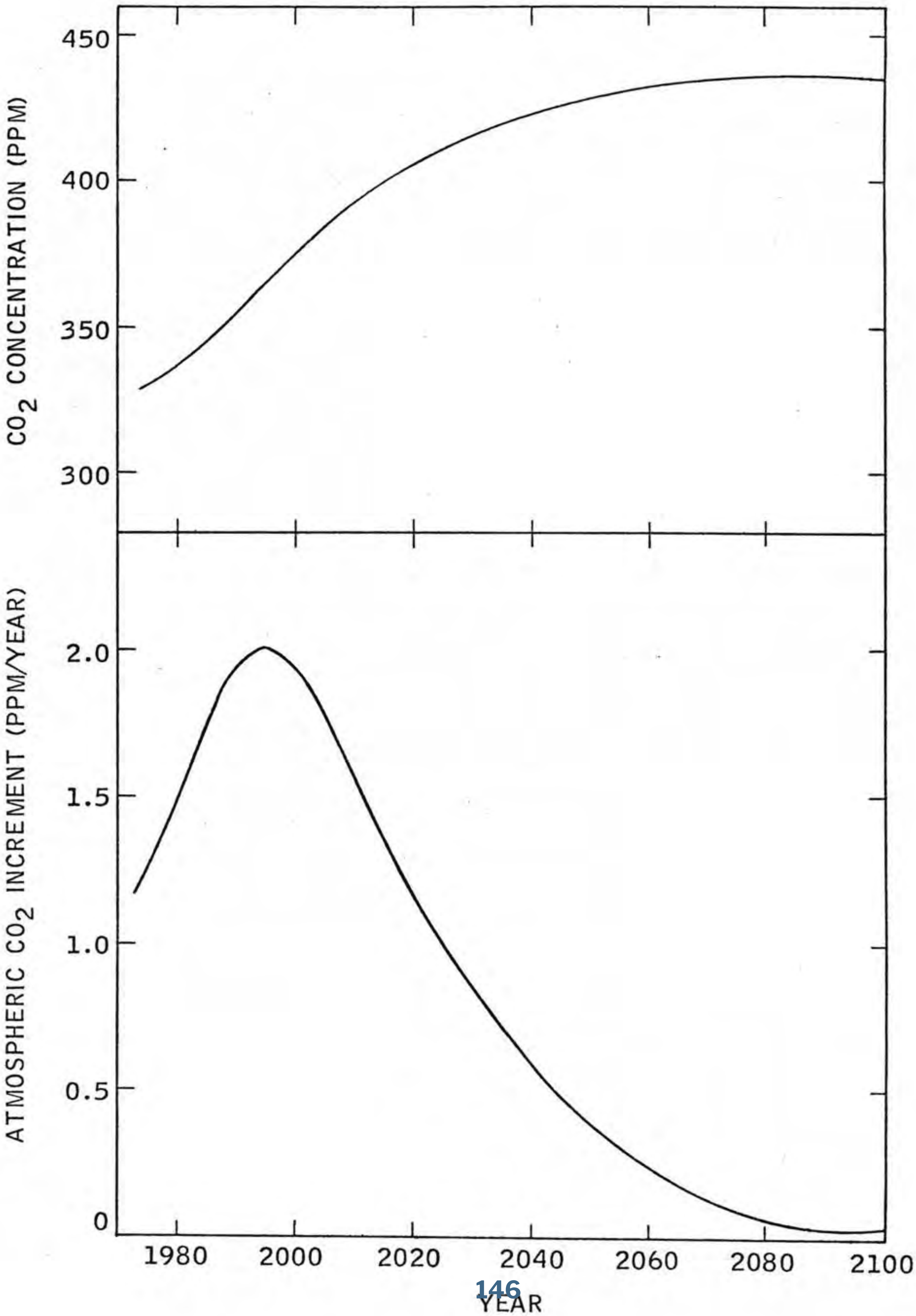


Figure 11

CO_2 IN ATMOSPHERE

RATE OF CO_2 BUILDUP



Minutes from 1980 meeting of the API CO_2 and Climate Task Force, *The CO_2 Problem*

American Petroleum Institute
2101 L Street, Northwest
Washington, D.C. 20037
202-457-7000

J. J. Nelson
(202) 457-6381

March 18, 1980

To: AQ-9 Task Force

Attached please find a copy of the minutes of the February 9, 1980 AQ-9 Task Force meeting. Please inform me of any errors or omissions.

Cordially,

J. J. Nelson

Attachment--minutes

/mi

CO_2 AND CLIMATE TASK FORCE (AQ-9)

Minutes of Meeting

9:15 a.m.
Friday, February 29, 1980

Manhatten Room
LaGuardia Airport
New York City, New York

MEMBERS PRESENT

K. Blower, Chairman	SOHIO
B. Bailey	Texaco
H. Shaw	Exxon R&E

OTHERS PRESENT

J. Laurman	Consultant
J. Nelson	API/EAD
C. Showers	SOHIO

OPENING REMARKS

K. Blower, Chairman, opened the meeting by listing the following goals of this meeting:

1. Increase industry's understanding of the CO_2 and climate problem.

2. Determine if there are feasibile and valuable research projects that could be accomplished by API.

3. Establish a mechanism to prepare any needed issue papers.

B. Bailey added the following items for consideration:

1. This Task Force should be the focal point and establish a basis for providing API comments on CO_2 and climate matters.

2. An overall goal of the Task Force should be to help develop ground rules for energy release of fuels and the cleanup of fuels as they relate to CO_2 creation.

CONSULTANT REPORT

Dr. J. A. Laurman, a consultant and a recognized expert in the field of CO_2 and climate,made a presentation to the Task Force entitled, "The CO_2 Problem; Addressing Research Agenda Development."

An outline is included as Attachment A.

In addition, a complete technical discussion, led by Dr. Laurman identified the problem, discussed the scientific basis and technical evidence of CO_2 buildup, impact on society, methods of modeling and their consequences, uncertainties, policy implications, and conclusions that can be drawn from present knowledge. A series of summary charts are attached as Attachment B.

API RESEARCH NEEDS

One area of possible API research was identified: Preparatory research to be able to answer questions dealing with the CO_2 problem and synthetic fuels.

COMMENTS ON DOE TECHNICAL PAPER

K. Blower and Bruce Bailey will modify the draft API letter back to DOE concerning an article submitted to the Task Force for comment. When the Task Force has approved the letter, it will be coordinated within API staff.

OTHER BUSINESS

The Task Force should set up a rationale and system for review of technical articles and responses to inquiries.

One potential area for R&D was discussed by the Task Force: "Investigate the Market Penetration Requirements of Introducing A New Energy Source into World Wide Use." This would include the technical implications of energy source changeover, research timing and requirements.

The meeting was adjourned at 4:25 p.m.

Prepared by:

J J Nelson

Jimmie J. Nelson

THE CO_2 PROBLEM; ADDRESSING RESEARCH AGENDA DEVELOPMENT

The difficulties of dealing with the pragmatic questions related to the CO_2/fossil fuel problem all relate to certain general features, these having A) high impact cost, B) large uncertainty, and being C) far distant and D) global. The problem is interdisciplinary in its scientific aspects and it has ramifications in many economic sectors and in most nations. Therefore, not only is addressing it difficult in anlytic terms, but the mulitiplicity of possible interest groups that can be affected means that choice of what constitute the critical research issues depends on the user. In the most general terms we can subdivide the motivational aspect into those who see the need as to

A) better understand the CO_2/climate system, resulting in an ability to predict a) short range and b) long range effects.

or to

B) assess the present day importance of the future impact, as viewed

i) from a world viewpoint

ii) by national entities

iii) by specific industrial sectors or interest groups

Highest priority investigations depend on which of these groups is involved. In particular, a highly relevant aspect for all of these groups is the influence of present and future information on public perception and governmental attitudes regarding the problem and the resultant effect on energy policy.

Instead of attempting to research all aspects of the CO_2 problem that bear on the concern of any particular group, we may select a feature that appears to be particularly important to that sector - for example, nuclear energy proponents might wish to address the problem of market penetration time lags as the most critical for making their case.

A) Reducing uncertainty in projections

CO_2 input

a) deforestation, past present and future.

b) effect of various energy use policies - coal, oil shale, nuclear, biomass, solar, synthetics.

c) turn-around scenarios for non-carbon based fuel use, impact calculations.

d) remedial measures: biomass, scrubbing, bacterial enzymes, fertilizing oceans.

Carbon cycle

a) CO_2 growth and photosynthesis

b) missing CO_2 since - detritus, humus, regrowth of deforested areas, oceans, non-stationary biosphere.

c) validity of box-model projections in short (50 yr) range.

d) organic material in oceans (detritus, dissolution, nutriant limitations)

e) estuarian regions

f) ground water

g) carbonate distribution

h) use of tracers

i) cataloguing on the biosphere

j) climatic change feedback effects - ocean temperature, plant growth.

Climate modeling

a) ocean dynamics

b) simplifying models

c) feedback effects : clouds, sea ice, vegitation change(albedo).

d) regional climatic change

B) Impact of climatic change

Socio-economic

I) General problems:

a) how to make estimates of costs of large perturbations, even assuming climatic changes are known?

b) how do we discount the future?

c) geopolitical problems, either from climatic change or from remediation measures

d) building in resilience. Can severity be versed in terms of critical rates of change of forcing of the societal system? Is a generic non-specific formulation possible?

II) Immediate policy questions. The physical facts agree on the probability of large effects 50 years away, but with large probable error. Source of the uncertainty arises from deforestation, poor climate models and uncertainty in CO_2 input (energy projections). The first may be settled in a year or two; the second will not. Hence we have to treat an unsure situation, which may be possible via decision analysis if error distribution can be quantified. This has not been done for impact costs, so first

a) can it be? If yes, there still remain two major difficulties:

b) what are market penetration times for new energy sources? and

c) what future (social) discounting rate should be used?

If fossil fuel use rates are reduced to 2% p.a. or under, it looks as if the immediate problem is considerably eased (but needs checking). So another question is

d) what is the 50 year future of fossil fuel use?

Of more parochial interest is

e) what roles do the different catagories of fossil or synthetic fuel play in future projections?

<u>The Natural Biosphere</u>

<u>The Managed Biosphere</u>

REASONS FOR INCREASED CONCERN WITH THE CO_2 PROBLEM

- DEVELOPMENT OF RELIABLE ATMOSPHERIC CO_2 GROWTH RATE MEASUREMENTS
- ITS CORRELATION WITH GLOBAL INDUSTRIAL CO_2 EMISSIONS, MOSTLY FROM FOSSIL FUEL COMBUSTION
- SCIENTIFIC CONSENSUS ON THE POTENTIAL FOR LARGE FUTURE CLIMATIC RESPONSE TO INCREASED CO_2 LEVELS
- REALIZATION THAT REMEDIAL ACTIONS WOULD TAKE A LONG TIME TO BECOME EFFECTIVE

ATTACHMENT B

OBSERVATIONAL EVIDENCE - CONCLUSIONS

- TWENTY YEARS OF GOOD CO_2 DATA, BUT ESSENTIALLY FROM ONE SOURCE
- PRESENT ATMOSPHERIC CO_2 CONCENTRATION = 335 ppm
  PRE-INDUSTRIAL (1860) " " ≈ 290 ppm
- CURRENT GROWTH RATE = 4.3% p.a. OF INCREASE SINCE 1860
- STRONG EMPIRICAL EVIDENCE THAT RISE CAUSED BY ANTHROPOGENIC RELEASE OF CO_2, MAINLY FROM FOSSIL FUEL BURNING
- ATMOSPHERIC RETENTION IS 56% OF RELEASE, ASSUMING NO EFFECTS FROM DEFORESTATION

ENERGY USE PROJECTIONS - CONCLUSIONS

- AVERAGE GROWTH RATE 3-4% p.a. FOR NEXT FIFTY YEARS, FOSSIL FUEL SLIGHTLY LESS
- THIS IS NOT CONSISTANT WITH LONG TERM PAST TREND
- PROJECTED CO_2 RELEASE ~~RATE~~ INCREASE (PROPORTIONAL TO INTEGRATED FOSSIL FUEL OUTPUT) CLOSE TO 3% p.a. UNTIL MID-21ST CENTURY; SUBJECT TO ERROR OF ABOUT ± 1% p.a.
- EFFECT OF FOSSIL FUEL DEPLETION MINOR IN NEXT FIFTY YEARS

CARBON CYCLE - CONCLUSIONS

- POSSIBLE CO_2 RELEASE CONTRIBUTION FROM DEFORESTATION, PERHAPS RIVALLING FOSSIL FUEL SOURCE
- ALL CARBON CYCLE MODELS BEHAVE LINEARLY UP TO 3-4 TIMES PRE-INDUSTRIAL ATMOSPHERIC CO_2 LEVELS
- HENCE GIVE THE SAME PROJECTED ATMOSPHERIC CO_2 LEVELS FOR THE SAME INPUT
- FOSSIL FUEL DEPLETION EFFECTS SMALL
- DEFORESTATION EFFECT ON PROJECTIONS ONLY SIGNIFICANT IF IT BECOMES DEPLETED
- CO_2 "DOUBLING" DATE IS 2038 AT A 3% p.a. GROWTH OF ATMOSPHERIC RELEASE RATE
- ERROR IN THIS ESTIMATE IS SMALL COMPARED WITH OTHER SOURCES OF ERROR

CLIMATE MODELING - CONCLUSIONS

- GLOBAL AVERAGED 2.5°C RISE EXPECTED BY 2038 AT A 3% p.a. GROWTH RATE OF ATMOSPHERIC CO_2 CONCENTRATION

- LARGE ERROR IN THIS ESTIMATE - 1 IN 10 CHANCE OF THIS CHANGE BY 2005

- NO REGIONAL CLIMATE CHANGE ESTIMATES YET POSSIBLE

- LIKELY IMPACTS:

  1°C RISE (2005): BARELY NOTICEABLE

  2.5°C RISE (2038): MAJOR ECONOMIC CONSEQUENCES, STRONG REGIONAL DEPENDENCE

  5°C RISE (2067): GLOBALLY CATASTROPHIC EFFECTS

UNCERTAINTY IN ESTIMATES

1) CARBON CYCLE MODELING - MINOR
2) DEFORESTATION - MAJOR EFFECT ONLY IF RATE IS LARGE AND DEPLETION SETS IN
3) NATURAL CLIMATE VARIABILITY - SMALL, ABOUT 0.5° C IN 50 YEARS
4) OTHER ANTHROPOGENIC SOURCES - LESS THAN CO_2, BUT POTENTIALLY MAJOR IF CONSIDERED IN TOTO
5) EFFECT OF A ± 1% VARIATION IN FOSSIL FUEL GROWTH RATE RELATIVELY MINOR
6) CLIMATE MODELING ERROR VERY LARGE; ALLOWANCE IN POLICY ANALYSIS ESSENTIAL

POLICY IMPLICATIONS

- GLOBAL PROBLEM, BOTH IN SOURCE AND FOR REMEDIES
- TIME SCALE FOR SIGNIFICANT IMPACT, VERY ROUGHLY 50 YRS
- HIGH RISK, HIGH UNCERTAINTY SITUATION, RELATIVELY FAR AWAY
- TIME FOR ACTION ? MARKET PENETRATION TIME THEORY SAYS
  THERE IS NO LEEWAY

CONCLUSIONS

- AT A 3% PER ANNUM GROWTH RATE OF CO_2, A 2.5°C RISE BRINGS WORLD ECONOMIC GROWTH TO A HALT IN ABOUT 2025.

Even if this estimate is grossly wrong it is still probable that

- WHETHER THERE ARE GROUNDS FOR IMMEDIATE RESPONSE TO THE THREAT DEPENDS ON THE VALIDITY OF THE LONG MARKET PENETRATION TIME CONCEPT.
- EVEN IF THE LATTER IS APPLICABLE, PRESENT DAY SIGNIFICANCE OF THE IMPACT DEPENDS STRONGLY ON CHOICE OF A FUTURE DISCOUNTING FACTOR.
- NEED FOR IMMEDIATE POLICY ACTION HINGES ON THESE LAST TWO FEATURES.

1981 memo from Exxon scientist Roger Cohen reviewing draft report on emissions consequences

ENERAL - 184-1-1B

INTER-OFFICE CORRESPONDENCE

DATE August 18, 1981

TO	REFERENCE
W. Glass	SUBJECT
FROM R. W. Cohen	

I have looked over the draft of the EED reply to the request from O'Loughlin. The only real problem I have is with the second clause of the last sentence in the first paragraph: "but changes of a magnitude well short of catastrophic..." I think that this statement may be too reassuring. Whereas I can agree with the statement that our best guess is that observable effects in the year 2030 are likely to be "well short of catastrophic", it is distinctly possible that the CPD scenario will later produce effects which will indeed be catastrophic (at least for a substantial fraction of the earth's population). This is because the global ecosystem in 2030 might still be in a transient, headed for much more significant effects after time lags perhaps of the order of decades. If this indeed turns out to be case, it is very likely that we will unambiguously recognize the threat by the year 2000 because of advances in climate modeling and the beginning of real experimental confirmation of the CO_2 effect. The effects of such a recognition on subsequent fossil fuel combustion are unpredictable, but one can say that predictions based only on our knowledge of availability and economics become hazardous.

I would feel more comfortable if the first paragraph concluded with a statement to the effect that future developments in global data gathering and analysis, along with advances in climate modeling, may provide strong evidence for a delayed CO_2 effect of a truly substantial magnitude, a possibility which increases the uncertainty surrounding the post-2000 CPD scenario.

ROGER W. COHEN

RWC:tmw

Attachment

cc: H. N. Weinberg
A. J. Callegari

ENERAL 154-1-1B

TER-OFFICE CORRESPONDENCE

DATE 8/14/81

O See Below	REFERENCE
ROM W. Glass	SUBJECT

J. F. Black
R. W. Cohen
S. A. Diamond
H. Shaw

Morey O'Loughlin has asked Ed David for ER&E's views on the realism of CPD's projections for fossil fuel combustion out to 2030 (attached) in view of potential "greenhouse" and "acid rain" problems. I have been asked to draft a short reply.

A preliminary draft for EED's reply is attached. It is based not on any calculations but on my "understanding" of what I think I've heard you say and write in the past. I would appreciate your reviewing this preliminary draft very critically and letting me know promptly of any changes you would like to see. EED wants to get an answer back to MEJO'L by August 21.

Thank you for your cooperation.

WG:bl
Attachments

c: T. K. Kett

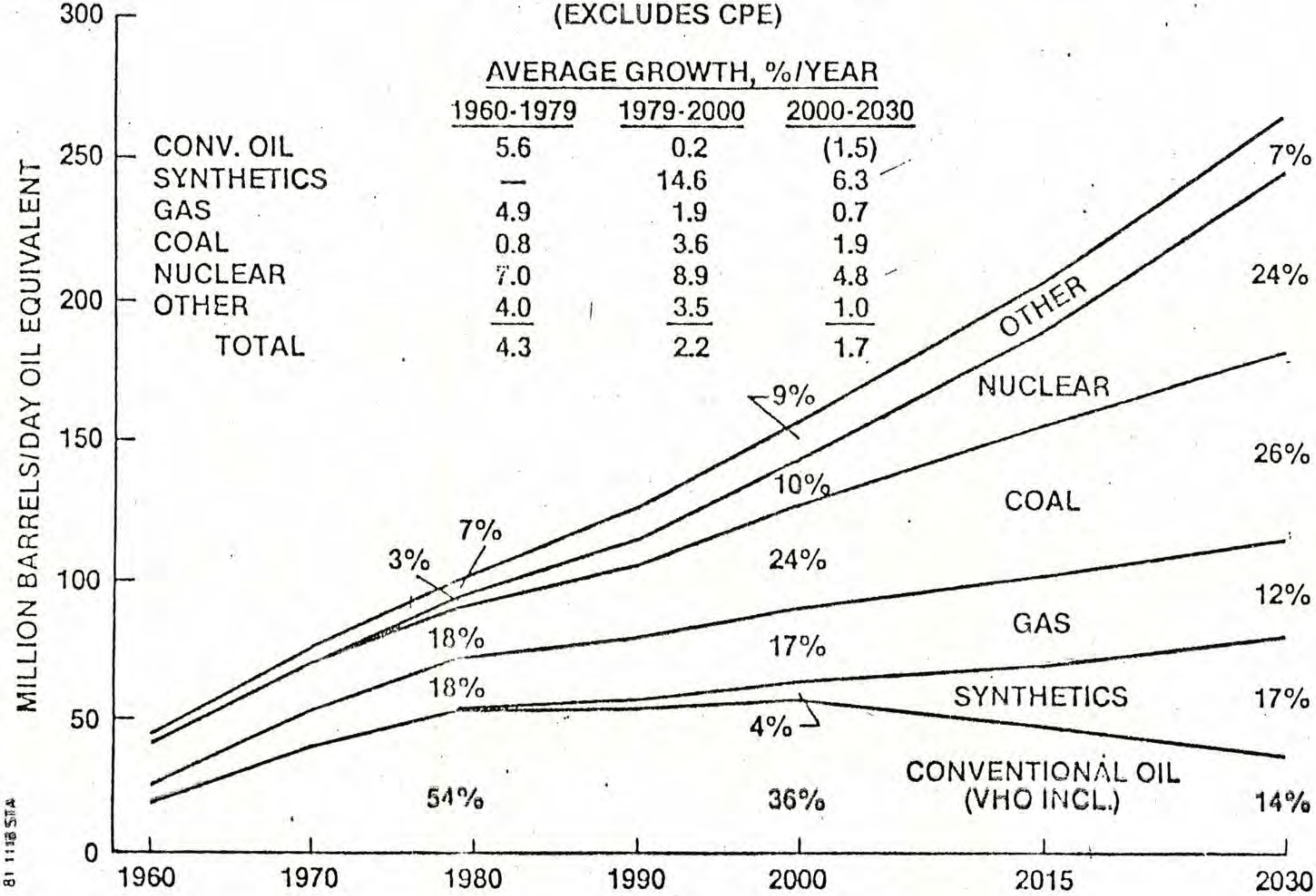
DRAFT
EED TO MEJO'L

You asked about our views on possible emission consequences of the CPD-projected fossil fuel consumption levels out to 2030. Much is still unknown about the sources and sinks for atmospheric CO_2, as well as about the climatic effect of increasing CO_2 levels in the air, so that prognostications remain highly speculative. The models that appear most credible (to us) do predict measurable changes in temperature, rainfall pattern, and sea-level by the year 2030 for the postulated fossil fuel combustion rates, but changes of a magnitude well short of catastrophic and probably below the magnitude that need trigger otherwise non-economic responses to the problem of energy supply.

The fossil fuel contribution to the localized problem of acid rain appears handlable by limiting the release of SO_x, NO_x, and chlorides to the atmosphere--which would decrease but by no means eliminate the economic advantage of fossil fuels.

We would be happy to discuss this with you in greater detail.

INITIAL PROJECTION
WORLD ENERGY SUPPLY
(EXCLUDES CPE)



AVERAGE GROWTH, %/YEAR

	1960-1979	1979-2000	2000-2030
CONV. OIL	5.6	0.2	(1.5)
SYNTHETICS	—	14.6	6.3
GAS	4.9	1.9	0.7
COAL	0.8	3.6	1.9
NUCLEAR	7.0	8.9	4.8
OTHER	4.0	3.5	1.0
TOTAL	4.3	2.2	1.7

1982 Exxon briefing,

The CO_2 ““Greenhouse Effect’’

EXXON RESEARCH AND ENGINEERING COMPANY

P.O. BOX 101, FLORHAM PARK, NEW JERSEY 07932

M. B. GLASER
Manager
Environmental Affairs Programs

Cable: ENGREXXON, N.Y.

November 12, 1982

CO_2 "Greenhouse" Effect

82EAP 266

TO: See Distribution List Attached

Attached for your information and guidance is briefing material on the CO_2 "Greenhouse" Effect which is receiving increased attention in both the scientific and popular press as an emerging environmental issue. A brief summary is provided along with a more detailed technical review prepared by CPPD.

The material has been given wide circulation to Exxon management and is intended to familiarize Exxon personnel with the subject. It may be used as a basis for discussing the issue with outsiders as may be appropriate. However, it should be restricted to Exxon personnel and not distributed externally.

Very truly yours,

M. B. Glaser

M. B. GLASER

MBG:rva

Attachments

H. N. WEINBERG
NOV 15 1982

Distribution List:

R. W. Cohen
M. J. Connor, Jr.
E. E. David, Jr.
C. M. Eidt, Jr.
W. R. Epperly
R. L. Hirsch
T. G. Kaufmann
D. G. Levine
G. H. Long
J. R. Riley
H. R. Savage
A. Schriesheim
J. F. Taylor
D. T. Wade
H. N. Weinberg

SUMMARY

Atmospheric monitoring programs show the level of carbon dioxide in the atmosphere has increased about 8% over the last twenty-five years and now stands at about 340 ppm. This observed increase is believed to be the continuation of a trend which began in the middle of the last century with the start of the Industrial Revolution. Fossil fuel combustion and the clearing of virgin forests (deforestation) are believed to be the primary anthropogenic contributors although the relative contribution of each is uncertain.

The carbon dioxide content of the atmosphere is of concern since it can affect global climate. Carbon dioxide and other trace gases contained in the atmosphere such as water vapor, ozone, methane, carbon monoxide, oxides of nitrogen, etc. absorb part of the infrared rays reradiated by the earth. This increase in absorbed energy warms the atmosphere inducing warming at the earth's surface. This phenomenon is referred to as the "greenhouse effect".

Predictions of the climatological impact of a carbon dioxide induced "greenhouse effect" draw upon various mathematical models to gauge the temperature increase. The scientific community generally discusses the impact in terms of doubling of the current carbon dioxide content in order to get beyond the noise level of the data. We estimate doubling could occur around the year 2090 based upon fossil fuel requirements projected in Exxon's long range energy outlook. The question of which predictions and which models best simulate a carbon dioxide induced climate change is still being debated by the scientific community. Our best estimate is that doubling of the current concentration could increase average global temperature by about 1.3° to 3.1°C. The increase would not be uniform over the earth's surface with the polar caps likely to see temperature increases on the order of 10°C and the equator little, if any, increase.

Considerable uncertainty also surrounds the possible impact on society of such a warming trend, should it occur. At the low end of the predicted temperature range there could be some impact on agricultural growth and rainfall patterns which could be beneficial in some regions and detrimental in others. At the high end, some scientists suggest there could be considerable adverse impact including the flooding of some coastal land masses as a result of a rise in sea level due to melting of the Antarctic ice sheet. Such an effect would not take place until centuries after a 3°C global average temperature increase actually occurred.

There is currently no unambiguous scientific evidence that the earth is warming. If the earth is on a warming trend, we're not likely to detect it before 1995. This is about the earliest projection of when the temperature

might rise the 0.5° needed to get beyond the range of normal temperature fluctuations. On the other hand, if climate modeling uncertainties have exaggerated the temperature rise, it is possible that a carbon dioxide induced "greenhouse effect" may not be detected until 2020 at the earliest.

The "greenhouse effect" is not likely to cause substantial climatic changes until the average global temperature rises at least 1°C above today's levels. This could occur in the second to third quarter of the next century. However, there is concern among some scientific groups that once the effects are measurable, they might not be reversible and little could be done to correct the situation in the short term. Therefore, a number of environmental groups are calling for action now to prevent an undesirable future situation from developing.

Mitigation of the "greenhouse effect" would require major reductions in fossil fuel combustion. Shifting between fossil fuels is not a feasible alternative because of limited long-term supply availability for certain fuels although oil does produce about 18% less carbon dioxide per Btu of heat released than coal, and gas about 32% less than oil. The energy outlook suggests synthetic fuels will have a negligible impact at least through the mid 21st century contributing less than 10% of the total carbon dioxide released from fossil fuel combustion by the year 2050. This low level includes the expected contribution from carbonate decomposition which occurs during shale oil recovery and assumes essentially no efficiency improvements in synthetic fuels processes above those currently achievable.

Overall, the current outlook suggests potentially serious climate problems are not likely to occur until the late 21st century or perhaps beyond at projected energy demand rates. This should provide time to resolve uncertainties regarding the overall carbon cycle and the contribution of fossil fuel combustion as well as the role of the oceans as a reservoir for both heat and carbon dioxide. It should also allow time to better define the effect of carbon dioxide and other infrared absorbing gases on surface climate. Making significant changes in energy consumption patterns now to deal with this potential problem amid all the scientific uncertainties would be premature in view of the severe impact such moves could have on the world's economies and societies.

EC-11-5/A4

PROPRIETARY INFORMATION

FOR AUTHORIZED COMPANY USE ONLY

CO_2 GREENHOUSE EFFECT

A TECHNICAL REVIEW

PREPARED BY THE

COORDINATION AND PLANNING DIVISION

EXXON RESEARCH AND ENGINEERING COMPANY

APRIL 1, 1982

EC-11-5/A2

CO_2 GREENHOUSE EFFECT

A TECHNICAL REVIEW

TABLE OF CONTENTS

EC-11-5/A5

CO_2 GREENHOUSE EFFECT

Background

The buildup of CO_2 in the atmosphere has been monitored continuously at the National Oceanic and Atmospheric Administration's (NOAA) Observatory at Mauna Loa, Hawaii, and periodically in other places since 1957. In addition to observing a trend between 1957-1979 that showed atmospheric CO_2 increasing from 315 to 337 ppm, Keeling and others also observed a seasonal variability ranging from 6 to 10 ppm between a low at the end of the summer growing season (due to photosynthesis) and a high at the end of winter (due to fossil fuel burning for heat, and biomass decay). There is little doubt that these observations indicate a growth of atmospheric CO_2 (see Figure 1). It is also believed that the growth of atmospheric CO_2 has been occurring since the middle of the past century, i.e., coincident with the start of the Industrial Revolution. There is, however, great uncertainty as to whether the atmospheric CO_2 concentration prior to the Industrial Revolution (ca., 1850) was 290-300 ppm which one would arrive at by assuming atmospheric CO_2 growth is due to fossil fuel burning and cement manufacturing, or 260-270 ppm based on carbon isotope measurements in tree rings. The information on CO_2 concentration prior to 1850 is important because it would help establish the validity of climatic predictions with respect to the inception of a CO_2 induced "greenhouse effect".

The "greenhouse effect" refers to the absorbtion by CO_2 and other trace gases contained in the atmosphere (such as water vapor, ozone, carbon monoxide, oxides of nitrogen, freons, and methane) of part of the infrared radiation which is reradiated by the earth. An increase in absorbed energy via this route would warm the earth's surface causing changes in climate affecting atmospheric and ocean temperatures, rainfall patterns, soil moisture, and over centuries potentially melting the polar ice caps.

Sources and Disposition of Atmospheric Carbon Dioxide - The Carbon Cycle

The relative contributions of biomass oxidation (mainly due to deforestation) and fossil fuel combustion to the observed atmospheric CO_2 increase are not known. There are fairly good indications that the annual growth of atmospheric CO_2 is on the order of 2.5 to 3.0 Gt/a* of carbon and the net quantity of carbon absorbed by the ocean is similarly 2.5 to 3 Gt/a. Thus, these two sinks (atmosphere and ocean) can account for the total fossil carbon burned (including 0.3 GtC/a** from cement manufacturing) which is on the order of 5-6 Gt/a and does not allow much room for a net contribution of biomass

* Gt/a = gigatons per annum = 10^9 metric tons per year.
** GtC/a = gigatons carbon per annum = 10^9 metric tons of carbon per year.

EC-11-5/A6

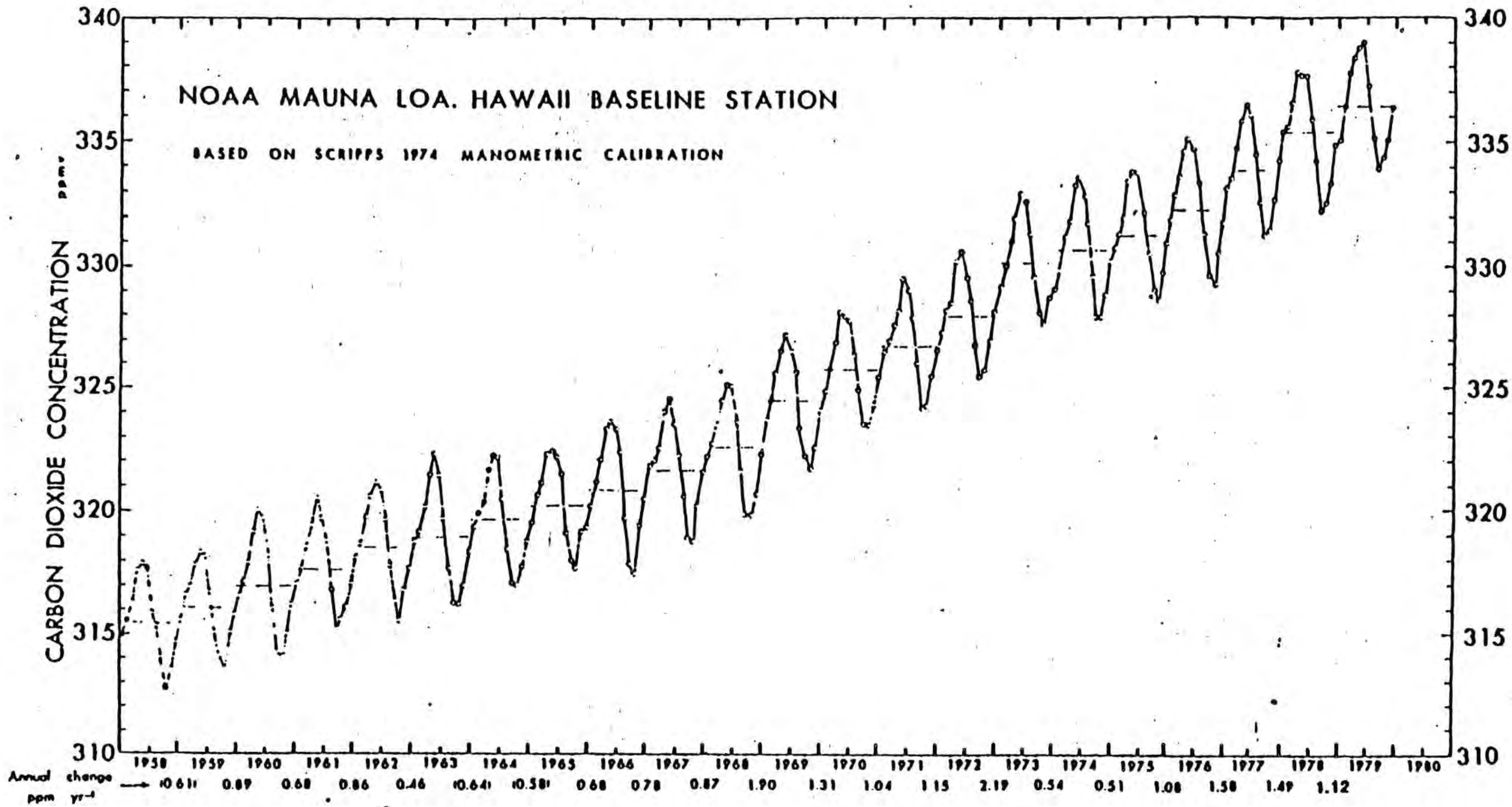


Figure 1 Modern record of atmospheric CO_2 concentrations. Mean monthly concentration measurements at Mauna Loa, Hawaii. Annual changes in parentheses are based on incomplete records; the solid dots are interpolated values (source: NOAA).

carbon. Yet, highly respected scientists such as Woodwell, Bolin and others have postulated a net biomass contribution to atmospheric CO_2 that ranges from 1 to perhaps 8 Gt/a of carbon. During 1980, a number of different groups produced new estimates of the contribution of organic terrestial fluxes to atmospheric CO_2. A consensus has not been reached, but estimates of the net annual terrestial biosphere emissions to the atmosphere now range between a 4 GtC/a source and a 2 GtC/a sink. Figure 2 summarizes the fluxes and reservoirs for the carbon cycle. It should be noted that the net biosphere contribution was assumed to be 0-2 GtC/a.

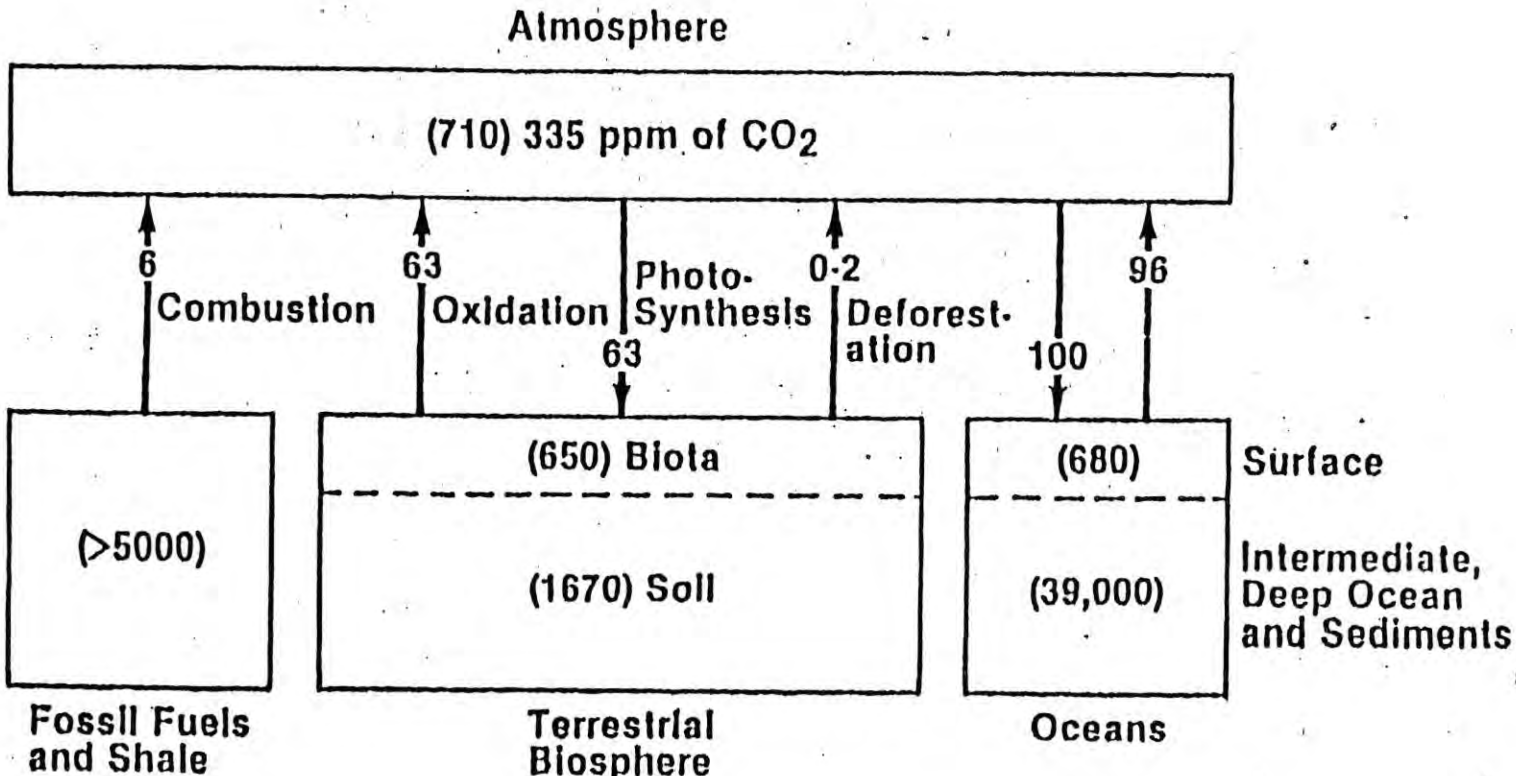
The rate of forest clearing has been estimated at 0.5% to 1.5% per year of the existing area. Forests occupy about 50 x $10^6 km^2$ out of about 150 x $10^6 km^2$ of continental land, and store about 650 Gt of carbon. One can easily see that if 0.5% of the world's forests are cleared per year, this could contribute about 3.0 Gt/a of carbon to the atmosphere. Even if reforestation were contributing significantly to balancing the CO_2 from deforestation, the total carbon stored in new trees tends to be only a small fraction of the net carbon emitted. It should be noted, however, that the rate of forest clearing and reforestation are not known accurately at this time. If deforestation is indeed contributing to atmospheric CO_2, then another sink for carbon must be found, and the impact of fossil fuel must be considered in the context of such a sink.

The magnitude of the carbon fluxes shown in Figure 2 between the atmosphere and the terrestial biosphere, and the atmosphere and the oceans are not precisely known. The flow of carbon between these reservoir pairs is generally assumed to have been in equilibrium prior to the Industrial Revolution. However, the errors in the estimated magnitude of these major fluxes are probably larger than the magnitude of the estimated man-made carbon fluxes, i.e., fossil fuels and deforestation. The man-made fluxes are assumed to be the only ones that have disturbed the equilibrium that is believed to have existed before the Industrial Revolution, and they can be estimated independently of the major fluxes. The man-made carbon fluxes are balanced in Figure 2 between the known growth rate of atmospheric carbon and the oceans. The carbon flux to the atmosphere is 6Gt/a from fossil fuels and cement manufacturing (cement manufacturing contributes about 4% of non-biosphere anthropogenic carbon) and 2Gt/a from deforestation, while 4Gt/a return to the ocean, resulting in a 50% carbon retention rate in the atmosphere. One cannot rule out, in view of the inherent uncertainty of the major fluxes, that the biosphere may be a net sink and the oceans may absorb much less of the man-made CO_2.

Projections of scientists active in the area indicate that the contribution of deforestation, which may have been substantial in the past, will diminish in comparison to the expected rate of fossil fuel combustion in the future. A few years ago a number of scientists hypothesized that a doubling of the amount of carbon dioxide in the atmosphere could occur as early as 2035. This hypothesis is generally not acceptable anymore because of the global curtailment of fossil fuel usage. Calculations recently completed at Exxon Research

FIGURE 2

Exchangeable Carbon Reservoirs and Fluxes



( ) = Size of Carbon Reservoirs in Billions of Metric Tons of Carbon

Fluxes (arrows) = Exchange of Carbon Between Reservoirs in Billions of Metric Tons of Carbon per Year and Engineering Company using the energy projections from the Corporate Planning Department's 21st Century Study*, indicate that a doubling of the 1979 atmospheric CO_2 concentration could occur at about 2090. If synthetic fuels are not developed and fossil fuel needs are met by new gas and petroleum discoveries, then the atmospheric CO_2 doubling time would be delayed by about 5 years to the late 2090's. Figure 3 summarizes the projected growth of atmospheric CO_2 concentration based on the Exxon 21st Century Study-High Growth scenario, as well as an estimate of the average global temperature increase which might then occur above the current temperature. It is now clear that the doubling time will occur much later in the future than previously postulated because of the decreasing rate of fossil fuel usage due to lower demand.

Description of Potential Impact on Weather, Climate, and Land Availability

The most widely accepted calculations carried on thus far on the potential impact on climate of doubling the carbon dioxide content of the atmosphere use general circulation models (GCM). These models indicate that an increase in global average temperature of $3^\circ \pm 1.5^\circ C$ is most likely. Such changes in temperature are expected to occur with uneven geographic distribution with greater warming occurring at the higher latitudes, i.e., the polar regions. This is due to increased absorption of solar radiation energy on the darker polar surfaces that would become exposed when ice and snow cover melt due to increasing temperature (see Figure 4). There have been other calculations using radiative convective models and energy balance models which project average temperature increases on the order of $0.75^\circ C$ for a doubling of CO_2. These calculations are compared in Figure 5. Figure 6 summarizes possible temperature increases due to various changes in atmospheric CO_2 concentration.

If the atmospheric CO_2 content had been 295 ppm prior to the Industrial Revolution, and an average global temperature increase above climate noise is detectable at the present time, this would add credibility to the general circulation models. However, if the CO_2 concentration and been 265 ppm prior to the Industrial Revolution, then detecting a temperature effect of $0.5^\circ C$ now would imply that the temperature for a doubling of CO_2 would be $1.9^\circ C$. The projected temperatures for both alternatives fall within the $3^\circ \pm 1.5^\circ C$ range. Temperature projections for alternate scenarios will be discussed later.

Climate modeling was studied by a committee of the National Research Council, chaired by Jules G. Charney of MIT, and the conclusions are summarized in

* The "21st Century Study" referred to here and in other places in this report has been superseded by a new energy study called the "2030 Study". The new study projects energy demands that are lower than the earlier figures, but not sufficiently different to change any of the conclusions of this report.

Figure 3

GROWTH OF ATMOSPHERIC CO_2 AND AVERAGE GLOBAL TEMPERATURE INCREASE AS A FUNCTION OF TIME

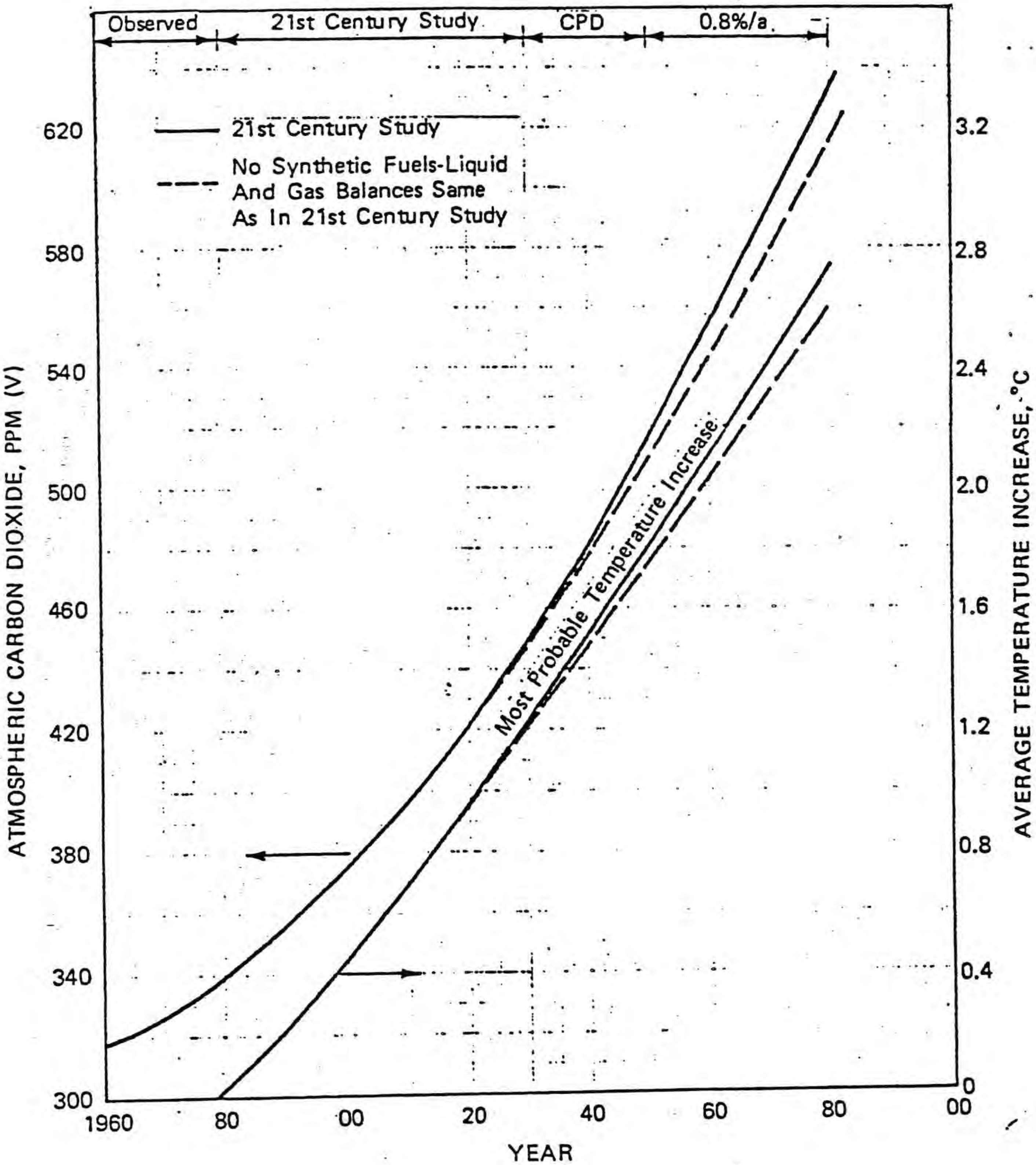
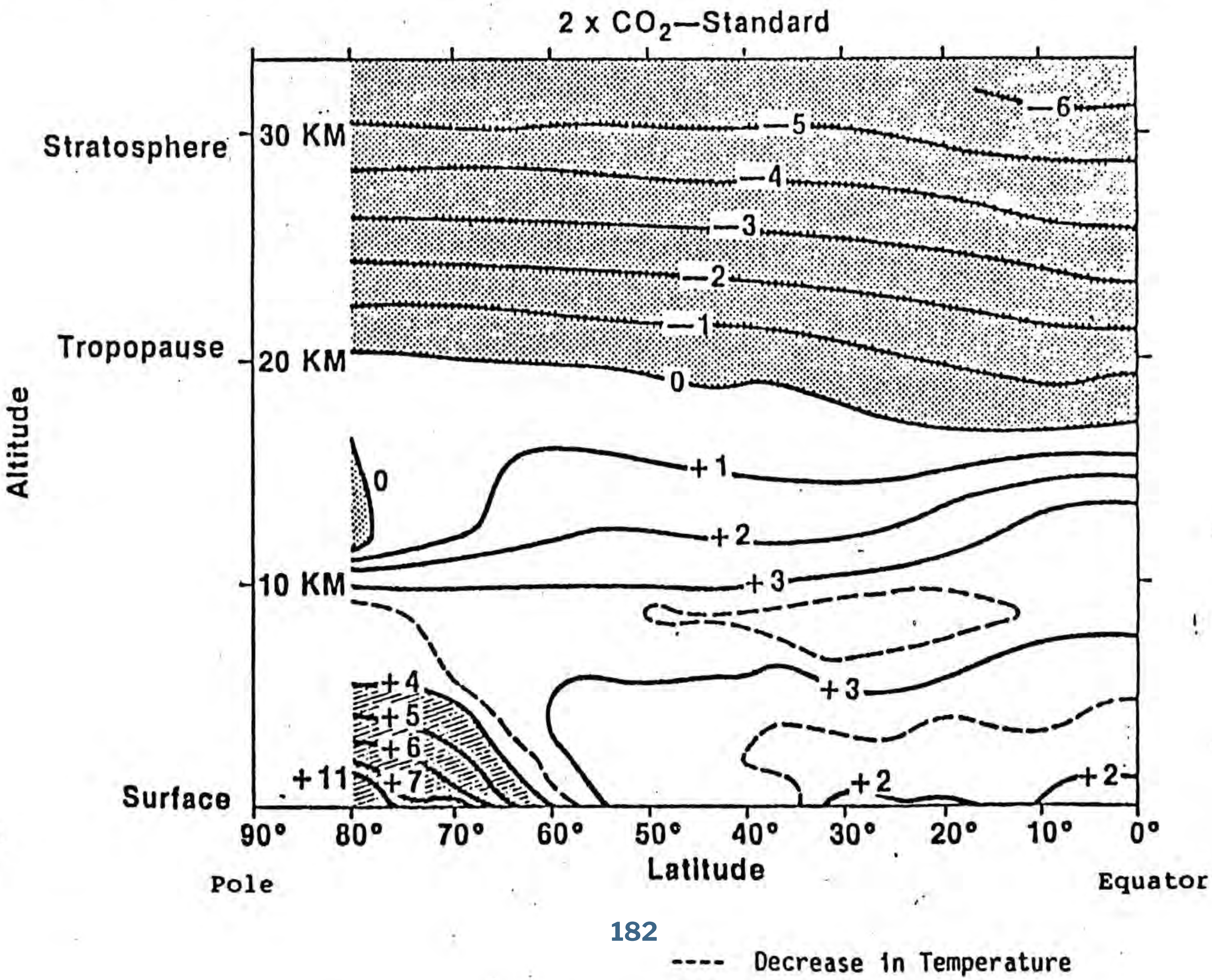


Figure 4

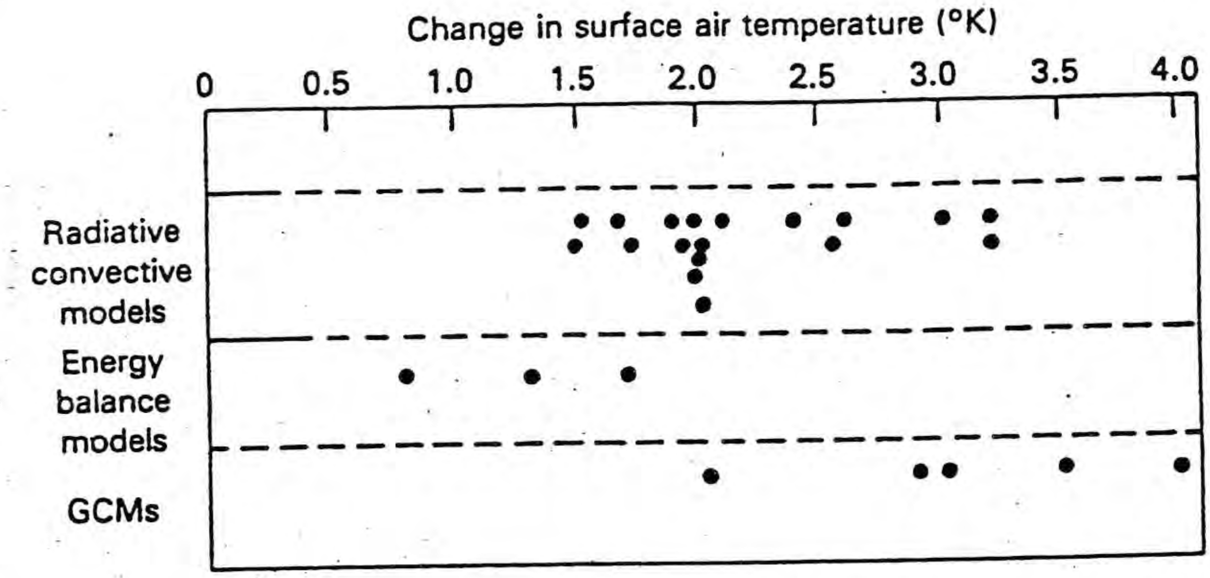
Temperature Change (^{o}C) Due to
Doubling CO_2 Concentrations

Basis: Computed by the U.S. National Oceanic and Atmospheric Administration using their general circulation model.



-8-

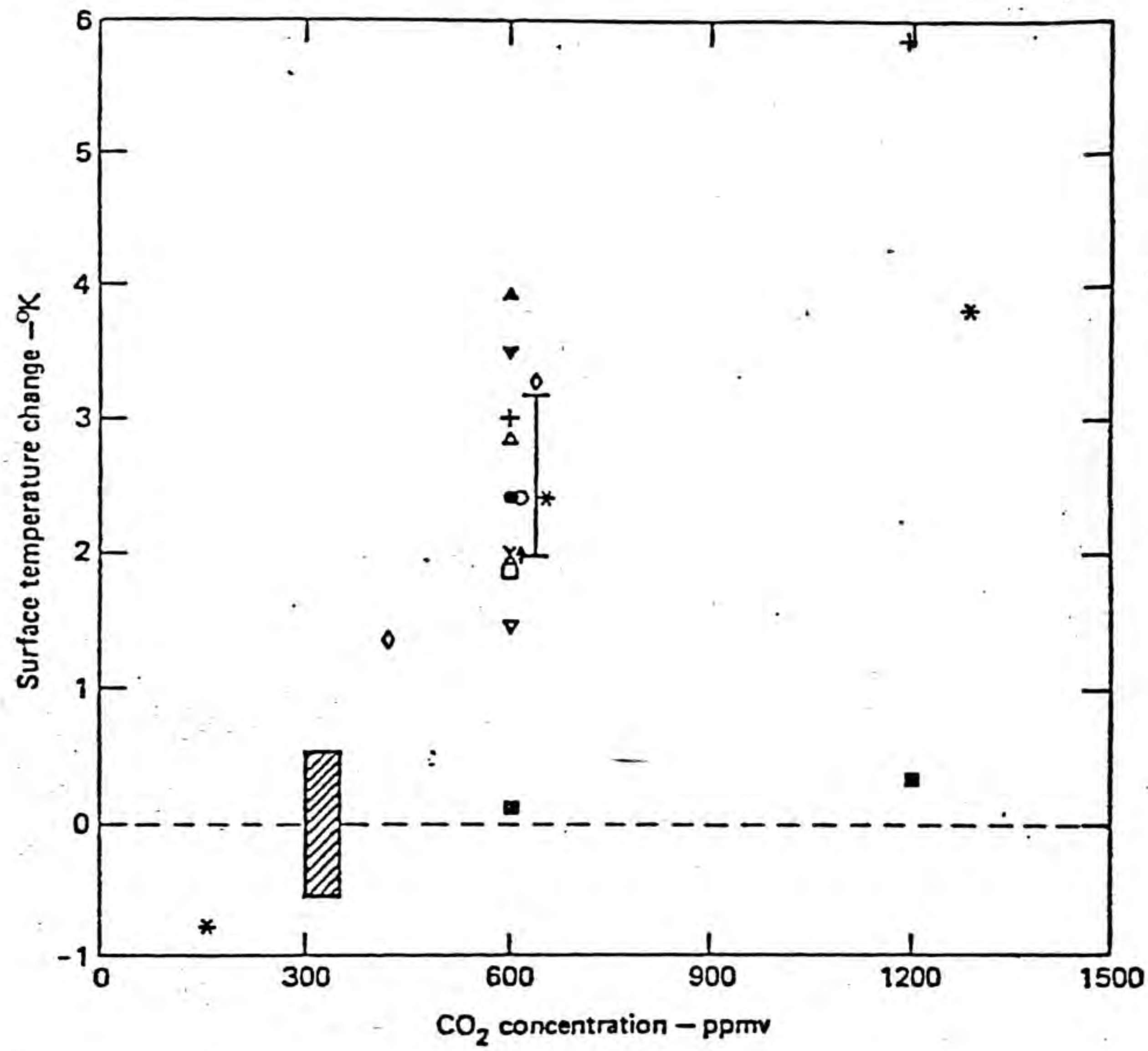
Figure 5



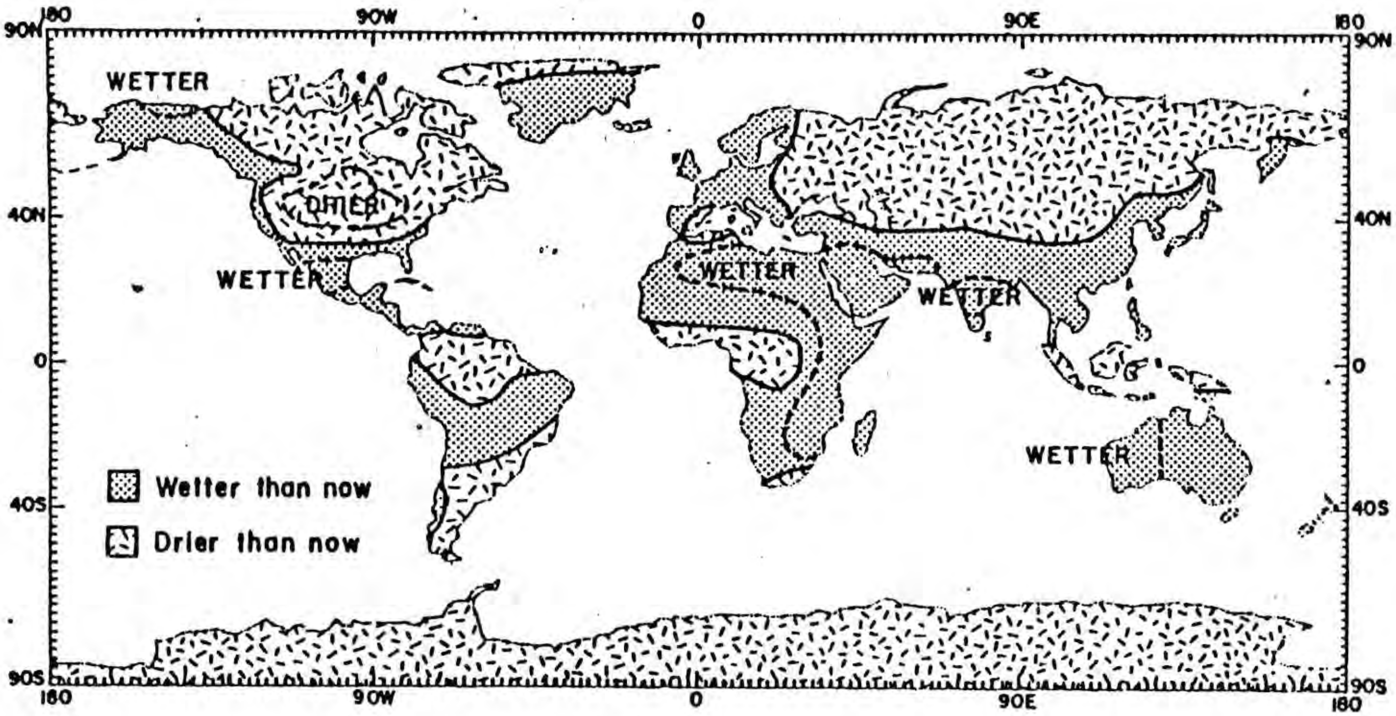
The change in globally averaged surface air temperature resulting from a doubling of atmospheric CO_2 as given by a variety of radiative-convective, energy balance, and global circulation (GCM) models. (From W. L. Gates, Oregon State University Technical Report no. 4.)

Figure 6

Estimates of the Change in Global Average Surface Temperature Due to Various Changes in CO_2 Concentration. Shading Shows Present Range of Natural Fluctuations.



<u>Figure 7</u>



Example of a scenario of possible soil moisture patterns on a warmer Earth. It is based on paleoclimatic reconstructions of the Altithermal Period (4500 to 8000 years ago), comparisons of recent warm and cold years in the Northern Hemisphere, and a climate model experiment. (For a discussion of these sources of information see Appendix C.) Where two or more of these sources agree on the direction of the change we have indicated the area of agreement with a dashed line and a label.

their report titled, "Carbon Dioxide and Climate: A Scientific Assessment." This National Research Council study concluded that there are major uncertainties in these models in terms of the timing for a doubling of CO_2 and the resulting temperature increase. These uncertainties center around the thermal capacity of the oceans. The oceans have been assumed to consist of a relatively thin, well mixed surface layer averaging about 70 meters in depth in most of the general circulation models, and the transfer of heat into the deep ocean is essentially infinitely slow. The Charney panel felt, however, that the amount of heat carried by the deep ocean has been under estimated and the oceans will slow the temperature increase due to doubling of atmospheric CO_2. The Charney group estimated that the delay in heating resulting from the effect of the oceans could delay the expected temperature increase due to a doubling of CO_2 by a few decades. Accordingly, the time when the temperature increases discussed above are reached must be assumed to have occurred at an instantaneous equilibrium.

Along with a temperature increase, other climatological changes are expected to occur including an uneven global distribution of increased rainfall and increased evaporation. These disturbances in the existing global water distribution balance would have dramatic impact on soil moisture, and in turn, on agriculture. Recently, Manabe et al., using GCM's calculated that the zonal mean value of soil moisture in summer declines significantly in two separate zones of middle and high latitudes in response to an increase in the CO_2 concentration of air. This CO_2 induced summer dryness results not only from the earlier ending of the snowmelt season, but also from the earlier occurrence of the spring to summer reduction in rainfall rate. The former effect is particularly important in high latitudes, whereas the latter effect becomes important in middle latitudes. Other statistically significant changes include large increases in both soil moisture and runoff rates at high latitudes during most of the annual cycle with the exception of the summer season. The penetration of moisture rich, warm air into high latitudes is responsible for these increases.

The state-of-the-art in climate modeling allows only gross global zoning while some of the expected results from temperature increases of the magnitude indicated are quite dramatic. For example, areas that were deserts 4,000 to 8,000 years ago in the Altithermal period (when the global average temperature was some 2°C higher than present), may in due time return to deserts. Conversely, some areas which are deserts now were formerly agricultural regions. It is postulated that part of the Sahara Desert in Africa was quite wet 2,000 to 8,000 years ago. The American Midwest, on the other hand, was much drier, and it is projected that the Midwest would again become drier should there be a temperature increase of the magnitude postulated for a doubling of atmospheric CO_2 (see Figure 7).

In addition to the effects of climate on global agriculture, there are some potentially catastrophic events that must be considered. For example, if the Antarctic ice sheet which is anchored on land should melt, then this

EC-11-5/A9

could cause a rise in sea level on the order of 5 meters. Such a rise would cause flooding on much of the U.S. East Coast, including the State of Florida and Washington, D.C. The melting rate of polar ice is being studied by a number of glacialogists. Estimates for the melting of the West Anarctica ice sheet range from hundreds of years to a thousand years. Etkins and Epstein observed a 45 mm raise in mean sea level. They account for the rise by assuming that the top 70 m of the oceans has warmed by 0.3°C from 1890 to 1940 (as has the atmosphere) causing a 24 mm rise in sea level due to thermal expansion. They attribute the rest of the sea level rise to melting of polar ice. However, melting 51 Tt (10^{12} metric tonnes) of ice would reduce ocean temperature by 0.2°C, and explain why the global mean surface temperature has not increased as predicted by CO_2 greenhouse theories.

In an American Association for the Advancement of Science (AAAS) and Department of Energy (DOE) sponsored workshop on the environmental and societal consequences of a possible CO_2 induced climate change, other factors such as the environmental effects of CO_2 concentration on weeds and pests were considered. The general consensus was that these unmanaged species would tend to thrive with increasing average global temperature. The managed biosphere, such as agriculture, would also tend to benefit from atmospheric CO_2 growth. This is a consequence of CO_2 benefiting agriculture, provided the other key nutrients, phosphorous and nitrogen, are present in the right proportions. Agricultural water needs can be met by new irrigation techniques that require less water. In addition, with higher CO_2 and higher temperature conditions, the amount of water needed by agricultural plants may be reduced. It is expected that bioscience contributions could point the way for dealing with climatological disruptions of the magnitude indicated above. As a result of the workshop, research in 11 areas was recommended:

1. CO_2 fertilization could have broad beneficial effects on agriculture. These effects need to be studied in detail and for a variety of plant, soil and climatic conditions.

2. There is a need for a fuller understanding of the dynamics of currents and water masses in the Arctic Ocean.

3. It is necessary to determine whether there was deglaciation of the West Antarctic ice sheet about 120,000 years ago and whether this caused a rise in global sea levels at that time. If this occurred, then the information could serve as an analog of future deglaciation.

4. It is necessary to develop and use scenarios which integrate (a) information about population, resources, energy consumption and fuel mixes; (b) buildup of atmospheric CO_2; (c) response of the climate system; (d) effects on various biological systems, especially agricultural, economic and social consequences, international and interregional conflicts; and (e) possible feedback among these forces.

EC-11-5/A10

5. CO_2 induced warming is predicted to be much greater at the polar regions. There could also be positive feedback mechanisms as deposits of peat, containing large reservoirs of organic carbon, are exposed to oxidation. Similarly, thawing might also release large quantities of carbon currently sequestered as methane hydrates. Quantitative estimates of these possible effects are needed.

6. Although all biological systems are likely to be affected, the most severe economic effects could be on agriculture. There is a need to examine methods for alleviating environmental stress on renewable resource production — food, fiber, animal, agriculture, tree crops, etc.

7. Information exists on the relationship of cultivated and non-cultivated biomes to climatic fluctuations. Similarly, there is considerable information on the response of various nations and economic sectors to climatic variations over the past few hundred years. This information, which is currently scattered and not uniformly presented or calibrated, is thus of limited usefulness.

8. Studies of climate effects are recommended for the semi-arid tropics because of the relatively large populations in these countries and because of special sensitivity to climate.

9. There are situations (soil erosion, salinization, or the collapse of irrigation systems) which are recommended for study as indicators of how societies respond, and how they might learn to cope and adapt more effectively to a shift in global climate.

10. Research is recommended on the flow of information on risk perception and decision making to and from both laymen and experts, the physiological aspects of understanding and perception, and the factors that influence decision making.

11. There is a need to be sure that "lifetime" exposure to elevated CO_2 poses no risks to the health of humans or animals. Health effects associated with changes in the climate sensitive parameters, or stress associated with climate related famine or migration could be significant, and deserve study.

In terms of the societal and institutional responses to an increase in CO_2, the AAAS-DOE workshop participants felt that society can adapt to the increase in CO_2 and that this problem is not as significant to mankind as a nuclear holocaust or world famine. Finally, in an analysis of the issues associated with economic and geopolitical consequences, it was felt that society can adapt to a CO_2 increase within economic constraints that will be existing at the time. Some adaptive measures that were tested would not consume more than a few percent of the gross national product estimated in the middle of the next century.

Major Research Programs Underway

The Department of Energy (DOE) which is acting as a focal point for the U.S. government in this area is planning to issue two reports to the scientific community and to policy makers. The first one, summarizing five years of study is due in 1984, and the second one in 1989. The current plan is to invest approximately 10 years of research and assessment prior to recommending policy decisions in this area which impact greatly on the energy needs and scenarios for the U.S. and the world. The strategic elements of the United States national total CO_2 program are summarized in Figure 8.

Much of the government sponsored effort to date has focused on delineating the research needed to enhance our understanding of the potential problems. Accordingly, a number of workshops and symposia were held to this end. The consensus of the key research needs is summarized in Figure 8 under the heading "Research Program Results." To date, most of the research effort has been concentrated on the first two research categories. It should be noted, however, that this research started in 1979 and there are few results to report. The most ambitious project being conducted at this time is called "Transient Tracer in the Ocean (TTO)." This research, jointly funded by the DOE and the National Science Foundation (NSF), is a 4M$ project to investigate ocean mixing processes in order to enhance the understanding of how surface water CO_2 is mixed into the deep ocean. Tracers normally found in the ocean, such as ^{14}C, ^{3}H, ^{3}He, ^{85}Kr and ^{39}Ar, are monitored in the North Atlantic Ocean from oceanographic vessels.

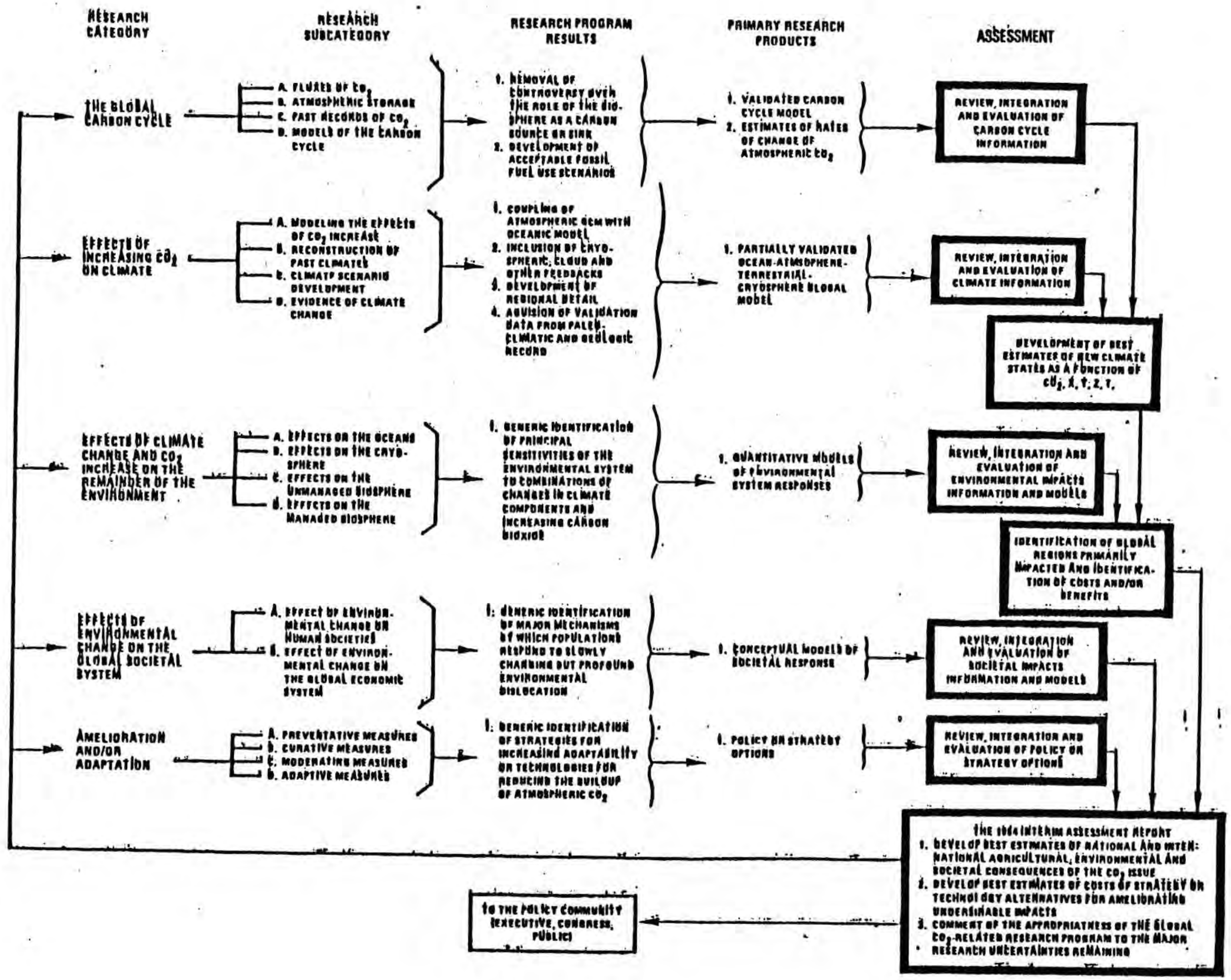
In addition to the mixing of surface waters into the bottom layers, carbon can be added to deep waters by the oxidation of organic matter and the dissolution of calcium carbonate. In order to separate these three processes and determine their relative significance, precise total carbon dioxide, alkalinity, and calcium concentration data are needed to construct and test mathematical models. Preliminary analysis of the limited data indicates that (1) lateral processes dominate the distribution of calcium and inorganic carbon in the deep oceans away from the polar regions, (2) the amount of calcium carbonate dissociated in the deep oceans is only a fraction of the previously estimated value, and (3) the excess CO_2 may have penetrated farther into the deep oceans than the currently available models predict.

Ultimately, CO_2 in the air should find its way into the deep ocean sediments. As currently understood, the deeper sediments have thus far been little affected by the fossil fuel era because of the slow mixing of the ocean. A group of scientists examined the contention that some shallow water sediments could now be dissolving and thus providing a sink for atmospheric CO_2, and concluded that the extent of dissolution is not great enough to have a large effect on the global carbon cycle.

It would be helpful if reliable estimates of the CO_2 concentration in the air could be obtained for the years prior to 1957, when the modern measurements

Figure 8

A NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY



began. Old Smithsonian Astrophysical Observatory plates of the solar spectrum taken in the early twentieth century might provide such an opportunity if they could be properly interpreted. A method for reducing the data has been developed and estimates of the CO_2 concentration should be available next year. As mentioned previously, determination of the CO_2 concentrations prior to the Industrial Revolution would help ascertain the validity of climate models, and thus the likely temperature due to a doubling of atmospheric CO_2.

Groups in Europe have used Antarctic and Greenland ice cores to independently estimate the CO_2 concentrations in the more distant past. While it is difficult to measure the CO_2 content of the dated ice cores, the results suggest that the atmospheric CO_2 concentration during the height of the last ice age (about 18,000 years ago) may have been about half its present value. This is consistent with recently published speculations derived from examination of the composition of ocean sediment cores.

There are currently approximately 40 carbon cycle and climate research projects in about 25 different institutions. Many of these projects are either supported jointly by the DOE and other agencies or exclusively by other agencies. The 1982 Federal budget request for CO_2 research was 23.9M$. The DOE, as the lead agency, would be allocated 14.0M$, NSF 6.4M$, NOAA 2.5M$, and the Department of Agriculture 1.0M$.

Future Energy Scenarios and Their Potential Impact on Atmospheric Carbon Dioxide

A number of future energy scenarios have been studied in relation to the CO_2 problem. These include such unlikely scenarios as stopping all fossil fuel combustion at the 1980 rate, looking at the delay in doubling time, and maintaining the pre-1973 fuel growth rate. Other studies have investigated the market penetration of non-fossil fuel technologies, such as nuclear, and its impact on CO_2. It should be noted, however, that fuel technology would need about 50 years to penetrate and achieve roughly half of the total market. Thus, even if solar or nuclear technologies were to be considered viable alternatives, they would not really displace fossil fuel energy for the next 40 to 50 years, and CO_2 growth would have to be estimated based on realistic market displacement of the fossil fuel technologies.

A draft report from Massachusetts Institute of Technology (MIT) and Oak Ridge (ORNL) authored by D. Rose and others considered the societal and technological inertia vis a vis decision making on the CO_2 issue. The CO_2 problem was considered as the major potential constraint on fossil fuel use. It was estimated in the study that the CO_2 problem may curtail fossil fuel use before physical depletion occurs. Considerable effort was devoted in the study to "option space," i.e., what are the potential energy alternatives, how long would it take to introduce them, and what type of material resources would be needed for effective market penetration. On reviewing the report we addressed only the technical questions relating to CO_2, and did not evaluate the plausibility of the scenarios relating to energy use in the future.

EC-11-5/A13

The study considered the implications of limiting atmospheric CO_2 at two different levels:

1. Rate of CO_2 addition to the atmosphere be limited to 450-500 ppm in 50 years.

2. The concentration ceiling for atmospheric CO_2 be in the range of 500-1000 ppm.

The rationale for choosing these limits is economic. If the rate of CO_2 increase is too rapid, then society may not be able to economically adapt to the resulting climate change. The second limit is based on a level where the harm due to CO_2 would greatly exceed the societal benefits that produced the CO_2. The second limit can be illustrated as an assumed threshold for inducing great irreversible harm to our planet, such as causing a large ocean level rise due to melting polar ice. In addition to improving the use of energy sources as a means of gaining time to understand the problem, it was concluded that vigorous development of non-fossil energy sources be initiated as soon as possible.

The study appears to be based on reasonable assumptions but has an inherent bias towards the accelerated development of non-fossil energy sources which, based on the present state-of-the-art, implies nuclear energy.

In his analysis, Rose introduced the concept of AIT (action initiation time), defined as the time when policies to modify or restrain fossil fuel use actually start to be effective. Based on this concept, Rose projects non-fossil growth rates of 6 to 9%/a over 40 to 50 years in order to limit atmospheric CO_2 to 500 to 700 ppm. These rates can be put in perspective by noting that such growth rates were achieved for natural gas introduction. However, nuclear or solar sources would have severe restrictions because such technologies are not as economically and politically attractive, technologically straightforward, and are encountering social and environmental opposition. In addition, Rose points out that the rate of growth of manufacturing facilities required to achieve a 6-9%/a growth rate in non-fossil fuel power generation is so large that it would be equivalent to increasing each year the U.S. power equipment manufacturing capability by an amount equivalent to the current capacity.

The study also indicated that other energy-use-related greenhouse gases (viz. carbon monoxide, methane, and oxides of nitrogen) may significantly contribute to a global warming. We believe the contribution of these gases to a global warming is highly speculative. Furthermore, N_2O, the only oxide of nitrogen that could contribute to a global warming is produced primarily by the microbial oxidation of ammonia from fertilizer use, and to a lesser extent from the combustion of fossil fuels. Additionally, N_2O is more reactive than CO_2 and is expected to have a relatively shorter atmospheric residence time. In a similar vein, methane is primarily emitted to the atmosphere via the anaerobic fermentation of organic material. The contribution of anthropogenic activities (mining, industrial processes, and combustion) are 1% to 10% of the total atmospheric methane sources. The atmospheric destruction of methane is more rapid than that of CO_2, and tends to yield CO, water vapor and formaldehyde. Also, methane is believed to contribute to tropospheric ozone formation by oxidizing to CO_2. The CO in the atmosphere can be traced to anthopogenic sources (50 to 60%) and to the atmospheric oxidation of methane (30%). The major CO sink is oxidation (70 to 90%) to CO_2. One can therefore consider CO and methane as precursors to CO_2. Accordingly, CO and methane ultimately contribute to climatological effects as part of atmospheric CO_2. The N_2O, on the other hand, may not be directly related to fossil fuel combustion. One should question whether the other "greenhouse" gases should be considered part of the CO_2 problem in view of the uncertainties regarding their connection to energy use. It is not clear, at this time, whether their effect would be additive to CO_2.

Forecast Based on Fossil Fuel Projected in Exxon's Long Range Energy Outlook

As part of the Exxon 21st Century Study, the rate of fossil fuel CO_2 emissions was estimated in late 1981. Specifically, the "High Case" volumetric data provided by the Corporate Planning Department was used to estimate the potential growth of atmospheric CO_2. The volumetric data was converted to an energy basis (Quads/a = 10^{15} Btu/year) using 5.55 MBtu/B for U.S., 5.64 MBtu/B for Canada and 5.85 MBtu/B for all other countries. In addition, a shale processing loss was added using a constant rate of 27.5% of the primary energy consumption from shale. This was based on the assumption that above ground retorting of relatively high quality oil shale (>30 gallons/ton) would be recovered with a thermal efficiency of 80%, and in-situ recovery of relatively poor oil shale (>15 gallons/ton) would be accomplished with a thermal efficiency of 65%. These efficiencies were averaged over the U.S. resource base to arrive at 72.5%. Table 1 summarizes the primary energy consumption of fossil fuels.

The total carbon dioxide that can be emitted from primary fossil fuels was estimated using the following factors:

Oil = 170 lb CO_2/MBtu = 21.0 MtC*/Quad.

Gas = 115 lb CO_2/MBtu = 14.2 MtC/Quad.

Coal = 207 lb CO_2/MBtu = 25.6 MtC/Quad.

In addition, the quantity of carbon dioxide that could be emitted from the decomposition of carbonate minerals in processing U.S. oil shale was estimated by averaging this potentially large CO_2 source over the Green River formation resource base. It should be noted that poorer shale resources tend to

* MtC = million metric tons of carbon.

PRIMARY ENERGY CONSUMPTION OF FOSSIL FUELS
21st CENTURY STUDY--HIGH CASE

Quads/a

Year	1979	1990	2000	2015	2030	2050
Oil						
U.S.	37.09	33.32	32.01	35.35	36.35	36.80
Canada	4.06	4.30	4.71	5.62	6.09	5.97
Others	96.62	111.93	128.16	139.63	148.57	132.75
Total	137.77	149.55	164.88	180.60	191.01	175.52
Gas						
U.S.	20.95	17.83	17.24	15.98	16.87	17.42
Canada	1.83	2.51	2.88	3.48	4.38	4.73
Others	30.88	55.54	74.95	86.24	99.65	108.68
Total	53.66	75.88	95.07	105.70	120.90	130.83
Coal						
U.S.	14.69	20.14	28.66	37.19	43.17	55.10
Canada	0.80	1.37	1.98	2.72	3.62	5.35
Others	60.17	81.44	103.90	125.55	175.55	261.14
Total	75.66	102.95	134.54	165.41	222.54	321.59
Fossil Fuels						
World Total	267.09	328.38	394.49	451.71	534.45	627.94

Rate %/a	1979–1990	1990–2000	2000–2015	2015–2030	2030–2050
Rate %/a	1.90	1.85	0.91	1.13	0.81

emit much more CO_2 from carbonate minerals than the more desirable high quality resources for the same quantity of shale oil produced. It was further assumed that 65% of the carbonate minerals decompose during processing. This very conservative assumption is based on the average of 100% decomposition that may occur in "hot spots" during in-situ recovery and 30% decomposition that is generally observed in above ground retorting. Table 2 summarizes the total CO_2 produced in GtC/a. Please note that CO_2 emissions resulting from CO_2 mixed with natural gas in producing wells can be substantial, but due to the unavailability of quantitative data this factor was assumed to contribute about 5% additional CO_2 currently rising to 15% in the year 2050. This trend of CO_2 contamination of natural gas is consistent with recent Exxon experience.

The contributions of shale oil to primary fossil fuel energy and primary fossil fuel carbon are summarized in Table 3. This table shows that the fraction of shale oil CO_2 emissions to total CO_2 is greater than the corresponding contribution of shale oil energy to total energy. Table 3 also indicates the breakdown between CO_2 generated in producing and consuming shale oil, and that due to carbonate mineral decomposition.

Table 4 presents the estimated total quantities of CO_2 emitted to the environment as GtC, the growth of CO_2 in the atmosphere in ppm (v), and average global temperature increase in $^{\circ}C$ over 1979 as the base year. In order to estimate the buildup of atmospheric CO_2, it was assumed that the average atmospheric CO_2 concentration was 337 ppm in 1979. The fraction of CO_2 accumulated in the atmosphere was assumed to be 0.535 of the total fossil fuel CO_2. This number is derived from the observed historic ratio of total atmospheric CO_2 to total fossil fuel CO_2. Inherent in this number is the assumption that biomass and cement production did not contribute to atmospheric CO_2. It should be noted, however, that this method of calculation would tend to predict total anthropogenic CO_2 as long as the ratio of biomass and cement manufacture to fossil fuel consumption remains constant. The average temperature increase since 1979 was estimated, assuming that a doubling of CO_2 would cause an average global temperature increase of $3.0^{\circ} \pm 1.5^{\circ}C$. It was also assumed that fossil fuel carbon would grow at a rate of 0.8%/a between 2050 and 2080, which is a reasonable decrease from the 0.97%/a rate projected between 2030 and 2050. The following section analyzes the implications of the temperature rise due to CO_2 doubling with respect to initial detection of a greenhouse effect.

One variation of the High Case scenario was considered. It was assumed that adequate quantities of oil and gas would be discovered to exactly match those estimated to be produced from synthetic fuels in the High Case scenario, and thus balance the primary energy needs of the 21st Century Study. The net quantity of carbon that would be saved is summarized in Table 5. The implications of the synfuel losses are compared with the High Case in Figure 3. The overall impact is relatively minor.

TABLE 2

PRIMARY CARBON DIOXIDE (AS CARBON) FORMATION FROM FOSSIL FUELS
21st CENTURY STUDY--HIGH CASE

GtC/a

Year	1979	1990	2000	2015	2030	2050
Oil	2.90	3.15	3.47	3.79	4.01	3.69
Inorganic Carbon	-	0.01	0.05	0.19	0.27	0.40
Total Oil	2.90	3.16	3.52	3.98	4.28	4.09
Gas	0.76	1.08	1.35	1.50	1.72	1.86
CO_2 in Gas	0.04	0.11	0.15	0.18	0.22	0.28
Total Gas	0.80	1.19	1.50	1.68	1.94	2.14
Total Coal	1.93	2.64	3.45	4.24	5.70	8.24
World Total	5.63	7.00	8.47	9.90	11.92	14.47
Rate %/a	2.00	1.92	1.05	1.25	0.97	0.80

TABLE 3

OIL SHALE LIQUID FUELS
PRIMARY ENERGY CONSUMPTION AND
CARBON DIOXIDE (AS CARBON) PRODUCTION
21st CENTURY STUDY--HIGH CASE

Year	1979	1990	2000	2015	2030	2050
U.S. Shale, Quads/a	--	1.01	3.65	14.38	20.66	30.79
Other Shale	--	0.21	1.49	2.56	5.55	11.10
Total	--	1.21	5.14	16.94	26.21	41.89
% Primary Shale Energy/Primary Fossil Fuels Energy	--	0.35	1.30	3.75	4.90	6.67
Shale Carbon, GtC/A	--	0.03	0.11	0.36	0.55	0.88
Carbonate Carbon	--	0.01	0.05	0.19	0.27	0.40
Total	--	0.04	0.16	0.55	0.82	1.28
% Primary Shale Carbon/Primary Fossil Fuel Carbon	--	0.55	1.89	5.55	6.87	8.85

TABLE 4

ESTIMATED ATMOSPHERIC CO_2 CONCENTRATION AND AVERAGE TEMPERATURE INCREASE 21st CENTURY STUDY--HIGH CASE

Year	Emitted, GtC		Stored in Atmosphere, GtC		Atmospheric Concentration, ppm		Average Temperature Increase, °C
	Incremental	Cummulative	Incremental	Cummulative	Incremental	Cummulative	
1979	--	--	--	715	--	337	0
1990	69.3	69.3	37.1	752	17.5	355	0.22
2000	77.2	146.5	41.3	793	19.5	374	0.45
2015	137.5	284.0	73.6	867	34.7	409	0.84
2030	163.3	447.3	87.4	954	41.2	450	1.25
2050	263.5	710.8	141.0	1095	66.5	516	1.84
2080	490.6	1201.4	262.5	1358	123.7	640	2.78
2090	191.3	1392.7	102.3	1160	48.2	688	3.09

TABLE 5

ESTIMATED INCREMENTAL CO_2 CONTRIBUTION FROM SYNTHETIC FUELS TO ATMOSPHERIC CO_2 CONCENTRATION AND AVERAGE GLOBAL TEMPERATURE INCREASE

GtC/a

Year	1990	2000	2015	2030	2050	2080
Shale Loss	0.004	0.025	0.069	0.114	0.181	
Carbonate Decomposition	0.013	0.047	0.186	0.267	0.398	
Total Shale	0.017	0.072	0.255	0.381	0.579	
Coal Loss	0.018	0.067	0.136	0.276	0.535	
Total Synfuels Loss	0.035	0.139	0.391	0.657	1.114	
Rate %/a		14.8	7.1	3.5	2.7	2.0
Incremental CO_2, GtC	-	0.80	3.73	7.73	17.38	45.79
Cummulative CO_2, GtC	-	0.80	4.53	12.26	29.64	75.43
Incremental Atmospheric CO_2, ppm	-	0.2	0.9	1.9	4.4	11.5
Cummulative Atmospheric CO_2, ppm	-	0.2	1.1	3.1	7.5	19
Net Atmospheric CO_2, ppm	355	374	407	446	506	616
Average Temperature Increase, °C	0.22	0.45	0.82	1.21	1.76	2.61

Detection of a CO_2 Greenhouse Effect

It is anticipated by most scientists that a general consensus regarding the likelihood and implications of a CO_2 induced greenhouse effect will not be reached until such time as a significant temperature increase can be detected above the natural random temperature fluctuations in average global climate. These fluctuations are assumed to be $\pm 0.5^{\circ}C$. The earliest that such discreet signals will be able to be measured is one of the major uncertainties of the CO_2 issue.

A number of climatologists claim that they are currently measuring a temperature signal (above climate noise) due to a CO_2 induced greenhouse effect, while the majority do not expect such a signal to be detectable before the year 2000. In order to quantify the implications of detecting a greenhouse effect now, as opposed to the year 2000, estimates were made on temperature projections as a function of the CO_2 concentration that existed prior to the Industrial Revolution. Available data on CO_2 concentration prior to the Industrial Revolution tend to fall into two groups: 260 to 270 ppm or 290 to 300 ppm. In Table 6, possible temperature increases were estimated as a function of initial CO_2 concentrations of 265 and 295 ppm. Temperatures were projected for three cases, viz., (1) a temperature increase of $3^{\circ}C$ occurs if current CO_2 concentration doubles, (2) the greenhouse effect is detectable now (1979), and (3) the greenhouse affect is detected in the year 2000.

One can see in Table 6 that if a doubling of atmospheric CO_2 will cause a $3^{\circ}C$ rise in temperature, then we should have seen a temperature increase above climate noise if initial CO_2 concentration was 265 ppm, or be on the threshold of detecting such an effect now, if the initial concentration was 295 ppm. If we assume that we are on the threshold of detecting a greenhouse effect, then the average temperature due to a doubling of CO_2 will be $1.9^{\circ}C$ for an initial CO_2 concentration of 265, or $3.1^{\circ}C$ for an initial concentration of 295 ppm. Finally, if the greenhouse effect is detected in the year 2000, then the doubling temperature for initial CO_2 concentrations of 265 and 295 ppm will be 1.3° and $1.7^{\circ}C$, respectively. Based on these estimates, one concludes that a doubling of current concentrations of CO_2 will probably not cause an average global temperature rise much in excess of $3^{\circ}C$, or the effect should be detectable at the present time. Alternatively, if the greenhouse effect is not detected until 2000, then the temperature due to a CO_2 doubling will probably be under $2^{\circ}C$. Using the Exxon 21st Century Study as a basis for fossil fuel growth patterns, the average global temperature increases due to CO_2 would range between 0.8 and $1.6^{\circ}C$ by 2030. A doubling of atmospheric CO_2 would be extropolated from the fossil fuel consumption rates of the 21st Century Study to occur at about the year 2090 with the temperature increase ranging between 1.3° and $3.1^{\circ}C$. The projected range presented above is considerably lower than the generally accepted range of 1.5° to $4.5^{\circ}C$. Figure 9 illustrates

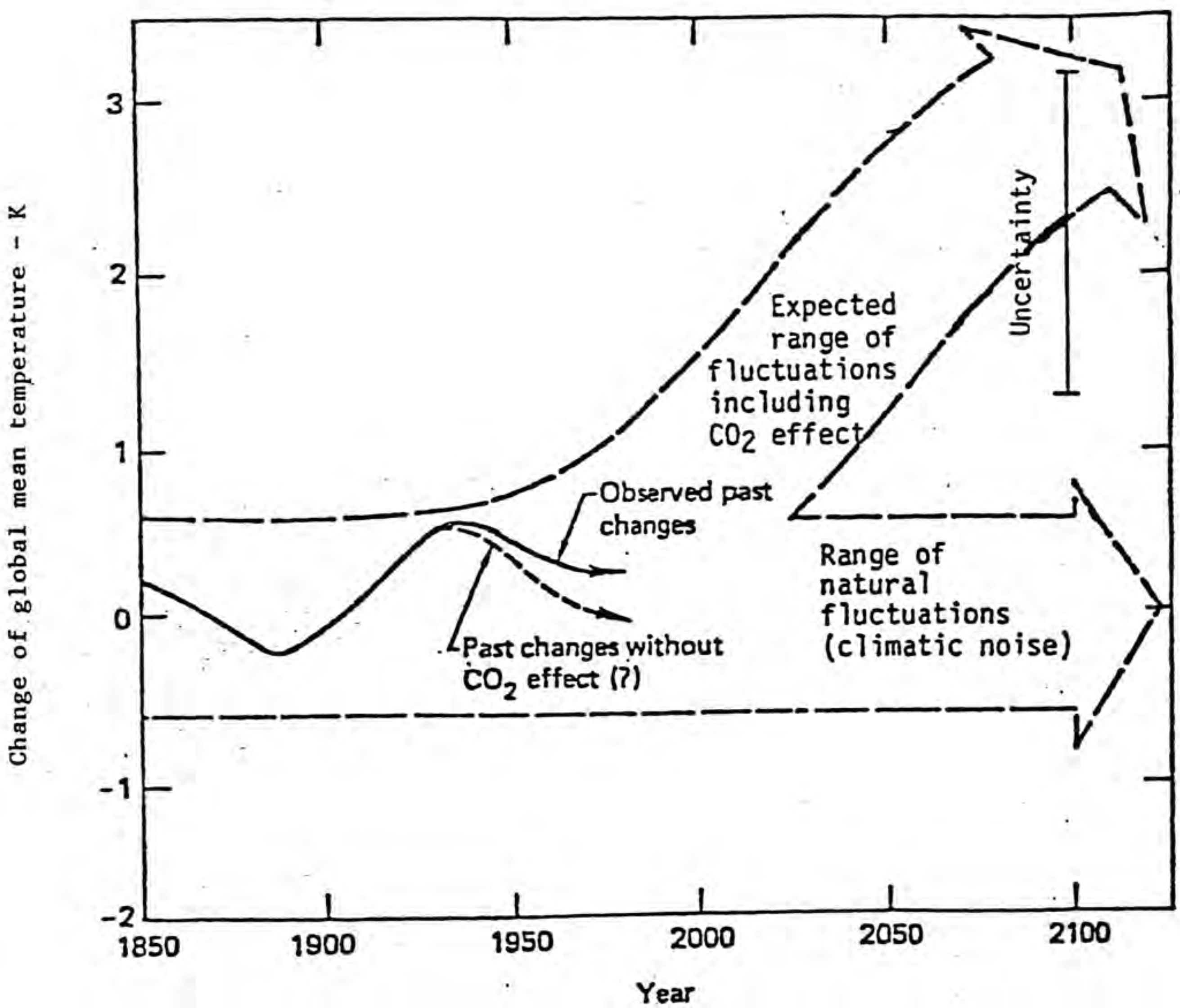
TABLE 6

EFFECT OF PRE-INDUSTRIAL ATMOSPHERIC CO_2 CONCENTRATION ON GLOBAL AVERAGE TEMPERATURE INCREASE

Atmospheric CO2 Concentration, ppm	Time (Instantaneous Equilibrium)	Temperature, °C: Doubling ~2090, 265	Doubling ~2090, 295	Detected 1979, 265	Detected 1979, 295	Detected 2000, 265	Detected 2000, 295
1,000	~2140	4.3	4.4	2.8	4.6	1.9	2.5
800	~2110	3.6	3.6	2.3	3.7	1.4	2.1
674 (Doubling)	~2090	3.0	3.0	1.9	3.1	1.3	1.7
451	2030	1.7	1.5	1.1	1.6	0.8	0.9
375	2000	1.1	0.9	0.7	0.9	0.5	0.5
337 (Current)	1979	0.8	0.5	0.5	0.5	0.3	0.3
295	~1850	0.3	0	0.2	0	0.2	0
265	~1850	0	–	0	–	0	–

Figure 9

Range of Global Mean Temperature From 1850 to the Present with the Projected Instantaneous Climatic Response to Increasing CO_2 Concentrations.



the behavior of the mean global temperature from 1850 to the present, contained within an envelop scaled to include the random temperature fluctuations, and projected into the future to include the 1.3° to 3.1°C range of uncertainty noted above for the CO_2 effect.

Depending on the actual global energy demand and supply, it is possible that some of the concerns about CO_2 growth due to fossil fuel combustion may be reduced if fossil fuel use is decreased due to high price, scarcity, and unavailability.

The above discussion assumes that an instantaneous climatic response results from an increase in atmospheric CO_2 concentration. In actuality, the temperature effect would likely lag the CO_2 change by about 20 years because the oceans would tend to damp out temperature changes.

Given the long term nature of the potential problem and the uncertainties involved, it would appear that there is time for further study and monitoring before specific actions need be taken. At the present time, that action would likely be curtailment of fossil fuel consumption which would undoubtedly seriously impact the world's economies and societies. Key points needing better definition include the impact of fossil fuel combusion and the role of the oceans in the carbon cycle and the interactive effect of carbon dioxide and other trace atmospheric gases on climate.

BIBLIOGRAPHY

Ad Hoc Study Group on Carbon Dioxide and Climate. 1979. Carbon Dioxide and Climate: A Scientific Assessment. Wash. DC: Nat. Acad. Sci. 25 pp.

Adams, J. A. S., Mantovani, M. S. M., Lundell, L. L. 1977. Wood versus fossil fuel as a source of excess carbon dioxide in the atmosphere: A preliminary report. Science 196:54-56.

American Friends Service Committee (AFSC) 1972. The Agnes Diaster and the Federal Response. Philadelphia, Pa.: AFSC.

Andrews, J. T., Mears, A., Miller, G. H., Pheasant, D. R. 1972. Holocene late glacial maximum and marine transgression in the Eastern Canadian Arctic. Nature Phys. Sci. 239:147-49.

Arrhenius, S. 1896. On the fluence of carbonic acid in the air upon the temperature of the ground. Philos. Mag. 41:237-76.

Augustsson, T., Ramanathan, V. 1977. A radiative-convective model study of the CO_2 climate problem. J. Atmos. Sci. 34:448-51.

Bacastow, R. 1979. Dip in the atmospheric CO_2 level during the mid 1960s. J. Geophys. Res. 84:3108-14.

Bacastow, R. 1976. Modulation of atmospheric carbon dioxide by the Southern Oscillation. Nature 261:116-18.

Bacastow, R. B., Keeling, C. D. 1973. Atmospheric carbon dioxide and radio carbon in the natural carbon cycle: Changes from A.D. 1700 to 2070 as deduced from a geochemical model. In Carbon and the Biosphere. CONF 720510, ed. G. M. Woodwell, E. V. Pecan, pp. 86-135. Springfield, Va.: NTIS.

Bach, W. 1976. Global Air Pollution and Climate Change. Rev. Geophys. Space Phys. 14:429-74.

Bach, W., Pankrath, J., Williams, J. 1980. Interactions of Energy and Climate. D. Reidel, Dordrecht, Holland.

Baes, C. F. Jr., Goeller, H. E., Olsen, J. S., Rotty, R. M. 1977. Carbon Dioxide and Climate: The Uncontrolled Experiment. Am. Sci. 65:310-20.

Baker, E. J., McPhee, J. G. 1975. Land Use Management and Regulation in Hazardous Areas: A Research Assessment, Boulder, Co: Inst. Behav. Sci. 124 pp.

Barney, G. O. 1980. The global 2000 report to the President. A report prepared by the Council on Environmental Quality and the Department of State. NTIS.

Berger, R., and Libby, W. F. 1960. Equilibration of Atmospheric Carbon Dioxide with Sea Water: Possible Enzymatic Control of the Rate. Science. 1395-6.

Boisvert, R. N. 1975. Impact of Floods and Flood Management Policy on Area Economic Development and Recovery. Dept. Agric. Econ., Cornell Univ., Ithaca, NY. 71 pp.

Bolin, B., Degeus, E. T., Kempe, S., Ketner, P., eds. 1979. The Global Carbon Cycle, SCOPE 13. New York: Wiley. 491 pp.

Bolin, B. 1977. Changes of land biota and their importance for the carbon cycle. Science. 196:613-15.

Bolin, B., Bischof, W. 1970. Variations of the carbon dioxide content of the atmosphere in the northern hemisphere. Tellus 29:171-80.

Broeker, W. S. 1975. Climatic Change: Are We on the Brink of a Pronounced Global Warming? Science. 189:460-3.

Broecker, W. S., Takahashi, T., Simpson, H. J., Peng, T. -H. 1979. Fate of fossil fuel carbon dioxide and the global carbon budget. Science. 206:409-18.

Broecker, W. S., Thurber, D. L., Goodard, J., Ku, T. -L., Matthews, R. K., Mesolella, K. J. 1968. Milankovitch hypothesis supported by precise dating of coral reefs and deep-sea sediments. Science. 159:298-300.

Bryan, K., Komro, F. G., Manabe, S., Spelman, M. J. 1982. Transient climate response to increasing atmospheric carbon dioxide. Science. 215:56-8.

Bryson, R. A., Wendland, W. M., Ives, J. E., Andrews, J. T. 1969. Radiocarbon isochrones on the disintegration of the Laurentide ice sheet. Arctic Alpine Res. 1:1-14.

Budd, W., McInnes, B. 1978. Modeling surging glaciers and periodic surging of the Antarctic ice sheet. In Climatic Change and Variability: A Southern Perspective. ed. A. B. Pittock, L. A. Frakes, D. Jenssen, J. A. Peterson, J. W. Zillman, pp. 228-34. New York: Cambridge Univ. Press. 455 pp.

Budd, W. F., Jenssen, D., Radok, U. 1971. Derived Physical Characteristics of the Antarctic Ice Sheet, Mark 1. Univ. Melbourne Meteor. Dept. Publ. No. 18, Melbourne, Australia. 178 pp.

Callendar, G. S. 1938. The artificial production of carbon dioxide and its influence on temperature. Q. J. Roy. Meteor. Soc. 64:223-27.

Carbon Dioxide and Climate Research Program. 1979. Summary of the Carbon Dioxide Effects Research and Assessment Program. U. S. Dept. of Energy. Wash. D.C. 37 pp.

Cess, R. D., Hameed, S., Hogan, J. S. 1980. Response of the global climate to changes in atmospheric chemical composition due to fossil fuel burning. ASME Paper 80-WA/HT-3.

Chen, K., Winter, R. C., Bergman, J. K. 1980. Carbon Dioxide from Fossil Fuels-Adapting to Uncertainty. Energy Policy, 8:318-330.

Choudhury, B., Kukla, G. 1979. Impact of CO_2 on cooling of snow and water surfaces. Nature. 280:668-71.

Clark, J. A., Lingle, C. S. 1977. Future sea-level changes due to West Antarctic ice sheet fluctuations. Nature. 269:206-9.

Climate Research Board. 1979. Toward a U.S. Climate Program Plan. Wash. D.C.: Nat. Acad. Sci. 91 pp.

Cochrane, H. C., Haas, J. E., Bowden, M. J., Kates, R. W. 1974. Social Science Perspectives on the Coming San Francisco Earthquake: Economic Impact, Prediction and Reconstruction. Natural Hazard Res. Working Pap. No. 25, Inst. Behav. Sci., Univ. Colo., Boulder, Co. 82 pp.

Colvill, A. J. 1977. Movement of Antarctic ice fronts measured from satellite imagery. Polar Record. 18:390-94.

Committee on Climate and Weather Fluctuations and Agricultural Production. 1979. Climate and Food. Wash. D.C.: Nat. Acad. Sci. 212 pp.

Council on Environmental Quality. 1981. Global energy futures and the carbon dioxide problem.

Dacy, D. D., Kunreuther, H. 1969. The Economics of Natural Disasters. New York: The Free Press.

Delmas, R. J., Ascencio, J. M., Legrand, M. 1980. Polar ice evidence that atmospheric CO_2 20,000 yr BP was 50% of present. Nature. 284:155-7.

Denton, G. H., Armstrong, R. L., Stuiver, M. 1971. The late Cenozoic glacial history of Antarctica. In The Late Cenozoic Glacial Ages, ed. K. Turekian, pp. 267-306. New Haven: Yale Univ. Press.

Economic Development Council of Northeastern Pennsylvania. 1972. Economic Impact of Tropical Storm Agnes on Luzerne County. Flood Recovery Task Force, Inc. Philadelphia, Pa.

Enrlich, P. R., Ehrlich, A. H., Holdren, J. P. 1977. Ecoscience. San Francisco: Freeman. 1051 pp.

Etkins, R., Epstein, E. S. 1982. The rise of global mean sea level as an indication of climate change. Science. 215:287-9.

Elliott, W. P., Machta, L., eds. 1979. Workshop on the Global Effects of Carbon Dioxide from Fossil Fuels. CONF-770385, Springfield, Va: NTIS. 122 pp.

Flohn, H. 1974. Background of a geophysical model of the initiation of the next glaciation. Quat. Res. 4:385-404.

Flohn, H. 1978. Abrupt events in climatic history. Climatic change and variability: A southern perspective, Ed. A. B. Pittock, et al., New York: Cambridge Univ. Press. pp 124-34.

Flohn, H. 1980. Possible climatic consequences of a man-made global warming. IIASA Report RR-80-30. 92 pp.

Garvey, E. A., Prahl, R., Nazimek, K., Shaw, H. 1982. Exxon global CO_2 measurement system. IEEE Trans. on Instr. and Measur. IM-31:32-36.

Geophysics Study Committee. 1977. Climate, Climatic Change and Water Supply. Wash. D. C. Nat. Acad. Sci. 132 pp.

Gilmour, A. E. 1979. Ross ice shelf sea temperature. Science. 203:438-39.

Ginsburg, N. 1972. The lure of tidewater: The problem of the interface between land and sea. In Pacem in Maribus, ed. E. M. Borgese, pp. 32-41. New York: Dodd Mead. 382 pp.

Giovinetto, M. B. 1970. The Antarctic ice sheet and its bimodel response to climate. In Int. Symp. Antarctic Glaciol. Explor. Int. Assoc. Sci. Hydrology (IASH) Commission on Snow and Ice. Publ. No. 86, pp. 347-58. Wash. D.C.: IASH (c/o Am. Geophys. Union).

Glantz, M. 1979. A political view of CO_2. Nature. 280:189-90.

Gornitz, V., Lebedeff, S., and Hansen, J. 1982. Global sea level trend in the past century. Science. 215:1611-4.

Hameed, S., Cess, R. D. 1980. Impact of a global warming on biospheric sources of methane and its climatic consequences. ASME Paper 80-WA/HT-2.

Hameed, S., Cess, R. D., Hogan, J. S. 1980. Response of the global climate to changes in atmospheric chemical composition due to fossil fuel burning. J. Geophys. Res. 85:7537-45.

Hansen, J., et. al., 1981. Climate impact of increasing atmospheric carbon dioxide. Science. 213:957-66.

Hirschler, M. M. 1981. Man's emission of carbon dioxide into the atmosphere. Atmos. Environ. 15:719-27.

Hoffert, M. I. 1974. Global distributions of atmospheric carbon dioxide in the fossil-fuel era: A projection. Atmos. Envir. 8:1225-49.

Hollin, J. T. 1965. Wilson's theory of ice ages. Nature. 208:12-16.

Hollin, J. T. 1969. Ice sheet surges and the geological record. Can. J. Earth Sci. 6:903-10.

Hollin, J. T. 1972. Interglacial climates and Antarctic ice surges. Quat. Res. 2:401-8.

Hoyt, D. V. 1979. An emperical determination of the heating of the earth by the carbon dioxide greenhouse effect. Nature. 282:388-90.

Hughes, T. 1973. Is the West Antarctic ice sheet disintegrating? J. Geophys. Res. 78:7844-7910.

Hughes, T. 1977. West Antarctic ice streams. Rev. Geophys. Space Phys. 15:1-46.

Hughes, T. 1975. The West Antarctic ice sheet: Instability, disintegration and initiation of ice ages. Rev. Geophys. Space Phys. 13:502-26.

Hughes, T. 1980. Climatic warming and collapse of the West Antarctic Ice Sheet. In Workshop on Environmental and Societal Consequences of a Potential CO_2 Induced Climate Warming. Wash. D.C.: USDOE. In press.

Idso, S. B. 1980. The climatological significance of a doubling of earth's atmospheric carbon dioxide concentration. Science 207:1462-3.

Ives, J. D., Andrews, J. T., Barry, R. G. 1975. Growth and decay of the Laurentide ice sheet and comparisons with Fenno-Scandinavia. Naturwissenschaften 62:118-25.

Jacobs, S. S., Gordon, A. L., Ardai, J. L. Jr., 1979. Circulation and melting beneath the Ross ice shelf. Science 203: 439-43.

Jason. 1979. The Long Term Impact of Atmospheric Carbon Dioxide on Climate. Tech. Rep. JSR-78-07. SRI Int., Arlington, Va. 184 pp.

Jason. 1980. The Carbon Dioxide Problem: DOE Program and General Assessment. Tech. Rep. JSR-80-06. SRI Int., Arlington, VA. 37 pp.

Kahn, H., Brown, W., Martel, L. 1976. The Next 200 Years: A Scenario for America and the World. New York: Morrow. 241 pp.

Keeling, C. D., Bacastow, R. B. 1977. Impact of industrial gases on climate. In Energy and Climate, ed. Geophys. Res. Board, pp 72-95. Wash. D.C.: Nat. Acad. Sci. 158 pp.

Keeling, C. D., Bacastow, R. B., Bainbridge, A. E., Ekdahl, C. A., Jr., Guenther, P. R., Waterman, L. S., Chin, J. F. S. 1976. Atmospheric carbon dioxide variations at Mauna Loa Observatory, Hawaii. Tellus 28:538-51.

Keeling, C. D., Adams, J. A. Jr., Ekdahl, Jr., C. A., Guenther, P. R. 1976. Atmospheric carbon dioxide variations at the South Pole. Tellus. 28:552-64.

Kellogg, W. W., Schneider, S. H. 1978. Global air pollution and climate change. IEEE Trans. Geosci. Electron. GE16:44-50.

Kellogg, W. W., 1977. Effects of human activities on global climate. WMO Tech. Note No. 156. WMO No. 486, World Meteor. Org., Geneva Switz. 47 pp.

Kellogg, W. W., Mead, M., eds. 1977. The atmospheric resources: Will mankind behave rationally? In The Atmosphere: Endangered and Endangering. Fogarty Intl. Cent. Proc. No. 39, Publ. No. NIH 77-1065. Wash. D.C.: Nat. Inst. Health, pp. 75-92.

Kellogg, W. S., Schwave, R. 1981. Climate Change and Society. Westview Press, Colorado.

Kneese, A. V. 1977. Economics and the Environment. New York: Penguin.

Kopec, R. J. 1971. Global climate change and the impact of a maximum sea level on coastal development. J. Geog. 70:541-50.

Kukla, G., and Gavin, J. 1981. Recent Changes in The Snow and Ice Marginal Belt. Science. 214:497-503.

Laurmann, J. A. 1979. Market penetration characteristics for energy production and atmospheric carbon dioxide growth. Science 205:896-98.

Lave, L. B., Seskin, E. P. 1977. Air Pollution and Human Health. Baltimore: John Hopkins Univ. 368 pp.

MacDonald, G. J. F. 1978. An overview of the impact of carbon dioxide on climate. Mitre Corporation Report M78-79.

Machta, L., Telegades, K. 1974. In Weather and Climate Modification, ed. W. N. Hess, pp. 697-725. New York: Wiley.

Machta, L. 1972. Mauna Loa and global trends in air quality. Bull. Am. Meteor. Soc. 53-402:20.

Madden, R. A., Ramanathan, V. 1980. Detecting climate change due to increasing carbon dioxide. Science. 209:763-8.

Manabe, S., Wetherald, R. T. 1975. The effects of doubling the CO_2 concentration on the climate of a general circulation model. J. Atmos. Sci. 32:3-15.

Manabe, S., Wetherald, R. T. 1980. On the distribution of climate change resulting from an increase in CO_2 content of the atmosphere. J. Atmos. Sci. 37:99-118.

Manabe, S., Wetherald, R. T., Stouffer, R. T. 1981. Summer Dryness Due to an Increase of Atmospheric CO_2 Concentration. Climate Change. 3:347-86.

Marchetti, C. 1975. Chem. Econ. Eng. Rev. 7:9-15.

Marchetti, C. 1977. On geoengineering and the CO_2 problem. Climatic Change. 1:59-68.

Marland, G., Rotty, R. M. 1979. Carbon dioxide and climate. Rev. Geophys. Space Phys. 17:1813-24.

McRae, J. E., Graedel, T. E. 1979. Carbon dioxide in the urban atmosphere: Dependencies and trends. J. Geophys. Res. 84:5011-17.

Meadows, D. H., Meadows, D. L., Randers, J., Behrens, W. W. III. 1972. The Limits to Growth. New York: Universe Books, 241 pp.

Mercer, J. H. 1978. West Antarctic ice sheet and CO_2 greenhouse effect: A threat of disaster. Nature 277:321-25.

Mercer, J. 1968. Antarctic ice and Sangamon sea level. In Int. Assoc. Sci. Hydrol. Commission of Snow and Ice, General Assembly of Bern, Publ. No. 79, pp. 217-25.

Meyer-Abich, K. 1980. Socioeconomic impacts of climate changes and the comparative changes of alternative political responses — prevention, compensation and adaptation. Climatic Change 3 (No. 3) In Press.

Michel, R. L., Linick, R. W., Williams, P. M. 1979. Tritium and Carbon-14 distributions in seawater from under the Ross ice shelf project ice hole. Science 203:445-46.

Mileti, D. S. 1975. Natural Hazard Warning Systems in the United States: A Research Assessment. Inst. Behav. Sci., Univ. Colo., Boulder, Colo. 97 pp.

National Climate Program Office. 1979. National Climate Program Preliminary 5-year Plan. NOAA. Wash. D.C. 150 pp.

National Defense University. 1978. Climate Change to the Year 2000. Wash. D.C.: Nat. Defense Univ. 109 pp.

Neumann, A. D., Moore, W. S. 1975. Sea level events and Pleistocene coral ages in the northern Bahamas. Quat. Res. 5:215-24.

Newell, R. E., Dopplick, T. G. 1979. Questions concerning the possible influence of anthropogenic CO_2 on atmospheric temperature. J. Appl. Meteor. 18:822-5.

Niethaus, F. 1976. A non-linear eight level tandem model to calculate the future CO_2 and C-14 burden to the atmosphere. IIASA Rep. RM-76-35, Int. Inst. Appl. Syst. Anal., Laxenburg, Austria.

Nordhaus, W. D. 1977. Economic growth and climate: The carbon dioxide problem. AM. Econ. Rev. 67:341-46.

Panel on the Public Policy Implications of Earthquake Prediction. 1975. Earthquake Prediction and Public Policy. Wash. D.C.: Nat. Acad. Sci. 142 pp.

Pearman, G. I. 1977. Further studies of the comparability of baseline atmospheric carbon dioxide measurements. Tellus 29: 171-80.

Pearson, C., Pryor, A. 1977. Environment: North and South — An Economic Interpretation. New York: Wiley 355 pp.

Perry, A. M. Fulkerson, W. 1982. Energy supply and demand implications of CO_2. Presented at the AAAS Meeting, Washington D.C.

Ramanathan, V., Lian, M. S., Cess, R. D. 1979. Increased atmospheric CO_2: Zonal and seasonal estimates of the effect on the radiation energy balance and surface temperature. J. Geophys. Res. 84:4949-58.

Rasmussen, R. A., Khalil, M. A. K. 1981. Increase in the concentration of atmospheric methane. Atmos. Environ. 15:883-6.

Risk/Impact Panel. 1980. Report of the Risk/Impact Panel of the U.S. NRC Comm. on Nuclear and Alternative Energy Systems. Risks and Impacts of Alternative Energy Systems. Wash. D.C.: Nat. Acad. Sci. In Press.

Robin, G. de Q. 1975. Ice shelves and ice flow. Nature 253:168-72.

Rust, B. W., Rotty, R. M., Marland, G. 1979. Inferences drawn from atmospheric CO_2 data. J. Geophys. Res. 84:3115-22.

Schneider, S. H. 1975. On the carbon dioxide-climate confusion. J. Atmos. Sci. 32-2060-66.

Schneider, S. H., Temkin, R. L. 1977. In Climatic Change, ed. J. Gribbin, pp. 228-46. Oxford: Cambridge Univ. Press.

Schneider, S. H., Washington, W. M., Chervin, R. M. 1978. Cloudiness as a climatic feedback mechanism: Effects on cloud amounts of prescribed global and regional surface temperature changes in the NCAR GCM. J. Atmos Sci. 35:2207-21.

Schneider, S. H., Thompson, S. L. 1979. Carbon dioxide and climate change: Importance of the transient response. J. Geophys. Res. Submitted for publication.

Schneider, S. H., with L. E. Mesirow, 1976. The Genesis Strategy: Climate and Global Survival. New York: Plenum. 419 pp.

Schneider, S. H. 1979. Comparative Risk Assessment of Energy Systems. Energy — the International Journal 4:919-31.

Schneider, S. H. Chen, R. S. 1980. Carbon dioxide warming and coastline flooding: Physical factors and climate impact. Ann. Rev. Energy. 5:107-40.

Schneider, S. H., Morton, L. 1981. The Primordial Bond: Exploring Connections Between Man and Nature Through the Humanities and the Sciences. New York: Lleunum. In Press.

Seiler, W., Crutzen, P. J. 1980. Estimates of gross and net fluxes of carbon between the biosphere and the atmosphere from biomass burning. Climatic Change. 2:207-47.

Siegenthaler, U., Oeschger, H. 1978. Predicting future atmospheric carbon dioxide levels. Science. 199:388-95.

Smil, V., Miltin, D. 1974. Carbon dioxide — alternative futures. Atmos. Envir. 8:1213-23.

Stuiver, M. 1978. Atmospheric carbon dioxide and carbon reservoir changes. Science 199:253-58.

Study of Man's Impact on Climate (SMIC). 1971. Inadvertent Climate Modification: Report of the Study of Man's Impact on Climate. Cambridge, Mass.: MIT Press 308 pp.

Sugden, D. E., Clapperton, C. M. 1980. West Antarctic ice sheet fluctuations in the Antarctic peninsula area. Nature. 286-378-81.

Sunquist, E. T., Miller, G. A. 1980. Oil shales and carbon dioxide. Science. 208:740-1.

Suomi, V. E., Chairman Climate Research Board, NRC. 1980. A strategy for the National Climate Program. National Academy of Sciences.

Takahashi, I., Yoshino, M. M. 1978. Climate Change and Food Production. Tokyo: Univ. Tokyo Press. 433 pp.

Thomas, R. H., Sanderson, T. J. O., Rose, R. E. 1979. Effect of climatic warming on the West Antarctic ice sheet. Nature 277:355-58.

Thomas, R. 1979. Ice sheets and ice shelves. Rev. Geophys. Space Phys. 17:1257-58, 1273-76.

Thomas, R. H. 1979. West Antarctic ice sheet: Present day thinning and holocene retreat of the margins. Science. 205:1257-58.

Thomas R. H. 1976. Thickening of the Ross Ice Shelf and equilibrium state of the West Antarctic ice sheet. Nature 259-180-83.

Thompson, S. L., Schneider, S. H. 1979. A seasonal zonal energy balance climate model with an interactive lower layer. J. Geophys. Res. 84:24-01-14.

U. S. Comm. for Global Atmos. Res. Program. 1975. Understanding Climatic Change: A Program for Action. Wash. D.C.: Nat. Acad. Sci. 239 pp.

Weertman, J. 1976. Glaciology's grand unsolved problem. Nature 260:284-86.

Weertman, J. 1974. Stability of the junction of an ice sheet and an ice shelf. J. Glaciol 13:3-11.

Williams, J. ed. 1978. Carbon Dioxide, Climate and Society. New York: Pergamon. 332 pp.

Wilson, A. T. 1969. The climatic effects of large-scale surges of ice sheets. Can J. Earth Sci. 6:911-18.

Wang, W. C., Yung, Y. L., Lacis, A. A., Mo, T., Hansen, J. E. 1976. Greenhouse effects due to man-made perturbations of trace gases. Science. 194:685-90.

Wittwer, S. H. 1980. Carbon dioxide and climate change: an agricultural perspective. J. Soil and Water Conserv. 35:116-120.

Wong, C. S. 1978. Carbon dioxide — A global environmental problem in the future. Marine Pollution Bulletin. 9:257-64.

Woodwell, G. M., Whittaker, R. H., Reiners, W. A., Likens, G. E., Delwiche, C. C., Botkin, D. B. 1978. The biota and the world carbon budget. Science 199:141-46.

Woodwell, G. M. 1978. The carbon dioxide question. Scientific American. 238:34-43.

CHAPTER THREE

Coming to Grips with the Impacts
1982—1989

Throughout the 1980's, the oil industry refined their predictions for the effects of climate change into specific, and alarming, impacts. As the impacts came into sharper focus, the companies began to seriously weigh their options for how to move forward.

Document 11, a 1982 memo from Exxon scientist Roger Cohen, reviews the company's research and affirms that their results "are in accord with scientific consensus on the effect of increased atmospheric CO_2 on climate." Cohen then notes the "unanimous agreement in the scientific community" that a temperature increase of 1.5°C-4.5°C "would bring about significant changes in the earth's climate." The memo also includes a plea for Exxon to publish its own results, as "to do otherwise would be a breach of Exxon's public position and ethical credo on honesty and integrity."

In 1982, Exxon Research and Engineering Company President E.E. David Jr. spoke to the Fourth Annual Ewing Symposium. In his remarks, **Document 12**, David discussed the scientific consensus on global warming and recommends market solutions to the issues. Notably, he states that "Few people doubt that the world has entered an energy transition away from dependence upon fossil fuels and towards some mix of renewable resources that will not pose problems of CO_2 accumulation." He goes on, "It is ironic that the biggest uncertainties about the CO_2 buildup are not in predicting what the climate will do, but in predicting what people will do. [It] appears we still have time to generate the wealth and knowledge we will need to invent the transition to a stable energy system."

"...the biggest uncertainties about the CO_2 buildup are not in predicting what the climate will do, but in predicting what people will do."

E.E. David, President, Exxon Research and Engineering, 1982

The industry was growing increasingly aware that their role in producing and marketing a product leading to global calamity could be problematic. A 1983 internal Mobil newsletter, **Document 13**, illustrates this growing concern. The newsletter begins with a brief summary of the science underlying climate change but moves on to articulate clearly the worry that "if the greenhouse effect should become an urgent national concern, restrictions on fossil fuel and land use might be established." It also notes that some scientists believe action should be taken very soon, given the long lead times that would be required for any sort of corrective action.

Other companies were concerned as well. In 1988, Shell produced a confidential internal report called simply: *The Greenhouse Effect*, **Document 14**. Summarizing the company's work over the previous years, the report is unnerving in its assessment of climate risks. The report notes that "...changes could be larger than any other that have occurred over the last 12,000 years. Such relatively fast and dramatic changes would impact on the human environment, future living standards and food supplies, and could have major social, economic and political consequences." The report also warns, "by the time the global warming becomes detectable it could be too late to take effective countermeasures to reduce the effects or even to stabilize the situation."

Armed with a greater understanding of the impacts of climate change, oil companies took further actions to protect their own holdings. In 1989, a New York Times article, **Document 15**, covered Shell's decision to increase the height of an oil rig, at increased expense, and linked the decision to predictions of risings seas due to climate change.

The mid-1980's saw the oil industry grappling with looming climate impacts and evaluating potential paths forward. Internally, they built protections for their own assets and considered pivots to renewables, but by the end of the decade that they would decide instead to create the world's most effective climate denial and disinformation machine.

1982 memo from Cohen summarizing internal climate modeling and the CO_2 greenhouse effect

0757-L-RWC

EXXON RESEARCH AND ENGINEERING COMPANY

CORPORATE RESEARCH
SCIENCE LABORATORIES

P. O. Box 45, Linden, N. J. 07036

DUANE G. LEVINE, Director

ROGER W.COHEN, Director
Theoretical and Mathematical Sciences Laboratory

September 2, 1982

H. N. WEINBERG
SEP 2 1982

Mr. A. M. Natkin
Office of Science and Technology
Exxon Corporation
1251 Avenue of the Americas
New York, New York 10020

Dear Al:

I would like to summarize the findings of our research in climate modeling and place our results in the context of the existing body of knowledge of the CO_2 greenhouse effect.

Although the increase of atmospheric CO_2 is well documented, it has not yet resulted in a measurable change in the earth's climate. The concerns surrounding the possible effects of increased CO_2 have been based on the predictions of models which simulate the earth's climate. These models vary widely in the level of detail in which climate processes are treated and in the approximations used to describe the complexities of these processes. Consequently the quantitative predictions derived from the various models show considerable variation. However, over the past several years a clear scientific consensus has emerged regarding the expected climatic effects of increased atmospheric CO_2. The consensus[+] is that a doubling of atmospheric CO_2 from its pre-industrial revolution value would result in an average global temperature rise of $(3.0 \pm 1.5)^{\circ}C$. The uncertainty in this figure is a result of the inability of even the most elaborate models to simulate climate in a totally realistic manner. The temperature rise is predicted to be distributed nonuniformly over the earth, with above-average temperature elevations in the polar regions and relatively small increases near the equator. There is unanimous agreement in the scientific community that a temperature increase of this magnitude would bring about significant changes in the earth's climate, including rainfall distribution and alterations in the biosphere. The time

+National Research Council Panel Report, Carbon Dioxide and Climate: A Second Assessment, National Academy Press, Washington, D.C., 1982.

required for doubling of atmospheric CO_2 depends on future world consumption of fossil fuels. Current projections indicate that doubling will occur sometime in the latter half of the 21st century. The models predict that CO_2-induced climate changes should be observable well before doubling. It is generally believed that the first unambiguous CO_2-induced temperature increase will not be observable until around the year 2000.

It should be emphasized that the consensus prediction of global warming is not unanimous. Several scientists have taken positions that openly question the validity of the predictions of the models, and a few have proposed mechanisms which could mitigate a CO_2 warming. One of the most serious of these proposals has been made by Professor Reginald Newell of MIT. Newell noted that geological evidence points to a relative constancy of the temperature of the equatorial waters over hundreds of millions of years. This constancy is remarkable in view of major climatic changes in other regions of the earth during this period. Newell ascribed this anchoring of the temperature of the equatorial waters to an evaporative buffering mechanism. In this mechanism, when heating increases at the equator, most of the extra energy induces greater rates of evaporation rather than raising temperatures. Newell proposed that this effect might greatly reduce the global warming effect of increased atmospheric CO_2.

In our climate research we have explored the global effects of Newell's evaporative buffering mechanism using a simple mathematical climate model. Our findings indicate that Newell's effect is indeed an important factor in the earth's climate system. As Newell predicted, evaporative buffering does limit CO_2-induced temperature changes in the equatorial regions. However, we find a compensatingly larger temperature increase in the polar regions, giving a global averaged temperature increase that falls well within the range of the scientific consensus. Our results are consistent with the published predictions of more complex climate models. They are also in agreement with estimates of the global temperature distribution during a certain prehistoric period when the earth was much warmer than today.

In summary, the results of our research are in accord with the scientific consensus on the effect of increased atmospheric CO_2 on climate. Our research appears to reconcile Newell's observations and proposed mechanism with the consensus opinion.

We are now ready to present our research to the scientific community through the usual mechanisms of conference presentations and publications in appropriate journals. I have enclosed a detailed plan for presenting our results.

As we discussed in the August 24 meeting, there is the potential for our research to attract the attention of the popular news media because of the connection between Exxon's major business and the role of fossil fuel combustion in contributing to the increase of atmospheric CO_2. Despite the fact that our results are in accord with those of most researchers in the field and are subject to the same uncertainties, it was recognized that it is possible for these results to be distorted or blown out of proportion. Nevertheless the consensus position was that Exxon should continue to conduct scientific research in this area because of its potential importance in affecting future energy scenarios and to provide Exxon with the credentials required to speak with authority in this area. Furthermore our ethical responsibility is to permit the publication of our research in the scientific literature; indeed to do otherwise would be a breach of Exxon's public position and ethical credo on honesty and integrity.

Sincerely yours,

ROGER W. COHEN

RWC:tmc

Enclosure

cc: A. J. Callegari
E. E. David, Jr.
B. P. Flannery
M. B. Glaser
D. G. Levine
P. J. Lucchesi
H. N. Weinberg

CO_2 Climate Modeling Research: Timetable for Presentations and Publications

I. Presentations

(1) DOE Sponsored CO_2-CLimate Meeting
September 19-23, 1982 (West Virginia)

(a) Results pertaining to general aspects of the model to be presented in an informal session by our collaborator Professor M. I. Hoffert of NYU. The CO_2 calculations will not be included.

(b) Preprints of the paper [#(1) below] to be distributed at this meeting to general peer comments and discussion.*

(2) Ewing Symposium (Lamont-Doherty/Exxon Foundation Supported)
October 25-27, 1982

(a) Results concerning general aspects of the model and the CO_2 calculations to be presented by B. P. Flannery (CR).

II. Publications

(1) Manuscript developing general aspects of the model to be submitted for publication to the Journal of Geophysical Research, September, 1982.*

(2) Manuscript on CO_2 related model predictions to be submitted in late 1982.

---

* Provided formal publication clearance has been granted by this time.

1982 E.E. David, President, Exxon Research and Engineering,
Inventing the Future: Energy and the CO_2
Greenhouse Effect

INVENTING THE FUTURE: ENERGY AND THE CO_2 "GREENHOUSE" EFFECT

E. E. David Jr.

President, Exxon Research and Engineering Company
Remarks at the Fourth Annual Ewing Symposium, Tenafly, NJ

Dennis Gabor, A winner of the Nobel Prize for Physics, once remarked that man cannot predict the future, but he can invent it. The point is that while we do not know with certainty how things will turn out, our own actions can play a powerful role in shaping the future. Naturally, Gabor had in mind the power of science and technology, and the model includes that of correction or feedback.

It is an important: Man does not have the gift of prophecy. Any manager or government planner would err seriously by masterminding a plan based unalterably on some vision of the future, without provision for mid-course correction. It is also a comforting thought. With man's notorious inability to create reliable predictions about such matters as elections, stock markets, energy supply and demand, and, of course, the weather, it is a great consolation to feel that we can still retain some control of the future.

As you may know, Exxon is a hundred years old this year; we have a long corporate memory of the very profound social and economic transformations that our business activities have helped bring about, and of how we and society have had to adapt further in response. That includes the at least temporary respite given to the whales through substituting kerosene lighting fuel for their rendered blubber; as well as the revolutionary changes wrought by the automobile and other machinery powered by liquid hydrocarbon fuels. The primary factors guiding such developments were technology and economic markets, though political systems also played their role.

But faith in technologies, markets, and correcting feedback mechanisms is less than satisfying for a situation such as the one you are studying at this year's Ewing Symposium. The critical problem is that the environmental impacts of the CO_2 buildup may be so long delayed. A look at the theory of feedback systems shows that where there is such a long delay the system breaks down unless there is anticipation built into the loop. The question then becomes how to anticipate the future sufficiently far in advance to prepare for it.

One answer is to invent the future in another way--through a system of contingency planning based on an assessment of a number of futures. As Harvey Brooks has noted, scenarios have limited use if they are merely surprise free projections of current trends; instead, they must somehow take into account those clouds on the horizon no bigger than a man's hand that can turn out to be dominant influences in twenty years. Inadequate scenario-making explains the poor performance of most social research to date--which so often gives the sense of too little too late, whether the topic is toxic waste, frost belt and sun belt, or the shift from manufacturing to information society. The key is to undertake research that will tend to be independent of future events, or, rather, relevant across a broad spectrum of scenarios.

This is not easy to do, but some of Exxon's own research and development strategy is aimed in that direction. And Exxon is not the only company with this attitude. That is why we and others in the petroleum industry have taken a strong interest in the issue of the greenhouse effect and your work. It is why we have participated in several initiatives to promote your research; it is why we are pleased to contribute to the holding of this symposium and to participate in it. And it is why we have begun our own modest research effort in the field, motivated also by the belief that perhaps the only way to understand a field is to do research in it. You have seen some of the results in a paper delivered yesterday afternoon. We are also in the process of evaluating the data on CO_2 concentrations collected over two years by an Exxon tanker plying between the Gulf of Mexico and the Gulf of Arabia.

Organization

Few people doubt that the world has entered an energy transition away from dependence upon fossil fuels and toward some mix of renewable resources that will not pose problems of CO_2 accumulation. The question is how do we get from here to there while preserving the health of our political, economic and environmental support systems. What I will do in the remainder of this talk is indicate how the world may invent a successful energy future, using the sort of corrective feedback system I have described. My perspective is of course an Exxon perspective, reflecting our own assumptions about the economic and social paths societies will prefer. And since fossil fuels, and liquid chemical fuels, are really the heart of the energy and the CO_2 problem, I will focus on those.

My plan of attack is, first, to consider the implications of recent energy developments. Then I will describe some of the key assumptions that are guiding Exxon's own R&D planning and which, I think, we have in common with many other actors in the scene. Finally, I will go on to mention some of the technical possibilities that may present themselves well beyond our usual twenty-year outlook period, that is, fifty years or more into the future.

While I am far from certain about the details, I think you'll find that I'm generally upbeat about the chances of coming through this most adventurous of all human experiments with the ecosystem.

Recent Energy History

It is ironic that the biggest uncertainties about the CO_2 buildup are not in predicting what the climate will do, but in predicting what people will do. The scientific community is apparently reaching some consensus about the general mechanisms of the greenhouse effect. It is considerably less agreed on how much fossil fuels mankind will burn; how fast economies will grow; what energy technologies societies will foster and when; and so how fast the buildup will occur.

But we do know about the recent past and the present. In the aftermath of the energy price increase of the past decade, consumers have reacted to the price feedback mechanism very much as classic economic theory would predict. They have sharply reduced their energy consumption and, in particular, their consumption of oil. They have substituted other fuels like coal and nuclear for petroleum, although more coal use does increase CO_2 emissions. Consumers have also conserved by turning to more energy efficient technologies, including smaller cars in the U.S. And they have done without.

It is difficult to disentangle the effects of conservation from the effects of recession. According to a recent report from the International Energy Agency, they are about equal. We think conservation effects are larger, but regardless, energy consumers have certainly broken the lockstep relationship between economic activity and energy consumption that seemed to prevail for a quarter century following World War II. For example, according to the International Energy Agency, it now takes 16 percent less energy and 26 percent less oil to produce 1 percent more of output in the non-communist industrialized countries than in 1973.

This development carries great significance for the CO_2 buildup. Consumers and technologists have been inventing and applying a wealth of methods to extract more work from less energy. For example, as one of our own biggest energy customers, we at Exxon have stepped up the efficiency of our refineries by twenty percent since 1973. Because refining is so energy-intensive, the energy savings, and the corresponding reductions of CO_2 emissions, have been very large indeed. Last year the savings amounted to the equivalent of some 28 million barrels of oil--equal to the production from a world-scale, 50,000-barrel-per-day synthetic fuels plant. On top of that, we have set the goal of doubling our refining efficiency by the year 2000, and we think the goal is realistic.

How far will the conservation trend go? It is too early to say for sure, but we think the implications apply very far into the future. And how far will the energy mix tend to favor fuels, such as coal, that produce large amounts of CO_2, rather than fuels with high ratios of hydrogen to carbon, such as gasoline and methane? To some extent the answer to that question depends upon our ability to come up with a source of low cost hydrogen based on non-fossil energy--a point I'll return to later.

Fossil Fuel Outlook: Key Assumptions

In assessing alternative futures, I would offer three assumptions in the form of predictions about the use of energy and fossil fuels.

First, nearly all societies will continue to give primacy to economic growth. The human desire to improve material conditions burns as bright as ever, if not brighter. As we have seen most recently in Poland, governments that fail to deliver at least a convincing promise of growth suffer dire consequences as a rule. With the overall world population expected to double over the next 50 years, economies and energy use will have to grow at a good clip just to hold per capita incomes even. Naturally, the pressures for growth will be greatest in the developing world, where populations are growing fastest.

A second assumption, one that follows from the first, is that in pursuit of growth most societies will prefer least-cost energy alternatives. I say this with the recognition that at least a few developing countries will prefer options that utilize local resources in order to conserve foreign exchange or use local labor, no matter what the cost. An example is Brazil's resort to alcohol fuels extracted from its sugar cane. However, such exceptions will not materially alter the world future.

The third assumption is that societies will continue to prefer the efficiencies of fossil-based liquid fuels in transportation uses. Because conventional petroleum resources will not suffice to meet the demand, a major industry will begin to grow around the turn of the century to produce synthetic fuels from oil sands, oil shale, and coal.

Despite the trend toward electricity, the electric vehicle will have trouble making significant inroads in transportation markets over the next twenty years. One problem is storage, which is partly a problem of energy density. Today's lead-acid batteries store about 1/300th the energy of a like weight of gasoline. We can improve on that; in fact, Exxon is in the middle of developing a zinc-bromine battery with two to three times the capacity of conventional lead-acid batteries. Another problem is the cost of batteries. They are expensive, mainly because of the cost of raw materials and typically short life cycles. Incidentally, we expect that load leveling, rather than the electric car, will be one of the earliest applications of our new battery. However, we would certainly not rule out the electric car one day--perhaps initially in the form of hybrid vehicles powered by batteries in tandem with small gasoline or diesel engines.

Another alternative features electric guideway systems in which vehicles use batteries on the feeder roads and electrically induced power along the main arteries. But the capital costs of such a system would be immense--making it a viable option only for much richer societies than we can foresee.

Granted, liquid fuels-like all chemical fuels-have their share of problems. In burning they may synthesize some unfriendly substances--such as PNA's, NO_x, SO_x and CO_2. Still, there are also well-known problems with producing electricity through non-chemical means, such as nuclear power. Solar voltaics overcome many of these drawbacks, but the inherent problems of the duty cycle and storage make me skeptical that solar voltaics will penetrate a large fraction of the electricity market in the near future, except in remote applications.

But to reiterate my main theme, such assumptions only act as a guide in determining where R&D managers can most usefully concentrate resources for inventing the future, subject to correction and further feedback. In any case we are not up against fatal, malthusian limits to growth. On the distant horizon, we may discern a peaking of petroleum production; because for more than a decade the world has been consuming pertroleum faster than the industry has been replacing it. But remaining non-petroleum fossil fuel resources are immense. As an example, in 1980 oil and gas production accounted for nearly 70 percent of the world's production of fossil energy. But oil and gas reserves account for only a little over 11 percent of the world's estimated total recoverable fossil energy resources.

As a practical matter, you would surely agree that the world economy is committed to using fossil resources for some time to come. The massiveness of the energy system in place simply forbids immediate displacement of one fuel or energy source by another. Historical market studies going back to wood and coal confirm this idea, suggesting that a new energy source requires about 50 years to achieve just half the total energy market.

What are Exxon's projections for fossil fuel use? Over the twenty years encompassed by our normal outlook we estimate the fossil fuel use will grow at the equivalent of about two percent per year. Much of this growth will occur in the developing countries, as they modernize their economies.

Beyond our normal twenty-year outlook period, we recently attempted a forecast of the CO_2 build-up. We assumed different growth rates at different times, but with an average growth rate in fossil fuel use of about one percent a year starting today, our estimate is that the doubling of atmospheric CO_2 levels might occur sometime late in the 21th century. That includes the impacts of synfuels industry. Assuming the greenhouse effect occurs, rising CO_2 concentrations might begin to induce climatic changes around the middle of the 21th century.

Manufacturing synthetic fuels will produce more CO_2 than conventional petroleum fuels, but the impact of substituting synthetics for depleting petroleum supplies will be relatively small. If, in our estimate, we back out synfuels and replace them with conventional petroleum fuels, the difference in CO_2 emissions would only add about five years to the doubling time. This is a highly conservative estimate, because it assumes that industry in the 21st century will continue using today's "Dinosaur" technologies for manufacturing synfuels, with no increase in the efficiency of these highly energy-intensive processes. And it takes no notice of the trends we are already seeing today in this budding information age. As John Pierce, the inventor of satellite communcations, likes to say, soon we may be traveling for pleasure but communicating to work. Such developments could eventually go very far in reducing the energy intensity and CO_2 emissions of advanced economies.

Exxon's Response in Science and Technology

The real point of these extrapolations is to get an understanding of how soon the problem may become serious enough to require action. And the lesson is that, while the issue is clearly important, we can still afford further research on the problem. And the world will have time to accumulate the material and scientific resources required to contend with the problem.

The same point is emphasized in the energy study published last year by the International Institute for Applied System Analysis, or IIASA. The study involved some 150 top scientists at one time or another and represents one of the most comprehensive assessments of the outlook for the next 50 critical years of what may well be in absolute terms the world's period of greatest population growth.

The IIASA study concludes that to make a successful transition from fossil fuels to an energy system based on renewable resources, the world economy must expand its productive powers. It must expand in all dimensions, but, most importantly, in the new knowledge and human skill that enlarge the technological base. For such knowledge and skill more than brute capital, is what enables societies in this age to use the same or even fewer resources to produce more.

The IIASA strategy for inventing that future resembles the one I have suggested: a strategy first, of gradual transition from clean, high quality resources--natural gas and oil--to dirtier unconventional fossil resources. The study also takes note of the CO_2 issue, recommending that society incorporate sufficient non-fossil options in the energy supply system so as to allow expansion of that base, if necessary, as the effects of carbon dioxide become better quantifiable through further research.

That means pursuing research leads in technologies that may not seem attractive by the fashionable standards of financial analysis. In a recent landmark article, Professors Hayes and Abernathy of the Harvard Business School warn strongly against such financially biased practices in American Industry; trying to outguess the economics of untried and untested technological approaches can be the death of an industry, and I might add, of a society, too. Some of the tools of this trade--for example, discounted cash flow analysis--are completely unrealistic. Sometimes they are called the Astrophysics of a non-existent universe.

As I have already suggested, Exxon's own R&D philosophy dictates searching for a diversified mix of short- and long-range technological options. I have already alluded to our efforts to boost the energy efficiency of our refineries--a highly immediate and apparent need to management. This need is apparent even though our R&D in some areas may not pay out for years--for example, in advanced separation systems that do not employ normal heat distillation techniques. Another of our major thrusts is in developing more versatile technologies for converting crude residuums to light transportation fuels. The need stems from an evident shift of demand in that direction and from the reduced quality of the average crude oil today. Exxon has begun deployment of an innovation in this area called FLEXICOKING, a processing "garbage can" that can convert virtually any heavy crude or residuum into transportation fuels and fuel gas.

As industry moves down to lower quality resources, there is synergism between such "resid" conversion technologies and our efforts to develop improved synthetics technologies. With the exception of established synthetics operations in South Africa and Canada, falling crude prices and escalating project costs have nipped the synthetic fuels industry in the bud. Many synthetics technologies have turned out to be far more expensive than anyone thought. So price feedback has told us that we must use R&D to bring capital and operating costs down through developing synthetics technologies adaptable to local conditions, resources, and markets. In the process, as I suggested earlier, we will certainly succeed in increasing their efficiency and so reducing CO_2 emissions. In the crucial conversion step, many of today's synthetics technologies operate at efficiences in the range of 60 percent. By the year 2000 we see possibilities for stepping up those efficiencies to nearly 80 percent. And this is not a fundamental limit.

Exxon is working on a very wide variety of synthetics options, including advanced shale retorting and direct coal liquefaction; a catalytic process for producing methane directly from coal; the generation of CO and Hydrogen, or synthesis gas, from coal, lignite, or remotely located natural gas; and the conversion of synthesis gas to fuels and chemicals. On the non-fossil fuel side, Exxon has for many years been doing R&D aimed at improving the fabrication of nuclear fuel elements; and we have been one of several companies in the race to produce cheaper solar voltaic cells made from amorphous silicon.

These efforts suggest primarily the early stages of the transition. For the later stages, some interesting options are beginning to present themselves. A prime difficulty with synthetics resources is their high carbon content. Chemically, that means low ratio of hydrogen to carbon. While the ratio is about four to one in natural gas and 1.8 in crude oil, it is only about 1.5 in oil sands bitumen or raw shale oil, and less than one in coal. In simple terms, a result is that producing these fuels means generating larger amounts of CO_2 than to produce comparable fuels from petroleum. Synfuels require more processing to manufacture and hence more processing heat generated by burning part of the resource.

Prompted by concerns about CO_2 emissions, among other things, some people have suggested a hydrogen economy, a fuel cycle based on hydrogen generated from water not using heat generated by fossil fuels. Perhaps there are ways to generate cheap hydrogen which could then feed directly into a synthetics process. One possible method would be to use thermochemical processes to split water, with advanced solar collectors or nuclear reactors supplying the process heat. The IIASA study notes that in manufacturing coal synthetics such a scheme would cut CO_2 emissions by one-fourth to one-third, compared to the usual coal conversion technologies envisioned. If they could generate hydrogen cheaply, such technologies would also cut overall costs sharply. For example, in the Exxon donor solvent coal liquefaction process, hydrogen accounts for well over a third of the total cost of producing coal liquids.

Summary and Conclusion

To sum up, the world's best hope for inventing an acceptable energy transition is one that favors multiple technical approaches subject to correction--feedback from markets, societies, and politics, and scientific feedback about external costs to health and the environment. This approach is not easy, or comforting to the uninitiated, because there is no overall neat and understandable plan. But prophecies leading to masterminded solutions that commit a society unalterably to a single course are likely to be dangerous and futile. A good sign is that, without any central plan, the world economy has already adopted conservation technologies that are reducing the rate of CO_2 buildup.

In shaping strategies for energy research and development, we must recognize that, generally, societies will give primacy to economic growth, to least-cost energy alternatives, and, in most transportation uses, to liquid fuels. Fortunately, these conditions give science and engineering a lot of room to maneuver. It appears we still have time to generate the wealth and knowledge we will need to invent the transition to a stable energy system.

I hope I do not appear too sanguine about the collective wisdom of our species. History bears ample testimony to the human capacity for grievous folly, as well as achievement and excellence. Clearly, there is vast opportunity for conflict. For example, it is more than a little disconcerting the the few maps showing the likely effects of global warming seem to reveal the two superpowers losing much of the rainfall, with the rest of the world seemingly benefitting. An acceptable future may require a degree of international cooperation that has eluded our grasp to date. An exception is of course science itself and in particular climatology, which even by the standards of science has been distinguished by a remarkable degree of interdisciplinary and international cooperation. As the world continues to grapple with the profound issues posed by the CO_2 buildup, it could seek few better models of international cooperation than what have already achieved.

1983 Mobil newsletter,

Is Burning of Fossil Fuels Affecting World Climate?

Mobil

Status Report
Environmental & Toxicology Issues

NUMBER 83-2

DATE 6/1/83

PUBLISHED BY
MOBIL OIL CORPORATION
ENVIRONMENTAL AFFAIRS AND TOXICOLOGY DEPARTMENT

ATMOSPHERIC GREENHOUSE EFFECT: IS BURNING OF FOSSIL FUELS AFFECTING WORLD CLIMATE?

INTRODUCTION

In theory, increasing levels of carbon dioxide produced by burning fossil fuels could alter the world's climate by raising the earth's temperature. This warming might occur because carbon dioxide in the air acts like glass in a greenhouse--trapping the sun's heat at the earth's surface--heat that would normally escape back into space.

The "greenhouse" effect is an emerging environmental issue characterized by considerable scientific uncertainty. But, some scientists argue that plans to cope with the greenhouse effect need to be made soon, because of the extremely long lead time for any conceivable corrective actions. Such plans could affect the energy industry by dictating what fuels could be marketed.

This report summarizes the background and status of the greenhouse effect, indicating possible impacts on Mobil operations.

DISCUSSION

Plants consume carbon dioxide during growth, and release it back to the atmosphere when they decay. There is a relationship between carbon dioxide in the air and carbonate salts in the oceans. Before 1850, man had little influence on the carbon dioxide cycle. There appears to have been a balance between carbon dioxide in the air and carbon compounds in the land and seas.

However, since the industrial revolution human activities, such as fossil fuel combustion and forest clearing, may have altered the carbon cycle. The net effect of these activities could add carbon dioxide to the atmosphere more rapidly than it can be removed by oceans and plants. Since 1850, carbon dioxide in the air has increased about 18 percent--reaching a level today of 335 parts-per-million. The most reliable atmospheric carbon dioxide monitoring programs-- established in 1957--show an 8 percent increase in just the past 25 years. Based on future world energy demand, many scientists believe that carbon dioxide levels could double within the next century.

The effects of such an increase are controversial. For example, using global climate theories, some scientists predict that a two-fold increase in atmospheric carbon dioxide could warm the earth's surface from 3° to 6°F. Temperature increases of 12°-18°F are predicted at the poles. If these estimates are correct, melting of the arctic ice packs could occur, and sea levels could rise 15 to 20 feet, inundating many of the world's coastal cities.

This large temperature change could bring on drought which might drop crop yield in the major grain growing areas of the northern hemisphere. On the other hand, the change in climate in equatorial and northern countries, where growing conditions are presently poor, could improve agricultural productivity. If these projections are accurate, Third World countries would have little incentive to control carbon dioxide emissions by restraints on fossil fuel consumption.

The scenario described offers one view of potential long-range climate impacts of increased carbon dioxide levels. But the climate response predicted by theory cannot yet be detected. Moreover, there are other plausible forecasts that suggest a completely different effect.

For example, some scientists say that more carbon dioxide will stimulate plant growth--partly offsetting projected warming trends. Still other scientists claim that more carbon dioxide will increase humidity and cloudiness, block incoming sun rays, and moderate the trend toward higher temperatures.

IMPACT ON INDUSTRY AND MOBIL OPERATIONS

The magnitude and timing of carbon dioxide-greenhouse effects could be closely tied to future energy consumption, with particular focus on coal and synfuels.

On an end-use energy equivalent basis, the production and combustion of coal and synfuels releases more carbon dioxide into the atmosphere than does production and combustion of natural gas or oil. Compared to oil, coal contributes about 25% more carbon dioxide, shale syncrude contributes about 25% more, and direct coal synfuel liquids contribute about 70% more. On the other hand, production and combustion of natural gas contributes about 25% less carbon dioxide than oil.

The greenhouse effect will continue to receive attention by government agencies charged with balancing energy and environmental policies. If the greenhouse effect should become an urgent national concern, restrictions on fossil fuel and land use might be established. Such restrictions could require changes in supply and distribution of oil, coal, and gas. Increased forest preservation could also be required.

Some people, perhaps realistically, believe society cannot react in time to prevent major climate changes. However, they suggest that society will adapt to the changes that will occur over a 100 year period.

MOBIL ACTIVITIES

Given the current lack of knowledge, additional research is needed and government programs to study this issue should be supported. Mobil's response should be to follow these research developments. Mobil participates in API sponsored research projects to improve climate models. Corporate Environmental Affairs and Mobil Research and Development Corporation monitor research activities in this area, and Mobil participation in Conservation of Clean Air and Water-Europe keeps us informed of European thinking and approaches to this problem.

1988 confidential Shell report,
The Greenhouse Effect

Report Series HSE 88-001

CONFIDENTIAL

THE GREENHOUSE EFFECT

SHELL INTERNATIONALE PETROLEUM MAATSCHAPPIJ B.V., THE HAGUE

Health, Safety and Environment Division (HSE)

Report Series HSE 88-001

CONFIDENTIAL

THE GREENHOUSE EFFECT

SHELL INTERNATIONALE PETROLEUM MAATSCHAPPIJ B.V., THE HAGUE

Health, Safety and Environment Division (HSE)

CONFIDENTIAL

THE GREENHOUSE EFFECT

Greenhouse effect working group
R.P.W.M. Jacobs HSE/35

M.H. Griffiths PL/15
P.E. Bright PAC/3
J.B. Homer SCCU
J.A.C.M. van Oudenhoven MFPA/435
J. Waller MFPA/435

Shell Internationale Petroleum Maatschappij B.V.
Health, Safety and Environment Division
Environmental Affairs
The Hague

April 1986 (completion of the study)
May 1988 (date of issue in this format)

Prepared for SECC
(Shell Environmental Conservation Committee)

SUMMARY

Man-made carbon dioxide, released into and accumulated in the atmosphere, is believed to warm the earth through the so-called greenhouse effect. The gas acts like the transparent walls of a greenhouse and traps heat in the atmosphere that would normally be radiated back into space. Mainly due to fossil fuel burning and deforestation, the atmospheric CO_2 concentration has increased some 15% in the present century to a level of about 340 ppm. If this trend continues, the concentration will be doubled by the third quarter of the next century. The most sophisticated geophysical computer models predict that such a doubling could increase the global mean temperature by 1.3-3.3°C. The release of other (trace) gases, notably chlorofluorocarbons, methane, ozone and nitrous oxide, which have the same effect, may amplify the warming by predicted factors ranging from 1.5 to 3.5°C.

Mathematical models of the earth's climate indicate that if this warming occurs then it could create significant changes in sea level, ocean currents, precipitation patterns, regional temperature and weather. These changes could be larger than any that have occurred over the last 12,000 years. Such relatively fast and dramatic changes would impact on the human environment, future living standards and food supplies, and could have major social, economic and political consequences.

There is reasonable scientific agreement that increased levels of greenhouse gases would cause a global warming. However, there is no consensus about the degree of warming and no very good understanding what the specific effects of warming might be. But as long as man continues to release greenhouse gases into the atmosphere, participation in such a global "experiment" is guaranteed. Many scientists believe that a real increase in the global temperature will be detectable towards the end of this century or early next century. In the meanwhile, greater sophistication both in modelling and monitoring will improve the understanding and likely outcomes. However, by the time the global warming becomes detectable it could be too late to take effective countermeasures to reduce the effects or even to stabilise the situation.

The likely time scale of possible change does not necessitate immediate remedial action. However, the potential impacts are sufficiently serious for research to be directed more to the analysis of policy and energy options than to studies of what we will be facing exactly. Anticipation of climatic change is new, preventing undue change is a challenge which requires international cooperation.

With fossil fuel combustion being the major source of CO_2 in the atmosphere, a forward looking approach by the energy industry is clearly desirable, seeking to play its part with governments and others in the development of appropriate measures to tackle the problem.

CONTENTS

FIGURES

TABLES

APPENDICES

1. INTRODUCTION

The life-supporting systems of the earth (such as light, energy, moisture, and temperature) can be affected by changes in global conditions. Many of such changes are occurring at present, some of them subtle and many of them caused by man. These effects on the life-supporting systems can have a substantial impact on global habitability. The rate at which many of these changes are occurring, especially during the past few decades, has been considerable. A obvious example of this is the rising level of atmospheric carbon dioxide (CO2). This has been described as a long-term global experiment, the outcome of which is very uncertain.

The global rise in atmospheric CO2 is well documented. It is estimated that human activities (e.g. fossil fuel burning, deforestation) have increased the CO2 concentration by about 15% during the past century. More than a century ago it was already hypothesised that an increase in the CO2 concentration of the atmosphere would lead to global warming, i.e. the so-called "greenhouse effect". Several other gases, having similar effects, also appear to be increasing as a result of human activities.

Many scientists believe that the major effect of increasing the CO2 content of the atmosphere will be a gradual warming of the earth's surface. Should average global temperatures rise significantly because of the greenhouse effect and should the earth's climate change, this could have major economic and social consequences. However, not everyone agrees with this view of possible disaster. They point to the demonstrable positive effects of elevated CO2 concentrations, and suggest a benefit to the biosphere without the generation of a climatic catastrophe. Against this backlog of disagreement scientists of both persuasions have searched for the first signs of any effects on a global scale.

It is estimated that any climatic change relatable to CO2 would not be detectable before the end of the century. With the very long time scales involved, it would be tempting for society to wait until then before doing anything. The potential implications for the world are, however, so large that policy options need to be considered much earlier. And the energy industry needs to consider how it should play its part.

In this report the latest (1986) state of knowledge is presented regarding the greenhouse effect to judge any counteractive measures. It describes the considerable research work being carried out world wide; it provides information to improve the understanding and it discusses the implications. For this reason additional information is added on legislation and policies (Appendix 3), relevant international organisations and information centres (Appendix 5) and institutes involved in greenhouse effect research (Appendix 6). Moreover, in addition to the references used, a list of relevant reports and books is added (Appendix 7) to provide the interested reader access to the enormous flow of information relative to the greenhouse effect.

References used in this section: 2, 14, 21, 25, 51, 59.

2. SCIENTIFIC DATA

2.1. Introduction

During the last century the concentration of carbon dioxide increased from an estimated 290 ppm in 1860 to 340 ppm in 1980. Approximately 25% of this increase occurred during the 1970s. Although the concentration of CO2 in the atmosphere is relatively small, it is important in determining the global climate. It permits visible and ultraviolet radiation from the sun to penetrate to the earth's surface, but absorbs some of the infrared energy that is radiated back into space. The atmospheric CO2 emits this energy to both the troposphere and to the earth's surface (see Fig. 1), resulting in a warming of the surface and the atmosphere in the way the glass in a greenhouse does - hence the term greenhouse effect.

The best known and most abundant greenhouse gas is carbon dioxide. However, some trace gases, particularly chlorofluorocarbons (CFC's), ozone, methane, and N2O are at least as important in changing the radiation energy balance of the earth-atmosphere system, as, collectively, they might cause an additional warming equal to 50-100% of the warming due to CO2 alone.

It has been generally accepted that any modification in the radiation energy balance of the atmosphere will affect the global circulation patterns. As a consequence regional climatic changes will then occur, which will be greater than the average global changes. The most promising approach to study the effects of increasing gas concentrations on the atmosphere, is to describe and predict the (future) global climate by complex General Climate Models (GCM's). The main factors and processes used to predict the earth's temperature profiles and climatic changes are presented in this section. The extent and rate of the changes, based on scenarios for energy consumption and emission of CO2 and other trace gases, will be discussed in section 3.

2.2. Data on emissions of greenhouse gases

2.2.1. Carbon dioxide

Although CO2 is emitted to the atmosphere as a consequence of several processes, e.g. oxidation of humic substances and deforestation, the main cause of increasing CO2 concentrations is considered to be fossil fuel burning. Only fossil fuel burning can be fairly accurately quantified.

Since the beginning of the industrial and agricultural revolutions the average annual increase in CO2 production has been 3.5%, with total emissions from mid-nineteenth century to 1981 being 160 GtC (1 GtC=1 gigaton of carbon = 10^{15} g C). In 1860 the annual emission was approximately 0.093 GtC and in 1981 5.3 GtC. Rising fuel prices in the 1970's slackened the CO2 production to yearly increases of 2.2% per year over the period 1973-1980 (see the first part of Fig. 2).

The CO2 emitted into the atmosphere is very quickly globally distributed. This is mainly due to the fact that the emissions are more or less evenly distributed over the continents. Moreover, the mixing time of the atmosphere within a hemisphere is only a few weeks and the interchange between the hemispheres takes 6-12 months. CO2 has a residence time in the atmosphere of 3-4 years, so is reasonably well mixed globally.

World CO_2 emissions based on energy growth rates (see Table 1) show that there has been a slowing in the upwards growth of emissions since 1973. In 1981, of the total emission of 5.3 GtC 44% came from oil, 38% from coal, and 17% from gas.

The production of CO_2 differs considerably from country to country. The largest quantities (based on 1975 figures) are produced in the developed countries with a world average of 1.2 tonnes C per person (see Table 3).

During the last century the concentration of carbon dioxide in the atmosphere increased from an estimated 290 ppm in 1860 (measurements from ice cores) to 340 ppm in 1980. More accurate measurements over the last 25 years at the Mauna Loa Observatory, Hawaii, show an average increase of 1.5% per year (see Fig. 4) with season-dependent fluctuations. Moreover, there is a latitudinal difference between ground-level CO_2 concentrations, reflecting the location of the main fossil fuel CO_2 sources in the northern hemisphere (see Fig. 5). The hypothetical increase of the atmospheric CO_2 concentration based on emissions due to fossil fuel burning, is also given in Fig. 4. It appears that only a proportion of the emission is retained in the atmosphere (i.e. the "airborne fraction", AF). The size of AF depends on how the total carbon inventory is partitioned among the oceanic, terrestrial and atmospheric pools. Over the period 1959-1974 the AF was 56%, whereas it was 59% for the period 1975-1980. It is assumes that this increase of AF might be a caused by a reduction of the absorption capacity of the oceans.

References used in this chapter: 1, 5, 18, 20, 30, 44, 54, 69.

2.2.2. **Other greenhouse gases**

The earth's atmosphere currently contains "trace gases" with atmospheric lifetimes that vary from much less than an hour to several hundred years (see Table 4). From a viewpoint of global climate effects, species with extremely short lifetimes are unlikely to play an important direct role. More persistent trace gases, however, may contribute to modifications of the energy balance of the earth-atmosphere system and amplify the estimated CO_2 warming. Increasing concentrations of these gases are directly or indirectly a consequence of human activities. Most of the man-made trace gases are listed in Table 4; the most important ones are briefly discussed below.

Nitrogen compounds

While a number of nitrogen containing compounds are relevant from a climatic point of view, the most important is N_2O. N_2O emissions result primarily from biological denitrification processes in soil and in the oceans. The global atmospheric concentration of N_2O has risen from an estimated pre-industrial value of 285 ppb to 301 ppb in 1980. Over the 4-year period 1976-1980 the rate of increase in N_2O concentration was 0.2% per year. Increasing future global food production will require increasing use of fertilisers adding further to atmospheric N_2O.

Methane

Principal sources of atmospheric methane are enteric fermentation in ruminant animals, anaerobic decomposition of organic matter (e.g. release from organic-rich sediments below water bodies and rice paddies), biomass decomposition, natural gas leakage, quite possibly production by termites and release of methane during mineral, oil, and gas exploration and gas transmission. The CH_4 concentration has approximately doubled in the last 350 years with a greater rate of increase in the last century. The concentration increased globally by about 0.5% per year between 1965 and 1975 and by 1-2% per year between 1978 and late 1980. In 1980 the concentration was about 1.65 ppm in the northern hemisphere, and about 6% lower in the southern hemisphere.

In the troposphere the CH_4 oxidation chain initiated by the reaction with hydroxyl radical (OH) leads to significant photochemical production of CO, H_2 and O_3:

$$CH_4 + 4O_2 \longrightarrow H_2O + CO + H_2 + 2O_3 \text{ (net cycle)} \qquad (1)$$

The initial reaction of OH with CH_4:

$$CH_4 + OH \longrightarrow CH_3 + H_2O \qquad (2)$$

and the reaction of OH with CO:

$$CO + OH \longrightarrow CO_2 + H \qquad (3)$$

controls the global destruction of OH, the dominant oxidising species in the troposphere. Reaction (2) is such a dominant loss mechanism for CH_4 that more than 90% of the global destruction of CH_4 occurs in the troposphere. So, CH_4 and CO are closely coupled photochemically through OH. The dominant sink of atmospheric CH_4, OH, is thus affected by increased levels of tropospheric CO or of CH_4 itself. Therefore, increasing concentrations of CO due to fossil fuel (incomplete combustion) usage and oxidation of anthropogenic hydrocarbons in the atmosphere , will reduce the rate at which CH_4 is destroyed.

Chlorofluorocarbons

Chlorofluorocarbons (CFC's) are entirely a product of human activity, being present in gas propelled spray cans, refrigeration equipment and insulated packaging materials. These chemicals came into major use in the 1960's and initially exhibited a rapid growth (10-15% per year). The global emissions of the major CFC's then declined somewhat from the mid-1970's through to 1982 in part due to a ban on some nonessential usages (e.g. spray cans) of CFC's and to adverse economic conditions. However, the emissions increased significantly since 1983. Eastern block countries have apparently never reduced their production of CFC's, so world wide use is now rising, and is expected to grow more because of the use in less industrialised countries. When CFC's are released to the atmosphere, their inertness to most biological processes allows them to be transported to the stratosphere, where they are broken down by sunlight. Liberated chlorine catalytically destroys ozone.

Ozone

The climatic effects of changes in ozone ($O3$) depend very strongly on whether these changes occur in the troposphere or stratosphere. There is some observational evidence that northern hemisphere tropospheric ozone has increased by 0.8-1.5% per year since about 1967, due to increases in combustion releases of NOx, CO2, H2 and increased CH4. In the southern hemisphere, given the smaller anthropogenic influences, O3 does not change at all.

Stratospheric ozone is also thought to be susceptible to perturbing influences, including man-made chloro- and chlorofluorocarbons, increasing CH4 and N2O concentrations and decreases in stratospheric temperature due to increasing CO2. The stratospheric ozone changes largely depend on the altitude, but concentrations are now about 12.5% greater at altitudes from 0 to 12 km than assumed pre-industrial concentrations.

A perturbation of the stratospheric ozone concentrations modulates the solar and infrared fluxes to the troposphere, and this solar effect would tend to warm the surface. On the other hand O3 changes in the lower atmosphere pose potential risks to air quality over the surface of the globe.

References used in this section: 33, 35, 39, 41, 43, 46, 47, 49, 61, 64.

2.3. The global carbon cycle

The carbon cycle (Fig. 6) involves numerous biological, geological, physical and chemical processes and can roughly be divided into two main cycles, a biological and a geological one. The geological cycle is a relatively long-term cycle characterised by slow processes, i.e. the release of CO2 through rock weathering and ultimate precipitation as calcium carbonate. Since man started to burn fossil fuel the slow processes have been unbalanced by affecting the major reservoir.

The worldwide use of fossil fuel in 1981 released about 5.3 GtC to the atmosphere as CO2. This figure seems very small compared to those of the amounts of carbon estimated to be present as organic and inorganic compounds in the four major reservoirs in the carbon cycle, i.e. 700 GtC in the atmosphere, 2,600 GtC in the biosphere, 40,000 GtC in the ocean and 65×10^6 GtC in the lithosphere (i.e. the solid part of the earth). However, taking into account a natural and balanced exchange rate of about 100 GtC per year between atmosphere and biosphere and between atmosphere and ocean, fossil fuel burnt yearly represents about 5% of the natural exchange. About 60% of the CO2 originating from burnt lithospheric carbon is retained in the atmosphere; the ocean is the major sink for the rest.

In contrast, the biological cycle is characterised by very rapid processes and is, in essence, very short and therefore extremely significant. Nearly all CO2 carbon that is assimilated (fixed) by the biosphere (i.e. the plants) is ultimately biodegraded by heterotrophic organisms and subsequently returns from the biosphere to the other major carbon reservoirs. The biological cycle is therefore essentially closed. Solar energy keeps the cycle going by providing the energy for the carbon-fixing process, i.e. photosynthesis.

Contrary to the near constancy of the fluxes in the biological cycle, one of the most important reservoirs therein (the land biota, i.e. the living organisms on land, of which the plants represent the major biomass) has been affected since man started releasing carbon dioxide by deforestation and expansion of arable land.

2.3.1 Atmosphere - ocean interactions

The reservoir of the world's oceans represents a volume of about 1.4×10^{18} m^3 water and holds about 40,000 GtC (this is about 57 times the total atmospheric carbon content) or on average 28 g/m^3. The content varies from 22 g/m^3 in cold surface water to 26 g/m^3 in warm surface water and to 29 g/m^3 in the deep-ocean.

The majority of the carbon in the ocean is present as an inorganic fraction, i.e. 39,000 GtC as dissolved inorganic carbon (DIC or C). The DIC is present as dissolved components of the carbon dioxide equilibrium system: CO2, bicarbonate and carbonate.

The remaining carbon is present as an organic fraction, of which only 1.5% is fixed in living organisms, and the rest is dead organic material present as dissolved organic carbon (DOC, about 1000 GtC), and particulate organic carbon (POC, about 30 GtC (see Fig. 6).

The gross exchange of CO2 between atmosphere and ocean is very rapid, characterised by a flux of about 100 GtC per year either way.
This interaction shows the strong regulation of the atmospheric CO2 by the ocean. The natural situation is characterised by a physico-chemical equilibrium. The principal effect of adding CO2 to the atmosphere is the tendency of the ocean to take up the excess in order to reach a new equilibrium with the atmosphere. Although the carbon content of the ocean is much greater than that of the atmosphere, the capacity of the ocean for CO2 uptake is limited (see Appendix 1). The absorption of CO2 by the ocean is buffered by reactions with dissolved carbonate and bicarbonate ions. In the surface mixed layer, the "buffer factor" increases with growing CO2 concentrations (see Fig. 7), and the capacity of the ocean to absorb the CO2 added to the atmosphere will decrease. Hence, the fraction of added CO2 remaining in the atmosphere will rise.

The capacity of the ocean for CO2 uptake is thus a function of its chemistry; the rate at which this capacity can be brought into play is, however, a function of ocean physics. The stratification of low- and mid-latitude oceans is stable and capped by a warm surface layer that is approximately in equilibrium with atmospheric CO2. Most of the deep waters of the world's oceans are formed in winter in the Norwegian and Greenland Seas and in the Weddell Sea. Here winter cooling increases the density of the surface waters until the stratification of the water column breaks down and the deep source regions are renewed. Once formed, the bottom waters flow to the south. The residence time of deep water in the Atlantic Ocean has been estimated as 275 years, in the Pacific Ocean about 600 years and in the Indian Ocean about 335 years. Thus, although the absorptive capability of the ocean is large, it is not rapid due to its slow circulation.

The cycle of organic carbon within the ocean is based on two main processes, i.e. production and decomposition of organic matter. Fixation of CO2 into organic tissues by the photosynthetic activity of phytoplankton occurs only in ocean surface water (the euphotic zone). This is the zone where light energy for photosynthesis and growth is not limited, so that the production of organic material is greater than the breakdown. In the tropics this zone is limited to the upper 100 m of the sea, while in temperate climates it is between 20 and 50 m in summer and zero in winter. In deeper waters, the aphotic zone, there is a net loss of organic material, since breakdown exceeds production.

Organic production and breakdown of organic material can conveniently presented as:

$$CO2 + H2O \underset{\text{breakdown}}{\overset{\text{production}}{\rightleftharpoons}} CH2O + O2 \qquad (4)$$

CO2 in (4) represents the total dissolved inorganic carbon content of the water, and CH2O is organic matter. Oxygen is produced in this process and the removal of CO2 concurrently raises the pH. Although the total biomass of the biota is low relative to that on land (see Fig. 6) and the annual productivity is approximately one half that on land, the turnover (i.e. amount of carbon fixed per biomass unit) is very high. Some 90% of the organic matter formed is consumed by grazing organisms within the euphotic zone. The remainder plus the material excreted by grazing organisms and dead animals fall through the water column and is subject to oxidative decomposition (breakdown), whereby CO2 is released (eqn 4). The majority is decomposed in the upper 1000 m of the water column; dissolution of CaCO3 (i.e. calcium carbonate, the main constituent of shells) occurs in deeper water, stimulated by lowered oxygen concentration and pH due to increasing CO2 levels. The dissolved calcium carbonate raises the total CO2 of the deep water further and increases the alkalinity (see Appendix 1). The majority of the CO2 therefore remains available in the oceanic cycle.

Effects of increasing atmospheric CO2 on the CO2 concentration in the ocean are difficult to measure. The most sensitive measurement to determine this is pCO2 (i.e. the pressure of CO2 gas that would be found in a small volume of air that had been allowed to reach equilibrium with a large volume of seawater). From these measurements it is clear pCO2 in ocean surface water is rising, with a rate comparable to the atmospheric increase. However, as a consequence of the oceanic buffering a 10% change in pCO2 produces only a 1% change in the oceanic CO2 concentration (see Appendix 1 for details). The oceanic CO2 concentration has increased 1-2% over this last century. This increase will not induce significant changes in primary production (i.e. growth of algae), as CO2 is already available in excess. Concurrent slight decrease in pH (attached as 0.06 pH units) will not be measurable effect, as the ocean surface pH varies between 8.0 and 8.3. Further increases of the CO2 concentration will certainly lead to detectable effects on pH.

If the increasing atmospheric CO2 causes significant changes in the global climate, indirect effects on primary production can be expected. If there were to be locally increasing cloudiness then this reduces the solar energy reaching the ocean and consequently also the primary production. Any warming of the upper layers would increase the formation of stable water masses, thereby reducing vertical mixing. The subsequent depletion of nutrients in the euphotic zone will cause a decrease in primary production.

If CO_2 is added to the ocean surface, the pH decreases and the tendency for dissolution of carbonate minerals (e.g. calcite and aragonite), either in bottom sediments or suspended in the water column, increases, thereby increasing both the alkalinity and the total DIC (see also Appendix 1). However, $CaCO_3$ is also a major constituent of shells of calcareous organisms and corals. Particularly in near-shore areas these organisms will be exposed to waters rich in CO_2 and with a low pH. Dissolution of shells and corals and subsequently local but massive deaths of organisms on a local scale is therefore not unrealistic. If dissolution of carbonates occurs, the alkalinity and CO_2 content increase and the net effect of the alkalinity increase generates an increasing capacity of the ocean for CO_2 uptake. This feedback mechanism might have reducing effects on a rising atmospheric CO_2 level, although probably not in the short-term, as there are kinetic limits and controls on carbonate dissolution.

References used in this section: 3, 6, 7, 11, 22, 36, 42, 56, 60.

2.3.2. Atmosphere - terrestrial biosphere interactions

The reservoir of carbon in living plant material (phytomass) in the land biota was about 600 GtC in 1980. Compared to this, the organic carbon fixed in animals (zoomass) and microorganisms is negligibly small (about 8 GtC). The total carbon retained in soils and in dead organic material has been estimated globally at about 2000 GtC (see Fig. 6). The biosphere can be roughly subdivided horizontally into six ecosystems (see Table 5) and vertically into leaves, branches, stemwood, roots, litter, young humus and stable soil carbon. By far the largest biotic reservoir is estimated to be in forest systems, which are also both the most active and vulnerable part of the biota. The expansion of human populations and changes in land use in recent centuries have been accompanied by an almost continuous decline in the area of forest (see Table 5). During the past century the reduction in the mass of vegetation (deforestation) and replacement with agricultural crops and urban development resulted in a considerable reduction of the carbon stored in terrestrial biota. The total net release of carbon from the biota between 1860 and 1980 has been estimated as 180 GtC. In recent years the rate of release has dropped slightly, as a consequence of net accumulation of carbon in the forests of North America and Europe (as result of renewed growth of forests and afforestation).

The cycle of carbon between biosphere and atmosphere is in essence a biological one, based on fixation of CO_2 by plants with the aid of solar energy (i.e. photosynthesis) and production of CO_2 through respiration and decomposition (eqn 4). The driving input of an ecosystem is the net primary production, the increase in biomass (NPP):

$$NPP = GP - R_A \qquad (5)$$

where GP is the gross production, the total photosynthesis of the system and R_A is the respiration of autotrophs, the green plants. Four, vertically arranged, components of the biosphere contribute to the NPP, i.e. leaves, branches, stems and roots. Estimates of NPP for the different ecosystems are given in Table 5.

The net flux of carbon between the atmosphere and any ecosystem is determined by the balance between gross production and respiration of all living organisms:

$$NEP = GP - (R_A + R_H) \quad (6)$$

where NEP is the net ecosystem production, the net flux of carbon into or from an ecosystem and R_H is the respiration of the heterotrophs, including all animals and decomposers. Thus, $R_A + R_H$ represent the natural flux of CO2 from the terrestrial ecosystems to the atmosphere. The primary evidence of the importance of the terrestrial biota for the CO2 content of the atmosphere is shown by the short-term oscillations of atmospheric CO2, reflecting the seasonal fluctuations in photosynthetic and respiratory activities of living organisms.

The NEP tends to be zero in a stable ecosystem, but is permanently positive when human disturbance is present. Estimates of the total NPP for all terrestrial ecosystems vary between 50-60 GtC per year; the mean total plant respiration of all ecosystems (R_A) is about equal to NPP; so, about 50% of GP is needed by the plants for respiration (R_A). The heterotrophic respiration (R_H) is 35-50 GtC per year. These fluxes characterise the natural and well-balanced exchange rate of about 100 GtC per year between terrestrial biota and atmosphere.

Human interference (cutting, burning, shifting of cultivation and changing of ecosystems) has not only large effects on the amount of carbon stored in the ecosystems (the reservoir), but also affects the fluxes. There has been a net release of carbon since at least 1860. Until about 1960, the annual release was greater than the release of carbon from fossil fuels. The total net release from terrestrial ecosystems since 1860 is estimated to have been 180 GtC (with a range of estimates of 135-228 GtC). The estimated net release of carbon in 1980 was 1.8-4.7 GtC, from 1958-1980 the release of C was 38-76 GtC. The ranges reflect the differences among various estimates for forest biomass, soil carbon, and agricultural clearing.

<u>Effects</u> of increasing atmospheric carbon on terrestrial biota can be expected to be caused directly by higher CO2 concentrations and/or indirectly by changed environmental conditions due to the higher CO2 concentrations. Among the factors affecting gross photosynthesis, light, moisture, availability of nutrients (particularly nitrogen and phosphorus) and CO2 are the most important.

Most information relative to CO2 effects on plants is based on data from short-term experiments under controlled conditions. Although considerable variability exists in responses of various species, an increasing growth and rate of photosynthesis is apparent and the following tentative generalisations have been made in the literature resulting mainly from experiments in glasshouses:

- The responses are greater in plants with indeterminate growth (e.g. cotton, soybean) than in plants with determinate growth (e.g. corn, maize, sorghum, sunflower).
  Plants with an indeterminate growth habit have an infinite growth potential and are the most productive, whereas the determinate plants complete their life cycle by primary growth with the production of a

complete plant.

- The response to higher levels of CO2 is greater in C3 plants (e.g. soybean, sunflower, tomato, lettuce, cucumber, velvetleaf, wheat, sugar-beet, potato, rice, trees) than in C4 plants (e.g. corn, sorghum, millet, sugar-cane).
  In C3 plants primary photosynthetic carbon fixation occurs via the enzyme ribulose diphosphate carboxylase (RuDP) and in C4 plants via phospho-enol-pyruvate (PEP). The higher carboxylation efficiency of C4 plants has an advantage in water use efficiency and therefore in exploiting arid environments.

- The largest response is in seedlings; in older plants the response decreases or ceases. Increasing CO2 concentration will therefore probably have the least effect on growth of plants in natural forests (dominating the biotic part of the carbon cycle), where light, water and mineral nutrition already limit the rate of photosynthesis. However, recent increases in the growth of some high-altitude trees (measured as increasing ring width) might be ascribed to increasing CO2 concentrations, although the discussion on the causal relationship is not yet ended.

- Water use efficiency (ratio of C fixed to water consumed) increases for all species with increasing CO2 concentrations, but particularly for C4 plants. Therefore, under conditions of significant water-stress, considerably greater proportional increases in plant productivity occur.

- Early depletion of nutrients causes a shortening of the growing season (only in C4 plants) and a significant increase of the C/N ratio in C3 plants. As N-poor plant tissue decomposes more slowly, nutrient cycling rates will then be affected in ecosystems.

Effects on ecosystems are determined by the stability of the system. In stable (climax) ecosystems (e.g. undisturbed forests) in which gross photosynthesis is equated by total respiration (NEP $\approx$ 0), the NEP might become positive depending on to what extent other factors are limiting (e.g. nutrients). In developing ecosystems, the NEP is permanently positive and will increase until a new (stable) equilibrium is reached. Increase of NEP will be greater where the supply of nutrients is greater, e.g. in highly productive agricultural systems. However, here the storage of carbon is only a small fraction of the annual production.

References used in this section: 5, 10, 15, 22, 24, 28, 37, 45, 67, 68, 69.

2.3.3. **Carbon cycle modelling**

Climate models are used to investigate the climatic response (e.g. temperature, precipitation) to changes of the atmospheric CO2 concentration (in fact the "airborne fraction", AF). Carbon cycle models (CCM's) are the main tool for predicting the future CO2 levels as a function of the total CO2 emissions. To calculate these levels all processes in which CO2 is exchanged have to be known and quantified, i.e. processes in which CO2 is exchanged, stored and converted between the atmosphere, terrestrial biosphere and ocean.

In the last few years CCM's have become more sophisticated. There are now several dynamic, process-oriented models which represent for example accumulation and decay of dead vegetation, processing of carbon in soils and humus, and chemistry, physics and biology of the ocean. Published models have been calibrated to agree well with the change in atmospheric CO2 concentration observed until now. However, no model has been properly validated against all trends and all data on emission rates. The most important uncertainties are:

- Future paths of energy and CO2 emissions.
  Many of the early analyses have produced estimates of future emissions and concentrations from extrapolative techniques based on present and past emissions.
  In an attempt to address uncertainties, a second generation of studies, employing scenario analysis has arisen, which also take into account future economic and energy developments. However, there are still a number of important uncertainties in the model, e.g. rate of population growth, the availability and cost of fossil fuels, etc. (see also 3.1.).

- Diffusion rate in the ocean.
  Most models represent some features of ocean chemistry quite well, but they represent ocean physics by simple vertical diffusion coefficients, sometimes related to stratification phenomena. These one-dimensional vertical models are viewed with considerable scepticism by physical oceanographers.

- Rate of deforestation and land reclamation.
  There is disagreement about whether significant renewed growth in some areas and stimulation of plant growth by increasing atmospheric CO2 will take place and counter losses from deforestation.

- Stimulation of growth by CO2.
  Most carbon cycle models in estimating biotic response have depended on the so-called beta (β) factor, a measure of how much plant growth increases as a result of atmospheric CO2 concentration.
  The numerical value of β is not known accurately at present, but is still of great importance as a parameter representing the response. However, it has been argued that the use of the β-factor should be replaced by separate analyses of the effects of changes in the area of forest and potential changes in NPP caused by both increased atmospheric CO2 and changes in climate.

References used in this section: 9, 15, 21, 22, 45.

3. SCENARIOS AND CLIMATE MODELLING

3.1. CO_2 emissions and future energy demand

It is generally accepted that the increasing concentration of CO_2 in the atmosphere is primarily determined by the combustion of fossil fuels. In order to estimate future quantities, it is first necessary to develop pictures of the future use of fossil fuels and then to use these scenarios, in conjunction with carbon cycle models, to calculate the atmospheric CO_2 concentrations.

Understandably, many pre-1975 studies assumed that future energy growth rates would be equivalent to the historical average of 4.5% per year. However, it is now acknowledged that the "CO_2 community" should make better use of the most recent scenarios in which world energy consumption is chiefly determined by economic and socio-political forces. Most recent estimates from such sources as the US Environmental Protection Agency (EPA), the International Institute for Applied Systems Analysis (IIASA), the International Energy Agency (IEA) and the US National Academy of Sciences show that, based on calculated future CO_2 emissions, pre-industrial atmospheric concentrations could double (i.e. pass 600 ppm) some time between 2040 and 2080 (see Fig. 8), the range reflecting the uncertainties with regard to future growth and energy developments.

By combining estimates of energy demand and fuel mix, CO_2 emissions can be estimated. In Fig. 2 a number of long range CO_2 projections are presented. Estimated average annual rates of increase of CO_2 emissions until 2030 generally range from 1 to 3.5%. Estimated annual emissions range from 7 to 13 GtC in the year 2000 and, with few exceptions, from 10 and 30 GtC in 2030. The US National Research Council (NRC) forecast in 1983 that the annual increase would be about 1.6% to 2025 and about 1% thereafter compared with an average growth over the past 120 years of 3.5%. The major reasons for the lower rate are, according to the NRC, an estimated slower growth of the global economy, further conservation and a tendency to substitute non-fossil fuels for fossil fuels. (see Appendix 2 for a discussion of the NRC Report).

The energy scenarios developed by Group Planning give estimates for CO_2 emissions in the lower part of the range for a number of reasons. In the first instance, global energy intensity has been falling for many years. Figure 9 shows that in the USA the fall has been continuous since the 1920's. Since 1973, two changes have occurred: oil intensity, which had been rising, began to fall, and the decline in energy intensity accelerated.

Four factors lie behind the fall in intensity: firstly a shift in developed country economies from heavy industry to less energy-consuming light industries and services; secondly, the introduction of new technologies and processes which both directly and indirectly, consume less energy; thirdly, the development of products (cars and refrigerators, for example) which are more energy-efficient, and finally, consumers have changed their behaviour patterns to reduce energy consumption as they have become more aware of the cost of energy. While the last of these is in some sense reversible as costs decline, the first three are structural and are unlikely to be reversed.

In the future, as portrayed in the Group scenarios, the intensity continues its downward course. Indexed to 1973 = 100, the energy intensity in the OECD countries is estimated as 47 (Next Wave) or 57 (Divided World) with a probable range of 45-75. The Next Wave scenario sees a rapid take-up of technology promoting a more rapid fall in intensity. However, this is outweighed by strong economic growth and hence a relatively large increase in energy demand. In Divided World, on the other hand, energy intensity declines more slowly but economic growth is also lower so that, overall, energy demand is less than in the Next Wave.

The impact of new technology is much less in the Less Developed Countries (LDC's) where the capacity to introduce energy efficient equipment and to apply energy conservation is much less. In these countries, energy intensities are still rising although at a lower rate as technology is transferred from the developed world. In part this rise is due to the development process - the introduction of the heavy industries the countries themselves need - and partly there is the move of energy demanding industries from developed to developing countries.

The world energy demands in the year 2005 in the two scenarios are, respectively. New Wave - 209 Mbdoe (million barrels per day oil equipment) and Divided World . 193 Mbdoe. At the same time, the probable ranges are 178-220 Mbdoe and the possible ranges are 158-240 Mbdoe.

While overall energy intensity is an important variable in estimating the future production of carbon dioxide, a second factor is the competition between different fuels in the major markets, in particular, the relative importance of the non-fossil fuels such as hydro and nuclear. The marginal energy sources, wind, waves, hydrogen, etc., are unlikely to make sufficient contributions to have any serious effect on CO_2 levels, nor is any large move away from hydrocarbon fuels in the transport market expected and consequently changes will relate to underboiler fuels and electricity generation. Coal is expected to dominate the large industrial under-boiler market with gas and electricity becoming the major energy sources at the commercial and domestic levels. Coal and nuclear will be the chief fuels for electricity generation. Only in the long term is a shift to other energy sources likely to occur. However, as the amount of CO_2 emitted per unit of energy differs considerably (see Table 2) for the different fossil fuels, future emissions not only depend on the global energy consumption but also on the relative proportions of the fossil energy sources (see Fig. 3).

On the basis of the demand estimates from the individual fuels in each scenario the CO_2 emissions can be calculated. These are given in Table 6.

An important source of energy often ignored because of the difficulty of measurement, is the non-commercial energy (NCE): Wood, crop residues, animal and human wastes burned by the poorest members of society for heating and cooking. The population of the LDC's is approximately 3.6 billion , one third of whom depend on NCE. By 2005 the LDC population will have risen to 5.3 billion (UN estimate) and although NCE cannot rise pro rata because of the constraints on availability, nonetheless there will be an increase and this, based on estimates developed by the FAO, is included in Table 6.

In the next century, the world energy pattern can only be guessed. A key feature, however, is that because of technological change there will be a wider variety of energy sources for exploitation than at present. However, no single new energy source will be able to meet more than 10% of the world's energy supply and coal will probably be the largest single source of hydrocarbon based energy. In addition to the main scenarios which extend only to the year 2005, some studies have been made within Group Planning on the possible use of energy in the year 2050. Based on some heroic assumptions not only of economic factors but also softer issues such as individual lifestyles and the role of government, three proto-scenarios have been developed and from these possible CO_2 emissions can be calculated. These are at the very bottom of the span of estimates made by other institutions and range from 10 to 11.5 GtC per annum.

There are, of course enormous uncertainties at this distance in time surrounding not only the fuel consumption but also the split of energy sources between fossil and non fossil fuels. It may be the case that large increases in the direct use of solar energy, indirect solar such as wind or wave energy and in nuclear energy will occur as a result of unforeseen technological developments.

In the light of the possible effects of an increase in greenhouse gases, it is important to examine the likely political responses to expressions of environmental concern. Awareness of environmental matters is much stronger now than it was only a few decades ago. At present, the focus is on acid rain and nuclear energy. While opposition to nuclear is strong in the USA, Australia and some European countries, it is possible that perception of a serious environmental threat could swing opinion away from fossil fuel combustion and lead to a revival of interest in conservation, renewable sources and particularly in nuclear energy. Of course, such a movement would be stillborn if there were to be any further accidents of the Three Mile Island, Sellafield or Tsjernobyl type.

The problem is that no obvious global solution is presently conceivable which would result in a major reduction in the rate of increase of atmospheric CO_2. A report issued by the US Environmental Protection Agency (EPA) in late 1983 (see Appendix 2) concluded that only draconian measures such as a global ban on coal combustion could have any significant effect. Since such actions are neither economically or politically feasible, individual countries should be urged to study ways of adapting to the inevitable rise in temperature. The NRC report referred to above, which was published at the same time, is less pessimistic in that it believes that strategies such as substantial taxation of fossil fuels might be effective.

References used in this section: 17, 21 Group Scenarios.

3.2. Projections of non-CO_2 greenhouse gases

Changes in atmospheric concentrations of several infrared absorbing gases, besides CO_2, result from human activities. Projections of future emissions of these trace gases are mostly at a more primitive stage than are the CO_2 projections, as they are usually based on assumptions of linear increase or exponential growth relative to development in recent years.

Recently, calculations have been applied to project the concentration of each gas species. The following data have been used:
- 1980 atmospheric concentrations and recent trend data,

- nature of sources (man-made, natural, etc.),
- projected growth in natural as well as man-made sources due to expected human activities over the next 50 years, and
- atmospheric lifetimes of the species.

The resulting estimates for the year 2030 are presented in Table 4. It appears that by 2030 atmospheric CFC's may increase by a factor of 10, the chlorocarbons by a factor of 3 and the nitrogen compounds and hydrocarbons by 20% and 60%, respectively. These estimates were of course made without taking into account the effects of possible countermeasures to reduce emissions.

References used in this section: 16, 33, 35, 39, 41, 43, 46, 47, 49, 57, 61, 64.

3.3. Temperature and climatic changes

The typical approach to understanding the relationship between atmospheric CO2 and temperature has been the development of increasingly complex models of the geophysical conditions that produce global climate. Several types of mathematical models have been developed differing in comprehensiveness with regard to treatment of the climate system components. Individual models can be broadly classified as either thermodynamic (EBM's, energy balance, and RCM's, radiative-convective models, both accentuating the prediction of temperature) or hydrodynamic (predicting both the temperature and the motion fields, and their mutual interactions) models. The last category includes the now widely favoured "three dimensional" General Circulation Models (GCM's). A new model hierarchy is formed by coupling atmospheric GCM's with different ocean and sea ice models.

The standard reference value for comparing alternative models is ΔT_s (the globally averaged temperature increase due to doubled CO2). The range of surface warming simulated by the groups EBM's and RCM's for doubled CO2 is in remarkable agreement, i.e. 1.3-3.3°C. In comparing results obtained by EBM's the high and low values are usually excluded as the deviation is ascribed to the use of models that require an energy balance for the earth's surface, rather than for the entire earth-atmosphere climate system. The main proponent of the surface energy balance model is S. Idso of the US Water Conservation laboratory. On the basis of empirical observations of climatic change in Arizona and measurements of solar radiation, he concluded that ΔT_s is 0.25°C, i.e. an order of magnitude less than that predicted by the other models. This controversy within the modelling community is fundamental and will continue.

The range of surface warming simulated by the GCM's is somewhat larger than that of the purely thermodynamic models, namely 1.3-3.9°C. For this comparison calculations based on sea surface temperature/sea ice simulations were excluded from consideration, as these show a calculated present temperature lower than the presently observed temperature.

None of the above mentioned computations take the trace gas effects into account. The only, very recent, RCM simulation employing the projected increases of all greenhouse gases refers to the period up to the year 2030, the year characterised by a estimated CO2 concentration of about 450 ppm. In that study the relative importance of about 30 gases, including CO2 is taken into consideration as well as coupled perturbations due to chemical-radiative interactions (see also section 2.2.2.). The simulation indicates that by 2030 the effects of the trace gases will amplify the CO2 surface warming by a factor ranging from 1.5 to 3.5 (see Fig. 10).

However, the warming is not the entire story; all GCM's show an increase in the intensity of the global hydrological cycle. If the planet is warmer more moisture will evaporate from the oceans, resulting in a increase of the atmospheric water concentration. The water vapour will also act as a greenhouse gas. In addition, cloud cover might change, as well as sea ice and snow cover, all producing either an amplification or a reduction of the original effects (positive or negative "feedbacks"). Although the process of CO2-induced warming is reasonably well understood and some of the gross features of the likely climatic change are reasonably well established qualitatively, the likely regional effects cannot be modelled with great confidence at the present time. The impact of the expected climatic change predicted by these models would be large at a doubled atmospheric CO2 concentration, even larger than any since the end of the last ice age about 12,000 years ago (see also Appendix 8):

- precipitable water content of the atmosphere would increase by 5-15%, the precipitation rate being increased particularly at higher latitudes of both hemispheres,
- sea-ice cover of the Arctic would be reduced to a seasonal ice cover,
- snow cover would change dependent on latitude, though extent is difficult to predict,
- ice-cap mass balance change: a warming of 3°C would induce a 60-70 cm rise of the global sea level, about half of which would be due to ablation of the Greenland and Antarctic land ice, the rest to thermal expansion of the ocean; a possible subsequent disintegration of the West Antarctic Ice Sheet would result in a worldwide rise in sea level of 5-6 m,
- rising sea surface temperature would be highly regional, and
- reduced evapo-transpiration of plants would make more water available as runoff and would tend to offset the effects of any CO2-induced reductions in precipitation or enhance the effects of precipitation increases.

Based on the modelling results, reconstruction of historical climatic conditions and studies of recent warm years and seasons, a markedly different climatic response is expected at different latitudes. The rise in the average temperature at the surface would increase from low to high latitudes in the northern hemisphere (see Fig. 1). There the projected increase would be much larger between October and May, than during the summer, thereby reducing the amplitude of seasonal temperature variations over northern lands. The models also show a large increase in the rates of precipitation and runoff at high northern latitudes (see Fig. 10). These changes could have profound effects on the distribution of the world's water resources, and large-scale effects on rain-fed and irrigated agriculture could be expected: large areas of Africa, the Middle East, India and a substantial portion of central China would cease to be water deficient areas and become favourable for agriculture. In contrast, the "food basket" areas of North America and the U.S.S.R. would become considerably drier.

References used in this section: 6, 9, 17, 21, 23, 28, 40, 43, 47, 48, 52, 53, 58, 61, 62.

3.4. Detection of the greenhouse effect

The increase in greenhouse gas concentrations from pre-industrial to the present values might have caused a significant perturbation of the radiative heating of the climate system, resulting in a warming of the global surface and lower atmosphere. The induced warming due to the increase of the CO2 concentration has been computed to be 0.8°C in recent RCM's and to be twice as large in a recent GCM taking into account the increase of the concentration of all (known) greenhouse gases.

Such a warming, had it indeed occurred, should have been detectable. However the search for definite evidence on whether the climate is responding to increasing concentrations of greenhouse gases, in the way that most models predict, has not yet been successful. Scientists argue that the warming is delayed through the inertia of the global system. They expect that the warming will not rise above the noise level of natural climatic variability before the end of this century. By then the ΔT_s may have risen above the natural surface temperature variation (typically ± 0.2-0.4°C for the northern hemisphere). This natural fluctuation in hemispheric or global mean temperatures, observed over the last century (see Fig. 12), is influenced by various climate forcing phenomena, e.g. solar irradiance, volcanic aerosols, and surface radiative properties, thereby making the sought-for CO2 signal unclear.

Other scientists argue that the models overestimate the temperature increase due to the increase of the greenhouse gases.In their view modellers have so far concerned themselves mainly with two climatic feedback processes, which are claimed to amplify any CO2 warming: the so-called ice-albedo feedback and the water vapour feedback. The critics argue that these two feedback processes are currently overestimated while others are completely neglected, underestimated or overestimated (for example, the carbon dioxide-ocean circulation-upwelling feedback, the CO2-ocean stability-winter down welling feedback, the CO2-Arctic sea ice-Artic biomass feedback, the CO2-rainfall distribution-tropical biomass feedback, the permafrost-methane release feedback, and the CO2-weathering of silicate minerals feedback). Overestimation of the ice-albedo feedback is particularly relevant.

It is also argued that the climate models have not been constructed with ocean surface temperature as the fundamental variable. Therefore, the inability to observe the model-calculated CO2 warming is a consequence of a lag due to thermal inertia of the ocean. In other words, the atmosphere cannot warm until the oceans do. Other studies indicate that the absorption of CO2 and heat by the oceans could possibly delay a greenhouse warming by five to twenty years.

Regardless of the continuing debate, confirmation of any view is important. If, as expected, the concentrations of the greenhouse gases gradually increase in the future, then the likelihood of achieving statistical confirmation increases. Improvements in climatic monitoring and modelling and in the historic data bases, would allow an earlier detection of any greenhouse effect with greater confidence.

References used in this section: 4, 12, 13, 17, 28, 31, 47, 58, 60, 63.

4. IMPLICATIONS

Although the greenhouse effect has been undetectable up till now, the atmospheric concentrations of the greenhouse gases are steadily increasing. Whether or not this will result in a significant global warming and if so, when it will occur, is still a matter of debate. However, without the direct need of a clear signal it is useful to give consideration to measures to counteract the likely effects. Potential effects are identified below assuming a future greenhouse effect , irrespective of uncertainties associated with timing and severity of the impact.

4.1. Potential effects of global warming induced by greenhouse gases

In this section possible effects of increasing concentrations of CO2 and the other greenhouse gases are enumerated, as well as the effects of a climate changed by global warming.

4.1.1. **Abiotic effects and biotic consequences**

I. Oceans

1. Increased water temperature	Increased growth/development rates and metabolic demands of all marine species, i.e. increased survival and growth of natural resources, through shifts of ranges and migration patterns.
2. Increased vertical stability of water masses	In turbulent (subpolar) waters increased phytoplankton production and increased fish yields. In stratified (subtropical) waters decreased phytoplankton production and decreased fish yields.
3. Decreased latitudinal and seasonal sea ice extent	Lower intensity but greater duration of primary production.
4. Temperate decrease and high latitude increase in net precipitation and runoff	Poleward species shifts due to shifts in salinity patterns.
5. Decrease in pH	Increasing tendency of dissolution of carbonate shells (e.g. shellfish), corals and sediments.
6. Rising sea level	Redistribution of nearshore and estuarine habitats, including adaptation or loss of natural resources.

II. **Agriculture**

Of the 20 food crops, that feed the world, 16 have a C3 photosynthetic pathway. The only exceptions are corn, sorghum, millet and sugarcane, which have a C4 pathway (see also chapter 2.3.2.). Of the world's 18 most noxious weeds, 14 have the C4 pathway.

1. Increasing atmospheric CO2	Increasing productivity, providing other factors affecting plant growth (light, water, temperature, nutrients) are not adversely affected; increase in yield and harvest index, improved quality and accelerated maturity. Increase in water use efficiency and a decrease in water requirements, i.e. a greater stability of production and less crop failures.
2. Increasing CO2 and specific crops	Greater water use efficiency with C4 plants than with C3 plants. Growth more stimulated in C3 than in C4 plants. Indeterminate plants benefit more than determinate plants. Thus, C3 plants and indeterminate plants have a higher competitive ability under optimal conditions and C4 plants will be less affected by water stress. Changes in crop/weed interactions and relationships.
3. Increased cloud cover	Increased quantum yield of net photosynthesis, i.e. beneficial effects of high CO2 on growth when light is limited.
4. Climatic change in general	Greater resilience to environmental stress, such as high temperatures and shortage of water. Redistribution of species. Impact of changed weather is sharp in marginal climates.
5. Decrease in precipitation at 40°N and 10°S	Decreased runoff for irrigation, increase of evaporation, and decrease in yield.
6. Increase in precipitation between 10° and 20°N, north of 50°N and south of 30°S	Increase of runoff, destructive floods, and inundation of low-lying farmland.
7. Latitudinal differences in temperature rise	Increased length of growing season in temperate zone and far north latitudes. Latitudinal differences in water requirements by plants.

III. **Terrestrial ecosystems**

1. Increased atmospheric atmospheric CO2	Increased water use efficiency. Positive response in seeding stage. Stimulation of NEP, competition induced change in total phytomass, and succesive development to a new climax vegetation. Shift of the biospheric action from CO2 source to CO2 sink.
2. Climatic change	Alterations of ecosystems especially in regions with strong gradients in evapo-transpiration. Major shifts in the global distributions of species.

References used in this section: 29, 32, 34, 37, 55, 65, 67.

4.1.2. Socio-economic implications

The changes in climate, being considered here, are at an unaccustomed distance in time for future planning, even beyond the lifetime of most of the present decision makers but not beyond intimate (family) association. The changes may be the greatest in recorded history. They could alter the environment in such a way that habitability would become more suitable in the one area and less suitable in the other area. Adaptation, migration and replacement could be called for. All of these actions will be costly and uncertain, but could be made acceptable. Of course, all changes will be slow and gradual and, therefore, adaptation and replacement, even migration, need not to be noticeable against the normal trends. Recognition of any impacts may be early enough for man to be able to anticipate and to adapt in time.

The adaptation of the ecosystems on earth to changes in climate, however, will be slow. It would be unrealistic to expect adaptation to occur within a few decades. Therefore, changes in ecosystem stability, disturbance of ecosystem structure and function and even local disappearance of specific ecosystems or habitat destruction could occur. This will be followed by an almost unpredictable, complex process of adaptation of the ecosystems to the changed conditions to reach a new stable situation, the so-called climax ecosystem. Quite clearly, this process of adaptation would become even more complex when it is interrupted more frequently or even continuously, such as through permanently changing climatic conditions. A new stable situation can only be expected to occur after a global settling of the change in climate. The time it then will take to reach a new stable situation depends largely on the seriousness of the disturbance of the ecosystems and, thus, on the effectiveness of the programmes to protect the earth's climate against change.

Changing temperature and precipitation are the key elements in climatic change. The main effects will be on the sea level and natural ecosystems. Socio-economic implications will be related to agriculture, fisheries, pests, water supply, etc. While the greenhouse effect is a global phenomenon, the consequences and many of the socio-economic implications will be regional and local with large temporal and spatial variations. The following outline of possibilities is therefore incomplete and speculative, but can be a basis for further consideration and study.

1. **Rise in sea level**
   - More than 30% of the world's population live within a 50-kilometre area adjoining oceans and seas, some even below sea level. Large low-lying areas could be inundated (e.g. Bangladesh) and might have to be abandoned or protected effectively.
   - Shallow seas, lagoons, bays and estuaries characterised by extensive tidal flats could become permanently inundated. Loss of these habitats would mean a loss of extremely highly productive and diverse areas, which serve as a nursery for juveniles of all kinds of animal species and which are rich in food for fish. Effects on natural resources dependent on these systems, might therefore be dramatic (e.g. shellfish culture and fishing, seaweed harvesting, some commercially important fish).
   - There might be a shift in distribution of amenities, and as a consequence local loss of income, though at other places new sources of revenue might emerge.

2. **Rise in sea temperature**
   - Survival and growth of marine species may increase in general, though not in stratified subtropical waters. However, shifts in ranges and migration patterns could result in local losses of food sources and revenues, and could require operation in other (more distant) fishing grounds.

3. **Acidification of seawater**
   - Dissolution of $CaCO_3$ increases with a decreasing pH. Particularly in shallow coastal areas, characterised by high concentration of respiratory CO_2 and a low pH, dissolution of carbonate materials (shells, corals and sediment) could be quite rapid and result in damage of natural resources and of natural protection of shorelines, and disappearance of complete coral islands.

4. **Agriculture**
   - The impact depends on both the amplitude of climatic changes and agriculture's vulnerability to climatic variability. This vulnerability varies from region to region and will have great implication for import and export patterns of food of the countries dependent on agriculture for a larger part of their earnings some will lose some will gain. Poorer countries would run the greatest risk, the more so as their capacity to adapt would be the smallest.
   - Most farm labour is applied outdoors and is therefore essentially dependent on weather and climate. Any substantial change therein could necessitate adaptation and require new investments.
   - Model calculations show that a warmer and drier climate could decrease yields of the three great American food crops over the entire grain belt by 5 to 10%, tempering any direct advantage of CO_2 enhancement of photosynthesis. Although estimates for other areas are not available, any decrease may certainly have an impact on the world food supply and its price.
   - A warming in northern latitudes could make additional land suitable for cultivation, although the quality of such land for crops is not promising. This would result in local changes in levels of income and

working arrangements.

5. **Area of forest**
   - With a growth rate of the world population of 1.5% per year the human area increases slowly, presently mainly at the expense of grassland and agricultural land. However, decreasing yields in combination with an increasing human population may require an extension of arable land. This would certainly have implications for the tropical (and temperate) forests.
     Based on the most pessimistic predictions a disappearance of forests is expected during the first half of the 21st century, should human population growth continue indefinitely. Such a decrease in area of forest means a significant decrease of carbon fixed in the terrestrial biosphere reservoir and, consequently, an increase of atmosphere CO_2
   - The natural transition line between deciduous and needle-leafed trees and the upper tree-line will shift to higher latitudes and higher elevations. Thus the total area suitable for growth of deciduous trees (mainly temperate and boreal forests) will increase.

6. **Changing air temperature**
   - Local temperature change may necessitate local adaptation of the buildings in which people live and work, technologies for heating or cooling, energy sources for heating and cooling, new food preparation technologies, new cultivation techniques, etc. All such adaptations are costly and some would drastically change the way people live and work.

7. **Water supply**
   - The prospects for water supply (sources, uses, transport, storage and conservation) are evidently of importance. Rainfall, snowfall, and evaporation are among the key elements in climate change. Level of groundwater or need of irrigation or drainage would be main determinants of whether increased rain and snow would be welcome and how costly reduced precipitation would be.
   - Local development of new sources of freshwater would be required. Water storage and transport, and inhibition of evaporation should receive continued attention.

References used in this section: 14, 15, 18, 26, 48, 50, 51.

4.1.3. **Implications for the energy industry**

Direct operational consequences can be expected from a rising sea level, impacting offshore installations, coastal facilities and operations (e.g. platforms, harbours, refineries, depots) with an uncertain magnitude. Costs of defending against a sea level rise will depend on the local situation (levels of security demanded for contingencies like extreme ocean storms, flooding, etc.) and national policies to compensate industry for the extra costs incurred.

Coal and the combined fuels of oil and gas contribute roughly equal amounts of CO_2 (see Table 7). Because natural gas produces less CO_2 per unit of energy, a swing from coal towards gas would reduce the CO_2 emission. This argument has been used in individual choices of fuels for new power stations, but since almost 90% of the world's recoverable coal is located in the U.S.S.R., China and the U.S., it is these countries which would have to be taking such an initiative if considered feasible.

An overall reduction in fossil fuel use would of course reduce CO_2 production and could be achieved by constraint on energy consumption, by improved thermal efficiency and by replacing fossil fuels with e.g. nuclear power. But such a course of action would imply a major shift in world energy supply and use.

Energy policy issues will be difficult to tackle because it is the world wide fossil fuel usage that affects the level of CO_2 in the atmosphere, but the mechanisms for developing world wide energy policy do not at present exist. There is little incentive for strong voluntary action by individual countries when the benefits would be shared with the rest of the world, but the costs would be borne wholly internally. Furthermore, world growth in fossil fuel use is expected to be greatest in developing countries, and they are unlikely to wish to constrain their development programmes.

The energy industry will clearly need to work out the part it should play in the development of policies and programmes to tackle the whole problem. It will not be appropriate to take the main burden, for the issues are ones that ultimately only governments can tackle, and users have an important role. But it has very strong interests at stake and much expertise to contribute, particularly on energy supply and usage. It also has its own reputation to consider, there being much potential for public anxiety and pressure group activity.

References used in this section: 2, 8, 14, 30, 50, 51, 66.

4.1.4. **Implications for Shell Companies**

For the purposes of this discussion, it is assumed that the consequence of increasing levels of carbon dioxide are as already set out, namely, an increase in air temperature, changes in weather patterns, a rise in sea level of less than 1 metre and some small increases in agricultural yields.

Possible implications include:
- Legislation affecting our products and/or processes.
- Location of Shell installations.
- Changing demand for our products:
  - liquid fuels
  - coal
  - chemicals, particularly agrochemicals
- Business opportunities:
  - alternative fuels
  - forestry
  - new varieties of plants (seeds business)

While, theoretically, it is possible to legislate for a reduction in fossil fuel use, it must be the case that any global reduction is most unlikely. However, in a paper produced as background information for the latest set of energy scenarios, Group Planning felt there was a possibility that an increasing awareness of the greenhouse effect might change peoples' attitudes towards non-fossil energy sources, especially nuclear.

Fossil fuels which are marketed and used by the Group account for the production of 4% of the CO2 emitted worldwide from combustion. Of these emissions, 80% comes from Group oil, 12% from Group gas and 8% from Group coal (see Tables 7 and 8).

It is thermodynamically unfavourable and technically very difficult to remove carbon dioxide from the air other than by planting trees. If an international effort were mobilised to do this, and the poor response to the World Bank's call for such effort currently makes it appear unlikely, then there would be some call on companies, including Shell, with experience in tropical forestry.

Of the other greenhouse gases, many are chemicals in commercial use which could in principle be replaced or banned; it is difficult, on the other hand to see what could be done about others such as methane.

There seems little need to consider changes in the location of Shell installations because of the slowness of changes in sea level in the chosen time-frame. Climatic change could alter the relative wealth of certain LDC's and lead us to examine the possibilities of expanding or contracting our business accordingly.

These same changes, by altering the patterns of agriculture could alter up or down the demand for our agricultural products both chemicals and seeds, though it is difficult to forecast the effect of the biotechnological revolution on this area - it might swamp any effect of increasing carbon dioxide.

5. SCOPE FOR FURTHER ACTION

The existing large uncertainties surrounding the possible consequences of the increasing atmospheric CO2 concentration divide those who at least see substance in the theory, in the following three basic categories:

1. Those who believe there is no need for short-term action and insufficient knowledge about how to tackle the problem, so that nothing need be done for the moment other than to narrow the existing uncertainties,
2. Those who believe that the threat is real, and seek to eliminate the problem, and
3. Those who believe that the threat is real and unavoidable, so that "learning to live with climatic change" is the only solution.

Some people may, of course, lie between these categories, e.g. those who believe the threat is not considerable and who seek both to reduce its intensity and to adapt to it.

From these groups came a number of actions and strategies which are believed most appropriate. Current (1986) official, government attitude mainly fit the first approach, though there is a tendency to carry out analyses that would eventually lead to discussion of remedial measures (see also Appendix 3).

First group

- Basic research and monitoring:
  - monitoring of causal factors:
    emission of greenhouse gases
    atmospheric concentration of these gases
    solar variations
    volcanic aerosol
    changes in area of forest
  - climatic effects:
    temperature
    radiation fluxes
    precipitable water content
    cloud cover
    sea level
    sea temperature
    snow and sea-ice cover (remote sensing)
- Applied research and development:
  - agriculture:
    responses of ecosystems
    crop yields
    physiology and growth
  - water resources

Second group

- Analysis of economic and social costs associated with climate change
- Reduction of releases of greenhouse gases other than CO2
- Management of biota:
  - freezing rate of deforestation
  - freezing land reclamation
  - freezing rangeland burning
  - promotion of re-/afforestation

  ° fertilisation of the ocean surface with phosphorus and nitrogen, thereby increasing the biotic fixation of CO_2 (generating other adverse effects)
- Removal of CO_2:
  ° deep-sea disposal of CO_2 produced at centralised location (consequently generating secondary effects)
  ° re-/afforestation
- Energy research and policy:
  ° development of renewable energy sources:
    solar energy
    biomass conversion
    geothermal energy
    hydroelectric energy
    utilisation of energy contained in waste
    wind energy
  ° rational use of energy:
    energy saving
    new energy carriers
  ° analysis of energy systems (energy-economy models):
    open ended versus closed ended systems (open ended systems are those which through evolution in the use of end products allow satisfaction of energy needs without increasing use of fixed carbon sources)
- Energy management:
  ° reduction of fossil fuel usage
  ° usage of low-carbon fuels
  ° usage of alternative energy sources

Third group
- Adaptation to climatic changes through:
  ° changes in environmental control
  ° migration
- Adaptation to sea level rise through:
  ° migration
  ° construction of (higher) dikes
- Adaptation to effects on agriculture through:
  ° migration
  ° change of crops
  ° modification of varieties
  ° alteration of husbandry

If the environmental problem develops as some predict, then the impact would be sufficiently large as to require a policy response. Re-direction of research emphasis towards analysis of energy and policy options will then require particular attention.

It should be noted that, when CO_2 becomes the focus of concerted international action, the developing nations will be particularly affected.

References used in this section: 8, 10, 14, 19, 30, 38, 51, 66,69.

6. REFERENCES

1. Ausubel, J.H.; Nordhaus, W.D.
A review of estimates of future carbon dioxide emissions.
In: National Research Council, Changing Climate, Report of the Carbon dioxide Assessment Committee. National Academy Press, Washington, D.C. pp 153-185, 1983.

2. Baxendell, P.
The changing energy balance in Asia Pacific.
Address to the PetroPacific '84 Congress, Melbourne, Australia, 8 pp., 1984.

3. Brewer, P.G.
Carbon dioxide and the oceans.
In: National Research Council, Changing Climate, Report of the Carbon Dioxide Assessment Committee. National Academy Press, Washington, D.C. pp 188-215, 1982.

4. Broecker, W.S.; Peteet, D.M.; Rind, D.
Does the ocean-atmosphere system have more than one stable made of operation?
Nature 315:21-25, 1985.

5. Brown, S.; Lugo, A.E.
Biomass of tropical forests: a new estimate based on forest volumes.
Science 123:1290-1293, 1984.

6. Bryan, K.
The role of the ocean in the transient climate response to increasing atmospheric CO2.
In: Proc. Joint Oceanographic Assembly 1982, Gen. Symp. Halifax, pp 43-46, 1983.

7. Byrne, R.H.; Acker, J.G.; Betzer, P.R.; Feely, R.A.; Cates, M.H.
Water column dissolution of aragonite in the Pacific Ocean.
Nature 312:321-326, 1984.

8. Compton, W.D.
Alternate fuels - a technology that is ready.
UP Front/Agricultural Engineering 66:12-13, 1985.

9. Crane, A.J.
Possible effects of rising CO2 on climate.
Plant Cell Environ. 8:371-379, 1985.

10. Dahlman, R.C.; Strain, B.R.; Rogers, H.H.
Research on the response of vegetation to elevated atmospheric carbon dioxide.
J. Environ. Qual. 14:1-8, 1985.

11. Duplessy, J.-C.; Shackleton, N.J.
Response of global deep-water circulation to earth's climatic change 135,000-107,000 years ago.
Nature 316:500-507, 1985.

12. Ellsaesser, H.W.
The climatic effect of CO2: a different view.
Atmospheric Environment 18:431-434, 1984.

13. Fritts, H.C.; Lough, J.M.
An estimate of average annual temperature variations for North America, 1602 to 1961.
Climatic Change 7:203-224, 1985.

14. Golanty, E.
The global experiment. Carbon dioxide and ocean temperature.
Oceans 17:66-69, 1984.

15. Goudriaan, J.; Ketner, P.
A simulation study for the global carbon cycle, including man's impact on the biosphere.
Climatic Change 6:167-192, 1984.

16. Hameed, S.; Cess, R.D. Hogan, J.S.
Response of the global climate to changes in atmospheric chemical composition due to fossil fuel burning.
J. Geophys. Res. 85:7537-7545, 1980.

17. Hansen, J; Johnson, D.; Lacis, A.; Lebedeff, S.; Lee. P.; Rind, D.; Russel, G.
Climate impact of increasing atmospheric carbon dioxide.
Science 213:957-966, 1981.

18. Hartwig, S.; Heudorfer, W.; Schnatz, G.
Possible climatic change by anthropogenic CO2 emission.
J. Chem. E. Symposium Series, No. 78, T4/15-T4/30, 1982.

19. Heintzenberg, J.; Hansson, H.-C.; Ogren, J.A.; Odh, S.-A.
Concept and realisation of an air pollution monitoring station in the European Arctic.
Ambio 14:152-157, 1985.

20. Hileman, B.
The greenhouse effect.
Environ. Sci. Technol. 16:90A-93A, 1982.

21. Hileman, B.
Recent reports on the greenhouse effect - what are some differences between the EPA and NRC studies?
Environ. Sci. Technol. 18:45A-46A, 1984.

22. Hobbie, J.; Dungan, J.; Houghton, R.A.; Peterson, B.
Role of biota in global CO2 balance: the controversy.
BioScience 34: 492-498, 1984.

23. Hoffert, M.I.; Callegari, A.J.; Hsiek, C.T.
The role of deep sea heat storage in the secular response to climatic forcing.
J. Geophys. Res. 85:6667-6679, 1980.

24. Houghton, R.A.; Hobbie, J.E.; Melillo, J.M.; Moore, B.; Peterson, B.J.; Shaver, G.R.; Woodwell, G.M.
Changes in the carbon content of terrestrial biota and soils between 1860 and 1980: a net release of CO2 to the atmosphere.
Ecol. Monogr. 53:235-262, 1983.

25. Hugill, J.A.
The carbon dioxide greenhouse effect.
KSLA, report AMGR.80.105, 9 pp, 1980.

26. Ichimura, S.
The impacts of climatic change on human society.
In: Carbon dioxide Effects Research and Assessment Program. Workshop on Environmental and Societal Consequences of a Possible CO2 Induced Climate Change. U.S.-DOE, Conf-7904143, pp 442-462, 1980.

27. Idso, S.B.
Temperature limitation by evaporation in hot climates and the greenhouse effects of water vapour and carbon dioxide.
Agric. Meterol. 27:105-109, 1982.

28. Idso, S.B.
The search for global CO2 ect. "Greenhouse Effects".
Environ. Conservation 12:29-35, 1985.

29. Idso, S.B.; Brazel, A.J.
Rising atmospheric carbon dioxide concentrations may increase streamflow.
Nature 312:51-53, 1984.

30. Jaske, R.T.
Carbon dioxide - the premier environmental challenge of our time.
Environ. Progress 2:145-148, 1983.

31. Kellogg, W.W.
Feedback mechanisms in the climate system affecting future levels of carbon dioxide.
J. Geophys. Res. 88:1263-1269, 1983.

32. Kendall, A.C.; Turner, J.C.; Thomas, S.M.
Effects of CO2 enrichment at different irradiances on growth and yield of wheat.
J. Exp. Bot. 36:252-260, 1985.

33. Kerr, R.A.
Doubling of atmospheric methane supported.
Science 226:954-955, 1984.

34. King, D.A.
Estimating the direct effect of CO2 on soybean yield.
J. Environ. Mngt 20:51-62, 1985.

35. Kondratyev, K. Ya.; Bunakova, A.M.
Factors of the greenhouse effect of the atmosphere and their influence on climate.
In: Williams, J. (ed.), Carbon Dioxide, Climate and Society. Pergamon Press, Oxford, pp 201-207, 1978.

36. Kratz, G.
Modelling the global carbon cycle.
In: Hutzinger, O. (ed.), The Handbook of Environmental Chemistry, Vol. 1, Part D. Springer Verlag, Berlin, pp 29-81, 1985.

37. Lallarche, V.C.; Graybill, D.A.; Fritts, H.C.; Rose, M.R.
Increasing atmospheric carbon dioxide: tree ring evidence for growth enhancement in natural vegetation.
Science 225:1019-1021, 1984.

38. Laurmann, J.A.
The global greenhouse warming problem: setting the priorities.
Climatic Change 7:261-265, 1985.

39. Levine, J.S.; Rinsland, C.P.; Tennille, G.M.
The photochemistry of methane and carbon monoxide in the troposphere in 1950 and 1985.
Nature 318:254-257, 1985.

40. Manabe, S.; Stouffer, R.J.
Sensitivity of a global climate model to an increase of CO2 concentration in the atmosphere.
J. Geophys. Res. 85:5529-5554, 1980.

41. Maugh, T.H.
What is the risk from chlorofluorocarbons?
Science 223: 1051-1052, 1984.

42. Mook, W.G.; Engelsman, F.M.R.
Het atmosferische CO2 gehalte en de rol van de oceanen.
Chemisch Magazine, Dec. 1983:669-671, 1983.

43. Nicoli, M.P. Visconti, G.
Impact of coupled perturbations of atmospheric trace gases on earth's climate and ozone.
Pageoph. 120:626-641, 1982.

44. Papaud, A.; Poisson, A.
Le cycle du carbone et sa perturbation par les activités humaines: un apercu du problème.
Oceanologica Acta 8:133-145, 1985.

45. Pearman, G.I.; Hyson, P.
Activities of the global biosphere as reflected in atmospheric CO2 records.
J. Geophys. Res. 85:4468-4474, 1980.

46. Ramanathan, V.
Greenhouse effect due to chlorofluorocarbons: climatic implications.
Science, 190,50-52, 1975.

47. Ramanathan, V.; Cicerone, R.J.; Singh, H.B.; Kiehl, J.T.
Trace gas trends and their potential role in climate change.
J. Geophys. Res. 90:5547-5566, 1985.

48. Revelle, R.
Carbon dioxide and world climate
Sci. Amer. 247:33-41, 1982.

49. Rinsland, C.P.; Levine, J.S.; Miles, T.
Concentration of methane in the troposphere deduced from 1951 infrared solar spectra.
Nature 318:245-249, 1985.

50. Schelling, T.C.
Climatic change: implications for welfare and policy.
In: Natural Research Council, Changing Climate, Report of the Carbon Dioxide Assessment Committee. National Academy Press, Washington, D.C. pp 449-482, 1983.

51. Schelling, T.C.
Climatic change: implications for welfare and policy.
Ambio 13:200-201, 1984.

52. Ichlesinger, M.E.
Climate model simulations of CO2-induced climatic change.
Adv. Geophysics 26:141-235, 1984.

53. Semtner, A.J.
On modelling the seasonal thermodynamic cycle of sea ice in studies of climatic change.
Climatic Change 6:27-37, 1984.

54. Shackleton, N.J.; Hall, M.A.; Line, J.; Shuxi, C.
Carbon isotope data in core V19-30 confirm reduced carbon dioxide concentration in the ice age atmosphere.
Nature 306:319-322, 1983.

55. Shugart, H.H.; Emanuel, W.R.
Carbon dioxide increase: the implications at the ecosystem level.
Plant Cell Environ. 8:381-386, 1985.

56. Smith, S.V.
Physical, chemical and biological characteristics of CO2 gas flux across the air-water interface.
Plant, Cell Environ. 8:387-398, 1985.

57. Stauffler, B.; Fischer, G.; Neftel, A.; Oeschger, H.
Increase of atmospheric methane recorded in Antarctic ice core.
Science 229:1386-1388, 1985.

58. Stewart, T.R.; Glantz, M.H.
Expert judgment and climate forecasting: a methodological critique of "climate change to the year 2000".
Climatic Change 7:159-183, 1985.

59. Tyndall, J.
On the absorption and radiation of heat by gases and vapours, and on the physical connection of radiation, absorption, and conduction.
Philosoph. Mag. Ser. 4:169-194 and 273-285, 1861.

60. Walker, J.C.G.; Hays, P.B.; Kasting, J.F.
A negative feedback mechanism for the long-term stabilisation of earth's surface temperature.
J. Geophys. Res. 86:9776-9782, 1981.

61. Wang. W.C.; Yung, Y.L.; Lacis, A.A.; Mo, T.; Hansen, J.E.
Greenhouse effects due to man-made perturbations of trace gases.
Science 194:685-690, 1976.

62. Washington, W.M.; Meehl, G.A.
Seasonal cycle experiment on the climate sensitivity due to a doubling of CO2 with an atmospheric general circulation model coupled to a simple mixed-layer ocean model.
J. Geophys. Res. 89:9475-9503, 1984.

63. Weller, G.; Baker, D.J.; Gates, W.L.; MacCracken, M.C.; Manabe, S.; Vonder Haas, T.H.
Detection and monitoring of CO2 induced climate changes.
In: National Research Council, Changing Climate, Report of the Carbon Dioxide Assessment Committee. National Academy Press, Washington, D.C. pp 292-382, 1983.

64. Wigley, T.M.L.
Carbon dioxide, trace gases and global warming.
Climate Monitor 13:133-146, 1984.

65. Wigley, T.M.L.; Jones, P.D.
Influences of precipitation changes and direct CO2 effects on streamflow.
Nature 314:149-152, 1985.

66. Williams, R.H.
Potential roles for bioenergy in an energy-efficient world.
Ambio 14:201-209, 1985.

67. Wittwer, A.J.
Carbon dioxide levels in the biosphere: effects on plant productivity.
CRC Crit. Rev. Pl. Sci. 2:171-198, 1985.

68. Woodwell, G.M.
Biotic effects on the concentration of atmospheric carbon dioxide: a review and projection.
In: Natural Research Council, Changing Climate, Report of the Carbon Dioxide Assessment Committee. National Academy Press, Washington, D.C. pp. 216-241, 1983.

69. Woodwell, G.M.; Hobbie, J.E.; Houghton, R.A.; Melillo, J.M.; Moore, B.; Peterson, B.J.; Shaver, G.R.
Global deforestation: contribution to atmospheric carbon dioxide.
Science 222: 1081-1086, 1983.

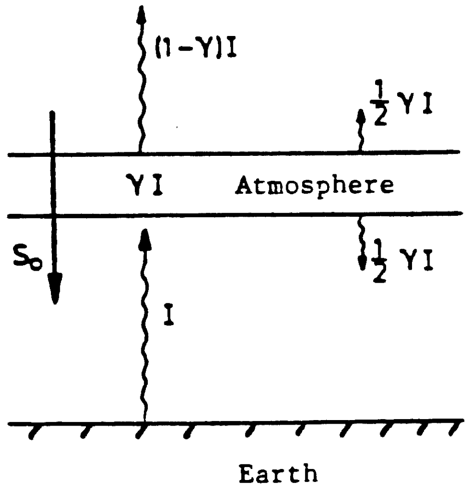


Figure 1

The greenhouse effect: S_o is the solar radiation, I the long-wavelength (infrared) radiation of the earth's surface and Y is the fraction absorbed by the greenhouse gases in the atmosphere (source: Mureau, R. Kooldioxyde (CO_2) en klimaat. In: Hermans, L.J.F.; Hoff, A.J. (eds), Energie een blik in de toekomst. Het Spectrum, Utrecht, The Netherlands, pp 68-86, 1982).

The sun's energy passes through the atmosphere, warms the earth's surface, and is then reradiated into space at longer, infrared wavelengths. The balance of incoming and outgoing radiation determines the planet's temperature. Some atmospheric gases absorb some of the outgoing infrared (e.g. CO_2 in a band of 14-16 µm), trapping heat in a "greenhouse effect".

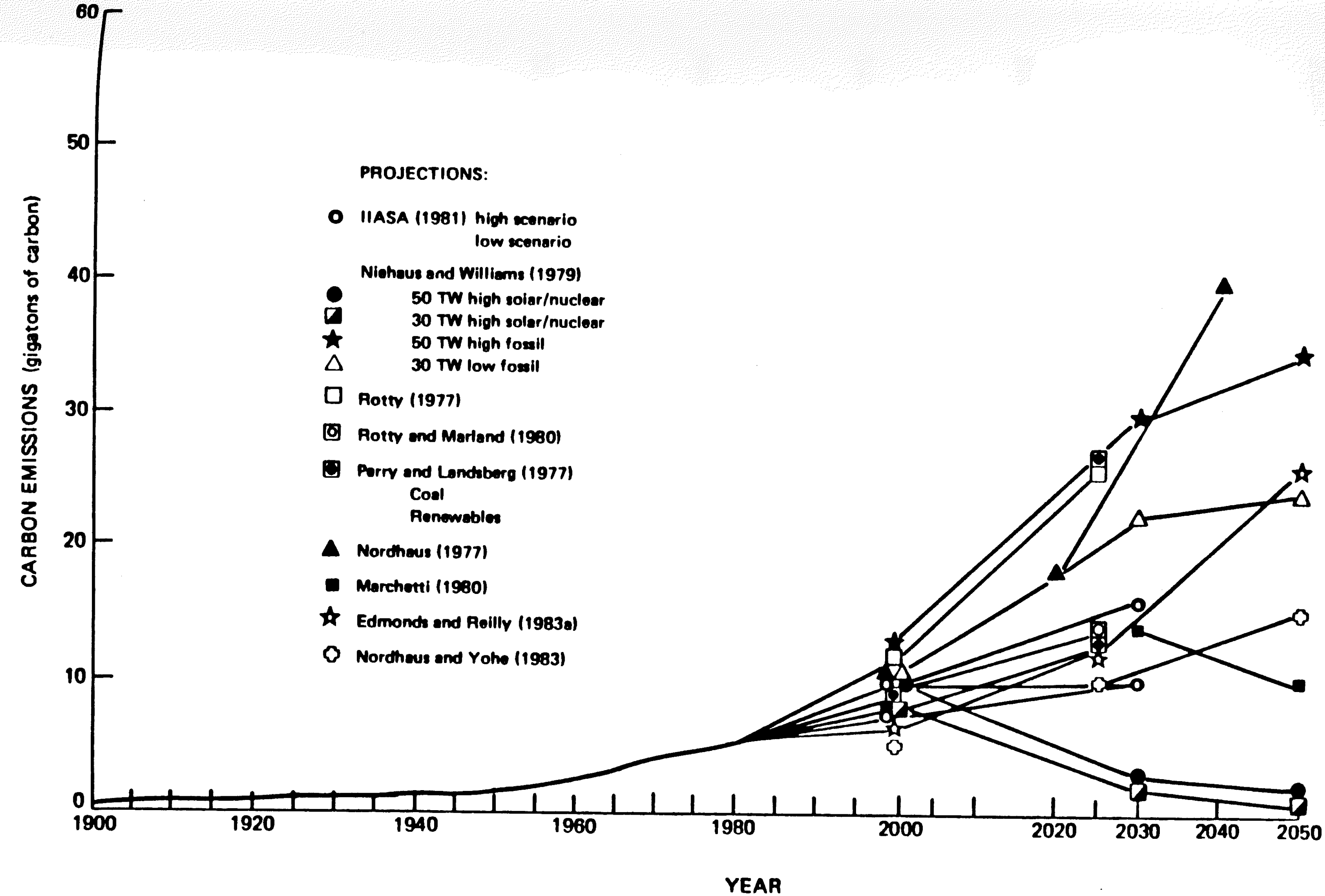


Figure 2

CO_2 emissions derived from long-range projections and historic production from fossil fuels. Data until 1980 are actual measurements; after 1980 model-calculated projections (source: Carbon Dioxide Assessment Committee, Changing Climate. National Academy Press, Washington, DC, 1983).

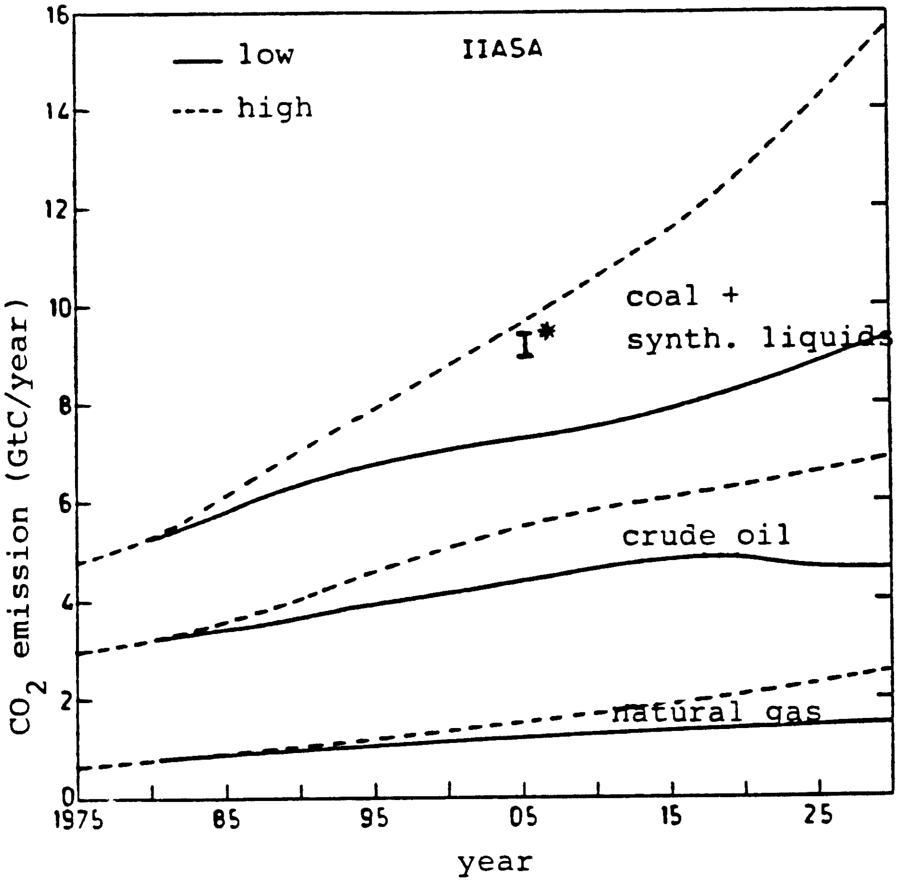


Figure 3

Projected CO_2 emissions generated with the IIASA Energy Systems Programme. For the individual fuels the emissions are cumulatively presented for the lower- and higher-demand cases (source: Deeladvies inzake CO_2-problematiek, Gezondheidsraad, The Hague, The Netherlands, 1983).

* Shell scenario figures for total emissions.

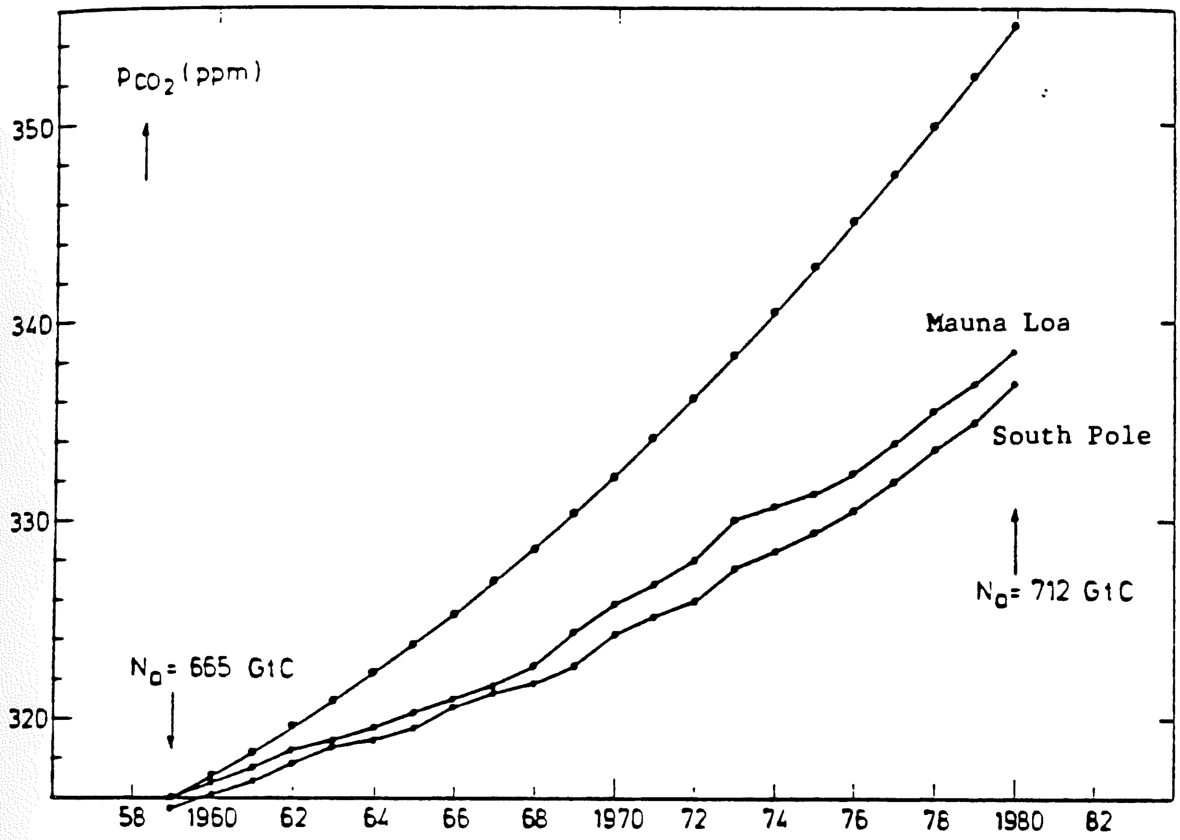


Figure 4

The hypothetical atmospheric CO_2 concentrations based on man-made CO_2 emissions with AF=100% (airborne fraction) and the observed concentrations at Mauna Loa and the South Pole with AF=56%; N_a is the amount of carbon present in the atmosphere (source: Deeladvies inzake CO_2-problematiek, Gezondheidsraad, The Hague, The Netherlands, 1983).

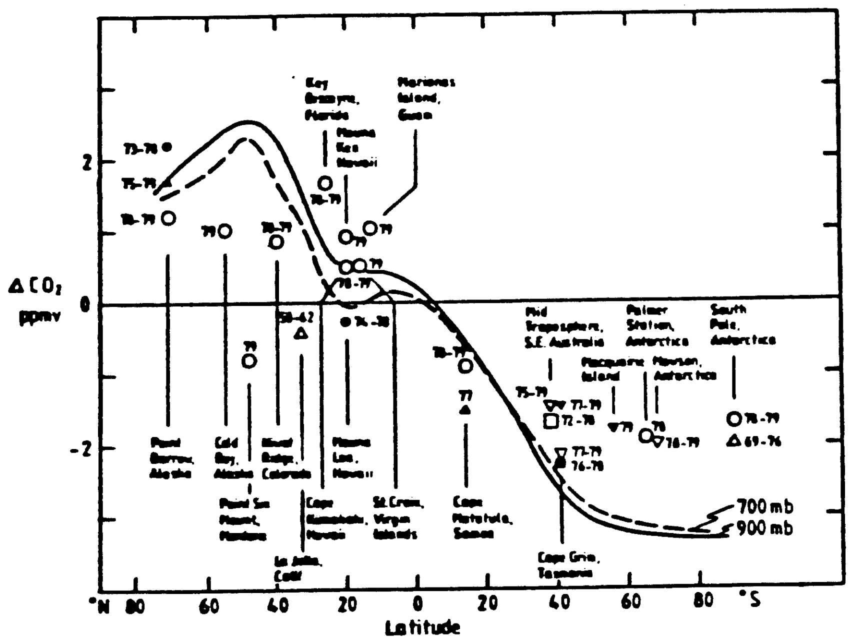


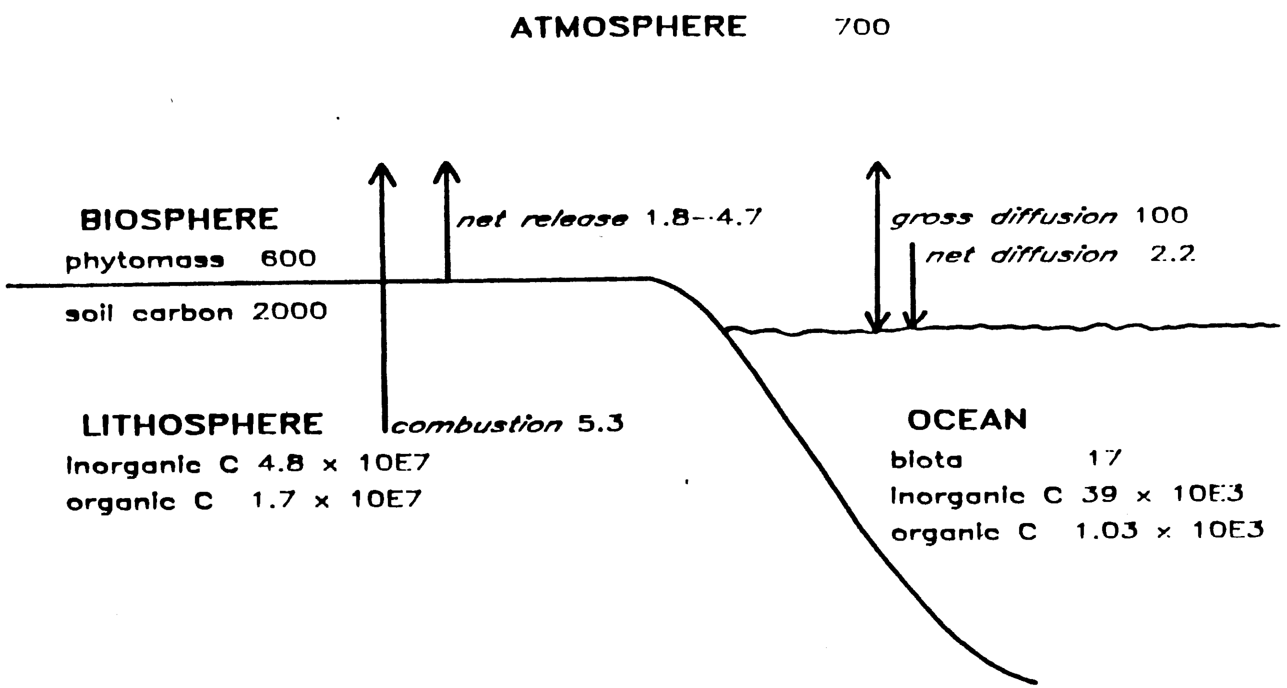
Figure 5

Difference between the annual mean CO_2 concentration in the air at ground-level observed at different places in the world and at Mauna Loa, Hawaii, plotted as a function of latitude. The numbers adjacent to the data points indicate the observation time (source: Papaud, A.; Poisson, A., Le cycle du carbon et sa perturbation par les activités humaines: un apercu du problème. Oceanologica Acta 8:133-145, 1983).

N.B. The two lines represent the model simulations at the altitudes corresponding with 700 and 900 mbar.

Figure 6

The global carbon cycle.
Major carbon reservoirs (in GtC), and natural and (quantified) anthropogenic fluxes (in GtC per year).
1 GtC = 1 gigaton of carbon = 10^{15} g C.



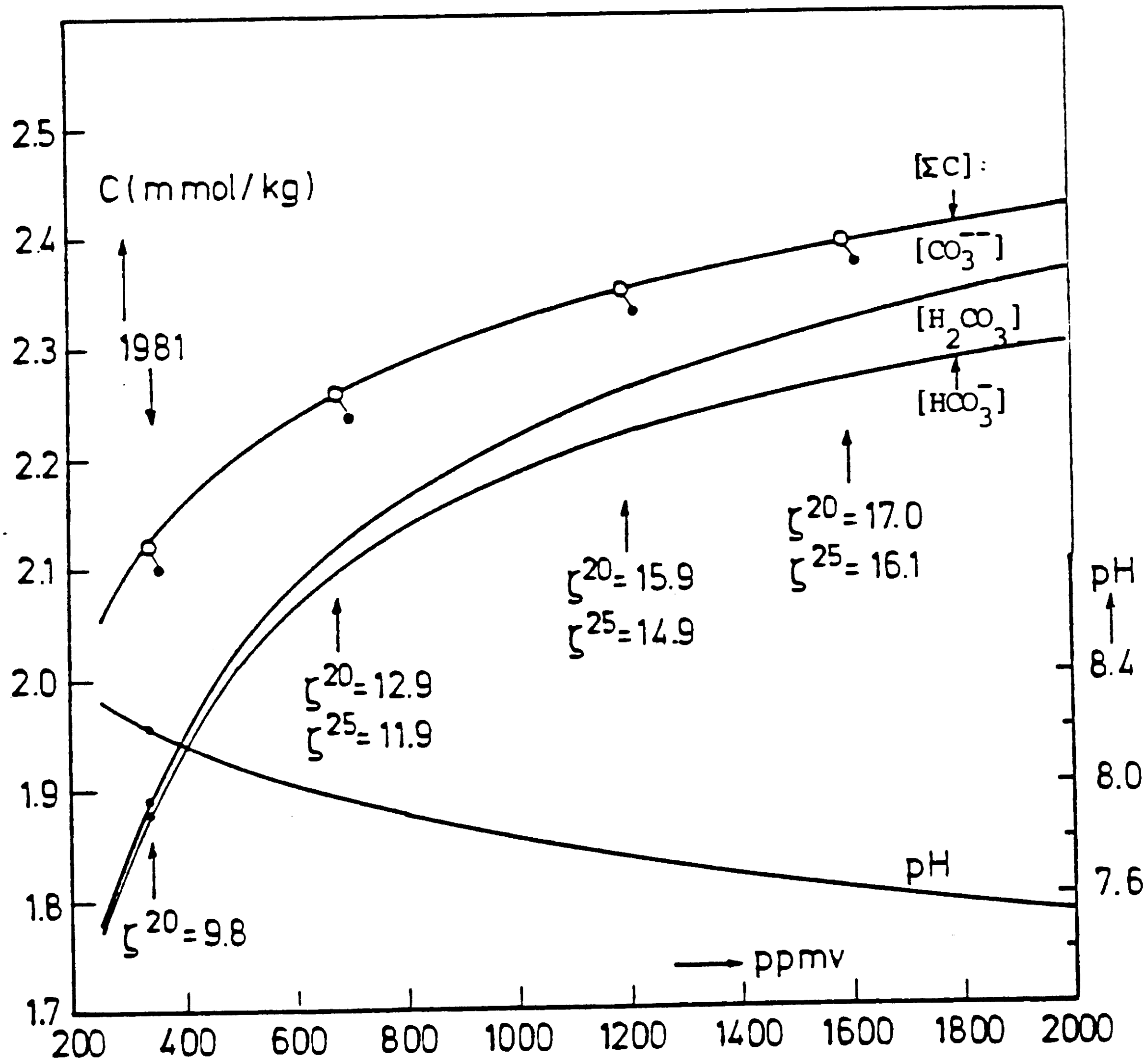


__Figure 7__

Variation of the buffer factor of seawater with changing total CO_2. Concentrations (at 20°C) of total dissolved inorganic carbon (DIC = Σ C) and of HCO_3^- in seawater (in mM/kg) are given in relation to the partial pressure of carbon dioxide gas (pCO_2 in ppmv). The concentrations of dissolved CO_2 (H_2CO_3) and of CO_3^{2-} are given as difference between the curves. For a few CO_2 concentrations (e.g. the 1981 value of 340 ppmv and its doubling) the buffer factors ς^{20} (at 20°C) and ς^{25} (at 25°C) are given. Increasing CO_2 levels raise the buffer factor, diminish the oceans tendency to absorb CO_2 (i.e. proportionally less increase in oceanic carbon) and decrease pH (source: Deeladvies inzake CO_2-problematiek, Gezondheidsraad, The Hague, The Netherlands, 1983).

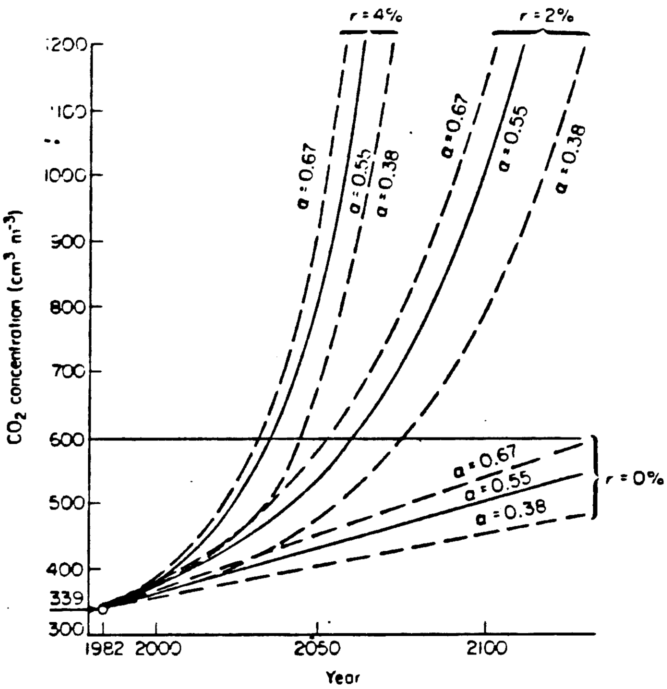


Figure 8

Increase in atmospheric CO_2 concentration over the next 150 years assuming growth rate in emissions of 4, 2 and 0% per year (r) for airborne fractions (α) of 0.38, 0.55 and 0.67 (source: Liss, P.S.; Crane, A.J., Man-made Carbon Dioxide and Climatic Change: a Review of Scientific Problems. Geobooks, Norwich, 1983).

The growth rate of CO_2 emissions from 1973 to the early 1980s fell to below 2% per year and there is a consensus now that the most likely time for a doubling of the CO_2 concentration (i.e. passing 600 ppm) lies in the third quarter of the next century.

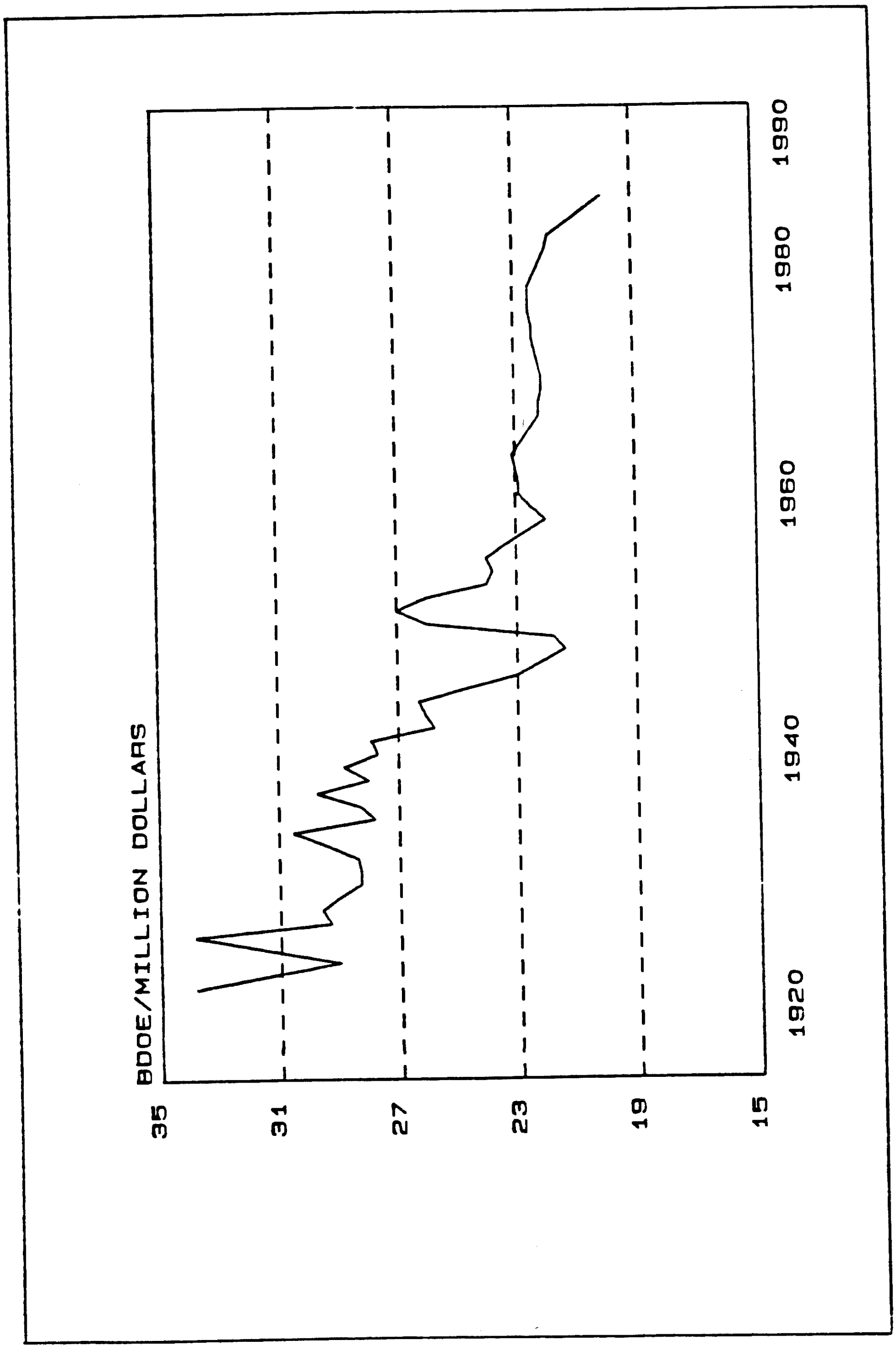
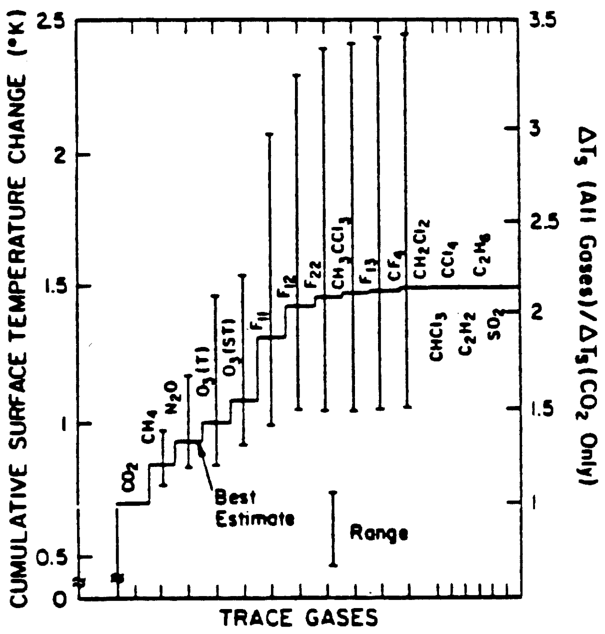


Figure 9

Falling energy intensity in the USA (source: Group Planning Scenarios).



<u>Figure 10</u>

Modelled cumulative surface warming due to increase in CO_2 and other gases over the period 1980 to 2030 (source: Ramanathan, V. et al., Trace gas trends and their potential role in climate change. J. Geophys. Res. 90:5547-5566, 1985).

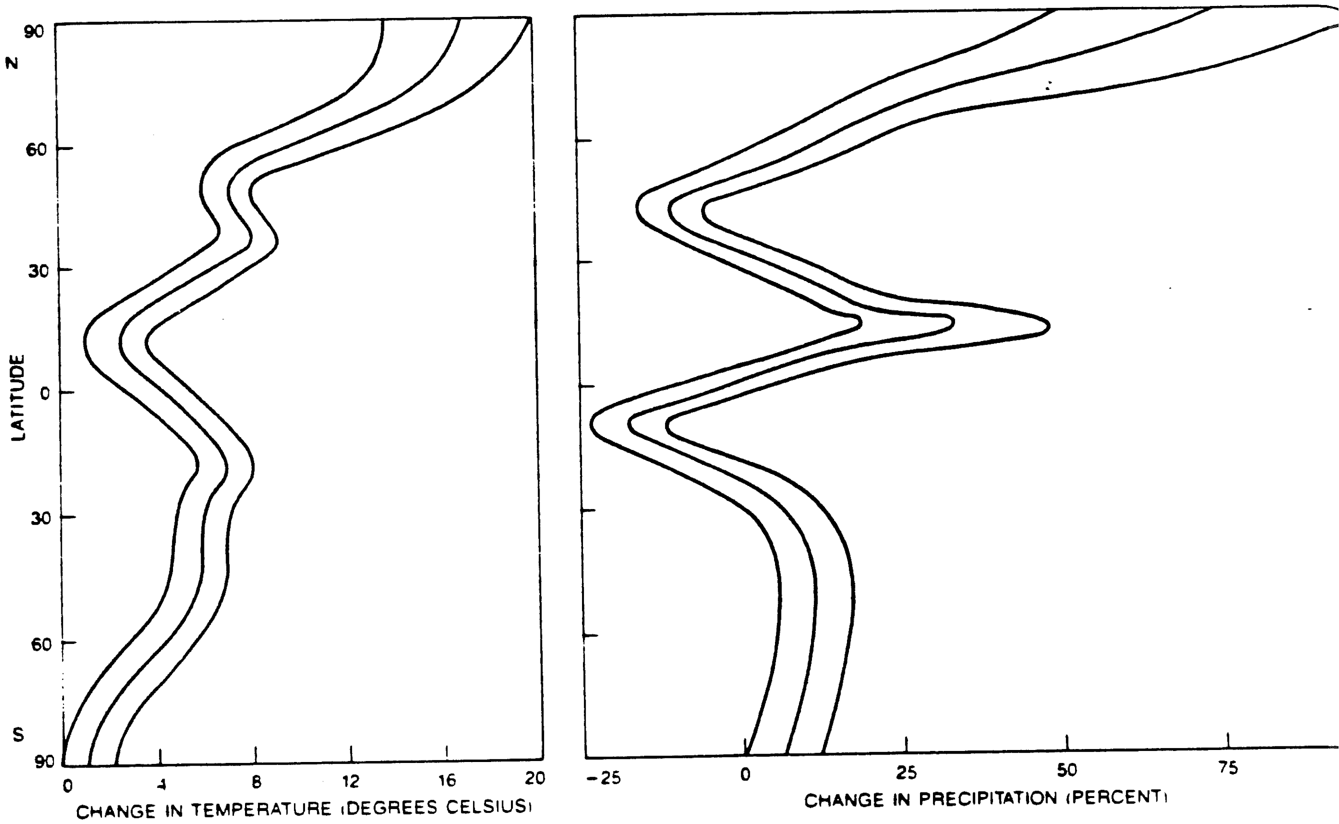


Figure 11

Modelled climatic effects of a doubling of the present atmospheric CO_2 concentration. The graphs show the projected variation by latitude in temperature and precipitation. The three curves in each group reflect the range of possibilities (source: Revelle, R., Carbon dioxide and world climate. Sci. Amer. 247:33-41, 1982).

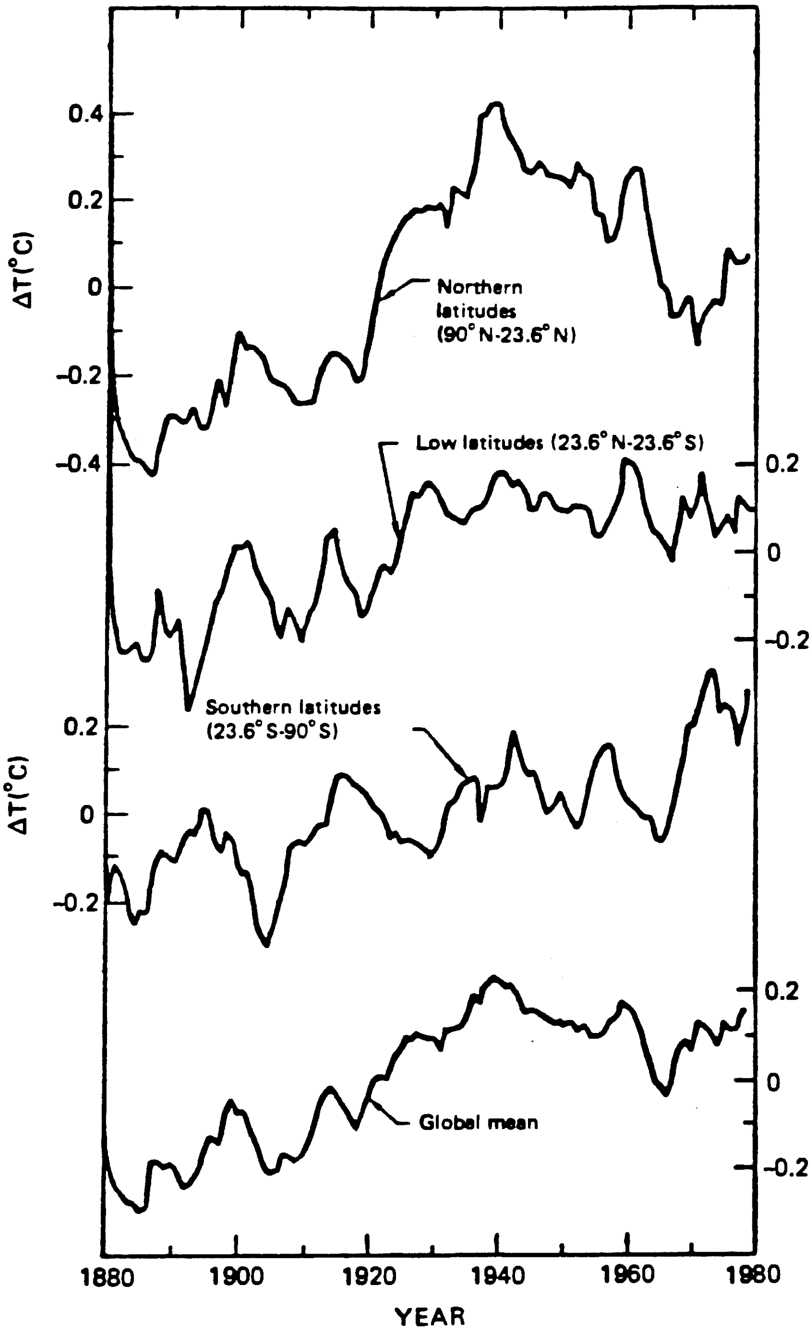


Figure 12

Reconstruction of surface-air-temperature anomalies for various latitude bands (source: Hansen, J. et al., Climate impact of increasing atmospheric carbon dioxide. Science 213:957-966, 1981).

Table 1. CO2 emissions per year by fuel type (10^6 tonnes C/year)
(source: Jaske, R.T., Carbon dioxide - the premier environmental challenge of our time. Environ. Progress 2:145-148, 1983)

	1950	1975	1980	% increase 1950-75	% increase 1975-80
all fossil fuels	1600	4400	5000	4.46	1.86
coal and coal products	1100	1600	1950	1.72	2.57
oil and refined products	400	2200	2300	2.11	1.11
gas and gas by-products	100	600	750	8.06	3.23

Table 2. Carbon produced (as CO2) from selected energy sources
(source: Jaske, R.T., Carbon dioxide - the premier environmental challenge of our time. Environ. Progress 2:145-148, 1983)

Fuel source or type	CO2 per fuel energy content (kg/MJ)
coal in direct combustion	23.9
liquid fuel from crude oil	19.7
natural gas	14.1
synthetic liquids from coal	37 - 42
synthetic liquids from shale	43 - 66

Table 3. CO2 emissions per region (in GtC) and per capita (in tC) in 1975 (GtC = 1 gigaton of carbon = 10^9 ton of C = 10^{15} g carbon = 44/12 GtCO2)
(source: Deeladvies inzake CO2-problematiek, Gezondheidsraad, The Hague, The Netherlands, 1983)

region	CO2 emission	population (millions)	CO2 emissions per capita
North America	1.426	237	6.017
USSR + E. Europe	1.218	363	3.355
W. Europe, Japan S. Africa, Australia Israel, New Zealand	1.391	560	2.484
L. and M. America	0.160	319	0.502
M. Africa + S.E. Asia	0.163	1422	0.115
Middle East + N. Africa	0.058	133	0.436
China + Central Asia	0.296	912	0.325
World	4.712	3946	1.194

Table 4. Estimates of the abundance of trace chemicals in the global atmosphere of 1980 and 2030 (source: ref. 47)

Chemical Group	Chemical Formula	Dominant Source*	Dominant Sink*	Estimated Average Residence Time (τ_r), years	Year 1980 Global Average Mixing Ratio, ppb†	Year 2030 Probable Global Average Concentration, ppb: Best Estimate	Year 2030 Probable Global Average Concentration, ppb: Possible Range	Remarks (also see text for details)
Carbon dioxide	CO_2	N,A	O	2	339 x 10^3	450 x 10^3		Based on a 2.4% increase over the next 50 years
Nitrogen compounds	N_2O	N,A	S(UV)	120	300	375	350-450	Combustion and fertilizer sources
	NH_3	N,A	T	0.01	< 1	< 1		Concentration variable and poorly characterized
	$(NO + NO_2)$	N,A	T(OH)	0.001	0.05	0.05	0.05-0.1	Concentration variable and poorly characterized
Sulfur compounds	CSO	N,A	T(O,OH)?	1(?)	0.52	0.52		Sources and sinks largely unknown
	CS_2	N,A	T	1(?)	< 0.005	< 0.005		Sources uncharacterized
	SO_2	A(?)	T(OH)	0.001	0.1	0.1	0.1-0.2	Given the short lifetime the global presence of SO_2 is unexplained
	H_2S	N	T(OH)	0.001	< 0.05	< 0.05		
Fully fluorinated species	CF_4 (F14)	A	I	> 500	0.07	0.24	0.2-0.31	Aluminum industry a major source
	C_2F_6 (F116)	A	I	> 500	0.004	0.02	0.01-0.04	Aluminum industry a major source
	SF_6	A	I	> 500	0.001	0.003	0.002-0.05	
Chlorofluoro-carbons	$CClF_3$ (F13)	A	S(UV),I	400	0.007	0.06	0.04-0.1	All chlorofluorocarbons are of exclusive man-made origin. A number of regulatory actions are pending. The nature of regulations and their effectiveness would greatly affect the growth of these chemicals over the next 50 years.
	CCl_2F_2 (F12)		S(UV)	110	0.28	1.8	0.9-3.5	
	$CHClF_2$ (F22)	A	T(OH)	20	0.06	0.9	0.4-1.9	
	CCl_3F (F11)	A	S(UV)	65	0.18	1.1	0.5-2.0	
	CF_3CF_2Cl (F115)	A	S(UV)	380	0.005	0.04	0.02-0.1	
	$CClF_2CClF_2$ (F114)	A	S(UV)	180	0.015	0.14	0.06-0.3	
	CCl_2FCClF_2 (F113)	A	S(UV)	90	0.025	0.17	0.08-0.3	
Chlorocarbons	CH_3Cl	N(O)	T(OH)	1.5	0.6	0.6	0.6-0.7	Dominant natural chlorine carrier of oceanic origin
	CH_2Cl_2	A	T(OH)	0.6	0.03	0.2	0.1-0.3	A popular reactive but nontoxic solvent
	$CHCl_3$	A	T(OH)	0.7	0.01	0.03	0.02-0.1	Used for manufacture of F22; many secondary sources also exist
	CCl_4	A	S(UV)	25-50	0.13	0.3	0.2-0.4	Used in manufacture of fluorocarbons; many other applications as well
	CH_2ClCH_2Cl	A	T(OH)	0.4	0.03	0.1	0.06-0.3	A major chemical intermediate (global production ≈ 10 tg/yr); possibly toxic
	CH_3CCl_3	A	T(OH)	8.0	0.14	1.5	0.7-3.7	Nontoxic, largely uncontrolled degreasing solvent
	C_2HCl_3	A	T(OH)	0.02	0.005	0.01	0.005-0.02	Possibly toxic, declining markets because of substitution to CH_3CCl_3
	C_2Cl_4	A	T(OH)	0.5	0.03	0.07	0.03-0.2	Possibly toxic, moderate growth due to substitution to CH_3CCl_3
Brominated and iodated species	CH_3Br	N	T(OH)	1.7	0.01	0.01	0.01-0.02	Major natural bromine carrier
	$CBrF_3$ (F13B1)	A	S(UV)	110	0.001	0.005	0.003-0.01	Fire extinguisher
	CH_2BrCH_2Br	A	T(OH)	0.4	0.002	0.002	0.001-0.01	Major gasoline additive for lead scavenging; also a fumigant
	CH_3I	N	T(UV)	0.02	0.002	0.002		Exclusively of oceanic origin
Hydrocarbons, CO, H_2	CH_4	N	T(OH)	5-10	1650	2340	1850-3300	A trend showing increase over the last 2 years has been identified
	C_2H_6	N	T(OH)	0.3	0.8	0.8	0.8-1.2	Predominantly of auto exhaust origin
	C_2H_2	A	T(OH)	0.3	0.06	0.1	0.06-0.16	No trend has been identified to date
	C_3H_8	N,	T(OH)	0.03	0.05	0.05	0.05-0.1	No trend has been identified to date
	CO	N,A	T(OH)	0.3	90	115	90-160	No trend has been identified to date
	H_2	N,A	T(SL,OH)	2	560	760	560-1140	
Ozone	O_3 (Tropospheric)	N	T(UV, SL,O)	0.1-0.3	F(Z)‡	12.5%		A small trend appears to exist but data are insufficient
Aldehydes	HCHO	N	T(OH,UV)	0.001	0.2	0.2		Secondary products of hydrocarbon oxidation
	CH_3CHO	N	T(OH,UV)	0.001	0.02	0.02		1980 concentration estimated from theory

*N, natural; A, anthropogenic; O, oceanic; S, stratosphere; UV, ultraviolet photolysis; T, troposphere; OH, hydroxyl radical removal; I, ionospheric and extreme UV and electron capture removal; SL, soil sink.

†These concentrations are integrated averages; for chemicals with lifetimes of 10 years or less, significant latitudinal gradients can be expected in the troposphere; for chemicals with extremely short lifetimes (0.001-0.3 years) vertical gradients may also be encountered.

‡Varies from 25 ppbv at the surface to about 70 ppbv at 9 km. The concentration was increased uniformly by the same percentage from the surface to 9 km.

Table 5. Net primary productivities (NPP) per given areas, total areas (in 1980), total NPP and actual biomass per ecosystem. The model calculated changes since 1780 are presented in brackets. (source: Ajtay, G.L. et al., Terrestrial primary production and phytomass. In: Bolin, B. et al. (eds), The Global Carbon Cycle, Scope Report No. 13, Wiley, New York, pp 129-187, 1979).

	(NPP) $gC.m^{-2}.yr^{-1}$	area 10^{12} m^2	NPP GtC yr^{-1}	biomass GtC
tropical forest	720	36.1 (- 8%)	27.8	324.7 (-18%)
temperate forest	510	17.0 (- 6%)	8.7	186.8 (-11%)
grassland	570	18.8 (+25%)	10.7	15.1 (+19%)
agricultural land	430	17.4 (+34%)	7.5	3.0 (+27%)
human area	100	2.0 (+1900%)	0.2	1.4 (+1200%)
tundra and semi-desert	70	29.7 (- 4%)	2.1	13.3 (+ 1%)
total		121.1	57.0	544.3

Table 6. Carbon emissions(in GtC) from the combustion of fossil and fuels (source: Group Scenario).

NEXT WAVE

	commercial fuels				
	oil	coal	gas	total	total + NCE*
1983	2.52	2.36	0.77	5.65	6.28
1985	2.61	2.56	0.83	6.00	
1990	2.61	2.83	0.89	6.33	
1995	2.61	3.14	0.97	6.72	
2000	2.70	3.62	1.07	7.39	
2005	2.84	4.23	1.16	8.23	9.39

DIVIDED WORLD

	commercial fuels				
	oil	coal	gas	total	total + NCE
1983	2.52	2.36	0.77	5.65	6.28
1985	2.59	2.50	0.81	5.90	
1990	2.70	2.66	0.87	6.23	
1995	2.81	2.95	0.92	6.68	
2000	2.88	3.28	0.98	7.14	
2005	3.03	3.66	1.01	7.70	8.87

* Non-Commercial Energy (biomass)

Table 7. Shell Group interest in fossil fuels in 1984 (source: 1985 information Handbook)

fuel	world production	Group interest	%
oil (million bbl/d)	58.2	4.5	7.7
gas (milliard m^3/yr)	1565	56	3.6
coal (million t/yr)	4147	32	0.8

Table 8. Contribution to global CO2 emissions from fuels sold by the Shell Group in 1984 (source: Shell Coal)

	carbon emissions (gigatonnes of carbon)	
fuel	total world	Group share
oil	2.56 (40%)	0.20 (3.1%)
gas	0.80 (12%)	0.03 (0.5%)
coal	2.46 (38%)	0.02 (0.4%)
NCE*	0.63 (10%)	0 (0.0%)
total	6.45 (100%)	0.25 (4%)

* NCE = Non-Commercial Energy (biomass)

APPENDIX 1

The CO_2/carbonate system in the ocean

The majority of carbon present in the ocean is in the form of dissolved inorganic carbon, i.e. 89% as bicarbonate ion (HCO_3^-), 10% as carbonate ion (CO_3^{--}) and 1% as dissolved CO_2. The thermodynamic equilibrium of all forms of inorganic carbon in the atmosphere and the oceans is determined by the following reactions:

$$CO_2 \text{ (atmosphere)} \rightleftharpoons CO_2 \text{ (dissolved)} \qquad (1)$$

$$CO_2 \text{ (dissolved)} + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons HCO_3^- + H^+ \qquad (2)$$

$$HCO_3^- \rightleftharpoons CO_3^{--} + H^+ \qquad (3)$$

$$H_3BO_3 \rightleftharpoons H_2BO_3^- + H^+ \qquad (4)$$

$$H_2O \rightleftharpoons OH^- + H^+ \qquad (5)$$

In water carbonic acid largely dissociates, while only about 10% of bicarbonate dissociates. The chemical equilibria exert a buffering action on the uptake of additional CO_2 by the ocean. The equilibrium constants of the above reactions are:

$$H = p\,CO_2 \,/\, [CO_2] \qquad (6)$$

$$K_1 = [HCO_3^-]\,[H^+] \,/\, [CO_2] \qquad (7)$$

$$K_2 = [CO_3^{--}]\,[H^+] \,/\, [HCO_3^-] \qquad (8)$$

where

[ ] = concentrations in water
H = Henry's law constant
pCO_2 = equilibrium partial pressure in the gaseous phase

The constant H is dependent on the temperature and K depends on temperature and salinity.

The concentration of total inorganic dissolved carbon is:

$$C = [CO_2] + [HCO_3^-] + [CO_3^{--}] \qquad (9)$$

and the alkalinity is defined as:

$$A = [HCO_3^-] + 2[CO_3^{--}] + [H_2BO_3^-] + [OH^-] - [H^+] \qquad (10)$$

The alkalinity arises from the dissolution of minerals in seawater, principally calcium carbonate. The alkalinity is defined as the amount of acid required to titrate 1 kg of seawater to a constant pH value, corresponding to conversion of bicarbonate and carbonate ions to carbonic acid.

An increasing concentration of CO_2 in seawater shifts equilibrium (2) to the right and by an increasing $[H^+]$ equilibrium (3) to the left. Thus, the principal effect is to consume carbonate ion:

$$\Delta H_2CO_3 + \Delta CO_3^{--} \longrightarrow 2\Delta HCO_3^- \qquad (11)$$

Δ: deviation from stationary state

The CO_2 added to the ocean (i.e. $\Delta\Sigma C$) is therefore:

$$\Delta \Sigma C = -\Delta[CO_3^{--}] \qquad (12)$$

As the concentration of bicarbonate is already very high, a change as a consequence of (11) is negligibly small and the relative changes in $[H_2CO_3]$ and $[CO_3^{--}]$ are practically of the same order:

$$\frac{\Delta[H_2CO_3]}{[H_2CO_3]} = -\frac{\Delta[CO_3^{--}]}{[CO_3^{--}]} \qquad (13)$$

Equations (12) and (13) can be transformed to:

$$\frac{\Delta[H_2CO_3]}{[H_2CO_3]} = \frac{\Delta\Sigma C}{[CO_3^{--}]} = \frac{\Sigma C}{[CO_3^{--}]} \times \frac{\Delta\Sigma C}{\Sigma C} \qquad (14)$$

As already mentioned above $[CO_3^{--}]$ is about 10% of the ΣC, so that the factor $\Sigma C/[CO_3^{--}]$ is about 10. As there is a simple relationship between the atmospheric CO_2 and the oceanic carbon concentration (1, 6), any change may be presented by:

$$\frac{\Delta pCO_2}{pCO_2} = \zeta \frac{\Delta\Sigma C}{\Sigma C} \qquad (15)$$

This yields the so-called evasion factor:

$$\zeta = \frac{\Delta pCO_2/pCO_2}{\Delta\Sigma C/\Sigma C} \qquad (16)$$

In case pCO_2 is explicitely identified to p_s (CO_2 partial pressure in the ocean surface layer), ζ is the evasion factor or the Revelle factor R, i.e. the "buffer factor". The factor varies with temperature and has a numerical value of about 10. In essence a 10% change in pCO_2 produces only a 1% change in CO_2.

If the CO_2 content of the atmosphere and therefore of the surface ocean increases, $[CO_3^{--}]$ decreases and the value of ζ rises (see also Fig. 7). The resistance to change subsequently increases, the ocean absorbs proportionally less CO_2, and the airborne fraction rises. This complex

system is sensitive to the alkalinity / total CO_2 ratio, and hence pH. Adding CO_2 gas to seawater (11) does not change the alkalinity since charge balance is not altered (10); the dissolution or precipitation of $CaCO_3$, however, does.
The principal forms of $CaCO_3$ in the ocean are calcite and aragonite, which are secreted by calcareous organisms to form their shells. Surface seawater is supersaturated with respect to both calcite and aragonite. The solubility of $CaCO_3$ increases with increasing pressure, decreasing temperature and increasing pH; thus, the deep ocean is undersaturated and dissolution of $CaCO_3$ occurs there.

If CO_2 is added to the surface ocean, the pH decreases and the tendency for $CaCO_3$ dissolution increases. If this occurs, both the alkalinity (10) and the total CO_2 (9) increase. Although this process generates an increase in total CO_2, the net effect of the alkalinity increase would be to enhance the ocean's capacity for CO_2 uptake by keeping the buffer factor constant and providing CO_3^{--}-ions (16).

1989 New York Times article,

Greenhouse effect: Shell Anticipates a Sea Change

New Materials Altering the Aircraft Industry

By JONATHAN P. HICKS

The race to develop stronger, lighter materials that will make aircraft sturdier and more fuel-efficient is intensifying. After a sluggish start a few years ago, a lighter version of aluminum, called aluminum lithium, appears to be gaining a foothold in the aerospace industry. But the use of advanced polymer composite materials — plastic resins reinforced by materials like glass or steel — is also growing quickly.

The debate over which product is better centers on the question of whether composite materials, which can be much more expensive than aluminum lithium, can more than offset the difference through their lighter weight, which allows planes to consume less fuel.

Since aircraft manufacturers began in earnest to substitute other materials for aluminum in making airplane bodies a decade ago, composite materials have jumped to an average of 14 percent of the structural weight of commercial and military airplanes from 2 percent.

Planes will be stronger and use less fuel.

Aluminum lithium is just starting to be used on a limited basis by airplane manufacturers and now accounts for about 1 percent of the aluminum that goes into aircraft. The metal is used primarily on wing edges at this point. Composite materials are used on a wide variety of aircraft parts, ranging from floors and door panels to blades of helicopters.

Among the companies beginning to use aluminum lithium are Airbus Industrie, the four-nation European aircraft manufacturing consortium, and its subcontractors, as well as the McDonnell Douglas Corporation, particularly in its military aircraft. And while they use some composite materials, they say they are looking to use more aluminum lithium.

The major producers of aluminum lithium are Alcoa, Alcan Aluminium, Reynolds Aluminum and Pechiney of France.

The Boeing Company has favored composites, saying it prefers a mixture of conventional aluminum and composites. "We have evaluated aluminum lithium thoroughly, but we feel that we have more cost-effective ways of eliminating weight," said Richard Schleh, a spokesman for Boeing. "With aluminum lithium being three to three and a half times as expensive as conventional aluminum, there has to be an awfully good reason to use it."

Mr. Schleh said Boeing's use of composites has risen to about 3 percent of the structural weight of commercial aircraft from about 1 percent a decade ago. And the use of composites at Boeing will probably increase in the next few years, he said.

The use of composites has grown particularly in military aircraft. While composites account for 45 to 50 percent of the structural weight of fighter and attack aircraft, they have reached 70 to 80 percent of the weight of military helicopters, aircraft manufacturers say. For commercial aircraft, the figure is now 7 percent. Because composites contain little metal, they are more effective in eluding radar signals, making them particularly attractive to military aircraft builders.

Major composite makers are Hercules Inc., BASF, Du Pont, Shell Chemical and Amoco.

Costs vs. Weight

While conventional aluminum alloys cost about $3 a pound, aluminum lithium costs $10 to $13 a pound. A composite material with a carbon graphite epoxy costs $40 to $70 a pound. But the composite material can produce a weight saving of as much as 20 percent over conventional aluminum, compared with the 10 to 12 percent weight reduction from aluminum lithium.

Increased Use Predicted

A year-old report by the Office of Technology Assessment, a Congressional support agency, predicted that increased use of advanced polymer composites would reduce aluminum in aircraft by at least 23 percent over the next decade. Moreover, some industry researchers predict that composites will account for as much as 55 percent of the structural weight of commercial aircraft within 10 years, up from the current 7 percent.

Aluminum industry officials predict that aluminum lithium will account for about 10 percent of the structural weight of the average commercial aircraft within five years, and 20 percent within 10 years.

Aluminum companies contend that aluminum lithium, which has been sold commercially for only a few years, will likely be the material of choice for the next generation of commercial and military aircraft because it is so much lighter than aluminum with conventional alloys, which use a combination of copper, nickel and magnesium to harden aluminum, and because it is cheaper than composites.

'Final Product Stiffer'

"Aluminum lithium is now becoming attractive because it gives the material the same properties that you get with conventional aluminum alloys," said Seymour G. Epstein, technical director of the Aluminum Association in Washington. "But it makes it significantly lighter without changing the stiffness. In fact, it makes the final product stiffer by about 10 percent."

"A wing made from conventional aluminum alloys would bend more easily than one made from aluminum lithium," said Frank H. Doyal, chief engineer of advanced development for Textron Aerostructures, a maker of airframe structures. The company, a Nashville-based subsidiary of Textron Inc., makes aircraft wing parts for the Airbus A330 and A340.

"Ten years from now, I presume, you're going to find that aluminum lithium will comprise the bulk of aluminum used," said Byron Davis, chief of technology for metallic materials for McDonnell Douglas in St. Louis. "It is just really coming on the scene now but I think it will win back some of the structural applications that aluminum lost to the advanced composites."

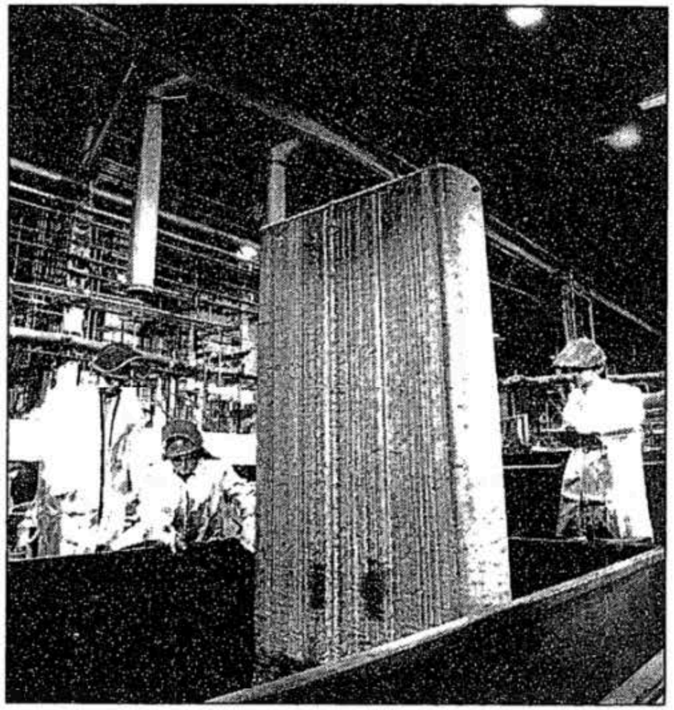
But several major chemical companies that produce composites are working to make them more competitive by cutting their cost. "Most of the companies in the composite and advanced materials business realize that it is such a labor-intensive business that we must all look at ways of producing them more efficiently," said Edmond J. Schneider, a spokesman for Hercules.

The production process for aluminum lithium is similar to that of aluminum made with conventional alloys. The major difference is that it requires cooling the metal with ethylene glycol, a combination of chemicals used in antifreeze, rather than water.

Alcoa officials say that the cost difference between aluminum lithium and conventional aluminum is unlikely to narrow until the use of the material is large enough to achieve economies of scale. Alcoa, the largest producer, has about 15 million pounds of aluminum lithium capacity, although domestic consumption of the material has reached only 5 million pounds. The total annual production of aluminum for aircraft use is now 400 million pounds.

Mr. Doyal of Textron said that while composite materials offer greater or comparable weight savings, aluminum lithium alloys "don't require the capital investment in new equipment that you have to have with composites; aluminum lithium can be processed with existing production methods."

Other experts also noted that with composites, new and expensive production processes must be established.



Alcoa

An aluminum lithium ingot being removed from an experimental casting pit at Alcoa Laboratories. The alloy, which is lighter than aluminum, appears to be gaining a foothold in the aerospace industry.

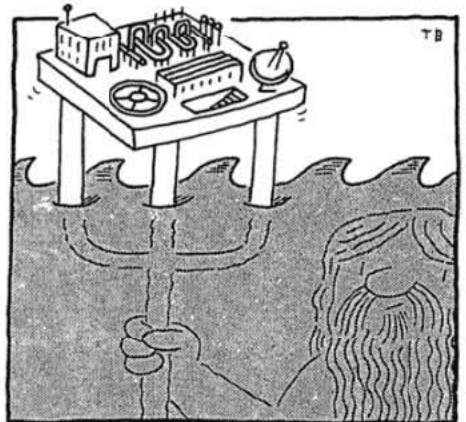
Greenhouse Effect: Shell Anticipates A Sea Change

Whether global warming will raise the level of the world's oceans is still being debated, but engineers who build natural-gas production platforms at Shell Oil do not want to take chances. In what is considered the first major project that takes account of the changes the greenhouse effect is expected to bring, the engineers are designing a huge platform that anticipates rising water in the North Sea.

Norske Shell, the company's Norwegian subsidiary, had been planning to build in the Troll gas field a 1.5-million-metric-ton structure that would stand in more than 300 meters of water, or about 1,000 feet, and rise 30 meters above the surface, or about 100 feet.

But if those are the dimensions of the structure when it is put in place in 1995, how much will be above the water in 2065, at the end of its life? Engineers are not sure. The global warming of the greenhouse effect, which is caused by carbon dioxide from combustion trapping the sun's heat in the atmosphere, is expected to raise the sea level in two ways: Warmer temperatures mean less water tied up in the ice caps, and therefore more in the oceans; also, warmer water occupies more space than cool water.

So the engineers are considering raising the platform from the standard 30 meters — the height now thought necessary to stay above the waves that come in a once-a-century storm — to 31 or 32 meters.



Tom Bloom

A one-meter increase would cost an additional $16 million, said Einar Knudsen, a spokesman for the company in Stavanger, Norway, and a two-meter rise roughly double that. The higher number is about 1 percent of the platform's projected cost.

Shell's problem with its gas platform is tougher than the engineering questions involved in building oil platforms, of which the North Sea has many. The oil platforms are typically expected to be in use for only 30 or 35 years. But according to Mr. Knudsen, "We have such huge gas reserves; we can see this production going on for up to 70 years."

PART TWO

Denial and Deception

Pivot to Denial
1988—1996

The year 1988 marked a turning point. In June 1988, James Hansen gave his historic testimony to Congress declaring that he and other scientists had detected a warming trend that could only be explained by human activities, primarily the burning of fossil fuels. With its core business in jeopardy, the oil industry began to construct a sprawling denial machine complete with massive advertising budgets, scientists for hire, and front groups to hammer home what they knew was not true, that climate science was too uncertain for the nation to act.

One of the first appearances of this change is a 1988 draft Exxon memo on *The Greenhouse Effect*, **Document 16**. The memo characterizes the climate models that the company's own scientists had supported years earlier as unreliable and adds the word "potential" to the term "enhanced greenhouse effect." The memo stakes out Exxon's leadership role in shaping API's position on global warming, which would transform the association into a major force for climate denial. Perhaps most revealing, the presentation presents Exxon's position clearly: to "emphasize the uncertainty in scientific conclusions regarding the potential enhanced greenhouse effect."

> **"The contrarian theories... do not offer convincing arguments against the conventional model of greenhouse gas emission-induced climate change"**
>
> *Global Climate Coalition (Exxon, Chevron, API, et. al), 1995*

Front organizations were formed with ambitious advertising plans. The Information Council for the Environment (ICE) presented itself as a resource for those concerned about global warming. ICE was funded primarily by coal companies, including two held by Chevron and Occidental. Exxon also had significant coal holdings at that time. In 1991, ICE ran a series of ads, **Document 17**, which claimed there to be no proof that CO_2 was the primary cause of global warming. The number one goal of the campaign was to "reposition global warming as theory (not fact)", an objective that itself reveals that global warming had long been accepted as scientific fact.

A 1994 internal Shell report, **Document 18**, reviews the company's new public position on climate science, which presents the conclusions of major scientific bodies along with unfounded suggestions of skepticism and uncertainty. The report highlights Shell's participation in various climate organizations whose goals were to discourage climate policy interventions— a clear change from its report published just six years earlier, which urged action before it became too late.

Another group, the Global Climate Coalition (GCC), became the largest industry voice in the public discussion around climate change. Exxon, Chevron, and API all played major roles. As described in their backgrounder, **Document 19**, the GCC argued that global warming was "part of natural warming trend" and discouraged climate action. In 1995, the GCC prepared a primer on climate change intended for the general public. A draft, **Document 20**, included remarkably direct statements confirming the scientific basis for the greenhouse effect and the impact of human emission, noting that global warming is real and "cannot be denied". But perhaps most revealing is a section that lists a series of "contrarian" arguments proposing alternate explanations for observed global warming. If just one could be shown to be valid, it would divert attention from efforts to control CO_2 emissions. Yet one by one, the primer knocks down these alternative explanations. In the end, the document concludes: "The contrarian theories raise interesting questions …but they do not offer convincing arguments against the conventional model of greenhouse gas emission-induced climate change." Not surprisingly, this section was removed from the final primer during a 1996 meeting of the GCC's Science and Technology Assessment Committee, **Document 21**.

1988 draft Exxon memo, *The Greenhouse Effect*

On file

Date 8/3/88

To: Dick

From: **Joseph M. Carlson**

Attached is a draft on the Greenhouse effect. As you can see, most of it is taken from the large II material. I haven't attempted to recheck any of the facts, given Brian's absence. The first two items on the last page are intended to address the question 'what do you think is the direct impact on Exxon's business.' I haven't checked them with Corporate Planning as yet.

Joe

THE GREENHOUSE EFFECT

ISSUE

THE GREENHOUSE EFFECT REFERS TO ATMOSPHERIC GASES WHICH RETAIN REFLECTED SOLAR RADIATION, WHICH IS ESSENTIAL TO THE SUPPORT OF LIFE ON EARTH. CURRENT CONCERN IS ASSOCIATED WITH THE "ENHANCED" GREENHOUSE EFFECT, OR THE POSSIBLE INCREASE IN GLOBAL SURFACE TEMPERATURES DUE TO AN INCREASED RATE OF BUILD-UP OF GREENHOUSE GASES.

BACKGROUND

- o THE GREENHOUSE EFFECT MAY BE ONE OF THE MOST SIGNIFICANT ENVIRONMENTAL ISSUES FOR THE 1990S.

- o GASES THAT FAVOR ABSORPTION OF INFRARED (IR) RADIATION: CARBON DIOXIDE, WATER VAPOR, METHANE, NITROUS OXIDE, CHLORO-FLUOROCARBONS, AND HALOGENS.

- THE PRINCIPAL GREENHOUSE GASES ARE BY-PRODUCTS OF FOSSIL FUEL COMBUSTION.

"ENHANCED" GREENHOUSE EFFECT

- MOLECULES OF CO_2 WHICH ARE EFFICIENT ABSORBERS OF REFLECTED SOLAR IR CAN CAUSE DISPROPORTIONATE WARMING OF THE ATMOSPHERE.

- THIS WARMING INCREASES THE EARTH'S SURFACE TEMPERATURE, IN TURN INCREASING WATER VAPORIZATION.

- WATER VAPOR MOLECULES ARE ALSO EFFICIENT IR ABSORBERS AND GREATLY MAGNIFY THE ORIGINAL CO_2 EFFECT. OTHER ATMOSPHERIC GASES LIKE TRACE QUANTITIES OF CHLORO-FLUOROCARBONS CAN TRIGGER THE WATER VAPOR WARMING CYCLE.

- THERE IS NO CONSENSUS ON THE NET EFFECT OF THESE PROCESSES.

- THERE IS SCIENTIFIC AGREEMENT ON TWO POINTS:
  - ATMOSPHERIC CO_2 IS INCREASING AND COULD DOUBLE IN 100 YEARS.

- Fossil fuels contribute about five billion tons/year of CO_2. Deforestation adds two-five billion tons per year.

Climate Models

o Most debate centers on projecting future impact using climate models.

o These models are extremely complex and require tracking CO_2 interactions in the atmosphere and biosphere and must address the role of trace gases, oceans, clouds, biomass and large ice formations at the poles. These interactions are not well understood.

  - The climate models are not very reliable because approximations are used to represent poorly understood interactions.

o Climate models predict a 1.5° C to 4.5° C global temperature increase in 100 years - depending on the projected growth in fossil fuel use.

- Such warming could result in partial polar ice cap melting with associated sea level rise and since CO_2 and H_2O vapor aid plant growth, there could be an acceleration or alteration in vegetation growth patterns favoring selected species.

- It is too early to specify the severity of the potential impacts of the enhanced Greenhouse effect.

- Actual measurements of northern hemisphere average temperatures show no clear pattern over a 20-year period from 1960 to 1980. When projected at a rate corresponding to about 2° C increase over 100 years, the trend does not escape from the uncertainty band for another 10 years.

Current Mitigation Efforts

- Reduction in chloro-fluorocarbon emissions to protect ozone in the upper atmosphere.

- o Protection of major global forest resources.

- o Continuing the emphasis on efficiency in energy generation and use.

Worldwide Research

- o National and international research programs are being established to monitor and evaluate the Greenhouse phenomenon.

- o In the U.S., about $25 million per year is budgeted for direct CO_2 Greenhouse research.

Exxon Research

- o In the last five years Exxon has supported both in-house and theoretical studies and outside research programs at key institutions.
  - Lamont Doherty Geological Observatory

- Columbia University Climate Center (total funds for both about $.6 million)

o Exxon scientists are interacting with key government agencies including the United Nations' Environmental Program, IPECA, OECD, DOE, and U.S. EPA.

o Exxon is providing leadership through API in developing the petroleum industry position.

<u>Exxon Position</u>

o Emphasize the uncertainty in scientific conclusions regarding the potential enhanced Greenhouse effect.

o Urge a balanced scientific approach.

o Due to current scientific uncertainty, Exxon is not conducting specific impact studies with respect to particular company operations or geographic regions.

o Exxon has not modified its energy outlook or forecasts to account for possible changes in fossil fuel demand or utilization due to the Greenhouse effect.

o Resist the overstatement and sensationalization of potential Greenhouse effect which could lead to noneconomic development of nonfossil fuel resources.

1991 collection of ICE marketing materials and strategy

May 2, 1991

Bill Brier
Edison Electric Institute
701 Pennsylvania Avenue N.W.
Washington, DC 20004-2696

<u>Information Council for the Environment Test Market Ad Materials</u>

Enclosed are the newspaper and radio ads as they will be running in Fargo, Flagstaff, and Bowling Green when our test campaign begins on May 12. We are still in production on a Bob Balling radio ad titled "Kentucky Colder" to be run only in Bowling Green. That ad will be completed next week and we'll send you your copy when we receive it.

Here's a listing of what you'll find in this packet:

1. Five newspaper ads
2. Schedule of the radio spots and newspaper ads for each market
3. Four sixty-second radio commercials (on tape), two scripts
4. Public Relations tour schedule*
5. Copy of letters that respondents requesting information will receive

*Schedule includes Fargo and Flagstaff. Bowling Green schedule with Dr. Pat Michaels will be completed next week.

The advertising will begin with full-page newspaper ads in each of the markets on May 12. The campaign will conclude on Sunday, June 9. Three full-page, two-color newspaper ads will run each of the four weeks of this campaign.

The cassette tape contains the four radio ads that will run in Flagstaff. The first two weeks of the schedule will feature the Dr. Bob Balling commercials exclusively. The final two weeks of the radio campaign will be an equal rotation of Dr. Balling and Bruce Williams.

The commercial rotations in Fargo and Bowling Green will differ. The scripts of the Rush Limbaugh commercials apply only to Fargo. These commercials will air in only the Rush Limbaugh radio program (11 AM to 1 PM, Monday through Friday.) In Fargo, Bruce Williams commercials will also run in only his Monday through Friday, 6 PM to 9 PM program. Dr. Balling commercials will air in all other Fargo radio schedules. We will send you the tape of the Rush Limbaugh radio commercials next week.

In Bowling Green, we will rotate three Dr. Balling commercials for the entire length of the radio schedule. The "Kentucky Colder" commercial will receive increased scheduling during the first two weeks of the campaign. The radio schedule will reach approximately 85% of our adult 25-54 target audience approximately 19 times in the four weeks of this campaign. This is a four-week, 1,600 gross rating point radio schedule.

Bill Brier
May 2, 1991
Page 2

The combined newspaper and radio reach is estimated to be 97% of our adult 25-54 target audience, with a combined frequency of 35.

We will begin follow-up research on Saturday, June 15, to determine the results of this campaign. Those results will be reported to all of our sponsors by August 5, 1991.

We appreciate all the help you've provided to make this test possible. Don't hesitate to call me if we can be of further assistance.

Fred Lukens

FL/srm

cc: Gale Klappa

INFORMED CITIZENS FOR THE ENVIRONMENT

Mission

The mission of the Informed Citizens for the Environment
is to develop an effective national communications program
to help ensure that action by the Administration and/or Congress
on the issue of global warming
is based on scientific evidence.

Strategies

1. Reposition global warming as theory (not fact).

2. Target print and radio media for maximum effectiveness.

3. Achieve broad participation across the entire electric utility industry.

4. Start small, start well, and build on early successes.

5. Get the test concepts developed and implemented as soon as possible.

6. "Test market" execution in early 1991.

7. Build national involvement as soon as "test market" results are in hand — summer 1991.

8. Go national in the late fall of 1991 with a media program.

9. Use a spokesman from the scientific community.

Our Plan

1. Build support for the concept of the ICE strategy among our neighbors.

2. Match Southern Company's commitment by having four or five of our neighbors join us in raising $125,000 by January 31, 1991.

3. Raise total commitments of $525,000 by January 31, 1991 to allow the test market project to proceed on schedule.

This report summarizes results of a benchmark survey of public awareness and opinion on issues related to global warming conducted in Chattanooga, Tennessee, Fargo, North Dakota, and Flagstaff, Arizona.

Methodology

The survey is based on a total of 1500 interviews, 500 in each of the three cities included in the sample. All interviews were conducted by telephone between February 13 and February 22, 1991. Other important points include the following:

- For each sample of 500 the margin of error is +/-4.4 percentage points at the midpoint of the 95% confidence interval;
- All interviews were conducted by trained, professional interviewers under the supervision of the Cambridge Reports Field Department;
- After the interviewing was completed, a 10% sample of the interviews was independently validated to ensure that proper interviewing techniques were followed;
- All interviews were returned to Cambridge Reports for coding and data processing.

Objectives

The survey and analysis were conducted to identify the following:

- Current awareness of and familiarity with the global warming issue;
- Recent exposure to information concerning global warming, including the types of media and sources in which the information appeared;
- Responses to various messages concerning global warming;
- Assessments of the credibility of various spokespersons and groups on topics related to global warming;
- Key audiences and media for messages concerning global warming.

technical sources also favor choosing the title "Information Council on the Environment" as the title for ICE, since this organization is perceived as a technical source, while "Informed Citizens for the Environment" carries both technical and activist connotations.

As a general strategy, we recommend that ICE concentrate on comparing possible solutions to the global warming problem, focusing in particular on the proper role of government, the need for research, and the costliness of inappropriate or premature legislation. The audience for these messages needs to see its personal stake in the issue if they are to become actively engaged and committed.

More specifically, the results of this study point toward two possible target audiences. One possible target audience includes those who are most receptive to messages describing the motivations and vested interests of people currently making pronouncements on global warming--for example, the statement that some members of the media scare the public about global warming to increase their audience and their influence. People who respond most favorably to such statements are older, less-educated males from larger households, who are not typically active information-seekers, and are not likely to be "green" consumers. Members of this group are skeptical about global warming, predisposed to favor the ICE agenda, and likely to be even more supportive of that agenda following exposure to new information. They are not, however, accustomed to taking political action. They are good targets for radio advertisements.

Another possible target segment is younger, lower-income women. These women are more receptive than other audience segments to factual information concerning the evidence for global warming. They are likely to be "green" consumers, to believe the earth is warming, and to think the problem is serious. However, they are also likely to soften their support for federal legislation after hearing new information on global warming. These women are good targets for magazine advertisements.

A campaign strategy reaching out to these target groups can help to change attitudes where change is most likely to occur, and also to strengthen support among favorable members of the public.

- Overall, a plurality of respondents choose the most conservative role for the federal government. Over one-third (36%) of the total sample (three cities combined) say the government should finance more research, while 30% support passage of legislation, and 24% would pass some laws but avoid costly programs.

- Similar to responses on other measures, Flagstaff residents (39%) are more likely than residents of Chattanooga or Fargo (25% each) to back federal legislation without any qualification concerning cost.

Specific responses to an open-ended question indicate that depletion of the ozone layer dominates top-of-mind concerns about global warming.

- Asked to describe global warming in their own words, just over one-quarter of all respondents cite destruction of the ozone layer, followed closely by changes in the weather and rises in temperature caused by pollution.

- Only 6% of all respondents name the greenhouse effect when asked to describe what global warming means to them.

Audience profile

In addition to perceptual and attitudinal measures, we also asked respondents about certain behaviors which might make them more or less receptive to information on global warming, and may also indicate the likelihood that they might take action on global warming issues. These behavioral measures are included frequently in the analyses discussed in this report, and include political activism, environmental activism, and likelihood of information-seeking.

- Looking at results for one measure of political activism, just under one-quarter (24%) of all respondents either contacted an elected official, wrote to an editor, or worked for a political candidate during the last year. Political activism is more common in Flagstaff (31%) than in either Chattanooga (22%) or Fargo (18%).

- Overall, 36% of all respondents have contributed to or been active in an environmental cause during the past year, and 22% identify strongly with the label "environmentalist." Combining these two measures, we find that 13% of all respondents in this survey meet the Cambridge Reports definition for "green" consumers--very close to our most recent national figure of 12% (March 1991).

Finally, the two statements referring directly to scientists say that scientists don't know whether carbon dioxide is causing global warming, and that some of the scientists predicting global warming said twenty years ago that the earth was getting colder.

- On average, respondents are as likely to agree with statements about motivations behind public information on global warming as they are to agree with statements about the evidence for global warming.
- On average, respondents are less likely to agree with statements about scientists and their theories than they are to agree with statements about motivations for public information or statements about evidence for global warming.
- Respondents are most likely to agree with the statement that recent satellite data shows the earth is getting warmer.
- Percentages of "don't know" responses reveal that members of the public feel more comfortable expressing opinions on others' motivations and tactics than they do expressing opinions on scientific issues. Nearly all respondents provide ratings for statements on motivations, while somewhat fewer express opinions on evidence, and still fewer are willing to pass judgment on scientists.

To explore these three types of messages further, we calculated an index for each set of statements (motivation, evidence, and scientists), based on results of the factor analysis. We then divided the sample into low, medium, and high agreement with each index, or set of items, to identify groups most likely to agree or disagree with each type of message.

- A plurality of Chattanooga residents agrees strongly with motivational statements saying that some groups scare the public about global warming to promote their own economic interests, while Flagstaff residents are most likely to disagree with these statements, and Fargo residents most often take a moderate position.
- Based on results for the evidence index, Fargo residents are least likely to agree that current evidence supports global warming, while Flagstaff residents are more likely to accept the evidence. Chattanooga residents are closely divided between low, moderate, and high agreement, although they are more likely than others to give "don't know" responses.

A factor analysis performed on the fourteen credibility ratings indicates that respondents group information sources into four types: industry spokespersons (local electric company, coal industry, Electric Information Council, and Paul Harvey); activist spokespersons (Ralph Nader, Sierra Club, Carl Sagan, Informed Citizens for the Environment); technical spokespersons (Information Council for the Environment, federal environmental officials, environmental scientist, Informed Citizens for the Environment); and individual spokespersons (Bruce Williams, Steven Schneider, Rush Limbaugh). (The second title for ICE–Informed Citizens for the Environment–is perceived as combining attributes of activist and technical sources, and is treated as a member of both groups in the analysis.)

- Technical sources receive the highest overall credibility ratings, followed closely by activist sources.
- Industry sources and individual spokespersons receive lower overall credibility ratings than either activist or technical sources.

Results also include extreme variations in recognition among the different information sources in the list. In fact, combining responses for those who have not heard of a source, do not know the source's credibility on global warming, or cannot rate the source as credible or not credible, the percentage not rating individual sources ranges from 13% (local electric company) to 92% (Steven Schneider).

- Industry sources are rated by more respondents than other types of sources, with the local electric company receiving the most ratings, and Paul Harvey second.
- Individual spokespersons (Bruce Williams, Steven Schneider, Rush Limbaugh) have lower overall recognition than other types of sources, receiving ratings from an average of only 15% of all respondents.
- In general, recognition for activist and technical sources falls in between recognition for industry sources and recognition for individual spokespersons.

- Those who are most likely to find activists credible typically are already familiar with global warming issues, and are likely to seek further information on the topic. They believe the earth is warming, rate the problem as serious, and support action through federal legislation. Demographically, they are most likely to be male, between 36 and 45 years of age, from higher education and income groups, or to be "green" consumers.

- Technical sources receive highest credibility ratings from younger females (especially those from 18 to 25 years of age) with lower incomes and some college education. Members of this group are not familiar with global warming, although they are likely to seek further information, and they are good targets for television advertising. They believe in global warming and support immediate federal legislation. They tend to rate global warming as a serious problem, and to rate it as even more serious after exposure to information on the topic.

Attitude change

As we reported earlier in this report, majorities of respondents see global warming as a problem which is at least somewhat serious, while a plurality endorse a limited role for the federal government in dealing with the problem. To identify audience members who are most likely to undergo attitude change in response to new information, we repeated these two items late in the interview, after respondents had heard the series of statements concerning global warming.

Comparing results on these key attitude measures, we find that exposure to information about global warming, regardless of its slant, leads to increases in perceived seriousness of global warming as a problem--most of those who "switch" attitudes on seriousness of global warming rate the problem as more serious after hearing the statements in the interview. However, the same messages lead to attitude change in both directions on the proper role for the federal government in dealing with global warming--respondents are just as likely to switch to less extreme positions (advocating further research) as they are to switch to more extreme positions (advocating legislation). In general, Chattanooga residents are more likely to change their positions than are residents of either Fargo or Flagstaff.

- Overall, nearly two in ten respondents (19%) rate global warming as more serious after hearing the statements in the interview. Notably, Chattanooga residents (24%) are most likely to switch to a more serious rating, compared with Fargo (19%) or Flagstaff (14%).

Similarly, we looked at associations between attitude change during the interview and the types of messages with which respondents tend to agree.

- Across the board, perceived seriousness of global warming increases with exposure to the statements in the interview.
- The same respondents who express skepticism on global warming issues nevertheless tend to rate the problem as more serious after hearing the statements in the interview.
- Respondents who are most dubious about scientists are likely to change toward supporting research, and away from supporting legislation.
- Those who agree that some sources scare the public for their own ends are more likely to switch toward support of research, and away from support of legislation.
- Those who agree most strongly that the evidence supports global warming are nevertheless more likely to switch toward support of research, and less likely to increase their support for federal legislation on global warming.

Key media

As noted above, three in ten respondents (31%) have heard or seen something about global warming during the last 30 days. To identify existing sources for awareness of global warming, we asked this group to identify the medium that carried the information, as well as whether they saw a news story, a paid advertisement, or both.

- The most common medium for information on global warming is television. Nearly half of Chattanooga residents recalling recent information on global warming name television as a source, compared with fewer than four in ten in Fargo and Flagstaff.
- Residents of the three cities are equally likely to have heard something about global warming on the radio, or to have read something about global warming in a magazine or newspaper.
- Nearly nine in ten of those recalling recent information on global warming say they saw or heard a news story, while one in ten recall both a paid advertisement and a news story.

- Respondents who switch to a less serious rating of global warming are more likely to have received their own information from radio or newspapers, compared with those who switch to a more serious rating.

- Respondents who switch from favoring legislative solutions toward favoring research funding are slightly less likely to have gotten information on global warming from television, compared with those who switch toward favoring legislation.

- Respondents who switch positions either way--toward research, or toward legislation--are unlikely to have gotten information on global warming from radio.

- Those who switch toward research are more likely to receive information on global warming from magazines, compared with those who switch toward legislative solutions.

- Respondents who switch toward favoring research and respondents who switch toward favoring legislation are equally likely to have received information on global warming from newspapers.

Conclusion: communication strategies

The results reviewed above support a series of conclusions concerning the types of sources and messages to which audiences are likely to respond most favorably.

- Technical and expert sources have the highest credibility among a broad range of members of the public.

- The Information Council for the Environment can be seen as an expert technical source.

- Moderate credibility of expert or industry sources is associated with a shift toward the ICE agenda.

Therefore, an "approachable" technical expert can present a good case for a cost-effective solution that meets the joint economic and environmental interests of consumers and industry.

Informed Citizens for the Environment

I.C.E.

Test Market Proposal

DATES: *February, 1991 - August, 1991*

OBJECTIVES:

1) *Demonstrate that a consumer-based media awareness program can positively change the opinions of a selected population regarding the validity of global warming.*
2) *Begin to develop a message and strategy for shaping public opinion on a national scale.*
3) *Lay the solid groundwork for a unified national electric industry voice on global warming.*

PROGRAM STRATEGIES:

1) *Select test markets that meet the following criteria:*
   a) *market derives majority of electricity from coal*
   b) *market is home to a member of the House Energy & Commerce Committee or House Ways & Means Committee*
   c) *market is smaller than #50, which translates into lower media costs*
2) *Determine most advantageous population, within specific markets, to base media awareness program.*
3) *Pre-test opinions of selected population regarding global warming.*
4) *Focus Group test I.C.E. name and creative concepts.*
5) *Proceed with media awareness program, utilizing radio/newspaper advertising and a public relations campaign.*
6) *Post-test opinions of selected population regarding global warming.*
7) *Program evaluation.*
8) *If successful, implement program nationwide.*

RESEARCH STRATEGY:

Determine most advantageous population, both attitudinally and demographically. Ascertain general level of understanding and measure degree of opinion shifts.

PUBLIC RELATIONS STRATEGY:

The public relations campaign will involve the research, writing and preparation of background materials for use with the media. A minimum of eight discussion points will be communicated to the media.

CREATIVE STRATEGY:

The radio creative will directly attack the proponents of global warming by relating irrefutable evidence to the contrary, delivered by a believable spokesperson in the radio broadcast industry.

The print creative will attack proponents through comparison of global warming to historical or mythical instances of gloom and doom. Each ad will invite the listener/reader to call or write for further information, thus creating a data base.

MEDIA STRATEGY:

A radio/newspaper execution is recommended for the following reasons:

a) believability

b) ability to use high frequency (radio) and detailed copy (newspaper)

c) cost effectiveness

d) production flexibility

FUNDING:

For the test markets, splitting costs evenly among five participating utilities is recommended. If the program is implemented on a national basis, it might be better to determine proportionate shares based on coal-produced kWh.

The test market funds will be collected as follows:

First 1/3 of commitment	*2/1/91*
Second 1/3 of commitment	*3/1/91*
Remainder of commitment	*4/1/91*

TIMELINE:	Pre-test Research (4 weeks)	2/11/91 - 3/10/91
	(3 weeks)	
	Focus Group Test (4 weeks)	4/1/91 - 4/28/91
	(2 weeks)	
	Media Awareness Program (4wks)	5/13/91 - 6/9/91
	(3 weeks)	
	Post-test Research (3 weeks)	7/1/91 - 7/21/91
	(2 weeks)	
	Final Presentation	8/5/91

BUDGET: $510,000 (three markets)

Fargo, North Dakota
Test Market

Byron Dorgan/House Ways & Means Committee

MEDIA (1200 GRPs/8 full-page ads)

$ 47,000

PUBLIC RELATIONS

$ 24,000

RESEARCH (500 interviews in each of two surveys/Focus Group)

$ 43,000

PRODUCTION (Radio/Newspaper/Phone Number/Brochure/Postage)

$ 54,000

TOTAL. $168,000

Potential Program Names

Informed Citizens for the Environment

Information Council for the Environment

Intelligent Concern for the Environment

Informed Choices for the Environment

M. William Brier
Vice President Communication

FEDERAL EXPRESS

Arizona Public Service Company
400 North 5th Street
Phoenix, AZ 85004

Dear Mark:

As I promised, attached is information on the newspaper and radio ads that will begin appearing in three test markets including Flagstaff on May 12. You should also note that the campaign includes public relations activities involving the Arizona Daily Sun, KNAZ-TV and KNAU-AM on May 20.

Of perhaps greater interest is the pre-test telephone interviews with 500 adults in Flagstaff (the results are also attached). The data indicates that:

- 89% say that they have heard of global warming
- 82% claim some familiarity with global warming
- 80% claim the problem is somewhat serious while 45% claim it is very serious
- 39% back federal legislation without any qualification of cost
- 22% consider themselves "green" consumers

With this high level of awareness and concern in Flagstaff it will be interesting to see how the science approach sells. My concern is that the absence in the messages of reasonable approaches to solving the problems of global warming may reduce their effectiveness.

In any case the research results should be useful in providing data that will allow the industry to fine tune its messages. Hopefully we can share this information, in a meaningful way, with members of your policy committee at an appropriate time.

INFORMATION COUNCIL FOR THE ENVIRONMENT

NEWSPAPER ROTATION

	Flagstaff	Fargo	Bowling Green
1.	Frost line	Mpls colder	Kent. colder
2.	How much (?)	Frost line	Kent. colder
3.	Frost line	Mpls colder	Frost line
4.	How much (?)	Frost line	Kent. colder
5.	Mpls colder	Mpls colder	Frost line
6.	Serious problem	Serious problem	Serious problem
7.	Mpls colder	How much (money bag)	Frost line
8.	How much (?)	Serious problem	How much
9.	Frostline	How much (money bag)	Serious problem
10.	Serious problem	Serious problem	How much
11.	Mpls colder	How much (money bag)	Serious problem
[illegible]	How much (?)	Serious problem	How much

RADIO PLACEMENT

Flagstaff	Fargo	Bowling Green
Dr. Balling #1	Dr. Balling #1	Dr. Balling #1
Dr. Balling #2	Dr. Balling #2	Dr. Balling #2
Bruce Williams #1	Rush Limbaugh #1	Dr. Balling #3
Bruce Williams #2	Rush Limbaugh #2	
	Bruce Williams #1	
	Bruce Williams #2	

FARGO MARKET

May 1991

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
			1	2	3	4
5	6	7	8	9	10	11
Forum: Minneapolis 12	KVOX FM 6x WDAY FM 5x KLTA FM 7x KOWB FM 3x KOWB AM 3x WDAY AM 4x 13	KVOX FM 6x WDAY FM 5x KLTA FM 7x KOWB FM 3x KOWB AM 3x WDAY AM 4x 14	Forum: Frost KVOX FM 6x WDAY FM 5x KLTA FM 7x KOWB FM 3x KOWB AM 3x WDAY AM 4x 15	KVOX FM 6x WDAY FM 5x KLTA FM 7x KOWB FM 3x KOWB AM 3x WDAY AM 4x 16	Forum: Pick-up Minneapolis KVOX FM 6x WDAY FM 5x KLTA FM 6x KOWB FM 3x KOWB AM 3x WDAY AM 4x 17	18
Forum: Pick-up Frost 19	KVOX FM 5x WDAY FM 4x KLTA FM 6x KOWB FM 3x KOWB AM 3x WDAY AM 4x 20	KVOX FM 5x WDAY FM 4x KLTA FM 6x KOWB FM 3x KOWB AM 3x WDAY AM 4x 21	Forum: Minneapolis KVOX FM 5x WDAY FM 4x KLTA FM 5x KOWB FM 3x KOWB AM 3x WDAY AM 4x 22	KVOX FM 5x WDAY FM 4x KLTA FM 5x KOWB FM 3x KOWB AM 3x WDAY AM 4x 23	KVOX FM 5x WDAY FM 4x KLTA FM 5x KOWB FM 3X KOWB AM 3x WDAY AM 4x 24	Forum: Serious Problem 25
Forum: Pick-up How Much 26	KVOX FM 4x WDAY FM 3x KLTA FM 5x KOWB FM 3x KOWB AM 3x WDAY AM 4x 27	KVOX FM 4x WDAY FM 3x KLTA FM 5x KOWB FM 3x KOWB AM 3x WDAY AM 4x 28	Forum: Pick-up Serious Problem KVOX FM 4x WDAY FM 3x KLTA FM 5x KOWB FM 3x KOWB AM 3x WDAY AM 4x 29	KVOX FM 4x WDAY FM 3x KLTA FM 5x KOWB FM 3x KOWB AM 3x WDAY AM 4x 30	Forum: How Much KVOX FM 4x WDAY FM 3x KLTA FM 6x KOWB FM 3x KOWB AM 3x WDAY AM 4x 31	

FARGO MARKET

June 1991

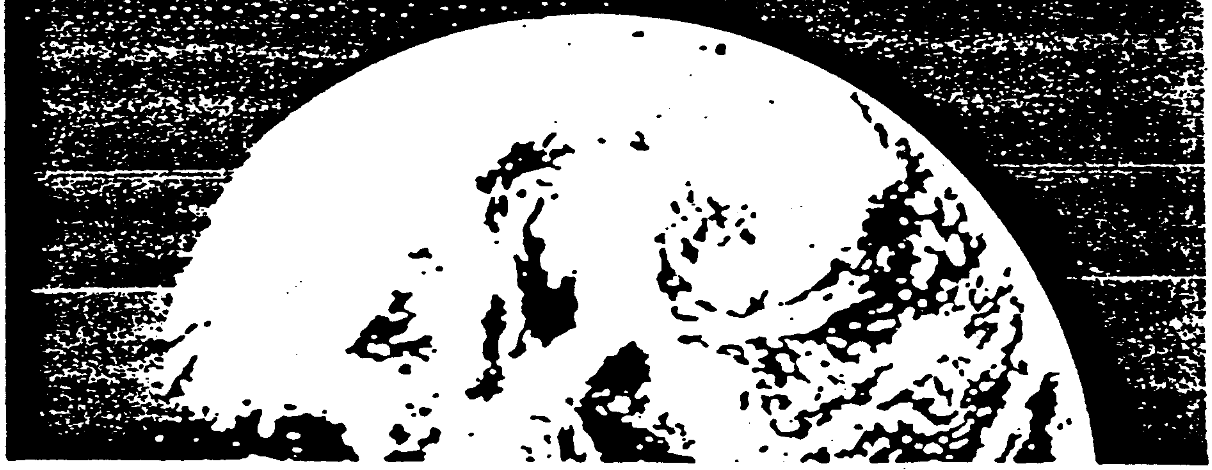
Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
						1
Forum: Pick-up Serious Problem 2	KVOX FM 5x WDAY FM 4x KLTA FM 6x KOWB FM 3x KOWB AM 3x WDAY AM 4x 3	KVOX FM 5x WDAY FM 4x KLTA FM 6x KOWB FM 3x KOWB AM 3x WDAY AM 4x 4	Forum: How Much KVOX FM 5x WDAY FM 4x KLTA FM 7x KOWB FM 3x KOWB AM 3x WDAY AM 4x 5	KVOX FM 5x WDAY FM 4x KLTA FM 7x KOWB FM 3x KOWB AM 3x WDAY AM 4x 6	KVOX FM 5x WDAY FM 4x KLTA FM 7x KOWB FM 3x KOWB AM 3x WDAY AM 4x 7	8
Forum: Pick-up Serious Problem 9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30						

PUBLIC RELATIONS TOUR

WEDNESDAY, MAY 15, 1991

12:30 p.m.	Meet with editors and writers at The Fargo Forum.
2:00 p.m.	Tape appearance on KX4 News Conference on KXJB-TV. Program is hosted by Kathy Coyle and airs on Sundays.
4:00 p.m.	Appear on KTHI-TV's On The Line hosted by Steve Poitras. Half-hour program.
5:00 p.m.	Meeting with editorial staff at WDAY-TV. Tape interview for evening news.

The most serious problem with catastrophic global warming is—it may not be true.



Some forecasters say the Earth's temperature is rising. They say that catastrophic global warming will take place in the years ahead.

But the U.S. Department of Agriculture—in the first update in 25 years of its "Plant Hardiness Report" —determined that on both coasts of this country, winter temperatures are 5 to 10 degrees cooler than previously reported.

The evidence can be seen in the increase in cold damage to Florida orange groves and California eucalyptus. And a moving frost line has led to a shorter growing season in some parts of the South.

Now, most of us aren't climatologists. But facts like these simply don't jibe with the theory that catastrophic global warming is taking place. Which seems to say we need more research. And more evidence

If you care about the Earth—but want to keep a cool head about it—now is your chance to get more facts.

Call the Information Council for the Environment, 1-800-346-6269 extension 522. We'll send you a free packet of information on global climate change. Or just mail us the coupon below.

Because the best environmental policy is a policy based on fact.

Please send me your FREE information packet on global climate change.

NAME ______________________

ADDRESS ______________________

CITY ______________________

Information Council for the Environment
1-800-346-6269

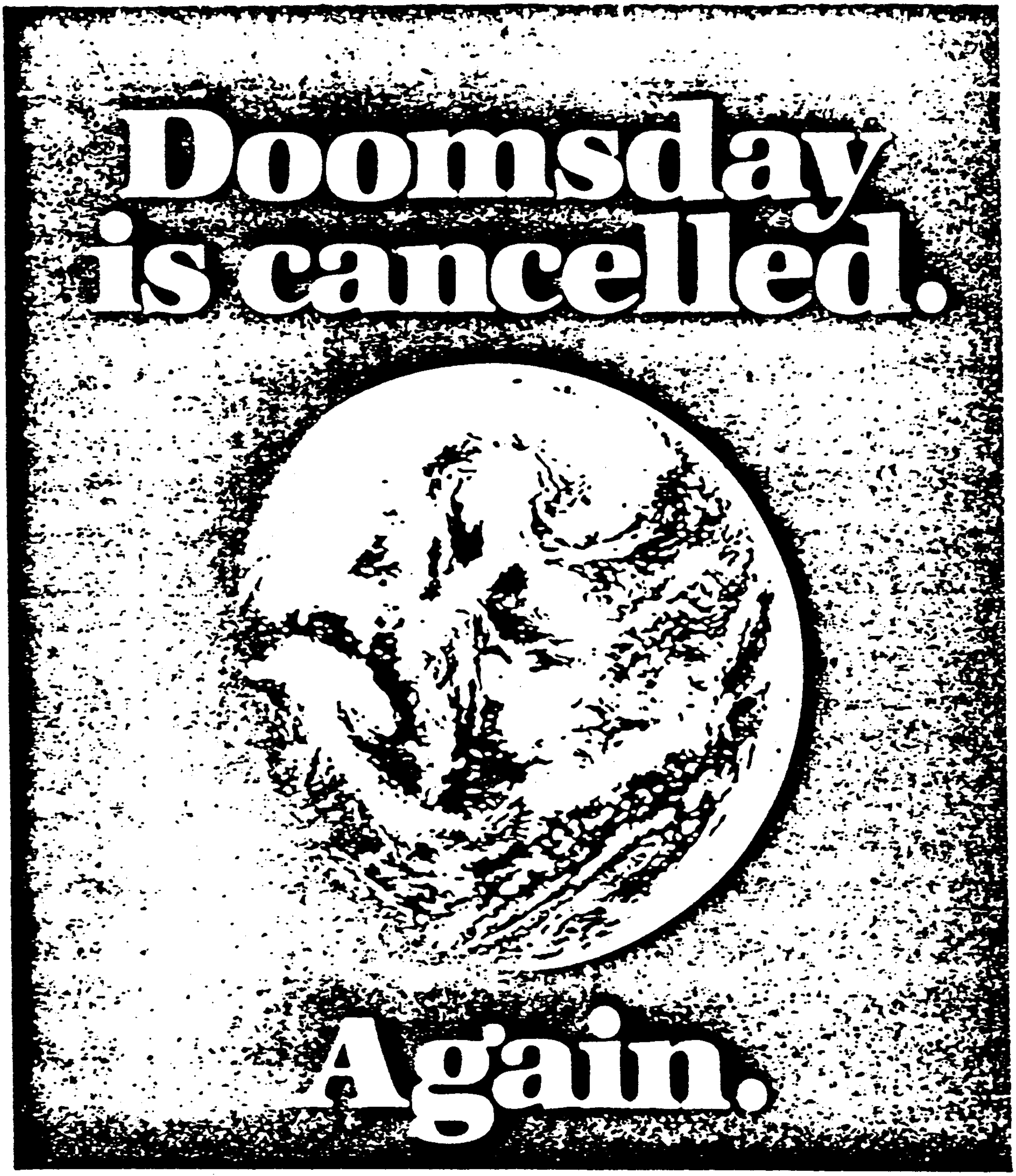
Who told you the earth was warming... Chicken Little?

Chicken Little's hysteria about the sky falling was based on a fact that got blown out of proportion.

It's the same with global warming. There's no hard evidence it is occurring. In fact, evidence the Earth is warming is weak. Proof that carbon dioxide has been the primary cause is non-existent. Climate models cannot accurately predict far-future global change. And the underlying physics of climatic change are still wide open to debate.

If you care about the earth, but don't want your imagination to run away with you, make sure you get the facts.

Write Informed Citizens for the Environment, P.O. Box 1513, Grand Forks, North Dakota 58206, or call toll-free 1-701-746-4573. We'll send today's



The twentieth century has seen many predictions of global destruction. In the 1930's, some scientists claimed we were in the middle of a disastrous warming trend. In the mid 1970's, others were sure we were entering a new Ice Age. And so on.

It's the same with global warming. There's no hard evidence it is occurring. In fact, evidence the Earth is warming is weak. Proof that carbon dioxide has been the primary cause is non-existent. Climate models cannot accurately predict far-future global change. And the underlying physics of the climatic change are still wide open to debate.

If you care about the environment, but don't care to be pressured into spending money on problems that don't exist, make sure you get the facts.

Write: Informed Citizens for the Environment, P.O. Box 1513, Grand Forks, North Dakota 58206 or call (701) 746-4573. We'll send you the facts about global warming.

Informed Citizens for the Environment

Client: Information Council for the Environment

Subject: Rush Limbaugh/2

Media: Rush Limbaugh Show Length: 60

Contact: T. Helland/K. Olsen

COPY

simmons advertising, inc.
125 south 4th street / P.O. box 1457
grand forks, north dakota 58208
(701) 746-4573 / fax: (701) 746-8067

GLOBAL WARMING. I KNOW YOU'VE BEEN SEEING MORE AND MORE STORIES ABOUT THE GLOBAL WARMING THEORY. STORIES THAT PAINT A HORRIBLE PICTURE. STORIES THAT SAY THE POLAR ICE CAPS WILL MELT. STORIES THAT SAY WE'RE HEADED FOR CATASTROPHE. WELL GET REAL! STOP PANICKING! I'M HERE TO TELL YOU THAT THE FACTS SIMPLY DON'T JIBE WITH THE THEORY THAT CATASTROPHIC GLOBAL WARMING IS TAKING PLACE. TRY THIS FACT ON FOR SIZE. MINNEAPOLIS HAS ACTUALLY GOTTEN COLDER. SO HAS ALBANY, NEW YORK. AND THE DEPARTMENT OF AGRICULTURE SAYS THAT ON BOTH COASTS OF THIS COUNTRY, WINTER TEMPERATURES ARE FIVE TO TEN DEGREES COOLER THAN PREVIOUSLY REPORTED. SO FOLKS, GRAB HOLD OF YOURSELVES AND GET THE WHOLE STORY BEFORE YOU MAKE UP YOUR MIND. RIGHT NOW, YOU CAN GET A FREE PACKET OF EASY-TO-UNDERSTAND MATERIAL ABOUT GLOBAL WARMING. JUST CALL THIS NUMBER: 1-800-346-6269 EXTENSION 505. THAT'S THE INFORMATION COUNCIL FOR THE ENVIRONMENT. AFTER YOU READ THE FREE MATERIALS THEY SEND YOU, YOU'LL HAVE A BETTER PICTURE OF WHAT THE FACTS ARE ALL ABOUT. THAT'S 1-800-346-6269 EXTENSION 505. CALL TODAY. BECAUSE THE BEST ENVIRONMENTAL POLICY IS BASED ON FACT.

Information Council for the Environment

May 15, 1991

#1

(name)
(title)
(company)
(address)
(city), (state) (zip)

Thank you for requesting more information about global climate change. I've been asked to respond to your request as a member of the Information Council for the Environment's Science Advisory Panel.

I'll give you some background on my credentials. I am a professor at the University of Virginia. My area of expertise is environmental sciences. *I am also one of many scientists who believe the vision of catastrophic global warming is distorted.* I have enclosed a copy of a letter and a booklet to help you better understand why we believe we [illegible] act in haste.

The enclosed letter, which was sent to President Bush in February, was co-written by Dr. Robert Balling of Arizona State University and myself. As you'll note, we urge the President not to support expensive legislation.

I'm sure you'll agree after you review the information I've enclosed, global warming is an issue we are still learning about. In fact, just two months ago, a panel of scientists who advise the United Nations suggested a 10-year research effort to answer the many uncertainties about global warming. To quote the article, "A 10-year delay in taking action to curb global warming would mean little further increase in the level of warming predicted by the end of the next century..."

But there's more to this issue. *Right now, there are costly proposals in Congress--including one that would impose a new tax on energy.* the intended purpose is to reduce carbon dioxide emissions and global warming.

What can *you* do?

1. Make sure you're informed. Your request for this information is a good first step.

2. If you'd like to know more, return the enclosed postcard and we'll send you more information on global climate change.

Thank you for caring enough to send for this information.

Dr. Patrick Michaels

Science Advisory Panel:

DR. ROBERT C. BALLING, JR.
Director, Office of Climatology
Arizona State University
Tempe, AZ

DR. SHERWOOD B. IDSO
Adjunct Professor of
Botany and Geography
Arizona State University
Tempe, AZ

DR. PATRICK J. MICHAELS
Virginia State Climatologist/
Professor of
Environmental Sciences
University of Virginia

P.O. Box 414998 / Kansas City, MO 64141-4998 / 1-800-346-6269

#2

Information
Council
for the Environment

May 15, 1991

(name)
(title)
(company)
(address)
(city), (state) (zip)

Thank you for requesting additional information on global climate change.

The science of global climate change is very complex. We are still learning how many of the components of our atmosphere interact with each other. We do know [illegible] years ago the Earth was warmer; vegetation thrived, and there was more carbon dioxide in the atmosphere than there is now. We also know that during the last ice age, carbon dioxide levels were lower than they are now.

We believe it is wrong to predict that higher levels of carbon dioxide will bring a catastrophic global warming.

The Information Council for the Environment was created to help foster better public understanding of global warming and to ensure that any legislation passed by Congress is based on scientific evidence.

The environment must be protected. We want a clean environment and we want a green Earth. *We also believe we must conduct more scientific research before we can accurately understand the complex forces of global climate change.*

Change often begins with one person. You can make a difference by sharing what you've learned with others.

Thank you for caring enough to request this additional information.

Dr. Patrick Michaels

P.O. Box 414998 / Kansas City, MO 64141-4998 / 1-800-346-6269

Information Council for the Environment

May 15, 1991

X
X
X
X

Thank you for requesting additional information on global climate change.

The science of global climate change is very complex. We are still learning how many of the components of our atmosphere interact with each other. We do know that years ago the Earth was warmer; vegetation thrived and there was more carbon dioxide in the atmosphere than there is now. We also know that during the last ice age, carbon dioxide levels were lower than they are now.

We believe it is wrong to predict that higher levels of carbon dioxide will bring a catastrophic global warming.

The Information Council for the Environment was created to help foster better public understanding of global warming and to ensure that any legislation passed by Congress is based on scientific evidence.

The environment must be protected. We want a clean environment and we want a green Earth. We also believe we must conduct more scientific research before we can accurately understand the complex forces of global climate change.

Change often begins with one person. You can make a difference by sharing what you've learned with others.

Thank you for caring enough to request this additional information.

Dr. Patrick Michaels

1994 Shell report,

The Enhanced Greenhouse Effect: A review of the scientific aspects

THE ENHANCED GREENHOUSE EFFECT

A review of the Scientific Aspects

Update : December 1994

THE ENHANCED GREENHOUSE EFFECT

A review of the Scientific Aspects

Update : December 1994

Author: P. Langcake, SIPM The Hague - HSE/3

THE ENHANCED GREENHOUSE EFFECT

A Review of the Scientific Aspects

Update: December 1994

CONTENTS

P. Langcake, HSE/3

THE ENHANCED GREENHOUSE EFFECT

1. Introduction

The threat of climate change remains the environmental concern with by far the greatest significance for the fossil fuel industry, having major business implications. It has been the focus of continuing scientific and political attention since the late 1980s. The UN Framework Convention on Climate Change, which was the showpiece of the UN Conference on Environment and Development in Rio (UNCED) came into force in March 1994 having been ratified by the requisite 50 signatory nations. Implementation of the Convention will ensure that the momentum of action to address potential global warming is maintained.

The purpose of this paper is to review major developments in scientific understanding and the implications for policy formulation.

2. The Nature of the Issues

The features which make potential human-induced global warming such a problematic and controversial issue are recalled in Figure 1. Each element in this scheme, together with the crucial interactions between the elements is subject to substantial uncertainty. The consequences of global warming could be dramatic, as could the economic effects of ill-advised policy measures. Furthermore, the time scales (decades to hundreds of years) which must be addressed far exceed normal planning experience and the global dimension raises intractable questions of international relations such as equity, trade relationships and conflicting national priorities.

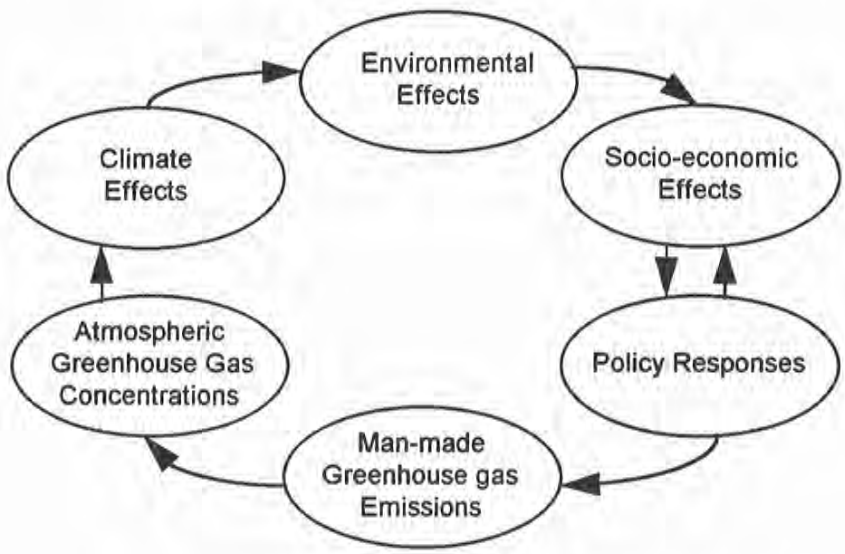


Figure 1: Global Warming, the Circle of Uncertainty

3. Expressions of Scientific Opinion

The Intergovernmental Panel on Climate Change (IPCC) represents the most coherent, authoritative and influential expression of scientific views on Climate Change. IPCC was established in 1988 under the auspices of the World Meteorological Organisation (WMO) and the United Nations Environment Programme (UNEP) and comprises several hundred leading independent experts from numerous countries. It should be recognised that IPCC was established by governments and the summaries of its deliberations are the work of officials or official nominees. The conclusions of the IPCC (first reports completed in 1990) can be regarded as the mainstream view: they provided the essential underpinning for government positions at the Rio conference. Post-Rio the IPCC has been kept in existence.

There are three Working Groups.

WG1 is concerned with the "Science of Climate Change'. It produced a "Supplementary Report to the IPCC Scientific Assessment" in 1992 and was due to produce a Special Report in November 1994. WGs II and III are concerned with "Impacts and Response Strategies" and "Cross-cutting Issues" respectively. The latter includes economic impacts and scenarios for future emissions. All three WGs will produce major new reports in 1995.

Although the IPCC position is often referred to as the scientific consensus, there is a range of views among IPCC scientists about the magnitude of the threat from global warming and its causes. Furthermore, there is a significant minority outside IPCC (which includes distinguished scientists) who take a contrary view, generally believing the concerns over global warming to be exaggerated and misguided. The views of these "sceptics" have received increasing attention in recent months (although IPCC members point out that only some of them are actually conducting research in the relevant fields).

4. Agreed Scientific Fundamentals

Notwithstanding the controversy indicated above, there is complete agreement on the following well-known scientific fundamentals:

- Natural Atmospheric Greenhouse Gases affect the retention of energy in the global system by re-reflecting part of the outgoing infra-red radiation from the earth (so called "radiative forcing").

- This maintains the <u>average</u> global temperature approximately 33°C higher than it would be in the absence of atmospheric greenhouse gases and reduces diurnal variation (This is the natural "greenhouse effect").

- The major greenhouse gas is water vapour (this point is often left aside in discussions on global warming). Trace greenhouse gases include carbon dioxide, methane, nitrous oxide, ozone and more recently man-made chloroflurocarbons (CFCs). Calculations of relative contributions are extremely difficult because of differences in atmospheric lifetimes, indirect effects and overlapping radiative effects but roughly speaking water vapour accounts for three quarters of the natural greenhouse effect with all other greenhouse gases making up the remainder.

- The concentration of greenhouse gases (other than water vapour) have increased rapidly since the industrial revolution. Expressing all these gases in terms of their CO_2 equivalent Global Warming Potential (GWP - a subject itself of some controversy) the increase is around 40% over pre-industrial levels. This has led to an increase in radiative forcing of about 1% of the total incoming radiation. While this may appear small, it is important since living organisms can only tolerate a relatively small range of temperature.

- This increase in radiative forcing will have some effect on the processes which determine global climate.

- Human activities have contributed to the increase in atmospheric greenhouse gas concentrations (AGGCs).

- The rate of increase in the concentration of atmospheric greenhouse gases is faster than previously experienced during the history of human civilisation (although not unprecedented on a geological time scale).

- Natural factors other than those directly contributing to AGGCs (volcanic activity, solar orbit, patterns of ocean circulation etc.) and human activities other than fossil fuel consumption (deforestation, agricultural practices, atmospheric pollution, hydrological projects, urbanisation, etc.) can also significantly affect climate causing warming or cooling.

Starting from this broad area of agreement, the controversies arise mainly from differences of view about the potential consequences of the increase in AGGCs and the interpretation of past and present climate observations.

5. Conclusions of the IPCC

The most recent statement of IPCC conclusions concerning the science of global warming is given in the 1992 assessment which re-examined the position presented in the full 1990 report in the light of further research and comment. IPCC conclusions are based on a comprehensive review of climatological, palaeoclimatological and experimental observations together with heavy dependence on the output of elaborate computer models which simulate global climate (General Circulation Models - GCMs).

To model future climate, it is necessary to make some estimate of future emissions of greenhouse gases and the resulting concentrations in the atmosphere. The IPCC calculations are based on a series of projections representing a simple extrapolation of existing trends (the reference case, mistakenly called "business as usual" by some - see later) and various levels of mitigating action (Figure 2).

The reference case leads to an approximate doubling of pre-industrial carbon dioxide concentrations by the year 2030. Clearly the nature of these projections, called scenarios by IPCC, is critical for the outcome of the modelling and is a matter of lively debate.

The 1992 Assessment confirmed (in the view of IPCC) the principal conclusions reached in 1990:

- Greenhouse gas concentrations in the atmosphere are increasing substantially, due to human activities (but see later comments in section 6).

- Evidence from observations and more particularly from GCMs indicates that global mean surface temperature will increase by 1.5 to 4.5°C, depending on the model, with a doubling of the equivalent carbon dioxide concentration (which, as indicated, would occur in approximately 2030 if present trends were to continue unaltered).

- There are many uncertainties with regard to the timing, magnitude and regional patterns of climate change.

- Global mean surface air temperature has increased by 0.3 to 0.6°C over the last 100 years. This warming is consistent with model predictions but also is within natural climate variability (see Figures 3 and 7).

- Alternatively this variability and other human factors (see below) could have offset a still larger human induced greenhouse warming.

- The unequivocal detection of the enhanced greenhouse effect is not likely for a decade or more (there is no clear evidence yet of a "greenhouse signal").

The 1992 report also contained new conclusions, including:

* Depletion of ozone in the lower stratosphere (largely associated with CFCs) results in a decrease in radiative forcing comparable in magnitude to the contribution of CFCs.

* Cooling by sulphur dioxide aerosols (partly resulting from man-made pollution) may have offset a significant part of the greenhouse warming in the Northern Hemisphere.

* Rates of increase of methane and CFC concentrations in the atmosphere have decreased. The latter is largely attributable to international agreements to restrict CFCs, but the reason for the former is not known.

* The anomalously high global temperatures of the late 1980s continued into 1990-1991 which are the warmest years on record (subsequent years 1992 and 1993 have been more in line with the longer term means).

6. Additional Significant Recent Developments

The latest IPCC WG I Supplementary Report (available to us in draft form) covers only those factors which cause radiative forcing of climate change. Revision of Global Warming Potentials of the long lived greenhouse gases to include indirect as well as direct effects indicates an increased importance of methane over a shorter (20 years) time span than previously thought. Improved estimates are made of the cooling effect of atmospheric particles (sulphate aerosols, aerosols from biomass burning and dust from volcanic eruptions). The IPCC latest views on the radiative forcing by various factors is shown in Figure 4. It should be emphasised that the cooling effect of particles and aerosols represent temporary and regionally distributed masking of the radiative forcing due to the long lived greenhouse gases (CO_2 etc.) produced over many decades.

The major volcanic eruption at Mount Pinatubo in 1991 is considered to have caused significant interference with short term climate, notably by emitting substantial quantities of dust particles into the atmosphere which have a cooling effect that could mask global warming for a limited period.

A recent observation is that there has been a remarkable and unpredicted slowing in the rate of increase of atmospheric carbon dioxide concentrations over the last 18 months, thus deviating from the trend which gave rise to climate change concerns. It is too early to say whether or not this is simply a minor perturbation. Some leading scientists active in the field attribute it to indirect effects from the Mount Pinatubo eruption (temporary cooling due to dust particles affecting biosphere respiration more than photosynthesis; see footnote [1]) or to transient effects associated with the El Nino process; see footnote [2]). Similar unexplained variations in the rate of atmospheric CO_2 increase have occurred before (e.g. in 1982). Latest measurements show that in late 1993, the rate of increase has risen again. These observations emphasise the limited state of knowledge concerning the carbon cycle and its inherent feedback mechanisms.

Other important scientific developments include new information from Greenland ice cores which suggests that substantial changes in climate occurred more frequently and rapidly in the past than previously realised and increasing awareness of the key role of ocean circulation patterns in determining regional climate. These patterns appear to be relatively unstable and potentially subject to disturbance.

7. Areas of Controversy and Alternative Scientific Views

Scientific criticism of the IPCC view falls under the following headings:

a. Understanding of the carbon cycle and the relationship with anthropogenic carbon emissions.

b. Reliability and interpretation of temperature records.

c. Understanding of climate processes and particularly the way they are represented in GCMs.

d. Consequences of global warming.

e. Ecosystem responses to climate change.

---

1 The terrestrial biosphere component of the carbon cycle is largely determined by the balance between respiration of biota (which emits carbon dioxide) and photosynthesis (which consumes atmospheric carbon dioxide). In general respiration is more sensitive to temperature than photosynthesis; hence it is argued that a rapid cooling effect would be expected to lead to a short term reduction in atmospheric carbon dioxide until the balance of the processes is restored.

2 The El Nino Southern Oscillation phenomenon is an irregular oscillation of the coupled ocean/atmosphere system in the tropical Pacific Ocean, occurring approximately every 3 to 5 years. During the peak of an El Nino, sea surface temperatures in the eastern tropical Pacific can be several degrees warmer than the climatological mean. El Nino events are associated with major climatological effects, such as failure of the Indian Monsoon. An opposite phase of cold events is referred to as La Nina. These phenomena are also associated with changes in the exchange of carbon dioxide between ocean and atmosphere.

The nature of the criticism under each heading is summarised below.

a. Understanding of the carbon cycle and the relationship with anthropogenic carbon emissions

Man-made carbon dioxide emissions are small compared with the amounts of carbon in the total carbon cycle (Figure 5). A small shift in the balance of processes governing this cycle could therefore account for changes in atmospheric carbon dioxide concentrations, or overwhelm any effects from human activity.

The carbon fluxes and sinks shown in Figure 5 represent the best estimates prepared by WG I (see Table 1). Of these, only the amount of carbon in the atmosphere and the amount of CO_2 released from fossil fuel combustion is known with any degree of accuracy. Even the uncertainty in the stated uncertainty ranges of the remaining figures is not known.

Table 1. Annual average anthropogenic carbon budget for 1980 to 1989

CO_2 sources		**GtC/yr.**
(1)	Emissions from fossil fuel and cement production	5.5 ± 0.5
(2)	Net emissions from changes in tropical land-use	1.6 ± 1.0
(3)	Total anthropogenic emissions = (1) + (2)	7.1 ± 1.1
Partitioning amongst reservoirs		
(4)	Storage in the atmosphere	3.2 ± 0.2
(5)	Ocean uptake	2.0 ± 0.8
(6)	Uptake by Northern Hemisphere forest re-growth	0.5 ± 0.5
(7)	Additional terrestrial sinks (CO_2 fertilisation, nitrogen fertilisation, climatic effects) - [(1) + (2)] - [(4) + (5) + (6)]	1.4 ± 1.5

The recent figures recognise that forest regrowth in temperate regions plus the "missing sink" (widely presumed to be net carbon storage in the rest of the biosphere) represent significant sinks. Moreover, the cold deep waters of the ocean are potentially capable of absorbing all the CO_2 that would be released if all known reserves of fossil fuel were to be burned (albeit over a timescale of hundreds of years).

What is clear is that currently, only about half of the anthropogenic CO_2 released accumulates in the atmosphere. How this relationship will change as CO_2 emissions and other global variables change is not clear.

Understanding of gases other than CO_2 such as methane and nitrous oxide and the complex role of water vapour is even less well developed.

b. Reliability and interpretation of temperature records

The best available surface temperature record indicates a rise of 0.45°C (±0.08°C) over the last century, but measuring global average temperatures is notoriously difficult. In general coverage of the earth's surface by reliable measuring stations is insufficient with the oceans in particular being under-represented and the coverage is even poorer when the earlier records are examined. The increase of 0.45°C is approximately half of the 1°C increase that has been predicted by various models based on the present rise in AGGCs.

Sceptics further argue that several other factors could have made a significant contribution to the observed temperature increase, including urbanisation, desertification and a decrease in stratospheric turbidity which has occurred over recent years (before the Mount Pinatubo eruption). They claim that when the effects of these factors are subtracted, the rise due to greenhouse gas effects is at most 0.3°C over the last century and could be negligible. Previous major eruptions (e.g. Mt. St. Helens) have also had noticeable effects on short term climate.

The rather imperfect surface temperature record described above does not agree well with more sophisticated temperature measurements made of the middle troposphere by satellite measurements. These allow true mean global temperature measurements to be made on a daily basis. Many models suggest that the global warming signal will be most evident in the middle troposphere , yet these satellite measurements suggest global cooling of -0.06°C /decade over the last 15 years versus ca. + 0.2°C /decade for the surface measurements. Even after empirical corrections for the El Nino Southern Oscillation and known major volcanic eruptions, the satellite data suggest warming of +0.09°C /decade, approximately half the uncorrected surface measurement. Unfortunately the time series for such measurements only goes back some 15 years.

The postulated link between any observed temperature rise and human activities has to be seen in relation to natural climate variability, which is still largely unpredictable. It is pointed out that the temperature variability over the last century is larger than the effect being sought and that the observed rise could be accounted for by a recovery from the Little Ice Age. Climate changes in the recent geological past, such as the relatively warm Roman period and the Little Ice Age, do not appear to have been associated with changes in CO_2 levels.

Other natural phenomena have been put forward as possible explanations for the observed warming. For example changes in solar activity show some correlation with temperature fluctuations and it has also been claimed that the temperature increased during the 1980s because the La Nina process failed to occur from 1975 to 1988. While none of these explanations has so far achieved widespread acceptance in the IPCC scientific community, they serve to emphasise again how incompletely the natural climate system is understood.

Figures 6 and 7 show graphically how temperature has fluctuated in the recent and distant past to provide a perspective against which to consider current anxieties.

c. Understanding of climate processes and particularly the way they are represented in GCMs

GCMs are massive, three dimensional climate models which attempt to describe and predict climate behaviour based on consideration of the input of solar energy and the resulting physical processes in the global system. These models generally describe climate in terms of temperature, precipitation and barometric pressure for grids covering the globe. They are impressive, but the task is formidable, given the need to take into account numerous climate processes and feedback effects that can either amplify or dampen the direct effects of increasing AGGCs. Climate modellers themselves recognise the following main limitations of the GCMs and go as far as to suggest that such models should not be used for making predictions, but merely to help increase our understanding of climate processes:

i. <u>There is insufficient understanding of major feedback mechanisms</u>

These mechanisms include the distribution of water vapour and heat, changes in cloud cover and albedo, exchange between atmosphere and ocean and changes in plant growth and area covered. A better understanding of the role of clouds is critically needed. Some of the complexities of the feedback processes can be illustrated here. Increased temperature will in principle lead to increased water vapour in the atmosphere. However, while water vapour is a greenhouse gas, water droplets in the form of clouds have a completely different effect, both reflecting and absorbing incoming radiation while also trapping outgoing radiation. Different approaches to the modelling of clouds provide estimates of equilibrium warming which vary by a factor of three. In general such feedback has been treated as positive in GCMs but the latest cloud research programme suggests on balance, a net cooling effect. Indeed, satellite measurements show that clouds may absorb 15-20% of incoming radiation, a figure much higher than previously estimated.

ii. <u>Models do not replicate global temperature history well</u> and they must be "tuned" to represent the current situation. Earlier climate models simulated either the atmosphere alone or the oceans alone and were reasonably good at representing today's climate. However, when "coupled" together as GCMs these models had to calculate their own values for the exchange of heat and moisture between ocean and atmosphere. Left to their own devices, the coupled models would "drift" even without changes to the input variables leading to very unrealistic climate representations. Accordingly the fluxes are "adjusted", sometimes by as much as 20-40% of the total incoming radiation. These adjustments are believed to disguise rather than to correct the underlying defects in the models.

When GCMs are used to "backcast", they indicate a pattern of accelerating warming over the past century: in fact the historical record (Figure 6) shows intermittent periods of warming (in the 1930s and 1980s) with long periods of little change and even cooling between the late 1930s and the late 1970s. Also regional predictions (e.g. effects at the poles) are not consistent with observations.

The introduction of factors to represent sulphate and other aerosols that may have masked global warming in recent years is reported to improve the "backcasting" capability of climate models. However, critics warn that the understanding of aerosols is poor (white particles reflect heat, while black particles absorb it) such that this may just be yet another 'tuning knob' to force models to give a better representation of the historical climate record.

iii. <u>GCMs have poor resolving power</u>

Limitations on computer speed and memory limit the resolution of GCM output to grid blocks whose cells are several hundred kilometers to a side. Such resolution is too coarse to reveal effects of certain processes (such as clouds and hydrology). Currently therefore it is not possible to predict how climate might change at the regional or local level and hence what the impact on ecosystems would be at these levels.

iv. <u>Chronology of carbon dioxide fluctuations and temperature</u>

While there is a remarkable correlation between past temperature (as deduced from ice isotopic composition) and the carbon dioxide profile, it is not clear that carbon dioxide changes ever significantly preceded the temperature signal. Clearly, factors such as changes in earth orbital patterns (external forcing) can produce temperature and other climate changes which in turn can lead to fluctuations in atmospheric carbon dioxide concentrations.

In summary there are serious limitations to the ability of models to predict climate change and these limitations are likely to remain for some time. The limitations are both inherent and practical. It is inherent that the climate system is chaotic in nature and therefore not amenable to deterministic prediction. At best climate could only be modelled in terms of probability. This can be observed in the natural variability of the present climate.

Practical limitations will also persist for some time. For example, while the Deep Ocean is critically important because of its ability to exchange both heat and CO_2, there are major uncertainties in our knowledge of its present state. The models themselves have errors in them, the magnitude of which is not known because of the limited availability of the computing power. Moreover, a number of important processes such as the carbon cycle and the impacts of clouds, continental glaciers, solar variability and volcanic activity, are either absent from climate models, or are poorly understood.

d. Consequences of global warming

GCMs and other projections predict various consequences from increased concentrations of greenhouse gases in addition to temperature rise, although different models do not always agree on the nature of these consequences. Climate features affected include increased precipitation and cloudiness, increased frequency and severity of storms and decreased diurnal temperature range. Secondary consequences include sea level rise, decrease of glaciers, disturbance of ecosystems.

The sceptics argue that there is no convincing, statistically significant evidence that climate features have been affected in the way predicted and that progressive refinement of the models has led to less alarming predictions. A good example is sea-level rise. In the 1980s some scientists predicted a 6m sea level rise due to break-up of Antarctic ice sheets. In 1990, the IPCC report suggested 66 cm by 2100 as a "best guess". By 1992, IPPC had reduced this estimate to 48 cm, while some scientists have predicted that sea level would actually fall due to increased snow cover on land.

e. Ecosystem Responses to Climate Change

Various models are available to examine the effect of climate and atmospheric changes on ecosystems, agriculture and the economy. As a general point the changes brought about by man's activities in the absence of climate change, are likely to be at least as important as those induced by climate change.

For terrestrial ecosystems there is widespread agreement that increased plant fertilisation due to raised CO_2 in the atmosphere plus increased nitrogen and other nutrients derived from atmospheric pollutants will increase plant growth. Estimates vary from 0% to 50%. The increase in net carbon storage will be less than this (possibly half) and insufficient to materially offset man-made emissions of CO_2. In the oceans, plant life is not thought to be limited by carbon and there is no CO_2 fertilisation effect.

Models of natural vegetation redistribution have been validated against historical records. Changes in higher latitudes, e.g. tundra ---> conifer forests, are reasonably well understood but in the tropics the changes will depend on moisture/rainfall rather than temperature. Climate models produce wide estimates of such changes and the impact on ecosystems is most uncertain.

Certain ecosystems transitions could be more problematic. For example, dieback of forests (with fire) could produce short term pulses of CO_2, offsetting the increased carbon storage potential of the overall ecosystem.

Agricultural systems are man-made and accordingly man can adapt them to changing climate. Whether this will produce an overall positive or negative effect on the agricultural economy will depend on societal choices, e.g. local self sufficiency versus changes in the patterns of world trade in (and prices for) agricultural products. On balance the effects in economic terms range from slightly positive to somewhat negative. At the regional level, different models can give quite contradictory results. The uncertainty in this part of the cycle (Figure 1) is no less than that in the other parts.

8. Conclusions concerning the Science of Climate Change

The array of arguments outlined in the last section may appear to represent a formidable case against the global warming hypothesis or at least to favour a healthy scepticism. However, many of them raise questions or point to uncertainties rather than offer convincing alternative positions. These arguments will have been familiar to IPCC scientists who have not materially changed their views. Those who conclude that global warming is likely would argue that uncertainty applies both ways - the effects could be larger then predicted.

A definitive, unequivocal position on the science of global warming would require an understanding of the immensely complex systems which determine the world's climate and biogeochemical cycles. This is quite simply beyond current capabilities. It is not surprising that there should be controversy and the only statements which can be made with confidence relate to the fundamentals stated in section 4 which may be summarised as follows:

- Human activities have contributed to an increase in atmospheric greenhouse gas concentrations which must have some effect on the radiation balance which ultimately determines global climate. However, it is not possible to quantify the consequences for global climate with respect to timing, magnitude or regional distribution nor to specify their significance in comparison with natural climate variation.

- It is thus not possible to dismiss the global warming hypothesis as scientifically unsound; on the other hand any policy measure should take into account explicitly the weaknesses in the scientific case.

9. Current Shell Activities

In addition to monitoring scientific and political developments, Shell specialists are involved in a range of national and international initiatives and activities targeted at the critical issues or organisations involved:

The overall objective is to promote an objective debate on the policy issues concerning possible climate change based on an understanding of the science. The Group position is that:

Scientific uncertainty and the evolution of energy systems indicate that policies to curb greenhouse gas emissions beyond 'no regrets' measures could be premature, divert resources from more pressing needs and further distort markets.

This objective is supported by a PA communications plan that will include a new Management Brief (further details from PAE). PL/12 have looked at the relationship between energy systems and CO_2 emissions through the work on evolution of energy systems. This shows that there is considerable potential for technological change on both the energy supply and energy use sides which would limit the increase in CO2. Market forces may drive such developments even in the absence of policy responses to limit CO_2 emissions. This work has been presented to a number of groups of government officials and at international fora such as the International Energy Agency and the World Bank (further details from PL/12).

Activities by Shell include:

- Scientific understanding
  As part of an industry consortium (IPIECA) support has been provided for research on key areas of scientific uncertainty (cloud processes at the UK Meteorological Office; ocean / atmospheric exchange processes at the Lamont Doherty Observatory, Columbia University, USA).

- Integrated Assessment of Science, Economics and Policy
  Shell is a part sponsor of the MIT Global Change Program which brings together a wide range of expertise in a fully integrated multi-disciplinary programme which addresses all of the processes shown in Figure 1.

- IPCC Technical Assessments

  Monitoring of and input to IPCC deliberations is conducted via IPIECA (International Petroleum Industry Environmental Conservation Association): HSE/3 is Vice-Chairman of the Global Warming Committee. Under the aegis of IPIECA, HSE/3, PL/12 and SMDF/7 have been officially accepted as members of the Peer Reviewers Panel for the next IPCC Technical Assessments. Industry viewpoints are also promoted via specialist workshops involving IPCC/COP participants together with industry experts and by liaison with the International Energy Agency (IEA), for example through the Coal Industry Advisory Board (CIAB).

- Direct input to the IPCC process has included participation in IPCC meetings and correspondence (by PL/12) challenging the OECD Economic model and the Scenarios adopted by IPCC and introducing ideas from the Long Term Energy Study. Contributions have also been made to a variety of seminars dealing with implementation of UNCED commitments.

- UN Framework Convention on Climate Change (UNFCCC) / UNCSD

  Shell (particularly Group PA) plays an active part in the International Chamber of Commerce which is the principal industry-wide vehicle for contributing to the UNFCCC process. Group PA also plays an active role in the World Business Council on Sustainable Development (WBCSD) (formed from a merger of WICE and BCSD) which, alongside the ICC, interacts with the UN Commission on Sustainable Development (UNCSD) and develops industry positions, for example on Agenda 21. Liaison with the Global Environment Facility (GEF) is being developed via IPIECA (HSE/4 is a member of the relevant IPIECA post-UNCED Working Group). There are also direct Shell contacts with GEF through involvement in the Brazil Biomass BIG project. Shell is also making an input to the OECD's work on climate change through the Business and Industry Advisory Committee (BIAC).

- National / Regional Policies

  Shell Staff interact with organisations developing national and regional plans to address climate change, either directly or via industry associations. For example in Europe, relevant bodies include EUROPIA, UNICE etc. The importance of making input at the national government level should not be underestimated.

  It is the national governments which determine the policy of UN bodies and which will subsequently implement it nationally. OpCos needing guidance on making an input to the climate change debate in their country are advised to contact HSE/3, PAE or PL/12.

* * * * *

Glossary of Abbreviations

AGGCs	Atmospheric Greenhouse Gas Concentrations
BCSD	Business Council for Sustainable Development
BIAC	Business and Industry Advisory Committee
CFC	Chlorofluoro Carbon
CH4	Methane
CIAB	Coal Industry Advisory Board
CO2	Carbon Dioxide
EUROPIA	European Petroleum Industry Association
GCM	General Circulation Model
GEF	Global Environment Facility
GWP	Global Warming Potential
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IPIECA	International Petroleum Industry Environmental Conservation Association
MIT	Massachusetts Institute of Technology
N2O	Nitrous Oxide
OECD	Organisation for Economic Cooperation and Development
UNCED	United Nations Conference on Environment and Development
UNCSD	United Nations Commission on Sustainable Development
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNICE	Union of Industrial and Employers' Confederations of Europe
WBCSD	World Business Council for Sustainable Development
WICE	World Industry Council for the Environment
WMO	World Meteorological Organisation

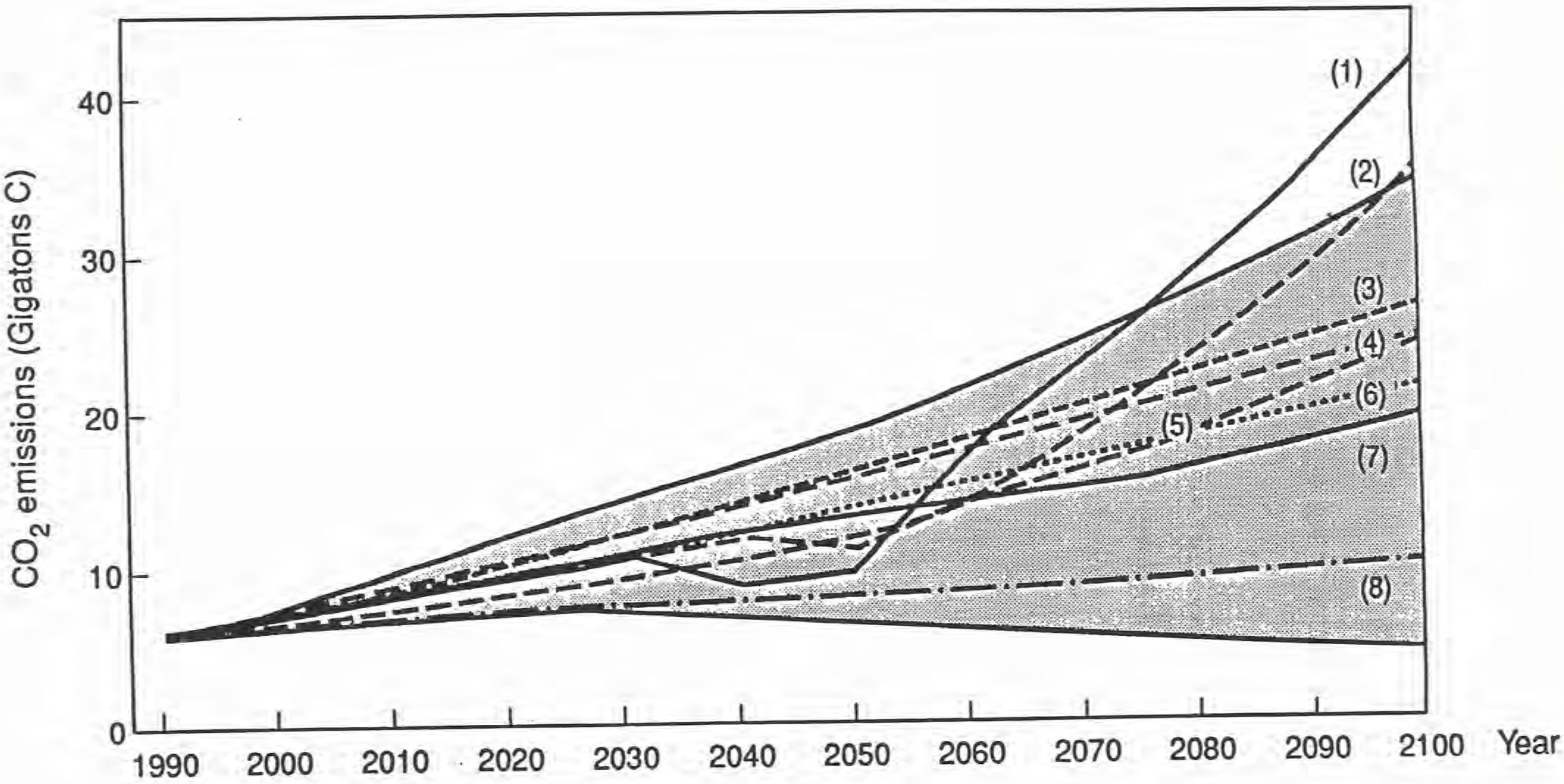


Figure 2
Representative published "emissions scenarios" based on various assumptions about population growth, industrial and economic activity. The shaded area indicates the range of the scenarios in the 1992 IPCC update and curve 7 represents the mid range IPCC scenario IS92a. The other curves are from different individual research groups or organisations.

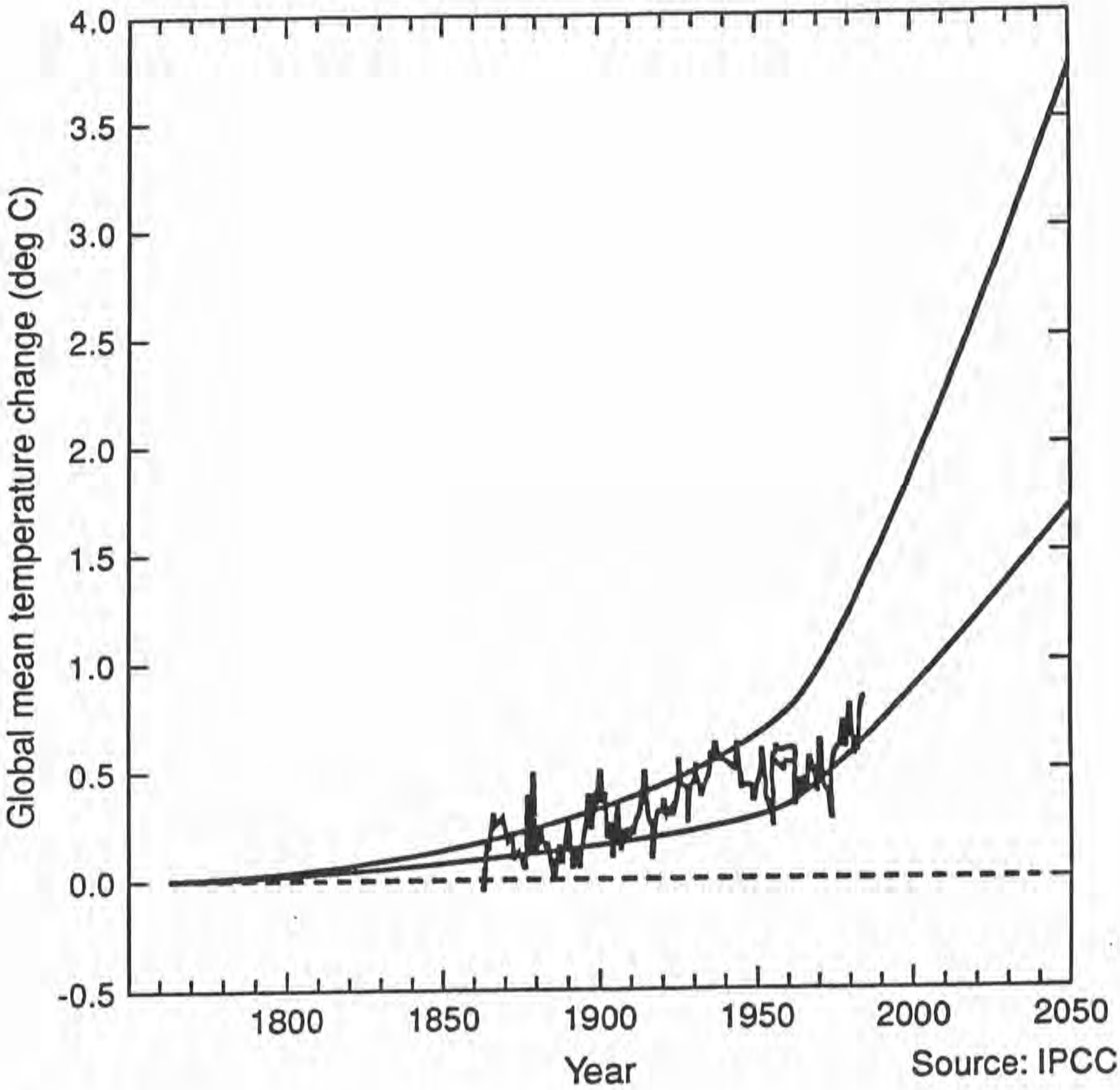
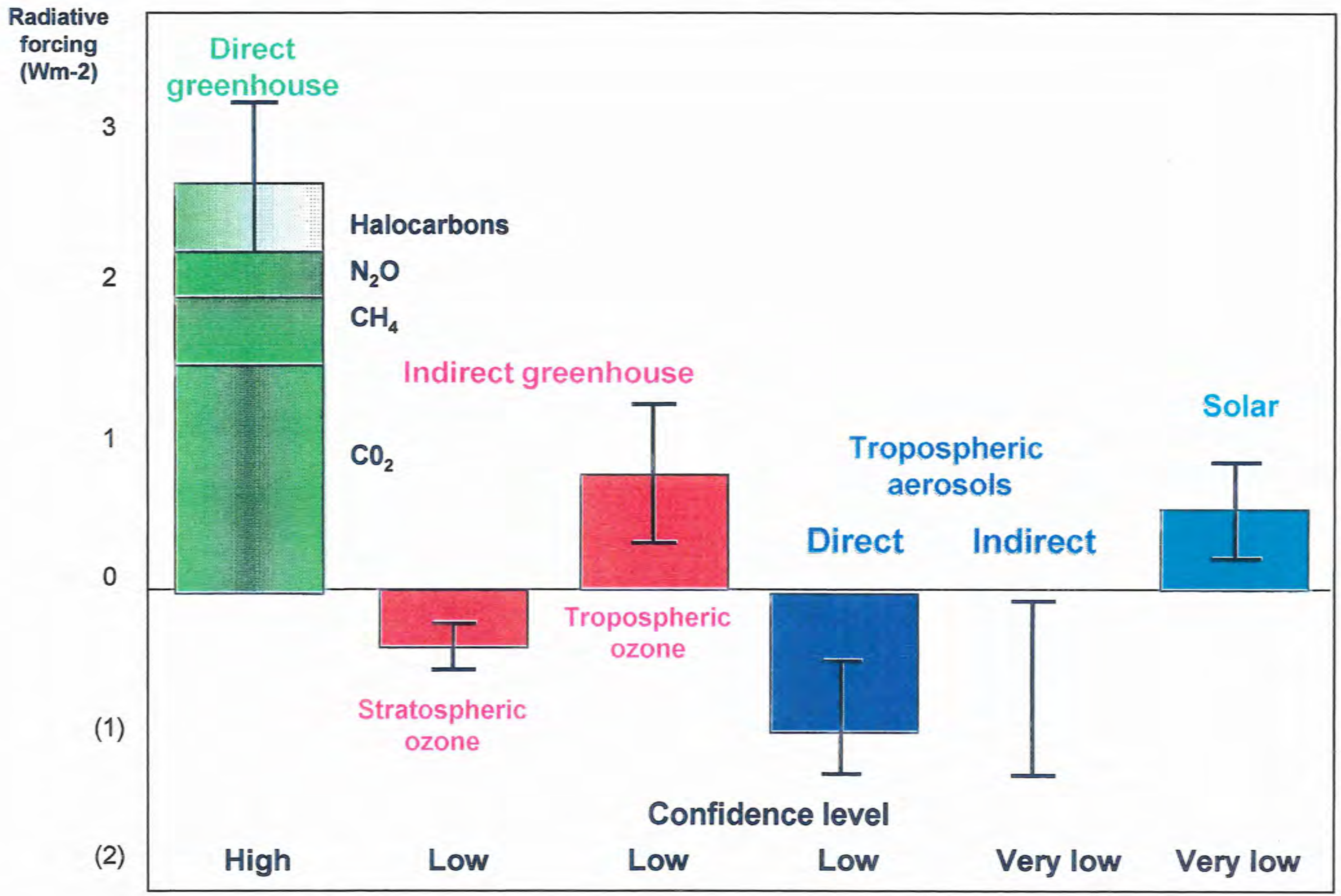


Figure 3
Observed versus predicted global warming. The smooth curves represent the upper and lower IPCC predictions for the warming which would occur with a doubling of pre-industrial CO_2 levels. The irregular curve represents the observed temperature pattern.

Figure 4. Radiative forcing by different factors



Explanation of Figure 4

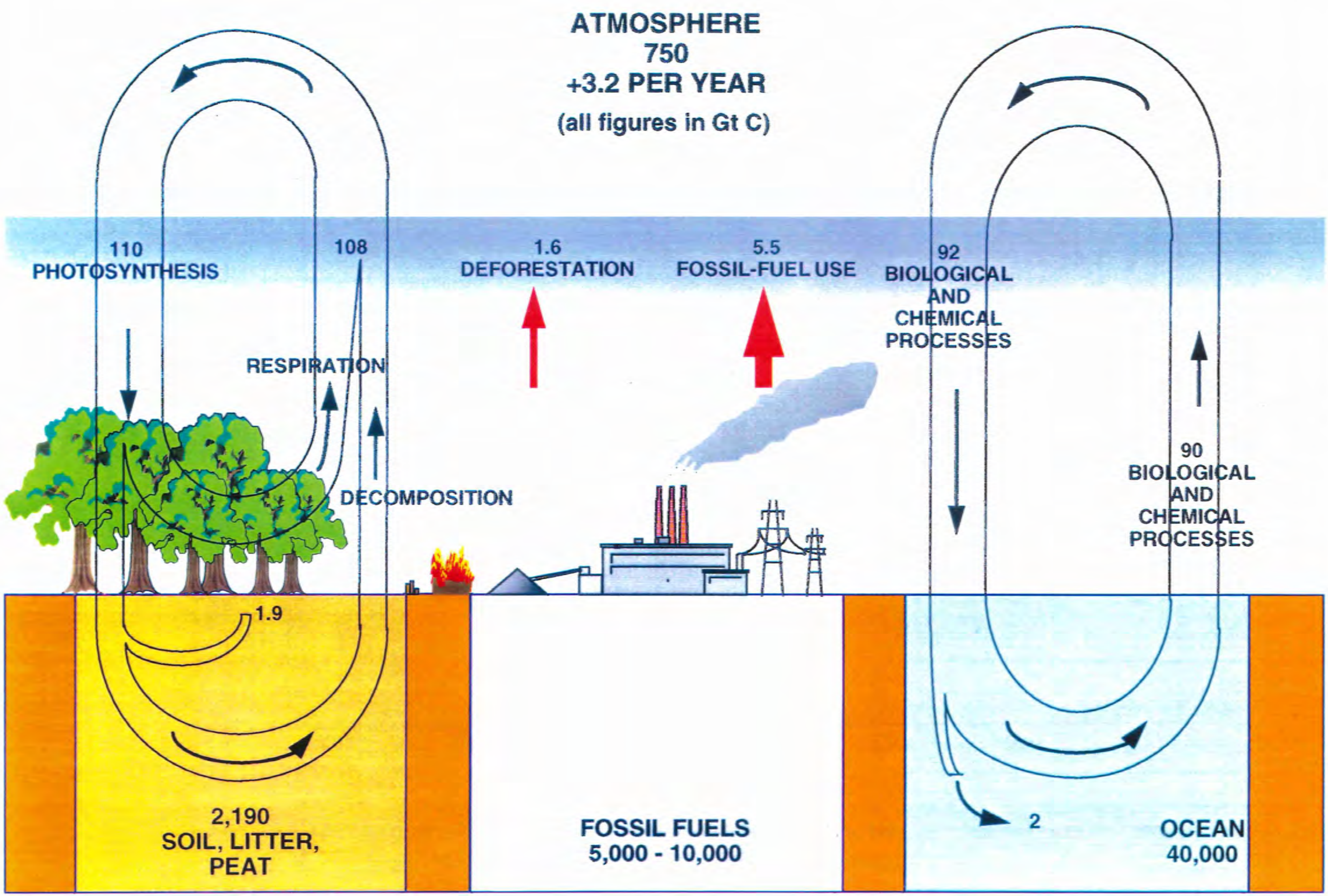
A number of factors contribute to radiative forcing (the enhanced greenhouse effect). Best known are the direct effects of the greenhouse gases themselves(CO_2, CH_4, N_2O, Halo carbons etc.). However, some of these gases, such as CH_4, may have indirect effects through chemical reactions in the atmosphere leading to changes in concentration of other radiatively active gases, especially ozone and water vapour. Tropospheric aerosols have direct effects through reflection of radiation back into space, as well as indirect effects, e.g. through promotion of cloud formation.

The figure shows estimates of the relative contributions to radiative forcing of the different factors. Measurements are made in Wm^{-2} and the bars show the confidence intervals. The total direct enhanced greenhouse gas radiative forcing of 2.5 Wm^{-2} is approximately 1% of incoming solar radiation. This is a small but nonetheless important figure.

Changes in solar radiation are also believed to have made a small contribution to the total radiative forcing.

The combined negative forcing of tropospheric aerosols and stratospheric ozone may have offset the positive direct effects of the greenhouse gases. However, the confidence level in such conclusions is low.

FIGURE 5


ATMOSPHERE
750
+3.2 PER YEAR
(all figures in Gt C)
110
PHOTOSYNTHESIS
108
RESPIRATION
DECOMPOSITION
1.6
DEFORESTATION
5.5
FOSSIL-FUEL USE
92
BIOLOGICAL
AND
CHEMICAL
PROCESSES
90
BIOLOGICAL
AND
CHEMICAL
PROCESSES
1.9
2,190
SOIL, LITTER,
PEAT
FOSSIL FUELS
5,000 - 10,000
2
OCEAN
40,000

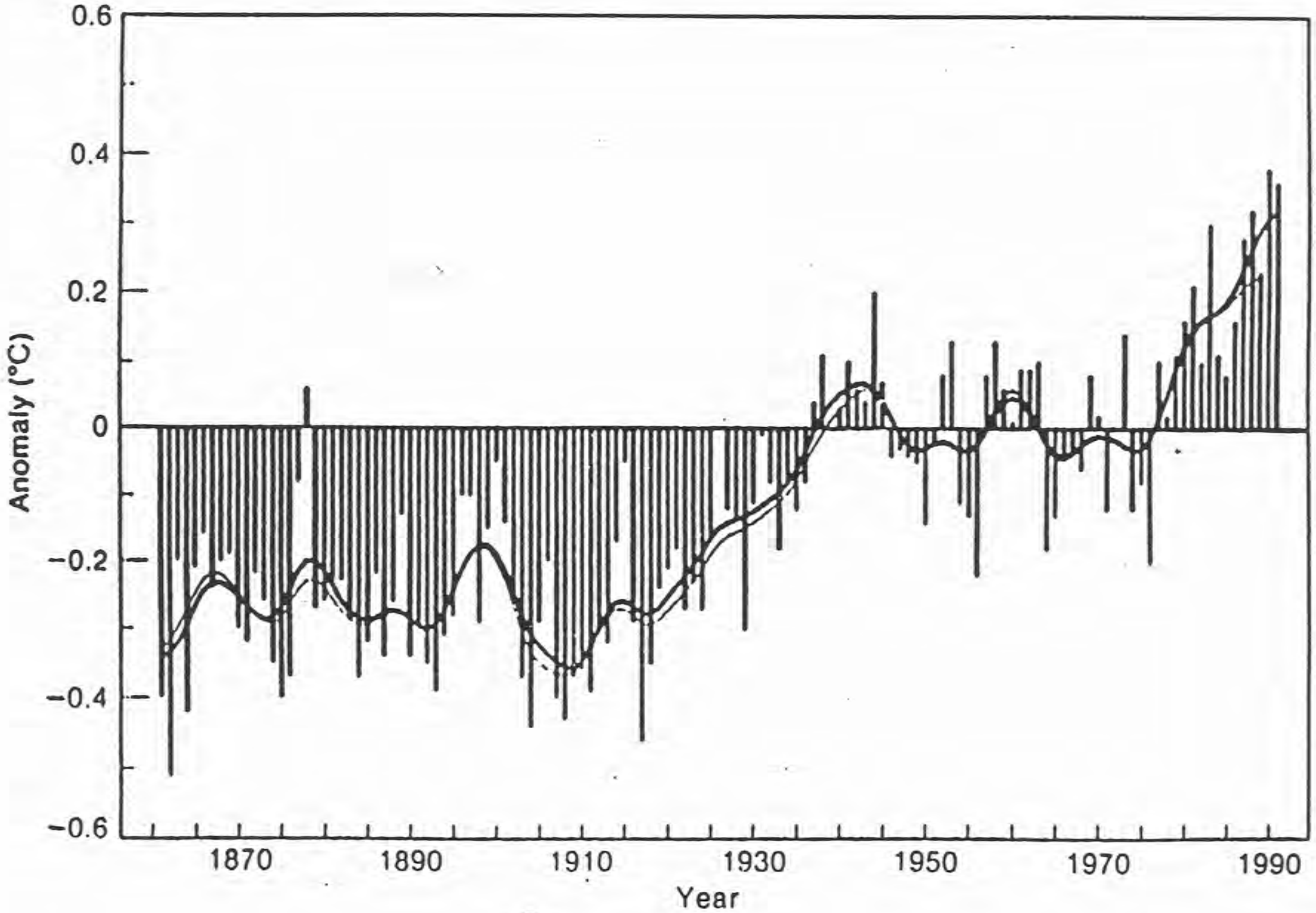
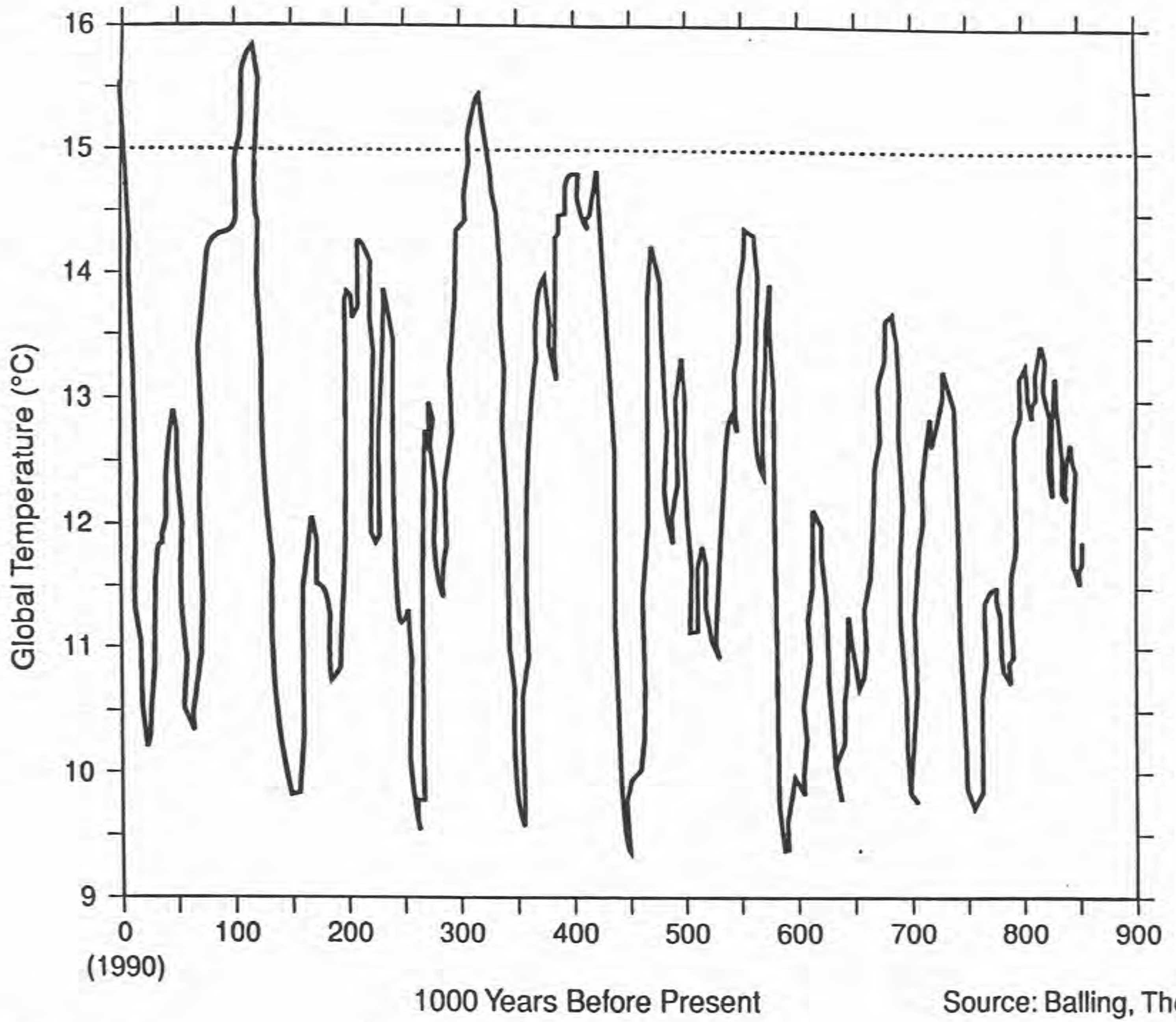


Figure 6. Combined land, air and sea surface global temperature anomalies, 1861-1991, relative to 1951 - 1980

SOURCE : Climate Change 1992. The Supplementary Report to The IPCC Scientific Assessment.



Source: Balling, The Heated Debate

Figure 7
Long term fluctuation of global mean temperature

Production: Shell Reprographics (ODHC/13), The Hague ®

1996 Global Climate Coalition overview backgrounder

Global Climate Coalition
An Overview

Mission

The Global Climate Coalition (GCC) is an organization of business trade associations and private companies established in 1989 to coordinate business participation in the scientific and policy debate on the global climate change issue.

GCC is dedicated to: 1) assessing scientific research on global climate change, 2) analyzing economic and social impacts of policy options, 3) creating an understanding of the global dimensions of the issue to ensure that solutions are addressed equitably by all nations, 4) encouraging transfer of technology to developing nations, and 5) promoting a voluntary commitment among members to "Guiding Principles for Business" that benefit the environment, are consistent with good business practices and are technically and economically feasible.

Programs

GCC is the leading voice for industry on the global climate change issue, and represents its members both internationally and domestically before government agencies, Congress, the media and the general public. The coalition contributes to a balanced debate on global climate change by sponsoring independent research and studies that examine the potential impacts of proposed global climate change policies on the economy. Through educational materials and programs, GCC supports an informed press and public, and an open scientific dialogue.

Position on Climate Change

GCC accepts the finding that there is a natural "greenhouse effect" which protects the Earth from the freezing rigors of space. GCC agrees that the amount of so-called greenhouse gases in the Earth's atmosphere is increasing. In addition, GCC also accepts that the Earth's climate has warmed about 0.5° C since the late 19th century. It is an open question however, what the cause

1331 Pennsylvania Avenue, NW • Suite 1500 North Tower • Washington, DC 20004-1703
Telephone: (202) 637-3162 • Fax: (202) 638-1032 • Fax: (202) 638-1043

of this warming has been. The GCC believes that the preponderance of the evidence indicates that most, if not all, of the observed warming is part of a natural warming trend which began approximately 400 years ago. If there is an anthropogenic component to this observed warming, the GCC believes that it must be very small and must be superimposed on a much larger natural warming trend. These positions are consistent with the following IPCC conclusions:

> *"...the long-term change of temperature could be interpreted as showing a gradual increase from the late 16th century, interrupted by cooler conditions in the 19th century."*[1]

> *"The rather rapid changes in global temperature seen around 1920-1940 are very likely to have had a mainly natural origin."*[2]

> *"None of the studies cited above has shown clear evidence that we can attribute the observed [temperature] changes to the specific cause of increases in greenhouse gases."*[3]

The GCC believes there is no convincing evidence that future increases in greenhouse gas concentrations will produce significant climatic effects. Such evidence necessarily must be based on projections produced by climate models. The IPCC Second Assessment Report (SAR) has highlighted a large number of inadequacies in current climate models which raise serious doubts about the credibility of current climate change scenarios, and therefore the policy-relevance of impact projections to policy makers.

> *"Furthermore, the differences between the internally-generated noise estimates from different GCMs translate into important uncertainties....These noise estimates are the primary yardsticks that must be used to judge the significance of correspondences between modeled and observed changes. They may be flawed on the century time scales of interest....The burden of proof this is not the case lies with climate modellers...."*[3]

If the "primary yardstick" is flawed, then doubts about the credibility and policy-relevance of climate scenarios and impact projections are justified. The GCC believes the scientific community has not yet met the "burden of proof" that greenhouse gas emissions are likely to cause serious climatic impacts.

In addition, the SAR makes it clear that in order to establish any evidence of a human influence on climate, potential human effects must be distinguished from the background "noise" of natural climate fluctuations. The SAR makes it clear that such quantification requires rigorous statistical analysis, which climate researchers have not yet performed. Consequently, we note the following IPCC conclusions :

> *"While some of the pattern-based studies discussed here have claimed a significant climate change, no study to date has positively attributed all or part of that change to anthropogenic causes. Nor has any study quantified the magnitude of a greenhouse-gas effect or aerosol effect in the observed data--an issue that is of primary relevance to policymakers."*[3]

Considerable uncertainty remains within the scientific community about fundamental questions relating to this issue. Significant reductions in these uncertainties are essential. For this reason, GCC supports a coordinated international research program, the continuation of U.S. climate research efforts ($1.8 billion requested for FY 1995), in addition to independent and industry sponsored research. GCC also supports activities to reduce greenhouse gas emissions that make sense in their own right, thus continuing sound business practices that will lead to more efficient use of energy while supporting economic growth.

GCC believes that there are trade-offs associated with many of the regulatory schemes to control greenhouse gas emissions. Some of these proposals would impose a direct tax on businesses and consumers through energy or environmental fees while other proposals would impose a hidden tax through other indirect, control measures. These trade-offs would include higher energy and product costs to American consumers, higher operating costs for industry and a potential negative impact on employment. Importantly, many of these proposals would create a competitive advantage for our international trading partners at the expense of U.S. jobs and economic growth.

The GCC believes, along with the IPCC, that policymakers should be realistic when considering greenhouse gas mitigation policies:

"The applicability of any option must be evaluated against (among other things) a background of a country's technology and human resources capability, financial resources, cultural and social acceptability, and the political and legal framework. This is not to suggest that these constraints are not insurmountable but that decision makers must be realistic when considering the range of options available to them."[4]

Membership

The current membership of GCC represents a broad cross-section of U.S. business organizations and companies representing a range of industrial sectors, including: oil, coal, paper, automobile manufacturing, railroads, chemical manufacturing, and utilities.

Organization

The GCC Board of Directors serves as the organization's governing body. The Operating Committee oversees the functional implementation of GCC activities, and John Shlaes, Executive Director, has oversight of day-to-day operations. To address specific aspects of the global climate change issue and to evaluate policy options, GCC utilizes ten committees, including Science and Technology, Communications, Economic Analysis, Federal Affairs, and International.

For More Information:

Global Climate Coalition
1331 Pennsylvania Ave. NW
Suite 1500 - North Lobby
Washington, DC 20004
Email: gcc@igc.apc.org
Internet: http://www.worldcorp.com/dc-online/gcc

Press Office
Phone: (202) 628-3622/Fax:(202) 639-8685
Executive Director
Phone: (202) 637-3158/ Fax:(202) 638-1043

1. IPCC Working Group I Report, section 3.6.4, Madrid 27-29 Nov., 1995
2. Climate Change, the 1990 IPCC Assessment, Cambridge University Press, section 7.12.
3. IPCC Working Group I Report, section 8.7, Madrid 27-29 Nov., 1995
4. IPCC Working Group II Report, section 9.6.3, Montreal 16-20 Oct., 1995

The Global Climate Coalition is an organization of business trade associations and private companies established in 1989 to coordinate business participation in the scientific and policy debate on global climate change.

[25104: 11/11/96 04:17 PM]

GLOBAL CLIMATE COALITION

GROWTH IN A GLOBAL ENVIRONMENT

CLIMATE MODELS: ISSUES AND CHALLENGES

The views of the Global Climate Coalition

SCIENCE: "The observation, identification, description, experimental investigation, and theoretical explanation of phenomena." The science of climate change is in its infancy.

Computer climate models are the primary tools employed to measure the complex variables that constitute the earth's climate system and to estimate the impact of these variables on climatic change. They are imperfect at best and have produced highly inaccurate projections of climate change.

Climate models consist of mathematical equations designed to simulate climate processes. A model incorporating every possible climate variable would be too complex to run on even the most advanced computer. Adjusting for this level of complexity calls for the use of a variety of simplifications, approximations and assumptions in the models.

Gerald Meehl of the National Center for Atmospheric Research described the difficulty of creating accurate climate models this way: "You can put...components [of climate] together if you have a lot of computing power, but we know from our own experience with ocean, atmosphere, and ice components that it's a major step from components to having it look like the planet Earth."

These challenges are echoed by an international panel of climate experts assembled by the United Nations. According to the Intergovernmental Panel on Climate Change (IPCC):

> "The current generation of models are simplistic and are poor representations of dynamic processes. The effect of climate change adaptation in particular is poorly understood." (WGIII, FSM, section 6.5.2.5)
>
> "GCM [Global Circulation Models] outputs, though physically plausible, often fail to reproduce even the seasonal pattern of present-day climate observed at a regional scale. This naturally casts some doubt on the ability of GCMs to provide accurate estimates of future regional climate. Thus

1331 Pennsylvania Avenue, NW • Suite 1500 • North Tower • Washington, DC 20004-1703
Telephone: (202) 637-3162 • Fax: (202) 638-1032 • Fax: (202) 638-1043

GCM outputs should be treated, at best, as broad-scale sets of possible future climatic conditions and should not be regarded as predictions." (WGII FSM (Chapter 26, Technical Guidelines), section 6.5.3)

Weaknesses in the climate models have led to inaccurate forecasts predicting that increases in greenhouse gases would bring a relatively rapid warming trend across the globe, on the order of 0.3 degrees Celsius to 0.5 degrees Celsius during the past 15 years. Highly accurate satellite temperature readings analyzed by the National Aeronautics and Space Administration (NASA) indicate that the observed warming trend is within the range of natural variation and that the computer models are overestimating global warming trends by as much as 400%.

Also, according to some computer simulations of the greenhouse effect, the average temperature in the United States should have increased by approximately 1.5 degrees Celsius during the past 100 years. Information collected by the National Climatic Data Center shows no significant warming in the U.S.

As for the future, according to the IPCC, much work remains to be done before the predictive capacity of computer climate models can be reliably used by policy makers.

> "It is worth noting here that while predictive models offer the most promising means of obtaining estimates of possible future impacts of climate change, in some sectors these are not yet sufficiently developed to be used for this purpose. Where the systems are complex and/or poorly understood (e.g., marine ecosystems), considerable efforts are still required to obtain an understanding even of variations in the present-day system. Only after such basic research is completed can meaningful projections be made in the future." (WGII FSM (Chapter 26, Technical Guidelines), section 5.3)

Currently no science exists to accurately forecast long-term climate change. Using the computer models to provide one layer of insight into the study of climate change--while monitoring the more accurate satellite measurement systems--and continually striving for improvement in the field of computer climate modeling, are responsible ways to narrow uncertainties in forecasting to better understand our variable weather. In the meantime, policy makers should recognize that current GCM projections cannot provide reliable information for policy purposes.

The Global Climate Coalition is an organization of business trade associations and private companies established in 1989 to coordinate business participation in the scientific and policy debate on global climate change.

WGI, WGII, WGIII = IPCC Working Groups One, Two and Three.
FSM = Full Supporting Material, the peer reviewed portion of IPCC's work.
[24815: 11/11/96]

ECONOMIC AND LIFESTYLE IMPACTS FROM PROPOSED GREENHOUSE GAS EMISSION RESTRICTIONS

The Views of the Global Climate Coalition

U.S. living standards and lifestyles would be seriously damaged by many of the greenhouse gas abatement proposals currently under consideration, especially those that would stabilize or reduce carbon emissions by taxing fossil fuels.

Studies have been conducted on the effects of carbon taxation by a number of experts in the field, including Dr. Lawrence Horwitz of DRI/McGraw-Hill, Dr. Alan Manne of Stanford University, and by the Energy Modeling Forum. All agree that energy taxation would appreciably shrink our economy. While carbon taxes might not be the policy chosen to reduce energy use, economists generally view carbon taxes as a "least-cost" estimate of the impact of other policies that might be used to reduce energy use.

Dr. Horwitz's study determined that about 40 percent of the cost increases brought by a carbon tax imposed to reduce carbon emissions to 1990 levels by 2010 would fall directly on households. This action would increase expenditures on energy use -- electricity for heating, cooling, lighting and running appliances. Carbon taxes would also drive up individual transportation costs.

This might seem like a fair price if it would stop a dangerous "global warming" as some special interests have claimed. But when the Intergovernmental Panel on Climate Change (IPCC), an international panel of climate experts assembled by the United Nations, issued a recent peer-reviewed report on what they actually know about future climate change, the results were enlightening.

(MORE)

> "Future population and economic growth are uncertain, future greenhouse gas emissions given population and economic activity are uncertain, future greenhouse gas concentrations given emissions are uncertain, future climate given atmospheric concentrations of greenhouse gases are uncertain, future physical impacts of climate change are uncertain, and the future valuation of the physical impacts attributable to climate change are uncertain." (WGIII, FSM, chapter 10, section "Elements of an Integrated Assessment Model")

The remainder of the cost increases compelled by carbon taxation would be borne by industry in the form of higher prices for goods and services, which would then be passed along to the general consumer. Real consumer spending would fall about 2 percent, or $452 per adult. Dr. Horwitz predicts that 89 percent of consumption categories would be negatively affected by the carbon tax.

In response to higher consumer prices and lower demand brought by the tax regime, real business fixed investment would plummet $56 billion annually by 2010, according to Horwitz. With a general slowdown in business, the employment rate would fall precipitously. Between 1995 and 2010, some 520,000 jobs would be lost annually.

Additionally, real disposable income levels would decline. By 2010 that decline would be in the range of $75 billion in 1992 dollars, or almost $400 less income for every American aged 16 to 65. The residual effects of carbon-based taxation would be significant, including a general trend toward smaller homes and a sharp decline in home buyers as the cost of owning and operating a home rises while real disposable income falls.

The damage done to the nation's Gross Domestic Product would be significant. The Energy Modeling Forum found a decline of about 2 percent in GDP assuming a 20 percent emissions reduction by 2010. The results of Horwitz's study were even more alarming, projecting a reduction of 2.3 percent or $203 billion dollars by 2010. This is about $862 for every adult in the U.S.

The IPCC, quoted above, offers additional insight into claims that U.S. taxpayers must be immediately forced into a new regime of energy taxation.

(MORE)

> "As a policy question, global climate is sometimes posed as a choice between doing nothing at all, and committing to an all out effort. Given the large current uncertainties about costs and benefits of greenhouse mitigation, this is the wrong way to frame the issue. A more useful formulation is: 'Given current knowledge and concerns, what actions should we take over the next one or two decades to position ourselves to act on new information that will become available.' " (WGIII, FSM, section 1.3.2)

Studies of the costs and benefits of emissions reduction policies demonstrate that a more gradual, long-term approach is advisable. In the place of carbon taxation, for example, energy saving is still possible within our economy. This and other alternatives should be explored thoroughly before instituting policies that would bring drastic and possibly unwarranted change to our living standards and lifestyles.

The Global Climate Coalition is an organization of business trade associations and private companies established in 1989 to coordinate business participation in the scientific and policy debate on global climate change.

WGI, WGII, WGIII = IPCC Working Groups One, Two and Three.
FSM = Full Supporting Material, the peer reviewed portion of IPCC's work.

[24820: 11/11/96]

# # #

ISSUES RELATED TO POTENTIAL HEALTH IMPACTS RESULTING FROM CLIMATE CHANGE

The Views Of The Global Climate Coalition

Attempting to link global climate change and adverse health impacts requires a long and very tenuous stretch. Attention to this labored hypothesis detracts from a much needed focus on solid, identifiable ways to improve public health around the globe.

Concerns that climate change might be the cause of various health problems rests on a number of unproved assumptions. Most of the existing literature concerning the potential health impacts of climate change is based on computer-generated projections of possible increases in global average temperatures into the next century. Climate related health impact projections reported in 1995 by the Intergovernmental Panel on Climate Change (IPCC), a panel of international climate and economic experts assembled by the United Nations, are based on the 1992 IPCC climate projections.

However, since 1992, improvements in climate models have resulted in significant reductions in the projected rate and magnitude of future climate change. For example, the IPCC in 1995 has stated that their "best estimate" is that global mean surface air temperature will increase about 2 degrees C by the year 2100. This estimate is approximately one third lower than the "best estimate" in 1992. As a result, health impact projections should be reassessed using the 1995 climate projections. The Global Climate Coalition believes that such a reassessment will produce significantly lower health impact projections than currently reported by the IPCC and in general media accounts on the topic.

In addition, when reviewing health impact projections based on regional forecasts from climate models, policy makers should consider that confidence in such projections can be no greater than the confidence which exists in the regional climate forecasts. According to the IPCC, confidence in regional climate forecasts "remains low". Therefore, confidence in health impact projections based on these models must also be low.

1331 Pennsylvania Avenue, NW • Suite 1500 • North Tower • Washington, DC 20004-1703
Telephone: (202) 637-3162 • Fax: (202) 638-1032 • Fax: (202) 638-1043

As a result, any assessment of potential health impacts suggested in the literature needs to be placed in context. Suggestions have been made that man-made greenhouse gases either have or will lead to death and illnesses from increased heat waves, climate-related droughts, floods and other disasters. Global warming alarmists also claim that infectious diseases would be spread to new regions of the world, especially "vector borne diseases" such as malaria and dengue, which are transmitted by mosquitoes, rodents and other carriers.

Duane Gubler, chief of the vector-borne disease branch of the U.S. Centers for Disease Control, is skeptical that any connection exists between global warming and the spread of disease. "Dengue is an example that all the people who talk about this use...," he told the Baltimore Sun recently. "But none of this has been associated with global warming...."

Dr. Gubler believes the primary culprits for the spread of disease are poverty, poor sanitation, increased world population and a declining health infrastructure. Dr. John La Montagnac, a director at the National Institute of Allergy and Infectious Diseases, agrees with this view and adds that mass human migration and the growing ineffectiveness of antibiotics are also responsible for the spread of disease.

The most recent scientific assessment of the Intergovernmental Panel on Climate Change states that:

> "Improved primary health care for vulnerable populations could play a significant role in reducing a range of health impacts, including some vector-borne and other communicable diseases, and the effects of extreme events." (WGII FSM, section 18.5)

The IPCC lists a number of actions that would be far more effective and far more responsive to human suffering than directing limited resources to cutting current greenhouse gas emissions. Disease vector distribution can change for a number of environmental reasons, including natural variability in weather patterns. There are many ways to respond to those changes according to the IPCC.

> "Improved sanitation and water treatment both reduce the spread of waterborne diseases and may provide a measure of safeguard against importing exotic enteric waterborne diseases such as cholera...Finally, disease surveillance could be strengthened and integrated with other environmental monitoring to design early warning systems; develop early, environmentally sound public health interventions; and develop anticipatory societal policies to reduce the risk of outbreaks and the subsequent spread of epidemics." (WGII FSM, section 12.5.6)

Since natural variations exist in the forces that control climate change, regional and global average temperature changes are likely to occur regardless of attempts to reduce man-made emissions of greenhouse gases. As a result, the most prudent and effective course of action to protect public health is to improve basic health services as outlined above.

The Global Climate Coalition believes that health professionals have a responsibility to focus on known health threats such as: the inadequacy of public health surveillance to provide early detection of diseases, the inadequacy of sanitation and water quality, inadequate nutrition and personal behavior. Nations with higher standards of living are generally healthier. Economic growth and development generate resources that enable societies to improve living standards, which include better access to health care facilities and disease prevention.

In short, climate change is a marginal factor in the broad range of public policy options that should be examined in addressing health concerns around the globe. The issue is one of priorities and proper use of scarce human and capital resources. Attention should be directed at those who suffer from inadequate nutrition, a lack of fresh water, subpar health care, deficient sanitation and similar problems. Improvements should also be made in disease warning networks and national vaccination programs, and disease prevention should be emphasized over treatment.

The Global Climate Coalition is an organization of business trade associations and private companies established in 1989 to coordinate business participation in the scientific and policy debate on global climate change.

WGI, WGII, WGIII = IPCC Working Groups One, Two and Three.
FSM = Full Supporting Material, the peer reviewed portion of IPCC's work.

[24817: 11/11/96]

GROWTH IN A GLOBAL ENVIRONMENT

GLOBAL CLIMATE COALITION

ECONOMIC AND EMPLOYMENT IMPACTS FROM PROPOSED GREENHOUSE GAS EMISSION RESTRICTIONS

The Views of The Global Climate Coalition

Any program geared to near-term stabilization or reduction in carbon emissions, whether voluntary or induced, is likely to produce significant economic dislocations in the United States, including profound job losses and major economic restructuring.

Profound economic consequences would result from some of the programs being considered to reduce greenhouse gas emissions in the next two decades. For example, a DRI/McGraw-Hill study of carbon taxation as a method to reduce carbon emissions to 1990 levels by 2010 suggests that such an approach would lead to job losses averaging more than 500,000 per year between 1995 and 2010, with peak losses of 1,000,000 jobs per year in the two years after the tax was fully implemented.

One reason that so many jobs would be lost is that current carbon-tax proposals would only apply to a limited number of countries. In fact, most countries in the world would be exempt. The result would be that energy intensive industries would be economically compelled to move to non-taxed countries, taking jobs with them. According to the Intergovernmental Panel on Climate Change (IPCC), a panel of international climate experts assembled by the United Nations, carbon-based energy taxes (advocated by anti-growth special interest groups and endorsed by the Clinton Administration) could provoke industry relocation, which would force jobs out of the United States.

> "Taxes that are not levied on a global scale may provoke industry relocation, which may adversely affect emissions efficiency as well as international competitiveness. Most countries are hesitant to embark on policy ventures that might endanger their international market position and their attractiveness as industrial locations...It is difficult for a single nation to impose full environmental cost accounting and remain competitive unless other nations do the same." (WGII FSM, section 20.5.3.3)

(MORE)

1331 Pennsylvania Avenue, NW • Suite 1500 - North Tower • Washington, DC 20004-1703
Telephone: (202) 637-3162 • Fax: (202) 638-1032 • Fax: (202) 638-1043

> "If different countries have different obligations to reduce greenhouse gas emissions, different implicit tax rates will result...possibly with little effect on total greenhouse gas emissions." (WGIII, FSM, section 1.3.6)

The carbon-tax proposals also would lead to the restructuring of large sectors of the American manufacturing community. The aluminum, ferrous metals, iron core mining, paper mills, fertilizer and metal container industries would experience severe impacts. Restructuring i these sectors would not come without significant job losses.

Longer term shrinkage in the job market could also result from other near-term emissions reduction proposals, which have been projected to cause anywhere from a 1 percent reduction in the Gross Domestic Product by the year 2000 to a 2.3 percent decline by 2010. This is doubly alarming considering that the U.S. GDP has already slowed from an annual growth rate of 4.2 percent annually between 1963 and 1972 to 2.6 percent over the past two decades.

A decline in investment spending also would result at a time when this category compares unfavorably to that of our major competitors. And our net saving rate is low compared to these nations, averaging 4.6 percent while Japan's net saving rate stands at 19 percent, Germany's at 11 percent and Canada's at almost 8 percent.

Fossil fuel detractors are pushing for the United States and other industrialized nations to bear the entire burden of greenhouse gas emissions reduction even though the developing countries will be responsible for the vast majority of future emissions. Such an approach would force U.S. taxpayers to pay enormous amounts to other countries with little environmental benefit. According to the IPCC, such unilateral action by the U.S. would produce exaggerated economic impacts and would be ineffective in reducing global greenhouse emissions:

> "... unilateral action by the US or by OECD countries are likely to be less effective than global action, and that unilateral actions are likely to exaggerate the impact on GDP." (WGIII, FSM, section 5.4)

(MORE)

Further rebuttal of the calls by various anti-growth special interest groups for new energy taxes is the finding by the IPCC that a range of other policy issues carry far greater impact on social welfare than potential future climate change.

> "Local environmental and socioeconomic situations are changing rapidly for reasons other than climate change. Worldwide, population growth, industrialization, urbanization, poverty, technological change, and government policy could overwhelm any effects of climate change." (WGII FSM, section 12.0)

The potential economic consequences of the greenhouse gas emissions reduction proposals now under consideration are large enough that policymakers should call for a rejection of the current direction. Policies that promote a more studied, balanced and less destructive approach should be encouraged. Studies have demonstrated a longer term, measured approach to emissions reductions can have an equal impact at considerably less cost to the economy, jobs, and growth.

The Global Climate Coalition is an organization of business trade associations and private companies established in 1989 to coordinate business participation in the scientific and policy debate on global climate change.

WGI, WGII, WGIII = IPCC Working Groups One, Two and Three.
FSM = Full Supporting Material, the peer reviewed portion of IPCC's work.

[24819: 11/11/96]

# # #

IMPACTS ON TRADE AND COMPETITIVENESS FROM PROPOSED GREENHOUSE GAS EMISSION RESTRICTIONS

The Views of the Global Climate Coalition

Imposing near-term goals to stabilize or reduce carbon emissions would weaken the U.S. economy and cripple the nation's competitiveness in the global marketplace. Given the uncertainties about the impact of carbon emissions on global climate change, a more studied approach to the development of these greenhouse gas mitigation policies should be adopted.

Economist Dr. Alan Manne of Stanford University studied typical abatement proposals intended to stabilize global carbon emissions between 1990 and the year 2000, reduce them to 80 percent of this level by 2010, and stabilize them thereafter. According to Dr. Manne's findings, price-induced energy conservation and shifts to low carbon fuels to reach the goals set forth in these proposals would result in annual losses ranging from 1 percent of the U.S. Gross Domestic Product to nearly 2.5 percent of the nation's GDP.[1]

Dr. Manne argues that these restrictive approaches to limit carbon emissions would hinder U.S. international competitiveness in such basic industries as chemicals, steel, aluminum, petroleum refining and mining -- all of which are energy intensive. He contends further that the U.S. coal exporting industry would be put out of business and severe strains would be placed on important trade pacts like NAFTA and GATT.

Dr. Manne's conclusions have been supported in studies conducted by Economist Lawrence M. Horwitz of DRI/McGraw-Hill, an economic modeling consultancy. Mr. Horwitz reports that efforts to reduce greenhouse gas emissions to 1990 levels by 2010 through the use of carbon taxes would reduce the U.S. GDP by 2.3 percent, or $203 billion, relative to the baseline forecast; decrease business investment by almost 5 percent; and reduce consumer spending by 2 percent. Overall, 89 percent of consumption categories would be negatively affected by the carbon tax. An American economy so weakened could be a handicapped player in the

1 "Costs and Benefits of Alternative CO_2 Emissions Reduction Strategies".

1331 Pennsylvania Avenue, NW • Suite 15[illegible] North Tower • Washington, DC 20004-1703
Telephone: (202) 637-3162 • Fax: (202) 638-1032 • Fax: (202) 638-1043

international marketplace.

According to the Intergovernmental Panel on Climate Change (IPCC), a panel of international climate and economic experts assembled by the United Nations, countries, such as the United States, that actually implement carbon taxes and other fiscal instruments to restrict greenhouse gas emissions may be at a severe disadvantage.

> "Taxes that are not levied on a global scale may provoke industry relocation, which may adversely affect emissions efficiency as well as international competitiveness. Most countries are hesitant to embark on policy ventures that might endanger their international market position and their attractiveness as industrial locations...It is difficult for a single nation to impose full environmental cost accounting and remain competitive unless other nations do the same." (WGII FSM, section 20.5.3.3)

The IPCC estimates the cost of carbon-based taxes is fairly high. Estimates range from $20 to $150 per ton for the carbon taxes required to hold emissions at 1990 levels in 2010 and from $50 to $330 per ton to reduce emissions by an additional 20 percent. While the impact on economies from fiscal instruments such as carbon-based taxes can be assessed fairly easily, the social and economic impacts from potential warming cannot, according to the IPCC.

> "The level of sophistication of climate change damage analysis is comparatively low. Damage estimates are generally tentative and based on several simplifying, and often controversial assumptions. The degree of uncertainty is correspondingly high, both with respect to physical impacts as well as their consequences for social welfare. No attempt has been made to specify confidence intervals. Rather, estimates are best guesses." (WGIII, FSM, section 6.1)

Economist Dr. W. David Montgomery, an IPCC lead author, argues that concentrating on near-term emissions reduction targets represents a costly and potentially unnecessary approach to climate policy. It would be much more cost effective to focus on the long-term stabilization of <u>atmospheric concentrations</u> of greenhouse gases rather than on short-term <u>emissions</u>.

Many of the reasons for this are cited in the IPCC Second Assessment Report.

> "There are several reasons why a less restrictive near-term emissions path may turn out to be less expensive. First, large emissions reductions in the near term will require premature retirement of the existing capital stock. This is apt to be costly. There will be more opportunities for reducing emissions cheaply once the current capital equipment turns over. Second, the availability and cost of substitutes are likely to improve over time. There is ample historical evidence for improvements in the efficiency of energy supply, transformation, and end-

use technologies (Chapter 8) , and expectation of substantial further improvement in the future... Finally, even if the costs of removing a ton of carbon were the same in all periods, a positive marginal productivity of capital will favor the deferral of reductions. This is because with a positive real rate of return on capital, it will be desirable to invest some of today's potential emission reduction dollars in enhancing our future productive capacity. As a result, the same level of cumulative emission reductions can be achieved at a lower total cost to society." (WGIII, FSM, chapter 10, section "Cost-effective Strategies for Stabilizing Atmospheric CO_2 Concentrations")

Montgomery suggests that various steps are necessary for a more rational approach to developing climate change policies. Among these:

- analyze implications for U.S. net costs and benefits of international sharing of the burden of response;
- inventory possible policy responses and analyze the economic merits of alternative response options.

Emissions reduction policies that promote grave economic consequences for the U.S. economy and threaten the nation's foreign trade position should be avoided. Instead, a studied approach to greenhouse gas policy development should be adopted along with continued investment in climate science and the development of new energy technologies.

The Global Climate Coalition is an organization of business trade associations and private companies established in 1989 to coordinate business participation in the scientific and policy debate on global climate change.

WGI, WGII, WGIII = IPCC Working Groups One, Two and Three.
FSM = Full Supporting Material, the peer reviewed portion of IPCC's work.

[24814: 11/11/96]

GROWTH IN A GLOBAL ENVIRONMENT

GLOBAL CLIMATE COALITION

EXTREME WEATHER EVENTS AND CLIMATE CHANGE

The Views of the Global Climate Coalition

No credible evidence exists to support the contention that hurricanes, tornadoes and other extreme weather events are on the rise or that man-made greenhouse gas emissions are causing increases in extreme weather events.

According to the Intergovernmental Panel on Climate Change (IPCC), an international panel of climate and economic experts assembled by the United Nations, there is no convincing evidence that man-made greenhouse gas emissions have led to any increase in extreme weather events. Claims that human activities have led to more extreme weather events have been made in a few media accounts and by a few special interest groups trying to frighten the general public into supporting unnecessary energy taxes and other restrictions on fossil fuel use. According to the peer-reviewed scientific literature:

> "Overall, there is no evidence that extreme weather events, or climate variability, has increased, in a global sense, through the 20th century, although data and analyses are poor and not comprehensive. On regional scales there is clear evidence of changes in some extremes and climate variability indicators. Some of these changes have been toward greater variability; some have been toward lower variability." (WGI FSM, section 3.5.4)

According to a study of global weather data by Accu-Weather, the world's leading commercial weather firm based in State College, Pennsylvania, a number of factors have contributed to misleading conclusions in the popular media that there has been an increase in weather-related natural disasters, specifically:

- Important statistical principles have been ignored leading to a reliance on data collected from regions of high natural variability.
- Incomplete information has been used about the behavior of complex meteorological variables resulting in simplistic conclusions.
- Important physical evidence has been ignored.

The IPCC was very specific on the issue of whether so-called global warming has led to

1331 Pennsylvania Avenue, NW • Suite 1500 - North Tower • Washington, DC 20004-1703
Telephone: (202) 637-3162 • Fax: (202) 638-1032 • Fax: (202) 638-1043

extreme weather activity such as occurred, for example, in many parts of the United States and Europe in 1995-1996.

> "Of course, it is not possible to attribute particular, isolated, events to a change in climate or weather pattern; other plausible explanations exist for each of them, and a number of different factors may combine to produce each event." (WGII FSM, section 18.7)

> "There is little or no evidence of consistent increases in such events. For instance, Ostby (1993) found no evidence of increased occurrence of strong or violent tornadoes in the USA, although the numbers of reports of less severe tornadoes appears to have increased, perhaps due to increased population, eagerness in reporting, or improved reporting procedures. Grazulis (1993) reported a drop in damaging tornadoes in the 1980s, over the USA." (WGI FSM, section 3.5.3.5)

The Accu-Weather study reports similar findings in a review of information compiled on the frequency of tornadoes. There is no evidence of an increase in strong or violent tornadoes observed in the 48 contiguous states from 1953 to 1993. Actually, the data point to a downward trend in the incidence of such events.

The data collected by Accu-Weather also show that hurricanes have not increased in number or intensity during the past few decades. In fact, it is entirely possible that the number of hurricanes in the Northern Hemisphere has actually decreased in recent years. Some storms detected today would have gone unnoticed 50 to 100 years ago.

A recent World Meteorological Organization report on global climate and extreme weather confirms that, "...there is no evidence that would indicate an increased frequency of such events."

As to the assertions by some special interest groups that the weather will become more extreme if global average temperatures increase during the next century, the IPCC peer-reviewed literature makes the following point:

> "Despite the often repeated assertion that climate variability could increase in a warmer world, there is little evidence from climate models to support this notion." (WGII FSM, section 9.3.2)

The Accu-Weather study attributes the ***impression*** of an increase in extreme weather to several factors: an increase in housing and related development in areas that were once sparsely populated, especially along coast lines; the ability of scientists to identify and track weather events using improved technology; and modern communications systems which allow rapid reporting of such events. The IPCC supports this point.

> "Although there is uncertainty, the extent of damage caused by great windstorm catastrophes has expanded in recent years. The concentrations of people living in high-risk coastal regions must be considered the main reason for this alarming trend...It is therefore quite possible to get a scientific assessment of low injury to an ecosystem combined with high economic loss value, especially given that the value of waterfront real estate is normally high." (WGII FSM, section 8.3.1.6)

In this regard, the World Meteorological Organization notes that, "...any increases in the number of fatalities, injuries and amount of damage and destruction caused by extreme events can often be related to population increases, especially in those regions most susceptible to climate variability." Here again, the IPCC provides useful insight, in this case on why insurance related damages may be increasing even though storm activity may not be.

> "There are several reasons for the escalation in the cost of severe weather. Developed countries have become wealthier. Many more people now live in coastal areas with costly infrastructures. Personal goods and business processes are generally more vulnerable to water damage. The built environment also contributes through inappropriate or incorrect design and construction. The insurance industry has compounded matters by extending the basis of coverage. It is a common perception in the insurance industry that there is a trend towards an increased frequency of severity of extreme climate events. The meteorological literature fails to substantiate this in the context of long-term change, though there may have been a shift within the limits of natural variability." (WGII FSM, section 17.0)

It is reasonable to expect extreme weather events to continue with a frequency and intensity that will match past patterns. Rather than attempting to blame weather variability on unfounded claims of "global warming," it would be more useful to prepare people to handle extreme weather events, improve forecasting, communicate warnings, support coastal land use restrictions, and design safer structures.

The Global Climate Coalition is an organization of business trade associations and private companies established in 1989 to coordinate business participation in the scientific and policy debate on global climate change.

WGI, WGII, WGIII = IPCC Working Groups One, Two and Three.
FSM = Full Supporting Material, the peer reviewed portion of IPCC's work.
[24816: 11/11/96]

1995 draft Global Climate Coalition primer,
Predicating Future Climate Change: A Primer

AIAM
The World's Leading Automakers®

TECH-96-29
1/18/96

TO: AIAM Technical Committee

FROM: Gregory J. Dana
Vice President and Technical Director

RE: **GLOBAL CLIMATE COALITION (GCC) - Primer on Climate Change Science - Final Draft**

Enclosed is a primer on global climate change science developed by the GCC. If any members have any comments on this or other GCC documents that are mailed out, please provide me with your comments to forward to the GCC.

GJD:ljf

Mobil Oil Corporation

ENVIRONMENTAL HEALTH
AND SAFETY DEPARTMENT
P.O. BOX 1031
PRINCETON, NEW JERSEY 08543-1031

December 21, 1995

To: Members of GCC-STAC

Attached is what I hope is the final draft of the primer on global climate change science we have been working on for the past few months. It has been revised to more directly address recent statements from IPCC Working Group I and to reflect comments from John Kinsman and Howard Feldman.

We will be discussing this draft at the January 18th STAC meeting. If you are coming to that meeting, please bring any additional comments on the draft with you. If you have comments but are unable to attend the meeting, please fax them to Eric Holdsworth at the GCC office. His fax number is (202) 638-1043 or (202) 638-1032. I will be out of the office for essentially all of the time between now and the next STAC meeting.

Best wishes for the Holiday Season,

Lenny

L. S. Bernstein

APPROVAL DRAFT

Predicting Future Climate Change: A Primer

In its recently approved Summary for Policymakers for its contribution to the IPCC's Second Assessment Report, Working Group I stated:

> ...the balance of evidence suggests that there is a discernable human influence on global climate.

The Global Climate Coalition's Science and Technical Advisory Committee believes that the IPCC statement goes beyond what can be justified by current scientific knowledge.

This paper presents an assessment of those issues in the science of climate change which relate to the ability to predict whether human emissions of greenhouse gases have had an effect on current climate or will have a significant impact on future climate. It is a primer on these issues, not an exhaustive analysis. Complex issues have been simplified, hopefully without any loss of accuracy. Also, since it is a primer, it uses the terminology which has become popular in the climate change debate, even in those cases where the popular terminology is not technically accurate.

Introduction and Summary

Since the beginning of the industrial revolution, human activities have increased the atmospheric concentration of CO_2 by more than 25%. Atmospheric concentrations of other greenhouse gases have also risen. Over the past 120 years, global average temperature has risen by 0.3 - 0.6°C. Since the Greenhouse Effect can be used to relate atmospheric concentration of greenhouse gases to global average temperature, claims have been made that at least part of the temperature rise experienced to date is due to human activities, and that the projected future increases in atmospheric concentrations of greenhouse gases (as the result of human activities) will lead to even larger increases in future temperature. Additionally, it is claimed that these increases in temperature will lead to an array of climate changes (rainfall patterns, storm frequency and intensity, etc.) that could have severe environmental and economic impacts.

This primer addresses the following questions concerning climate change:

1) Can human activities affect climate?

   The scientific basis for the Greenhouse Effect and the potential impact of human emissions of greenhouse gases such as CO_2 on climate is well established and cannot be denied.

2) Can future climate be accurately predicted?

   The climate models which are being used to predict the increases in temperature which might occur with increased atmospheric concentrations of greenhouse gases are limited at present both by incomplete scientific understanding of the factors which affect climate and by inadequate computational power. Improvements in both are likely, and in the next decade it may be possible to make fairly accurate statements about the impact that increased greenhouse gas concentrations could have on climate. However, these improvements may still not translate into an ability to predict future climate for at least two reasons:

- limited understanding of the natural variability of climate, and
- inability to predict future atmospheric concentrations of greenhouse gases.

The smaller the geographic area considered, the poorer the quality of climate prediction. This is a critical limitation in our ability to predict the impacts of climate change, most of which would result from changes in a local or regional area.

3) Have human activities over the last 120 years affected climate, i.e. has the change been greater than natural variability?

Given the limitations of climate models and other information on this question, current claims that a human impact on climate has already been detected, are unjustified. However, assessment of whether human activities have already affected climate may be possible when improved climate models are available. Alternatively, a large, short term change in climate consistent with model predictions could be taken as proof of a human component of climate change.

4) Are there alternate explanations for the climate change which has occurred over the last 120 years?

Explanations based on solar variability, anomalies in the temperature record, etc. are valid to the extent they are used to argue against a conclusion that we understand current climate or can detect a human component in the change in climate that has occurred over the past 120 years. However, these alternative hypotheses do not address what would happen if atmospheric concentrations of greenhouse gases continue to rise at projected rates.

Can Human Activities Affect Climate?

The Sun warms the Earth and is the source of energy for the climate system. However, as shown in Figure 1, the process by which this occurs is complicated. Only about half of the incoming radiation from the Sun is absorbed by the Earth's surface. About a quarter is absorbed by the atmosphere, and the remainder is reflected back into space by clouds, dust and other particulates without being absorbed, either by the surface or atmosphere.

The energy absorbed by the Earth's surface is reradiated to space as longwave radiation. A fraction of this reradiated energy is absorbed by greenhouse gases, a phenomenon known as the Greenhouse Effect. Greenhouse gases are trace gases - such as water vapor, CO_2, methane, etc. - which have the ability to absorb longwave radiation. When a greenhouse gas molecule absorbs longwave energy, it heats up, then radiates energy in all directions, including back down to the Earth's surface. The energy radiated back to the Earth's surface by greenhouse gas molecules is the Greenhouse Effect that further warms the surface. The warmer the surface of the Earth, the more energy it reradiates. The higher the concentration of greenhouse gases, the more energy they will absorb, and the more they will warm the Earth. The average temperature of the Earth depends on the balance between these two phenomena. Naturally occurring greenhouse gases, predominantly water vapor, account for 95-97% of the current Greenhouse Effect. They raise the average temperature of Earth's surface by about 30°C. Without this natural Greenhouse Effect, the Earth would probably be uninhabitable. The science of the Greenhouse Effect is well established and can be demonstrated in the laboratory.

Human activities can affect the energy balance at the Earth's surface in three ways:

- combustion, agriculture and other human activities emit greenhouse gases and can raise their concentration in the atmosphere, which would directionally lead to warming;
- combustion emits particulates, and gases such as sulfur dioxide which form particulate matter in the atmosphere, which would directionally lead to cooling; and
- changes in land-use, such as removing forests, can change the amount of energy absorbed by the Earth's surface, the rate of water evaporation, and other parameters involved in the climate system, which could result in either warming or cooling.

These three factors create the potential for a human impact on climate. The potential for a human impact on climate is based on well-established scientific fact, and should not be denied. While, in theory, human activities have the potential to result in net cooling, a concern about 25 years ago, the current balance between greenhouse gas emissions and the emissions of particulates and particulate-formers is such that essentially all of today's concern is about net warming. However, as will be discussed below, it is still not possible to accurately predict the magnitude (if any), timing or impact of climate change as a result of the increase in greenhouse gas concentrations. Also, because of the complex, possibly chaotic, nature of the climate system, it may never be possible to accurately predict future climate or to estimate the impact of increased greenhouse gas concentrations.

The usual approach to discussing the impact of the increased atmospheric concentrations of greenhouse gases on climate is to convert them to an equivalent amount of CO_2, then discuss the effect of some fixed increase in equivalent CO_2. Most of the discussion is about doubled equivalent CO_2. The conversion to equivalent CO_2 introduces a number of errors, because the effects of some greenhouse gases depend on their location in the atmosphere, but since the convention is well established, it will be used in this discussion. A more accurate approach is to refer to increased radiative forcing, which is the increase in energy radiated to the Earth's surface, taking into account all of the complexities in the physics of greenhouse gases.

Can Future Climate Be Accurately Predicted?

Climate models, called General Circulation Models (GCMs), are used to predict the change in temperature, rainfall, cloud cover and other climate parameters that would result from a change in equivalent CO_2 and sometimes aerosols. The estimates of climate parameters are then used to predict impacts of climate change, such as frequency and severity of tropical storms, effects on agriculture and biodiversity, etc. While most discussions of models focus on their predictions of changes in average temperature, factors such as changes in maximum and minimum temperature, soil moisture content, and prevalence of conditions which favor the formation of tropical storms are far more important in determining potential climate change impacts.

GCMs are three-dimensional grid models which cover the whole Earth, the atmosphere to a sufficient height to include all climate processes, and the oceans in multiple depth layers. GCMs are also referred to as coupled atmosphere-ocean climate models. Most of the debate about the prediction of climate change centers around the quality of both the models and the input data they use, and the degree to which both can be improved. The concerns about these models can be grouped into five categories:

(1) limits in scientific understanding of climate processes,

(2) how they model "feedbacks,"

(3) how they describe the initial conditions, i.e., the current state of the climate,

(4) how well we understand the natural variability of climate, including the possibility that the climate system is chaotic, and

(5) the computational power required to accurately model climate.

A sixth concern, not directly related to GCMs, but important to the question of whether future climate can be accurately predicted, is whether future atmospheric concentrations of greenhouse gases can be accurately predicted. The problem has two components, economic and scientific. The economic question is whether we can accurately predict both the future level of global economic activity and the technology which will be employed. Past predictions in both areas have been highly inaccurate. The scientific question is whether we understand the fate of greenhouse gases well enough to accurately predict the effect their emissions will have on atmospheric concentrations. For example, only about half of the CO_2 emitted from human activities ends up in the atmosphere. The remainder is believed to be absorbed by increased plant growth or in the oceans. Estimates of the amount of CO_2 absorbed by these two sinks are highly uncertain. There is also a great deal of scientific debate on what, if any, impact higher temperatures and related climate change will have on the rate of CO_2 absorption by plants and the ocean.

Limited Scientific Understanding of Climate Processes

Quantifying what we don't know about climate processes is an impossible task. However, the huge volume of important new findings about the processes that are critical to climate generated over the past few years make it obvious that there is a great deal more to be learned about the basic science of climate. For example, in 1995, Prof. Cess and his co-workers at the State University of New York published a paper on the energy balance around clouds which indicated that the values being used in climate models were incorrect by 25%. Cess *et al.* were unable to identify the physical processes which led to this different estimate of energy absorption. Since clouds are a critical part of the climate system, a correct characterization of their properties is essential. Other recent studies indicate that vegetation may be absorbing much more CO_2 than previously believed, allowing less of it to accumulate in the atmosphere.

Feedbacks

Climate models predict that the direct effect of doubling equivalent CO_2 from pre-industrial levels is relatively small. Global average temperature would rise by 0.5 - 1°C, an amount which is not generally considered to represent a problem. However, even that rise in temperature would cause a variety of changes, some of which would act to further increase temperature, others of which would act to decrease temperature. These secondary changes are called "feedbacks." The popular usage is that a positive feedback is one which acts to further increase temperature, and a negative feedback is one which acts to decrease temperature. The technical definition is that a positive feedback is one which exaggerates the initial perturbation, which could either increase or decrease temperature, and a negative feedback is one which decreases the initial perturbation. Since the popular usage is so common, it will be used in this paper.

The most important positive feedback is the impact which rising temperatures will have on the amount of water vapor in the atmosphere. Water vapor is the most important natural greenhouse gas in the atmosphere, accounting for the majority of the natural Greenhouse

Effect. As temperature increases, more water evaporates, the concentration of water vapor in the atmosphere rises, the Greenhouse Effect is enhanced, and temperatures rises further. An example of a negative feedback is that more evaporation of water results in the formation of more clouds. Low level clouds reflect sunlight, preventing its energy from reaching the Earth's surface, thus providing a cooling effect. As noted below, high level clouds provide a positive feedback.

Modeling feedbacks is one the major challenges in developing accurate climate models. The role of clouds is a particularly difficult modeling task. Low level clouds reflect sunlight and therefore are a negative feedback. However, clouds are made up of water vapor and therefore also absorb radiation. For high level clouds the absorption of radiation is more important than the reflection of radiation; they provide a positive feedback. Better estimates of the energy balance around clouds are becoming available, and preliminary modeling results indicate that the use of these better estimates improves the ability of GCM's to match current conditions.

Prediction of Current Conditions

GCMs are supposed to be theory-based models, not empirical models. As such they should be able to match current climate conditions using only the independent variables that determine climate (solar radiation, greenhouse gas concentrations, the current temperature of the oceans, etc.) as inputs. GCMs fail this test because they do not accurately predict the transfer of energy from the oceans to the atmosphere, a critical climate parameter. To correct this error, most GCMs are adjusted with "flux corrections," that on a point-by-point basis adjust the amount of heat being transferred from the oceans to the atmosphere to match actual conditions. The "flux corrections" can be quite large, as much as 10 - 20 times the effect of doubling equivalent CO_2. Having to make this large a correction to obtain model results which provide a reasonable description of the baseline is a cause for serious concern.

Flux corrections are correcting for one of two possible errors: missing climate processes, or errors in the description of the climate processes used in the model. New data, such as a better description of the energy balance around clouds, should lead to improvements in models and a reduction in the flux corrections.

Whether modeling capability will improve to the point where the flux corrections can be eliminated or reduced to a more reasonable level is an open question. To eliminate the flux corrections it is necessary to accurately model all climate processes and have an accurate description of initial conditions. Distribution of heat in the oceans is poorly understood, and the cost of collecting the necessary data makes it unlikely that a better understanding will be developed anytime soon.

Natural Variability and the Possibility that Climate is Chaotic

Thus far, GCMs have been described as relatively mechanical models - plug in the right processes and initial conditions and the model will describe climate. However, climate has natural variability, on both long and short time scales. The existence of Ice Ages and the warm periods between them is proof of climate's natural variability on very long time scales. But climate is also naturally variable on shorter time scales. For example, the milder temperatures in the North Atlantic at about 1000 AD allowed the Vikings to settle Iceland and Greenland, and explore the North American coast. The colder temperatures of the Little Ice Age after 1400 wiped out the Viking settlement in Greenland and nearly did the same to Iceland. This was climate variability on a time scale of several centuries. To accurately model future climate, we need an good estimate of the natural variability of climate on still shorter periods, decades to a century, which is currently unavailable.

Understanding the natural variability of climate on a decadal time scale and its causes would greatly improve our understanding of current climate data. Reasonable temperature records exist for only the last 120 years. Data on factors which could be causes for the variability of climate, such as changes in ocean circulation, is either non-existent or available for much shorter time periods. Until we have a better understanding of natural variability, it will be impossible to determine whether a part of the rise in average temperature experienced over the past century is due to human activities.

In addition, climate may be a chaotic system, which is extremely sensitive to very small changes in initial conditions. Weather is known to be chaotic, and since climate is the long-term average of weather, it, too, may be chaotic. In discussing the ability of GCMs to simulate climate, IPCC WG I, in section 6.2.6 of its Second Assessment Report, does not use the term chaotic, but states

> The models produce a high level of internal variability, as observed (Chapter 5), leading to a spread of possible outcomes for a given scenario, especially at the regional level.

This is a functional definition of chaotic behavior. The reference to Chapter 5 is to a discussion of the ability of models to describe observed climate over the last 120 years. If climate is chaotic, our ability to predict future climate or the effect of anthropogenic changes such as the increase in greenhouse gas emissions will be limited.

Computational Limits

GCMs are huge models which require supercomputers to run in any reasonable time. Computational limitations require that they use large grid sizes, typically 500 km. on a side. These cells are larger than many of the important physical features in the system they are trying to model, for example, the width of the Gulf Stream. Computational limits also mean that some critical factors, such as the atmospheric interactions between greenhouse gases and the chemistry of aerosol formation, are not included in the model. The rapid increase in computational power may make it possible to overcome these limitations in the future, but at present they severely limit the quality of GCM predictions.

Capabilities of GCMs

Even with flux corrections, GCMs still cannot describe climate features on a 1000 mile scale which are critical to any discussion of the impacts of climate change. Also, there is considerable concern about the ability of GCMs to predict future climate because the flux correction is constant with changing equivalent CO_2. There is no reason to assume that the flux correction should remain the same if climate changes in response to increased CO_2. As a result, statements such as: "Doubling CO_2 will lead to x°C. increase in temperature." do not seem justified.

While climate models currently are incapable of accurate predictions of future climate, rapid improvement in their capability is possible. Better understanding of climate processes, such as the role of clouds, could significantly improve the models as could the ever increasing power of computers. Whether we can ever accurately predict future climate is still uncertain because of two problems. First, as mentioned above, climate may be chaotic. Second, even if climate is not chaotic, a model's predictions are only as good as the input data used. Our ability to predict future greenhouse gas emission rates depends on being able to predict the future level of global economic activity and the technology which will be used to generate that activity. Past predictions in both areas have been highly inaccurate.

A critical problem in climate modeling is the prediction of regional climate change. Most of the impacts of climate change will be felt on the regional or local level. The change in global average temperature and rainfall will not help predict the effect of climate change on farmers in the mid-West. The ability to predict regional climate change is poorer than the ability to predict global climate change. The IPCC sums up the situation as follows:

> Confidence is higher in hemispheric-to-continental scale projections of coupled atmospheric-ocean models than in the regional projections, where confidence remains low.

Have Human Activities Over the Last 120 Years Affected Climate?

As part of its contribution to the IPCC (Intergovernmental Panel on Climate Change, the UN body charged with assessing the peer-reviewed literature on the science, impacts and economics of climate change) Second Assessment Report, WG I (Working Group I, the sub-group assessing science), after considering the uncertainties in the scientific information, concluded:

> Nevertheless, the balance of evidence suggests that there is a discernable human influence on global climate.

This statement is stronger than those which appeared in the draft of the underlying report, where the authors stated:

> Any claims of positive detection and attribution of significant climate change are likely to remain controversial until uncertainties in the total natural variability of (the) total climate system are reduced.

As used by the IPCC,

> "Detection of change" is the process of demonstrating that an observed change in climate is highly unusual in a statistical sense, but does not provide a reason for the change. "Attribution" is the process of establishing cause and effect relations, including the testing of competing hypotheses.

At the conclusion of the WG I Plenary Session that approved the statement on a human impact on climate, the authors of the underlying report were instructed to modify their report to bring it into agreement with the summary statement. This process is the reverse of what is called for by the IPCC rules of procedure and normal scientific practice.

WG I considered four types of information in evaluating whether the observed change in climate was in fact "highly unusual in a statistical sense," and whether it could be attributed to human influences. A discussion of each type of information follows. Specific scientific studies are mention in three cases; they are the studies which have received the most publicity, but are not the only studies in the category.

1) Model-based estimates of natural variability - The Max Planck Institute (MPI), a German government laboratory and developer of one of the GCMs, ran their model for 1000 years into the future with only random perturbations to assess "natural" variability of temperature. They then determined, with 95% confidence, that the changes in temperature observed over the last 100 years could not be explained by their measure of "natural" variability. German politicians and press have reported this result as meaning that there is 95% confidence that the temperature changes of the last 100 years have been caused by human emissions of greenhouse gases, a significant overstatement of the scientific finding.

   The MPI finding does not prove that the temperature changes of the last 100 years are due to human greenhouse gas emissions for two reasons:

o Models are simplifications and therefore less variable than the real world. Actual "natural" variability of temperature is almost certain to be larger than the estimate from the MPI computer study.

o The temperature change of the past 100 years may be due to natural changes in climate. Changes of this magnitude have occurred naturally in the past without any human influence. Section 3.6.3 of IPCC WG I's contribution to the Second Assessment Report states:

"The warming of the late 20th century appears to be rapid, when viewed in the context of the last millennium. But have similar, rapid changes occurred in the past? That is, are such changes a part of the natural climate variability? Large and rapid changes did occur during the last ice age and in the transition toward the present Holocene period which started about 10,000 years ago. Those changes may have occurred on the time scale of a human life or less, at least in the North Atlantic, where they are best documented. Many climate variables were affected: atmospheric temperature and circ, precipitin patterns and hydrological cycle, temperature and circulation of the ocean."

2) Pattern-based studies - The Hadley Centre, a U.K. government laboratory and the developer of another GCM, has added sulfate aerosol effects to its model and calculated temperature from 1860 to 2050. The addition of aerosol effects provides an improved, but still relatively poor, match for observed temperature from 1860 to the present, and addresses one of the key concerns about climate models, their inability to "backcast" the temperature record. The study ties the increase in temperature over the past 100 years to emissions of greenhouse gases and aerosols.

There are two concerns about the Hadley Centre's work:

o They considered only the direct effect of sulfate aerosols, i.e., their scattering of incoming sunlight. They did not consider the indirect effects of the aerosols - their impact on cloud formation - which could have an equally large impact on temperature.

o Adding historical sulfate aerosol effects to the model requires a large number of assumptions about fuel usage rates and emission factors which cannot be tested. The validity of this approach is suspect.

The draft IPCC report discussed the Hadley Centre study and similar work and concluded:

> While some of the pattern-based studies discussed here have claimed detection of a significant climate change, no study to date has positively attributed all or part of that change to anthropogenic causes. Nor has any study quantified the magnitude of a greenhouse gas effect or aerosol effect in the observed data ...

This statement may also change as a result of the instructions given to authors to bring their report into agreement with the summary statement.

3) Studies of the vertical temperature profile of the atmosphere - Climate models predict that an increase in greenhouse gases should lead to a warmer troposphere but a cooler lower stratosphere. The fact that this pattern has been observed is being used to argue for the fundamental correctness of climate models and for the validity of their predictions that human emissions of greenhouse gases will cause changes in climate. However, the effect may be due to stratospheric ozone depletion rather than to the buildup of greenhouse gases in the troposphere. IPCC WG I's part of the Second Assessment Report (Section 8.4.2.1) cites two studies which could be interpreted as supporting this conclusion. If stratospheric ozone depletion is the cause it is "a human forcing of climate" but a different one from the buildup of greenhouse gases in the troposphere. Model agreement with the stratospheric ozone effect does not "prove" that the model is correct in predicting the effects of greenhouse gases in the troposphere.

4) Statistical models fitted to observations - T. R. Karl and three other researchers at National Climatic Data Center (NCDC) evaluated U.S. climate data since 1910 using an index of specific weather events which included: above normal minimum temperatures, above normal precipitation from October to April, below normal precipitation from May to September, and a greater than normal proportion of precipitation coming from heavy rainfalls. These are the types of climate "signature" that many scientists believe will be the first indication of climate change. Karl *et al.* concluded that there is a 90 - 95% probability that climate in the U.S. since 1976 has been affected by the increase in greenhouse gases in the atmosphere.

MIT researchers question the choice of factors included in the NCDC index, since the index is strictly empirical and has not been developed from basic principles. However, the parameters in the index are variables which other researchers have claimed could change as the result of climate change. As in the case of the other studies claiming to show that there has already been a human impact on climate, one can question whether the observed changes are the result of greenhouse gases or other climate influences.

The limitations which prevent climate models from accurately predicting future climate also limit their ability to assess whether a human impact on climate has already occurred. Claims that human activities have already impacted climate are currently unjustified. However, the improvements in climate models could make an assessment of human impacts on climate possible. Alternatively, a sufficiently large, short term change in climate consistent with model predictions could be used as proof of a human impact on climate.

Are There Alternate Explanations for the Climate Change Which Has Occurred Over the Last 120 Years?

Several arguments have been put forward attempting to challenge the conventional view of greenhouse gas-induced climate change. These are generally referred to as "contrarian" theories. This section summarizes these theories and the counter-arguments presented against them.

Solar Variability

Contrarian Theory

Solar radiation is the driver for the climate system. Any change in the intensity of the solar radiation reaching the Earth will affect temperature and other climate parameters. Dr Robert Jastrow, Director of the Mt. Wilson Observatory, and others have shown a close correlation between various sun spot parameters, which they believe are a measure of solar intensity, and global average temperature for the past 120 years, the period for which reasonable quality data exist for both sun spots and global average temperature. The correlation has been pushed back to about 1700 using less accurate data for both temperature and sun spots. In addition, observations of Sun- like stars indicate that they show the amount of variability in radiation intensity needed to account for recent changes in the Earth's climate.

More recently, Tinsley and Heelis at the Univ. of Texas have proposed a mechanism by which changes in solar activity can impact on climate in by a mechanism other than the direct change in the intensity of solar radiation impacting on the Earth's atmosphere.

Counter-arguments

Direct measures of the intensity of solar radiation over the past 15 years indicate a maximum variability of less than 0.1%, sufficient to account for no more than 0.1°C temperature change. This period of direct measurement included one complete 11 year sun spot cycle, which allowed the development of a correlation between solar intensity and the fraction of the Sun's surface covered by sun spots. Applying this correlation to sun spot data for the past 120 years indicates a maximum variability on solar intensity of 0.1%, corresponding to a maximum temperature change of 0.1°C, one-fifth of the temperature change observed during that period.

If solar variability has accounted for 0.1°C temperature increase in the last 120 years, it is an interesting finding, but it does not allay concerns about future warming which could result from greenhouse gas emissions. Whatever contribution solar variability makes to climate change should be additive to the effect of greenhouse gas emissions.

The Tinsley and Heelis proposed mechanism may revive the debate about the role of solar variability. To date is has not entered the climate change debate.

Role of Water Vapor

Contrarian Theory

In 1990, Prof. Richard Lindzen of MIT argued that the models which were being used to predict greenhouse warming were incorrect because they predicted an increase in water vapor at all levels of the troposphere. Since water vapor is a greenhouse gas, the models predict warming at all levels of the troposphere. However, warming should create convective turbulence, which would lead to more condensation of water vapor (i.e. more rain) and both drying and cooling of the troposphere above 5 km. This negative feedback would act as a "thermostat" keeping temperatures from rising significantly.

Counter-arguments

Lindzen's 1990 theory predicted that warmer conditions at the surface would lead to cooler, drier conditions at the top of the troposphere. Studies of the behavior of the troposphere in the tropics fail to find the cooling and drying Lindzen predicted. More recent publications have indicated the possibility that Lindzen's hypothesis may be correct, but the evidence is still weak. While Lindzen remains a critic of climate modeling efforts, his latest publications do not include the convective turbulence argument.

APPROVAL DRAFT

Anomalies in the Temperature Record

Contrarian Argument

The temperature record of the last 120 years cannot be explained by greenhouse gas emissions, which rose steadily through that period. If greenhouse gases were the explanation for recent climate, one would have expected temperature also to have risen steadily through the period. However, temperature rose from 1870 to 1930, then the leveled off to 1940, dropped between 1940 and 1970, and has been rising since 1970.

Satellite measurements covering over 98% of the globe indicate that global average temperature has decreased slightly over the past 15 years, during a time when land-based temperature measurements indicated a series of record high temperatures.

Counter-arguments

While atmospheric concentrations of greenhouse gases have risen steadily since 1870, their total increase has been too small for greenhouse warming to be distinguishable above the cooling effect of aerosols and the variability caused by all of the other factors which affect climate (volcanic eruptions, solar variability, random variability possibly due to the chaotic nature of climate, etc.). This does not mean that a further increase in greenhouse gas concentrations will not add to measurable warming.

Satellites measure the average temperature of a column of air from the surface to about 6 km. above the surface, while the land-based measurements are surface measurements. Also, the land-based measurements are for land only. The oceans, which cover 70% of the Earth's surface, are not included. The oceans would be expected to warm more slowly than the land surface, lowering global average temperature.

While raw data from the satellite measurements indicate a cooling of 0.06°C/decade, correcting the raw data for known effects (volcanos and periodic warming of the Eastern tropical Pacific Ocean as part of the El Nino cycle), yields 0.09°C/decade warming. The corrected satellite measurements still do not agree with the land-based temperature record, but they both show warming.

Detailed temperature records do not agree with predictions about greenhouse warming. Prof. Patrick Michaels of the University of Virginia presented a series of hypotheses about how greenhouse warming should affect temperature. Only two will be discussed in detail.

First, if greenhouse gases were responsible for the increase in global average temperature, one would expect daytime maximum temperatures to increase. What is actually happening is that daytime maximum temperatures are staying constant, while nighttime temperatures are increasing. Michaels argues that the increase in nighttime temperatures is due to the urban heat island effect.

Second, one would also expect Northern Hemisphere temperatures to have increased more than Southern Hemisphere temperatures, since greenhouse gas concentrations are higher in the Northern Hemisphere. However, Southern Hemisphere temperatures have increased more than Northern Hemisphere temperatures. Michaels argues that the smaller increase in the Northern Hemisphere is due to cooling by aerosols, a position which is now becoming generally accepted.

While some scientist argue that greenhouse warming has already occurred, most say that it cannot be separated from all of the other factors affecting climate, including the urban heat island effect and aerosol cooling. Thus, the fact that the recent temperature record does not agree in detail with a greenhouse gas warming scenario does not diminish the potential threat from substantially higher atmospheric concentrations of greenhouse gases.

Conclusions about the Contrarian Theories

The contrarian theories raise interesting questions about our total understanding of climate processes, but they do not offer convincing arguments against the conventional model of greenhouse gas emission-induced climate change. Jastrow's hypothesis about the role of solar variability and Michaels' questions about the temperature record are not convincing arguments against any conclusion that we are currently experiencing warming as the result of greenhouse gas emissions. However, neither solar variability nor anomalies in the temperature record offer a mechanism for off-setting the much larger rise in temperature which might occur if the atmospheric concentration of greenhouse gases were to double or quadruple.

Lindzen's hypothesis that any warming would create more rain which would cool and dry the upper troposphere did offer a mechanism for balancing the effect of increased greenhouse gases. However, the data supporting this hypothesis is weak, and even Lindzen has stopped presenting it as an alternative to the conventional model of climate change.

primer1.wp6

1996 GCC meeting notes, including review of draft primer

TECH-96-138
2/27/96

TO: AIAM Technical Committee

FROM: Gregory J. Dana
Vice President and Technical Director

RE: **GLOBAL CLIMATE COALITION (GCC) - Science and Technology Assessment Committee (STAC) Meeting - February 15, 1996 - Summary**

On February 15, 1996, the Science and Technology Assessment Committee (STAC) of the Global Climate Coalition (GCC) met. Enclosed is an agenda, minutes of the last meeting of January 18, 1996, a draft primer on predicting climate change, a draft GCC statement in support of research, an order form for publications, and a copy of a presentation on climate change by EEI. Also enclosed is a brief summary of the meeting. The next meeting is scheduled for April 1996.

GJD:ljf

ASSOCIATION OF INTERNATIONAL AUTOMOBILE MANUFACTURERS, INC.
1001 19TH ST. NORTH ■ SUITE 1200 ■ ARLINGTON, VA 22209 ■ TELEPHONE 703.525.7788 ■ FAX 703.525.8817

February 15, 1996 GCC STAC Meeting
Summary

It was noted that a response to the Jessica Matthews article in the Post was being drafted (contained in the minutes of the January meeting).

A State Department briefing was held just prior to the STAC meeting. A summary of the government position was given:

1. Atmospheric concentrations of greenhouse gases is increasing due to human activity

2. There is a distinct human impact on climate -- estimated range in 0.8 - 3.5 degrees C by 2100.

3. Cost-effective policies and measures exist in both developing and undeveloped countries to reduce greenhouse gases.

4. There is justification for going beyond a no regrets policy -- now doing insurance.

It was noted that this was a significant shift in the Administration's view, that it was being taken from the back office and probably would become an election issue.

Some additional comments from the State briefing: Wirth said that the recent extreme weather has boosted interest in this issue and Eileen Claussen said she didn't see anything coming out of the IPCC process that the U.S. couldn't sign up to.

There was also a report on some discussions with Steve Seidel at CEQ. He is in charge of the update to the Climate Action Plan. He said that there is a lot of analytical work going on, but not all efforts would be released and he wouldn't say who was doing the studies. There is apparently great unhappiness at the White House with studies that have been done -- they have not been favorable on costs or jobs. Expectations are the voluntary efforts have not been working -- oil prices are low, growth is high meaning more emissions. A draft of the plan is expected in about six weeks and then allow six weeks for internal review. The chances for any external review are slim. There is some indication that the government may come out with a call for non-voluntary actions.

Much of the rest of the meeting was taken up discussing the upcoming Intergovernment Panel on Climate Change (IPCC) meeting in Geneva during the last week of February and the first week of March.

From the last meeting of the IPCC in October, a list of 13 items was developed for additional IPCC work. One of those present suggested that some modeling of gases other than CO_2, for their impact on climate change, be done.

The next meeting of the STAC is tentatively scheduled for April 18, 1996.

GLOBAL CLIMATE COALITION
SCIENCE AND TECHNOLOGY ASSESSMENT COMMITTEE
DRAFT AGENDA for the MEETING OF FEBRUARY 15, 1996

The February 15, 1996 meeting of GCC-STAC will be held at the offices of Edison Electric Institute, 701 Pennsylvania Avenue, NW, starting at **Noon**. The draft agenda is as follows:

1. Minutes from January, circulated by Southern Company
2. GCC Report - Holdsworth/Shlaes
3. State Dept. Briefing on Upcoming SBSTA, SBI, and AGBM Meetings - Bernstein, et al.
4. Workshop on NGO inputs at SBSTA Meeting - Bernstein, et al.
5. Follow-up on Science Primer - Bernstein
6. GCC Position Paper on Funding of Climate Research - Gerhi, et al.
7. GCC Follow-up to IPCC Report - Womeldorff
8. Health Issues - Bernstein, et al.
9. Plans for Future Meetings - 3/14 at NRECA, 4/18 at ?
10. Other Business
11. Adjourn (no later than 4:00 p.m.)

GLOBAL CLIMATE COALITION
SCIENCE AND TECHNOLOGY ASSESSMENT COMMITTEE
MEETING MINUTES JANUARY 18,1996

The Global Climate Coalition Science and Technology Assessment Committee met in their regularly scheduled monthly meeting on January 18, 1996 in the offices of Southern Company Services, Inc. An agenda for the meeting was sent to all committee members and is attached to these minutes along with a list of the meeting attendees.

1. The minutes from the November STAC meeting at CMA were approved without comment. The was no December meeting of the committee due to the Christmas holidays. Ned Leonard of Western Fuels Association was introduced to the STAC as one of the GCC's newest members. Western Fuels will be joining at the Board Level.

2. GCC Report - No one from the GCC staff was present at the meeting to provide an update on coalition activities. Connie Holmes, who is the new chairman of the Operating Committee was present as an observer. It was requested that the GCC prepare a generic policy statement on Research. Porter and Lenny will work with representatives from the Economics Committee to develop a draft. The first draft of the document will be developed by the end of the month (January). STAC and Economics Committee members will get a draft prior to their next meeting. Bob Gehri from Southern Company, John Holt from NRECA, and Ned Leonard from Western Fuels Association volunteered to assist in reviewing and finalizing a draft policy statement.

3. Draft Paper on State Of Science - The STAC next took up the draft paper on the State Of The Science paper that has been developed by Lenny Bernstein. Lenny indicated that so far general comments had been constructive on the first portion of the paper. Most suggestions had been to drop the "contrarian" part. This idea was accepted and that portion of the paper will be dropped. The ideas brought out in the "contrarian" section may be dealt with in a future paper.

   Most of the remainder of the meeting was spent conducting a paragraph by paragraph review and of the document by STAC members.

4. Communication Committee Request - David Banks requested help in identifying a medical person or persons that could assist the GCC with the health effects issue. So far, the candidates offered by member companies did not have appropriate credentials to be a spokesman for the issue. It was felt that someone with a medical degree and some reputation (i.e. C. Everett Koop). All materials currently being used by the Communications Committee need to be updated in light of the IPCC SAR and the developments in the AGBM process.

5. Articles recently published in the Washington Post, The New York Times, and Newsweek concerning recent weather events and global warming were distributed to those attending. Charles Krauthammer (sp?) is preparing a response article to the Jessica Matthew's article.

Attendees List GCC STAC Mtg. 1-18-96

Name	Company	Phone / Fax
Robert Gehri	Southern Company	205/870-6720 + 877-7938
NED LEONARD	WESTERN FUELS ASSN	~~202~~ 703/907-6163 FX 6161
HOWARD FELDMAN ✓	API	202 682 8340 Fx 8270
ERIC KUHN ✓	CINERGY CORP.	513/287-4061 / 3499
JOHN HOLT	NRECA	703 907 5805/5517
CHUCK SHARP	AAMA	202 326-5542/5567
CHUCK HAKKARINEN	EPRI	415 855 2592 / 106[illegible]
Jerrel Smith	Union Electric	415-554-2106/4830
Eric Reiner ✓	3M for CMA	612 778-5079/6176
Connie Holmes	NMA	202-463-2654 / 202-833-9631
P. J. WOMELDORFF	IL POWER CO	217/422-9174 T/F auto switch
Lenny Bernstein ✓	Mobil	
Roy Hammie	Duke Power	704/875-5935 /5493
Bob McFadden	AAMA	202/326-5523 / 5528
John Kinsman	EEI	202/508-5711 / 5150
DAVID BANKS	API	202/682-8119 / 8115

Ramping up Deception
1996—1998

Within a few years, the massive campaign of climate denial was churning out books, radio and print advertisements, op-eds, 'educational material' for reporters, and speeches all designed to manufacture doubt about climate science and redirect fear away from the catastrophic events the science had long predicted.

In 1996, API released Reinventing Energy: *Making the Right Choices*, **Document 22**, which opines, "We do not yet know the answers to fundamental scientific questions regarding how and when climate might change." API deliberately misleads the reader, stating, "Currently, no conclusive—or even strongly suggestive– scientific evidence exists that human activities are significantly affecting sea levels, rainfall, surface temperatures or the intensity and frequency of storms."

In truth, both scientific evidence and pressure to take action were building. In 1997, a new focus for the deception campaign emerged: a UN meeting on climate change to be held in Kyoto that had the potential to create legally-binding emissions reductions. Mobil used the advertorial space it purchased in New York Times every Thursday from 1972—2001 to criticize the pending agreement. In a selection of ads from 1997, **Document 23**, Mobil attacks the scientific consensus, writing "Let's face it: The science of climate change is too uncertain to mandate a plan of action that could plunge economies into turmoil…Scientists cannot predict with certainty if temperatures will increase, by how much, and where changes will occur. We still don't know what role man-made greenhouse gases might play in warming the planet."

Victory Will Be Achieved When Average citizens "understand" (recognize) uncertainties in climate science

Global Climate Coalition (Exxon, Chevron, API, et. al), 1998

In a 1997 speech to the World Petroleum Congress, **Document 24**, Exxon CEO Lee Raymond warns against fossil fuel cuts and again attacks the scientific consensus his own company's scientists helped to construct 20 years earlier. Raymond makes some astonishing claims, including that "the indications are that a warmer world would be far more benign than many imagine. . . moderate warming would reduce mortality rates in the US, so a slightly warmer climate would be more healthful." After tying global warming to natural fluxes and discussing differing temperature forecasts, he argues "the case for so called global warming is far from air tight. You would think that all the uncertainty would give political leaders pause. Unfortunately, it hasn't, and officials continue to insist that agreement is needed in Kyoto."

A 1998 memo by the Global Climate Science Communications Team of the aforementioned API, **Document 25**, provides the masterplan for the industry's campaign. Featuring an extensive action plan, detailed strategies, million-dollar budgets, and metrics for measuring success, the memo states, ""it not known for sure whether (a) climate change actually is occurring, or (b) if it is, whether humans really have any influence on it" and declares that "Victory Will Be Achieved When…Average citizens (and the media) "understand" (recognize) uncertainties in climate science; when recognition of uncertainties becomes part of the 'conventional wisdom', and when supporters of the Kyoto Treaty are thought to be 'out of touch with reality.'" Their use of quotation marks around the word understand leaves no doubt that the understanding they sought was based on undermining the science that their own scientists told them was real.

In the 1998 article *A Cleaner Canada*, **Document 26**, Imperial Oil (Exxon's Canadian subsidiary) Chairman Robert Peterson both ties "warming observed during this century" to natural variations and argues "There is absolutely no agreement among climatologists on whether or not the planet is getting warmer…the view that burning fossil fuels will result in global climate change remains an unproved hypothesis." In 2011, Canada announced its withdrawal from the Kyoto Protocol, joining the US, Andorra, and South Sudan as the only UN member states that are not Parties to the agreement.

1996 API book, Reinventing Energy:
Making the Right Choices

Reinventing Energy

MAKING THE RIGHT CHOICES

American Petroleum Institute

[redacted]

CONTRIBUTORS

Sally Brain Gentille, Team Leader
Willis E. Bush
Russell O. Jones
Thomas M. Kirlin
Barbara Moldauer
Edward D. Porter
Garrett A. Vaughn

The Reinventing Energy project was a joint effort within the American Petroleum Institute of the Editorial and Special Issues Department and the Policy Analysis and Strategic Planning Department, with valuable assistance from the Health and Environmental Affairs and Federal Relations departments. The team wishes to thank **Mary L. Tabor**, Director of Editorial and Special Issues, for her direct involvement and leadership on this effort.

We also wish to recognize the contributions made to the project by:

Mitchell T. Baer
Paul Bailey
Jerome Becker
Leonard Bower
Rick Brown
Mary Elizabeth Buhot
John B. Fuller
Thomas J. Lareau
Donald A. Norman
Michael Rusin
Jeff Trask

Falender Communications and Consulting
Project Management and Editorial Services

Devoluy/Lynch
Art Direction and Design

CONTENTS

CHAPTER 5

Is global climate change a reason to phase out oil use?

Critics often use their belief that the burning of fossil fuels causes global warming to justify policy measures aimed at curbing oil use. Implementing such policies would dramatically change current patterns of social and economic activity, both here and in other countries because fossil fuels provide most of the energy to power the modern lifestyle. Industrial countries such as ours should examine claims of climate change with an eye toward the facts before forcing a major, wrenching transformation of American society. This is particularly the case now that the Conference of the Parties to the Framework Convention on Climate Change (the "Rio Treaty") have agreed to a negotiating process that could impose additional greenhouse gas emission constraints on industrialized countries.[1]

Additional scrutiny is needed because climate change is enormously complex and there are manifold unknowns. We do not yet know the answers to fundamental scientific questions regarding how and when climate might change. Such answers relate directly to issues of taking potentially painful economic action to avoid a concern that may or may not materialize. Dr. Bert Bolin, the chairman of the Intergovernmental Panel on Climate Change (IPCC), refers to these questions and issues in comments delivered to the first Conference of the Parties in Berlin in March 1995. According to Dr. Bolin:

> "The key issue that is coming to the forefront is: how serious is the climate change that is being envisaged and how rapidly will a change occur? The answer to this question will obviously influence the need and urgency for action. It is not possible to give a very specific answer at this time, since the regional patterns of the expected global climate change cannot yet be derived with sufficient confidence....
>
> "The issue at stake is not to agree on policies for decades into the next century but rather to adopt a strategy whereby needed actions could be formulated as more knowledge becomes available."[2]

Currently, **no** conclusive—or even strongly suggestive—scientific evidence exists that human activities are significantly affecting sea levels, rainfall, surface temperatures or the intensity and frequency of storms. After all, a conclusion that the global climate is changing as a result of human activity would require much more scientific knowledge about the **entire** earth system than exists today. Scientific inquiry has to include the natural geophysical and geochemical cycles responsible for the changing concentrations of atmospheric gases, the systems of winds, the patterns of ocean currents, and the changing weather (including rain, evaporation and clouds), as well as the role of humans and every other plant, animal and biological form of life on the planet.

More than two decades of scientific scrutiny of the global climate has produced uneven results. A recent article in *Discover—The World of Science,* recalls that not so long ago the apocalypse was supposed to be the coming ice age, which would cover portions of North America with an ice sheet and lower the world's sea level a few hundred feet. According to *Discover*:

> "[T]he Science Digest article proclaiming the forthcoming ice age was written a mere 20 years ago and was based on the best scientific information then available. Reports of 'galloping glaciers' and world-wide drops in surface temperatures had led climatologists to begin speculating during the 1960s that Earth might be entering a new period of chill. At then-predicted rates, it would be only some 200 to 2,000 years before temperatures had dropped sufficiently to create ice age conditions. Measurable effects on glaciation, sea level, and precipitation could be expected well before that. Climatologists, as we all know, are no longer predicting an impending ice age. On the contrary, their current worry is global warming."[3]

Dr. Richard S. Lindzen, Alfred P. Sloan Professor of Technology at the Massachusetts Institute of Technology, reached a similar conclusion several years ago. In testimony before the Senate Committee on Energy and Natural Resources, Dr. Lindzen noted that "in the unlikely event that [significant warming] occurs, it most certainly will not be for the reasons currently put forth....In point of fact, there is neither observational nor theoretical basis for expecting substantial warming."[4]

This is not to suggest that concerns about the use of oil, including its potential impact on the global climate, are inconsequential. They are not, and industry continues to find ways to minimize the environmental impact of fossil fuel use.

Much can be done to provide the information needed for the decisions about potential climate change. The Massachusetts Institute of Technology, for example, recently proposed developing a new generation of climate models aimed at narrowing the range of scientific uncertainty about climate systems. The Scripps Institute of Oceanography, as well as others, has proposed studying more closely the link between clouds and ocean activity. The federal government's Global Change Research Program also continues to devote considerable talent and money to this issue. In fiscal year 1993, the U.S. government allocated $1.4 billion for climate research to 18 federal departments and executive offices of the president.[5] For fiscal year 1995, the program has a budget of $2.3 billion, and an additional $230 million is allocated to the U.S. Climate Action Program.[6] Many other nations also are funding a variety of climate research programs.

Ongoing scientific analysis of climate systems, plus greater public awareness of the possible costs and benefits of climate change, are key to properly framing the difficult choices climate policymakers face. But government leaders are not the only contributors to climate change solutions. The market, too, has its place—and it has made contributions. In recent decades, energy-efficient technologies have become increasingly common in industrialized countries. Private companies also are developing new technologies aimed at easing the cost of a possible future transition to a lower energy lifestyle. As technologies improve and societies evolve, others will copy the most successful innovations. This is a far more likely path to sustainability than any path chosen by "the few and the wise."

What are "greenhouse" gases?

Little is known about why the climate changes from decade to decade or even from millennium to millennium. Scientists are focusing on the rising levels of atmospheric gases that absorb and emit radiated energy in different wavelengths, affecting the global heat balance. These gases, called greenhouse gases, let energy from the sun through to the earth's surface. But they also trap outgoing energy, which warms the earth.

Without the natural greenhouse effect, the earth would be largely frozen. Water vapor accounts for about two-thirds of the overall greenhouse effect. Of the remainder, carbon dioxide (CO_2) comprises about half; all other greenhouse gases (methane and nitrous oxide, as well as others such as chlorofluorocarbons) account for the rest.

Concerns about climate change arise because the atmospheric concentrations of several greenhouse gases have grown, and emissions from increased human activities have contributed to their buildup. For example, atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased from the time of the Industrial Revolution (1750-1800) until today.[7]

The increases in carbon dioxide in the atmosphere have generally been associated with fossil fuel use and deforestation. But the science of determining the flows of carbon into and out of the atmosphere is far from exact—and the impact of human activity on that flow is also unclear. For example, carbon dioxide emissions from natural processes are estimated at roughly 190 gigatonnes of carbon (GtC) per year.[8] Human activity, by contrast, accounts for a modest 7 GtC annually.[9] Of this amount, fossil fuel emissions probably account for about 5.5 GtC per year, while deforestation probably accounts for the balance of 1.6 GtC. However, these numbers are only estimates and may contain errors. Scientists on the IPCC believe the fossil fuel estimate could be off by as much as 0.5 GtC a year, and the deforestation estimate could be off by 1.2 GtC per year.[10]

Moreover, climate scientists are not yet able to track exactly what happens to carbon emissions from humans. Approximately 3 GtC per year apparently enter the atmosphere. The other 4 GtC presumably are absorbed by one or more natural carbon sinks, such as oceans.

Other greenhouse gases pose similar "accounting" problems. Nitrous oxide has been associated with seven natural sources, though only six anthropogenic sources have been identified.[11] Natural sources for methane emissions range from wetlands to termites to oceans. Anthropogenic sources of methane include coal mining, natural gas production, rice paddies, animal waste, domestic sewage, landfills and biomass burning. If scientists could isolate each of these sources, on a global scale, they still would face the problem of tracking methane's removal from the atmosphere. This process is complicated and difficult because methane is removed from the atmosphere by interaction with other gases as well as by interaction with the soil. In short, the scientific uncertainty associated with climate science does not surprise those who have become familiar with the complex dynamics greenhouse gases exhibit as they move among various sources and sinks globally.

Why are scientists studying greenhouse gases?

Greenhouse gases are being examined because some scientists are concern that growing concentrations of these gases may affect climate. Initially, some scientists and environmental activists predicted dire consequences. According to a 1988 Special Report by the Environmental and Energy Study Institute, for example:

But there have been technical difficulties in linking the models as well:

> "The result [of linking] was that even when a coupled model was set to simulate existing climate, it would drift away to something quite unreal. In the 1989 version of the NCAR coupled model, for example, wintertime ocean temperatures around ice-bound Antarctica were 4°C above zero, while the tropical ocean was as much as 4°C too cold."[20]

A standard approach used by modelers to avoid drift is to tweak the models—"...adjusting the flows of heat and moisture between ocean and atmosphere to nudge the model into agreement with today's climate. Actually, shove might be a better word than nudge: adjustments have typically been at least as big as the model-calculated fluxes—in some places five times as large."[21] But a study to be published in the *Journal of Climate* by three scientists from the Massachusetts Institute of Technology, cited by Kerr, concluded that "flux adjustments disguise—but may not correct—a model's underlying defects...."[22]

The second major hurdle occurs because gaps exist in the scientific theory needed to understand climate issues. Scientists don't yet fully understand how nature works—how clouds, ocean circulation, atmospheric chemistry, solar variability and other physical factors affect climate. Even the carbon dioxide cycle, one of the core aspects of climate change, is not completely understood; yet net flows into and out of the atmosphere are critical.

How cloud formation might respond to changing conditions and whether increases in humidity would occur (and, if so, at what altitudes and at what latitudes) also are not known with accuracy. As one scientist pointed out:

> "In all current models, upper tropospheric (3 to 12 km above the Earth's surface) water vapor, the major greenhouse gas, increases as surface temperatures increase. Without this feedback, no current model would predict warming in excess of 1.7°C—regardless of any other feedback. Unfortunately, the way these factors (like clouds and water vapor) are handled in present models is disturbingly arbitrary. In many instances, the underlying physics is simply not known. In other instances there are identifiable errors."[23]

In short, climate modelers have attempted to build models that mimic climate and predict changes over 100 years or longer without knowing important components of the science of climate. As a 1991 National Academy of Sciences report stated:

> "One major drawback common to all current [global climate models] is that they lack adequate validated representations of important factors like cloud cover feedback, ocean circulation, and hydrological interactions."[24]

The report also noted that every [global climate model] "incorporates untested and invalidated hypotheses. They may be sensitive to changes in ways that current calculations have not yet revealed."[25] But scientists continue to both improve their models and make new discoveries that one day will help explain the complex process that is climate change. For example, in 1990, global climate models rarely included aerosols—small particles in the atmosphere from sources such as sulphur from fossil fuel use, seasalt or windblown soil dust. But recently a group of scientists concluded that aerosols were critically important to any assessment of climate change because their impact was large and offset the impact of greenhouse gases.[26]

What do the climate models show?

Models are improving. However, the best models can neither explain observed climate changes nor replicate the planet's temperature history. These deficiencies call into serious question the ability of current models to predict future climate change.

Global climate models used to "backcast" history show a pattern of warming that accelerates over the past century. But the historical record doesn't match: It shows intermittent periods of warming. Much of this century's warming occurred before 1940, prior to most of the growth of greenhouse gas concentrations in the atmosphere. More than 70 percent of the amount of warming over the past century took place before the Second World War. Moreover, the actual warming, or increases in temperature, occurred before the buildup of greenhouse gases observed since the mid-1940s.[27]

Much is made of the temperature rise—an increase of 0.46°C over the past 100 years. But whether this rise is unusual remains debatable. A statistical analysis of temperature data inferred from tree rings over the past 1,500 years displayed no trend. "The upward drift over the past century could easily be a cyclical upswing of the type that has occurred many times in the past."[28] In short, the observed warming of 0.46°C over the past century is statistically indistinguishable from a random event.

Moreover, according to at least one noted climatologist, were atmospheric concentrations of carbon dioxide to double, "we might expect a warming of 0.5°C to 1.5°C. The general consensus is that such warming would present few if any problems."[29]

Little is known about the impact of climate change on humanity and ecosystems

Scientists are having difficulty evaluating the potential impact on humanity and ecosystems of any global warming that might occur. As noted in a recent Resources for the Future study:

> "Society has a great interest in the risks posed by global climate change...Unfortunately, this interest is not matched by available knowledge. Physical science aspects of climate change—how much warmer, wetter, or drier, and how variable climate might be in different regions with different atmospheric concentrations of greenhouse gases—are uncertain and likely to remain so for many years to come. And even if one posits particular climatic shifts, the ecological, social, economic, and other human consequences are elusive."[30]

Already developed are long lists of **possible** impacts on the environment—changes in ice and snow, oceans and coasts, the hydrological system, and ecosystems and vegetation, as well as lists of possible impacts on society—changes in water resources, food and agriculture, coastal areas, economic activity, and human settlements and health.[31]

Current climate models cannot assess the impacts of climate on crops, local ecosystems or the people living in a specific area. Hypothetical climate change and possible impacts are sometimes discussed, but because of modeling limitations, no one hypothesis is any more relevant than any other. Even if local climate impacts could be specified accurately, scientists don't know how a change in climate conditions might affect a given ecosystem, plant or animal.

The scientific understanding of climate is itself in a state of flux. We need to know more about how climate factors operate to predict future changes. For many years it was argued that rising global temperatures would raise sea surface temperatures and increase the frequency and severity of tropical storms. According to the United Nations, "Of particular concern is the possibility that climate change could increase the frequency or intensity of severe storms. Tropical storms, such as typhoons and hurricanes, only develop at present over seas that are warmer than about 26°C. In a warmer world the area of sea having temperatures over this value will increase."[32]

However, an article in the *Bulletin of the American Meteorological Society* has since refuted the assertion. Six conditions are necessary for the formation of tropical storms; sea surface temperatures above 26°C is only one. The other five conditions limit, or even offset, the possibility of increased storm activity due to any global climate change. A recent study by Accu-Weather, the world's largest meteorological company, reaches a similar conclusion:

> "No convincing, observational evidence exists that hurricanes, tornadoes, and other extreme temperature and precipitation events are on the rise because of the recent slight increase in the Earth's surface temperature. Rather, the greater attention weather events now receive may simply reflect two non-weather related facts: a) More people live in areas that were once sparsely populated or even uninhabited, and b) local media are now able to quickly report extreme weather events that are occurring, or have just occurred, in distant parts of the globe."[33]

Climate change could have both negative and positive impacts

Scientists recognize that climate change, if it occurred, could have both negative and positive impacts. For example, carbon dioxide fertilization increases with the carbon dioxide concentration in the atmosphere, so many plant species grow better. Concern has been expressed that climates may change faster than ecosystems can adapt and that species extinction might occur.[34] However, less severe climate change may only involve modest changes in local growing conditions, and they could be offset by natural adaptation and by changing where crops are planted.

In 1994, Mendelsohn, Nordhaus, and Shaw[35] completed a detailed study of the possible impact of climate change on U.S. agriculture. The study made a crucial distinction between the traditional approach to analyzing climate change impacts, called the production function or "dumb-farmer scenario," and a scenario that allows farmers to adjust their production techniques and crops to changing conditions. Their analysis showed that if no adjustments occur in what, how and where crops are grown (hence the name "dumb-farmer scenario"), climate change would have negative impacts. But, if farmers are smart enough to change their crop plans, climate change could have a positive impact on U.S. agriculture—even excluding the likely benefits of carbon dioxide fertilization of crops.

Climate change would not affect all regions of the world equally. Considerable evidence indicates that climate change would affect industrialized economies minimally.

For the United States, a 1991 economic study estimated that climate change on more than 85 percent of the economy would be negligible. Perhaps 10 percent of U.S. output—sectors such as construction and recreation—might be moderately affected. Only agriculture and forestry, comprising about 3 percent of U.S. gross domestic product, have a high potential of being affected.[36] More recently, Nordhaus estimated that a doubling of carbon dioxide would reduce U.S. economic output about 1.0 percent to 1.3 percent.[37]

Climate change, however, would seriously affect some regions of the world. Low-lying island nations, for example, are concerned that sea levels might rise under various global warming scenarios. However, any rise would be gradual and over an extended period of time. Most societies (even without government policies) would likely adapt—as did Holland, which to a large degree lies below sea level. The degree of adaptation needed may or may not be significant. For example, dikes could be built or businesses and people could relocate to higher ground. If a change occurred in air temperature (rather than sea level), relatively little adaptation would be needed—especially if average temperature rose slightly only at night and remained the same during the day. This happened during the 1980s, and most people easily adapted. Given these historical patterns, we have no need to worry if the global climate becomes somewhat warmer over a 100-year period.

If climate change was more dramatic, society would take greater steps to adapt. The U.S. government might, as has already been suggested for reasons other than climate change, stop offering low-cost flood insurance for high-risk coastal areas. Damages associated with rising sea levels or increased storms would be less, perhaps significantly less, than hypothesized under current scenarios because areas at high risk would not be covered with expensive vacation condominiums or urban development. Additionally, there might be gradual migration of population, not unlike the substantial shifts in population within the United States that occurred over the last 100 years. Or building standards might be raised, leading to greater investment in insulation or steps taken to aid the adaptation of sensitive ecosystems.

What government action is appropriate, given what we (don't) know?

Given the possibility that, at some time, human activities could alter the climate, policy leaders should consider what action might be both reasonable and effective, and when such actions might most economically be implemented.

A broad range of policy options is available, at least theoretically. Some options are reasonable—such as investing in science to narrow the tremendous range of uncertainties involved in climate science, promoting voluntary adoption of available measures to reduce greenhouse gas emissions and researching more energy-efficient technologies. Other policy options are unreasonable—such as mandating much higher fuel efficiency standards for vehicles, equipment and buildings; imposing additional energy taxes; or seeking to alter lifestyles by placing restrictions on the use of personal vehicles.

This last option is a recurring favorite among those who believe Americans waste energy, import too much oil and, by using it, pollute their local environment while endangering posterity—both by pursuing unsustainable activities and by creating, in the words of Greenpeace, a lethal "climate time bomb."

In the context of known facts, the policy choices need not be as draconian as the doomsayers advocate. Climate policies should not take precedence over more pressing human needs. At a minimum, they should make sense in their own right. As one commentator has observed, "While the Rio Earth Summit ended with Western leaders agreeing to devote billions of dollars to sustaining the natural environment, essentially nothing was done for the 7.8 million poor children—many of them in cities—who die each year from what they drink and breathe...."[38]

Moreover, the costs of government policies to control greenhouse gas emissions should not outweigh the possible benefits. In *Global Warming: The Economic Stakes*, William Cline of the Institute for International Economics analyzes policy options. His analysis makes a number of assumptions that might suggest the need for rigorous government action. For example, he constructs very long time horizons. He includes damages to both human activity and ecological systems, as well as nonlinear damage functions as assumed temperature rises.

However, Cline also argues that large uncertainties exist in our understanding of climate science as well as the potential impacts of climate change. To deal with these uncertainties, he evaluates his model of climate change and greenhouse gas abatement policies by evaluating benefits and costs for 36 scenarios. **In only 10 of the 36 cases are the benefits of greenhouse gas abatement policies greater than the costs of those policies.**[39]

Most analyses do not attempt to undertake cost and benefit analyses of greenhouse gas abatement policies. Most concentrate on potential costs. For example, John Weyant, director of Stanford's Energy Modeling Forum, summarized the short-to-intermediate run costs to the economy, and concluded that:

> "First, if the emissions target requires moving faster than the natural rate of capital stock turnover and technology development, significant additional adjustment costs are likely to be incurred…."[40]

More specifically, Weyant, argues:

> "The costs of stabilizing global carbon emissions appear likely to be in the range of about 4 percent of GDP per year by the year 2100."[41]

A recent study by the U.S. Office of Technology Assessment (OTA) connects the timing of abatement efforts and the availability of technology to reduce the growth in emissions. For example, the OTA study noted that:[42]

- "Large emission reductions are likely to be costly, but phasing emission controls in over a long period can reduce the cost substantially."
- "Delaying the implementation of emission controls for 10 to 20 years will have little effect on atmospheric concentrations."
- "Costs of controlling emissions are highly dependent on assumed rates and determinants of technology innovation, and this process is not adequately understood or modeled at present."

Dr. Alan S. Manne, Professor Emeritus of Operations Research at Stanford University, recently reached a similar conclusion:

> "Since global temperatures are not likely to rise significantly during the next several decades, an aggressive CO_2 abatement policy is unwarranted for the near term. Such policies, if implemented, could cost many hundreds of billions of dollars. Even after 2020, there would still be enough time to adapt the global economy to a sharp decline in carbon emissions if we learn that such action is warranted."[43]

Climate policymakers need to be aware of more than just costs and benefits. If climate change occurred, impact would likely be global. This suggests that **all** countries should bear some of the burden of reducing emissions. Currently this is not the case. Under the Framework Convention on Climate Change (FCCC), developed countries assume all the obligations for limiting carbon emissions. On the other hand, developing countries need only report their emissions—even though they account for more than half of the world's current carbon dioxide emissions.[44]

Moreover, developing countries are expected to be the overwhelming source of future growth in greenhouse gas emissions.[45] In other words, severe reductions in greenhouse gas emissions by the United States, or even all developed countries, would impose large costs on those countries but yield little in the way of benefits—even under drastic climate change scenarios.

A rational policy on climate change must seek to balance the present known costs of policies to control greenhouse gas emissions against the uncertain and distant future benefits of avoided climate change. Included in that calculation is a core question about sustainable development—namely, that funds used to promote the potential welfare of future generations cannot be used to promote the welfare of today's poor. Thomas Schelling framed this difficult choice confronting many developing economies this way: "[I]t would be hard to make the case that the countries we now perceive as vulnerable would be better off 50 to 75 years from now if 10 or 20 trillions of dollars had been invested in carbon abatement rather than in their economic development."[46]

The body of current scientific evidence does not indicate a need to make such a choice. Neither an apocalyptic crisis nor an inevitable Malthusian meltdown of society looms over the horizon. Rather, the issue of potential climate change is but one of many long-term issues that humanity has had to address, and will continue to address. These issues include the sustainability of food supplies, the exhaustibility of natural resources and the preservation of ecosystems. Climate change differs from most environmental and sustainable development issues, however, because if it does exist, no single country or individual can effectively address it.

Given the current state of knowledge, society must weigh the potential impact of energy use on the climate against the services that energy products provide. In reaching any decisions that would limit energy use, society must consider ways to minimize the costs of moving to lower energy consumption levels. Radical action by the United States alone or even by all the OECD countries to rapidly reduce energy use would be very costly and would have relatively little effect on long-term atmospheric concentrations of greenhouse gases. Moreover, most levels of emission reductions now under consideration lack sound analytical basis.

NOTES TO CHAPTER 5

1 United Nations Framework Convention on Climate Change, Conference of the Parties, "Review of the adequacy of Article 4, paragraph 2 (a) and (b) of the Convention, including proposals related to a protocol and decisions on follow-up." FCCC/CP/1995/L.14, 7 April 1995, 2-3.

2 Bouin, Beat, Chairman of the Intergovernmental Panel on Climate Change, "Statement to the First Session of the Conference of the Parties to the UN Framework Convention on Climate Change," *Berlin*, 28 March 1995, 3-4.

3 Robert Root-Bernstein, "Future Imperfect," *Discover—The World of Science*, November 1993, 42.

4 Richard S. Lindzen, "On the Absence of a Scientific Basis for Global Warming Scenarios," statement presented to the Senate Committee on Energy and Natural Resources, 6 May 1992, 7.

39 Cline, 76.

40 John Weyant, "Costs of Reducing Global Carbon Emissions," *Journal of Economic Perspectives*, (Fall 1993), 38-39.

41 Ibid., 35.

42 Congress, Office of Technology Assessment, *Climate Treaties and Models: Issues in the International Management of Climate Change*, OTA-BP-ENV-128 (Washington, D.C.: U.S. Government Printing Office, June 1994), 17.

43 Manne, Alan S., "Global Carbon Dioxide Reductions—Domestic and International Consequences," American Council for Capital Formation Center for Policy Research, (Special Report, 1995), 4.

44 Department of Energy, Energy Information Administration, *Energy Use and Carbon Emissions: Some International Comparisons*, DOE/EIA-0579(94) (Washington, D.C.: U.S. Government Printing Office, March 1994), 14.

45 Bert Bolin, "Report to the Tenth Session of the Intergovernmental Negotiating Committee for a Framework Convention on Climate Change," Geneva, 22 August 1994, 2.

46 Thomas C. Schelling, "Some Economics of Global Warming," *The American Economic Review* 82, no. 1 (March 1992), 7.

1997 collection of weekly Mobil advertorials in the New York Times

Display Ad 22 -- No Title
New York Times (1923-Current file); Mar 6, 1997;
ProQuest Historical Newspapers: The New York Times (1851-2007) with Index (1851-1993)
pg. A23

Display Ad 6 -- No Title
New York Times (1923-Current file); Jun 23, 1997;
ProQuest Historical Newspapers: The New York Times (1851-2007) with Index (1851-1993)
pg. A8

Climate change: Let's get it right

As world leaders gather at the United Nations to review our planet's progress on sustainable development, we expect they also will caucus on the issue of climate change. The reason: In just six months in Kyoto, Japan, nations are poised to settle on a plan to reduce greenhouse gases.

It began five years ago in Rio de Janiero, when nations agreed to formulate a plan to reduce greenhouse gases. The concern is that the build-up of these gases (carbon dioxide, methane and nitrous oxide) in the atmosphere could cause climate change.

The agreement that will likely emerge from the Kyoto meeting will commit only industrialized nations to binding targets and timetables to control their emissions of greenhouse gases; other nations may be asked to participate in this process, but they are not bound to action. Emission abatement plans have focused primarily on CO_2, which is produced when coal, oil and natural gas are burned. Much is at stake in these upcoming global climate discussions—not just a habitable planet for future generations, but also a world where all nations can provide for the economic well-being of their citizens.

We encourage governments to take the time to do it right—to examine the science, decide if emission levels are dangerous and then evaluate steps to effectively mitigate or reduce future emissions. If the wrong decision is made, it could be divisive—pitting industrialized countries against developing nations—and derail the serious effort that may be needed to stabilize emission levels.

A number of emission proposals have been tabled. They deserve the attention of all government actors—not only environmental ministers, but also the economic and finance ministers. Abatement measures need to be flexible so nations can benefit from new technology and improved understanding of the science and economics of climate change.

Instead of rigid targets and timetables, governments should consider alternatives, including:

- Adopt consensus objectives; encourage voluntary initiatives and government-industry partnerships that will help attain these goals.
- Target all greenhouse gases, not just CO_2; encourage development of sinks—activities that offset or reduce these gases—like reforestation and improved agricultural practices.
- Encourage development and dispersion of new technology to assure widespread adoption of cost-effective abatement approaches.

While the likely Kyoto agreement will directly affect only industrialized nations, the burden will ultimately be borne by others. Many studies point out that in a world where economies are increasingly integrated, energy exporters and developing nations will suffer as well. As industrial economies are driven to switch fuels and revamp their industrial bases, their growth will falter, altering trade patterns throughout the world.

A draft U.S. Department of Energy study on six energy-intensive industries indicates that high energy prices, which would follow from stiff commitments to reduce CO_2 emissions, would have a crushing effect on these sectors. And despite the blow to U.S. jobs and this industrial base, it is unlikely that overall emissions would be reduced because the manufacturing capacity would migrate to countries not bound by emission limits.

Congress is also concerned. Sixty-one U.S. senators are calling for further review of the climate change issue. Since a binding agreement signed by the U.S. will require Senate ratification, many legislators believe any emission reduction plan should include an estimate of its economic impact.

Clearly, curbing greenhouse gases is the responsibility of all nations. By early next century, fast-growing, developing nations will be the largest carbon emitters. That's why it is incumbent on all nations to participate in the solution even in the short term.

As officials head home, we urge them to reflect on the decisions that they will enter into later this year. The world is counting on wise and prudent action.

Mobil The energy to make a difference.

http://www.mobil.com

©1997 Mobil Corporation

Display Ad 18 -- No Title
New York Times (1923-Current file); Jul 31, 1997;
ProQuest Historical Newspapers: The New York Times (1851-2007) with Index (1851-1993)
pg. A23

The Senate speaks

Once a distant blip on the radar screen, the issue of climate change is getting a great deal of media and political attention. And that's fine as long as such attention doesn't stampede nations into adopting unwise and disruptive quick fixes.

Assessing the potential dangers from the buildup of greenhouse gases (mainly carbon dioxide and methane) and developing an action plan to combat emissions in an equitable manner has produced serious disagreement among scientists, economists and climate change negotiators for the past five years.

The issue seems headed for a showdown this December in Kyoto, Japan, as industrialized nations negotiate a reduction in greenhouse gas emissions. A number of plans have been tabled—each with varying economic costs.

While industrialized nations are divided on the sacrifices each is willing to assume, the drive for action is running strong. In June, President Clinton promised to bring to the Kyoto conference "...a strong American commitment to realistic and binding limits...[to] reduce emissions of greenhouse gases."

That commitment, though, must be balanced against the concerns expressed in a Senate resolution on the terms under which the U.S. should sign an agreement on greenhouse gas emissions.

The Senate, in discharging its constitutional authority, must ratify any binding agreement or treaty. Exercising its oversight responsibility, the Senate frequently expresses its views to the administration long before final negotiations begin. Which is why the recent vote on Senate Resolution 98 deserves more than passing comment.

Introduced by Senator Byrd of West Virginia and cosponsored by 64 senators, both Democrat and Republican, Senate Resolution 98 passed by a 95 to 0 vote. It signals genuine concern about ratifying a treaty that doesn't involve participation by all nations or could jeopardize the U.S. economy. Mobil has expressed similar concerns in this space during the past year.

Here is what the resolution cautions about any agreement emerging from Kyoto:

"(1) *the United States should not be a signatory to any protocol which...would—*

"(A) *mandate new commitments to limit or reduce greenhouse gas emissions* [for the industrialized nations] *unless the protocol ...also mandates new specific scheduled commitments to limit or reduce greenhouse gas emissions for Developing Country parties....*

"(B) *result in serious harm to the economy or the United States; and*

"(2) *any such protocol...should be accompanied by a detailed explanation of any legislation or regulatory actions that may be required to implement the protocol...and should also be accompanied by an analysis of the detailed financial costs and other impacts on the economy of the United States....*"

When the Congress speaks this forcefully, the American public as well as the administration should take notice. The issue of climate change will loom large in the coming months. We urge each and every citizen to study the issue, engage in the debate and express your opinion. No one ever said making democracy work is easy.

Mobil The energy to make a difference.

http://www.mobil.com

Whose Life Is It?

By George McGovern

WASHINGTON

Freedom of choice in our everyday lives is a treasured right in America. That freedom should, of course, be balanced with a sense of responsibility for our personal well-being and that of others.

Two high-profile lawsuits that hinged on the issue of choice were decided in early May. In the first case, a Florida jury decided that the R. J. Reynolds Tobacco Company did not have to pay damages to the family of Jean Connor, who died of lung cancer at 49 after smoking for 34 years. A day later, a North Carolina man, Thomas Richard Jones, was given a life sentence for killing two people while driving under the influence of alcohol and drugs.

Mrs. Connor chose to smoke. Millions of Americans have quit smoking, and Mrs. Connor admitted in a videotape made during the last stages of her illness that she could have quit puffing had she cared enough.

I know too well the ravages of alcoholism, having lost my daughter to her addiction. But I also know that people are able to make choices. In the case of Mr. Jones, he was aware of the lethal effect of combining prescription drugs with alcohol. One can argue that as an alcoholic, Mr. Jones had a disease and therefore had no choice but to drink. But he had the choice to take public or other transportation. Instead he decided to drive while drunk, and now has to accept the consequences.

Despite the death of my daughter, I still appreciate the differences between use and abuse. I still enjoy a glass of wine with friends. I also would not have denied Mrs. Connor her cigarettes. Nor do I condemn the current trend in cigars. As the former owner of a Connecticut inn, I always allowed my adult guests wide latitude in their habits. Scotch was available at dinner, and there were convenient designated areas for smokers.

Today, however, there are those who would deny others the choice to eat meat, wear fur, drink coffee or simply eat extra-large portions of food, to give a few examples. Wearing perfume in public raises the ire of certain organized interest groups.

While on any day each of us may identify with the restrictive nature of a given campaign, there is a much larger issue here. Where do we draw the line on dictating to each other? How many of these battles can we stand? Whose values should prevail?

Life in America has remained relatively peaceful compared with that in other societies. But we are becoming less tolerant and more mean-spirited in everyday social interactions. We have become less forgiving. Suing institutions as well as each other for perceived harms has become a ruinous sport.

It was reported in June that a 61-year-old man, Norman Mayo, is suing Safeway and the Washington State dairy industry for failing to warn about the dangers of drinking whole milk. A self-described "milkaholic," Mr. Mayo wants warning labels on all milk cartons to protect others. Where does this end?

The new paternalism threatens our freedom to make our own choices.

Some issues, like the proper treatment of animals, deserve public debate. But that doesn't mean activists should assault people who wear furs, destroy animal research laboratories or firebomb restaurants that serve meat. These actions transform differences of opinion into dangerous intolerance and intimidation.

On other issues, like gambling, the messages can be confusing. Is casino gambling a moralistic issue when state lotteries and horse racing are socially acceptable? Is the stock market different, or is it just a harder game to understand?

New attempts to regulate behavior are coming from both the right and the left, depending only on the cause. But there are those of us who don't want the tyranny of the majority (or the outspoken minority) to stop us from leading our lives in ways that have little impact on others.

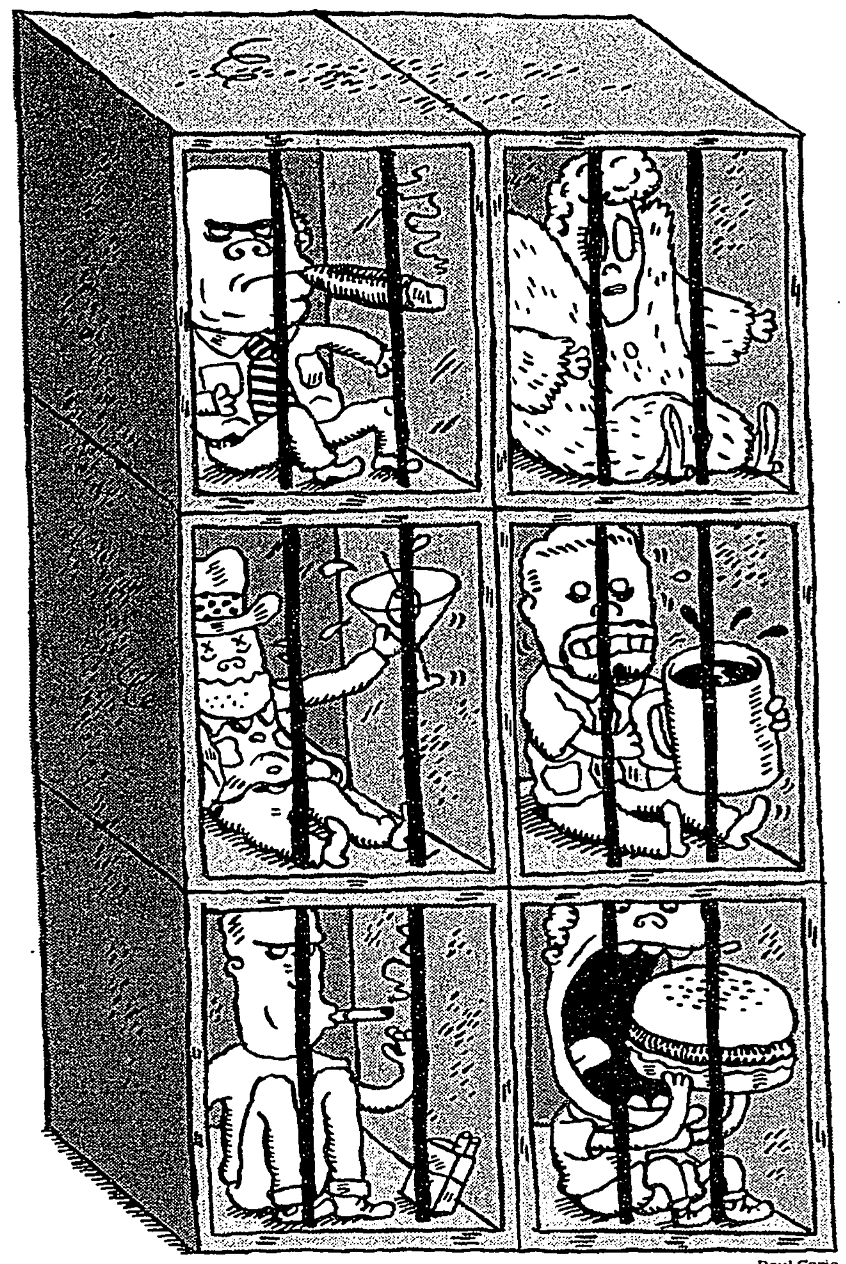
While the choices we make may be foolish or self-destructive — bungee jumping is my favorite example of insanity — there is still the overriding principle that we cannot allow the micromanaging of each other's lives. When is the thrill too risky? How many drinks are too many? When is secondhand smoke too thick? All of these questions need to be considered with some measure of tolerance for the choices of others.

We are witnessing a new age in this country: the fragmentation of society along lines that do not break on typical demographics like race, age or income. These new divisions are based on paternalism — what we believe is best for each other.

The beauty of choice is that it allows some people to drive a high-powered car to dinner, allows others to have a drink with dinner and allows a cigarette to be smoked after dinner. In all cases, we require individuals to make certain their behavior does not have an impact on others. To the degree that it does, they will be held responsible for their choices.

But when we no longer allow those choices, both civility and common sense will have been diminished. □

George McGovern, the Democratic nominee for President in 1972, is the author of "Terry: My Daughter's Life-and-Death Struggle with Alcoholism."



Paul Corio

In America

BOB HERBERT

One More Police Victim

At what point will Mayor Rudolph Giuliani and Police Commissioner Howard Safir decide that things have gone too far, that it is time to put a stop to the barbaric behavior of so many New York City police officers?

The latest outrage occurred early Saturday morning in the 70th Precinct station house in Brooklyn. At least two uniformed officers are said to have tortured and humiliated a man named Abner Louima by yanking down his trousers and driving the wooden handle of a toilet plunger so far into his rectum it punctured his small intestine and damaged his bladder. The filthy handle was then driven into Mr. Louima's mouth with enough force to break his teeth.

One officer, Justin Volpe, was arrested last night and charged with assault and aggravated sexual abuse.

Lawyers for Mr. Louima, who is Haitian, said the cops called him a nigger and shouted other slurs while they abused him. And they said the officers threatened to kill him if he filed a complaint.

Mayor Giuliani professed to be shocked by the attack. Perhaps he was. But the only thing shocking to most close observers of the Police Department was the grotesque psychosexual nature of the assault. The fact that police officers would brutalize a civilian is not shocking at all. Many other attacks by police officers in recent years have been more violent, including several that have been fatal. These include:

- The killing of Nathaniel Gaines Jr., a 25-year-old Navy veteran, on a Bronx subway platform in July 1996. Mr. Gaines was shot in the back by Police Officer Paolo Colecchia, who was convicted last month of manslaughter.
- The killing of Anthony Baez, who was locked in an illegal choke hold by Officer Francis X. Livoti after a dispute erupted over a touch football game. Mr. Livoti was dismissed from the police force but was acquitted of criminal charges.
- The killing of Charles C. Campbell, who was beaten and shot in a Dobbs Ferry parking lot by an off-duty New York City police officer who didn't like where Mr. Campbell had parked. The officer, Richard D. DiGuglielmo, has been charged with second-degree murder.
- The near-fatal attack on Lebert Folkes, a 29-year-old Queens man who was dragged from his sister's car by police officers and shot in the face at point-blank range. The cops said they thought the car was stolen. It was not. The next day police officials apologized for the shooting.

There are many, many cases of savage abuse of civilians by police officers. Seldom are the officers charged with a crime and in most cases they are not even disciplined. Thousands upon thousands of lawsuits alleging police brutality are filed against the city and millions of dollars each year are paid to settle such suits. But little is done to prevent these hideous miscarriages from occurring. Only in the most extreme cases will the public hear critical comments from the Mayor or Police Commissioner about the behavior of the police. And the vast majority of the cases are ignored by the media.

Will Giuliani ever rein in the cops?

The message that is picked up by the average police officer is clear: Brutal behavior will be tolerated, if not encouraged. That is an affront to the majority of officers who do their jobs legally, courageously and well. More important, it undermines the faith of New Yorkers in the Police Department as a whole. Most important, this tendency to give a wink and a nod to most instances of brutality results in the grievous harm and sometimes the death of human beings who have done nothing to warrant such vicious treatment.

A great deal is being made of the fact that Mayor Giuliani has not rushed to the defense of the officers accused of attacking Mr. Louima. His usual inclination is to support the police no matter what, and whenever possible to draw an impenetrable curtain between evidence of police misconduct and the curious eyes of the public.

Maybe this case is sensational enough to result in a sustained and honest look by the Mayor and the Commissioner at the extent of police brutality in the city. They could stop a great deal of it, thus saving lives.

Denunciations after the fact are not enough. Cops who cannot or will not control their violent impulses are a menace. And so are public officials who have the power to do something about those officers, but choose not to. □

Clinton's Great and Timid Step

By Dan Coats

WASHINGTON

President Clinton's use of the line item veto this week was a timid act of great importance. The cuts themselves — two tax breaks and a special Medicaid provision for New York — were on the margin of a margin, about 0.002 percent of the total budget. But they were sufficient to clarify an important principle.

This principle concerns the often misunderstood constitutional balance of power between the legislative and executive branches on budgetary matters. The President has the line item veto because Congress was shamed last year into renouncing a power it had grabbed and clearly abused.

It used to be that a President could simply refuse to write checks for spending approved by Congress; the precedent for such action, known as impoundment, goes as far back as Thomas Jefferson. But in 1974 Congress made impoundment illegal and required the President to accept or reject appropriation bills in full. The result was an outbreak of bipartisan self-indulgence (mollusk research, pointless museums and the like), which made even those who benefited from it feel guilty.

The line item veto controls Congress.

The line item veto is a stripped-down version of impoundment. It allows the President to cut specific items from the budget, yet permits Congress to reinstate them by a two-thirds vote. It is not, as some critics contend, a violation of constitutional principle. It is the redress of an imbalance in power that had been created, enjoyed and misused by Congress. President Clinton's use of the line item veto will provide an important test case for the Supreme Court.

Could a petty President abuse this authority, holding the pet project of some member of Congress hostage to gain agreement on another issue? Well, yes. Could a bitter President use the veto over and over again to wage war against a Congressional agenda? I suppose. But these scenarios exaggerate the influence of the line item veto — an influence that is substantial, but not revolutionary.

Even with the line item veto, Congress remains the lead player in the budget process. A President who wants particular legislation passed cannot risk angering Congress by repeatedly using this power as a weapon. Senator John McCain of Arizona and I designed the line item veto law so that there is every incentive for a President to use it judiciously, in only the most egregious cases of excess.

If a President, whatever his motives, eliminates some foolish budget item or tax policy that two-thirds of Congress cannot justify, good riddance. If the President is being arbitrary or punitive, Congress can manage quite well, thank you — as it did for 198 years under the stronger threat of impoundment.

I would prefer the line item veto in the hands of a Republican President, but it would be unprincipled to oppose it in the hands of a Democratic one. So it falls to conservatives who championed this measure for many years to defend President Clinton.

Some Republican leaders may object that the fine print on their budget agreement with the President has been smudged. But the line item veto — Ronald Reagan's chief budgetary priority — is a more substantive development than the oversold budget deal they have been promoting. □

Dan Coats is a Republican Senator from Indiana.

Vindication, Not Vengeance

By Olivia Goldsmith

For a domestic dispute, the "alienation of affection" case of Dorothy Hutelmyer vs. Margie Cox Hutelmyer has attracted a lot of national attention. But this is not a story of greed or vengeance, as the press would have it. It's about the need for vindication.

As almost everyone now knows, a jury in North Carolina ordered the second Mrs. Hutelmyer — Margie — to pay the first Mrs. Hutelmyer — Dorothy — $1 million for stealing away her husband.

"Do you think she's going to get $1 million?" Margie Hutelmyer said after the jury's judgment. "I own no property. I have no savings."

She just doesn't get it. The lawsuit was not about money. Nor was it Dorothy Hutelmyer's aim to blame "the other woman" for her ex-husband's behavior. The lawsuit was about honor and loyalty; it was about the marriage contract. The lawsuit was simply a way for the first Mrs. Hutelmyer to send a message: What happened to her was neither fair nor appropriate.

A lawsuit defends first wives everywhere.

In our society, it is difficult to get *anyone* to admit to *anything*. Margie Hutelmyer appears to feel no responsibility. In fact, she blames the first Mrs. Hutelmyer for the whole mess. "Until she can acknowledge that she shares in the responsibility in the breakdown of that marriage," Margie Hutelmyer said, "she can never get on with her life." Thank you, Dr. Ruth.

But we are not talking about a failed marriage where two people agree they are growing apart and decide to separate. We're talking about betrayal and deception. Joseph Hutelmyer and Margie Hutelmyer have admitted they had an affair while he was married. He is responsible for his actions, certainly, but isn't she also culpable?

The disastrous changes in divorce laws over the last two decades have not only failed to protect many wives financially, but also given them no emotional succor. Since the antiquated "alienation of affection" law is still on the books in the state where she lives, why shouldn't Dorothy Hutelmyer press her case in the courts?

The decision is not a victory for conservative family values, as some politicians have said. It's not even a practical solution for most women in her situation. After all, only 12 states still have the "alienation of affection" law on the books.

The jury's decision is a vindication. What the resourceful Dorothy Hutelmyer did was ask a jury of her peers if her anger was justified. In less than three hours they came in with a decision supporting her. What's wrong with that? □

Olivia Goldsmith is the author of "The First Wives Club" and "The Bestseller."

Display Ad 25 -- No Title
New York Times (1923-Current file); Oct 23, 1997;
ProQuest Historical Newspapers: The New York Times (1851-2007) with Index (1851-1993)
pg. A27

Global climate change

If this issue hasn't captured your attention yet, it will shortly. That's because government representatives will meet in Kyoto, Japan, in early December to see if they can agree on a plan to control carbon dioxide (CO_2) and other greenhouse gases that may be linked to global warming and climate change.

Because our products—oil and gas—are at the center of the climate change debate, some say we are indifferent to growing concerns over the buildup of man-made greenhouse gas emissions. Not so. We share many of these concerns. But some key questions remain unanswered.

Others say we're not doing anything to reduce emissions; we only care about finding more oil, making more money. Not true. We have already taken steps to cut emissions and we're ready to do more. Yes, we're looking for more hydrocarbons because energy demand is increasing and, for now, there's no real alternative. And yes, the financial stakes are important. Just ask shareholders, employees and others who benefit.

We want to play a constructive role in the policy debate on climate change. It's an issue that defies simplification and doesn't lend itself to easy solutions.

In the coming weeks, we'll wade into the debate, beginning with what we do and don't know about greenhouse gases and climate change. Then we'll look at emission control strategies and examine their economic impact. We'll also describe what Mobil is doing and give you our point of view.

Because we believe there is potential reason for concern, there are measures we can take that will give us time to get better data so governments don't have to commit to policies that will damage economies. Many companies are taking such steps. Here is what Mobil is doing:

Inside Mobil. Programs to reduce our own emissions include use of energy-saving technology at refineries, energy management audits, initiatives to reduce gas flaring offshore, elimination of methane leaks and participation in government-sponsored programs in the U.S. and elsewhere. In the last three years, we've cut our carbon emissions by more than one million tons; this pace will accelerate.

Our products. Mobil synthetic lubricants increase engine efficiency, cutting carbon dioxide emissions. Since 1990, use of these products has reduced vehicular carbon emissions by one million tons.

Research. Mobil is continuing to fund research to improve the science and economics of climate change.

Technology. Through business/university consortia, we're supporting development of refining and hydrocarbon fuel technologies that promise higher efficiency and lower emissions.

Reforestation. Working with leading environmental groups, Mobil will underwrite international projects to plant and protect trees which absorb significant amounts of CO_2. Initiatives like these, which are good for the environment, can be taken while the debate continues.

As the deadline in Kyoto approaches, there's considerable pressure to reach an agreement. Frankly, the pressure seems misplaced. Let's not rush to a solution before we fully understand the dimensions of the problem. A measured approach—one that relies on actions by businesses, consumers and governments—gives us time to clear up the uncertainties surrounding climate change.

Sustained actions, better science and improved technologies will point the way to realistic policies. We all share the same goal: protecting Earth's environment while raising living standards for all.

Mobil The energy to make a difference.

http://www.mobil.com/climatechange

Display Ad 25 -- No Title
New York Times (1923-Current file); Oct 30, 1997;
ProQuest Historical Newspapers: The New York Times (1851-2007) with Index (1851-1993)
pg. A31

Reset the alarm

The alarm is about to go off as the Kyoto deadline approaches. Government negotiators meet in a month to decide on a mandatory plan for industrialized nations to cut their emissions of carbon dioxide and other heat-trapping gases. But imposing a solution before the problem has been defined could prove a rude awakening for the developed and developing countries.

Basically, three proposals are under consideration. The European Union plan wants industrialized nations to cut greenhouse gas emissions 15 percent below 1990 levels by 2010. Japan's plan calls for reducing emissions five percent below 1990 levels between 2008 and 2012. The U.S. plan targets a return to 1990 emissions levels over the 2008–2012 period, with additional cuts coming later.

The U.S. plan also encourages joint implementation projects—where one country invests in an emission-reduction project in another country and earns credit for the reductions at home—and emissions trading. More importantly, the U.S. plan recognizes that developing countries, which will become tomorrow's largest carbon emitters, must participate in the solution. The president said the U.S. will not "assume binding obligations unless key developing nations meaningfully participate in this effort." The problem is that if they aren't signatories and participants to a treaty that binds them to action, then there's no global solution.

Energy conservation and development of energy-efficient technologies in the U.S. via tax cuts and other incentives are also under consideration.

At first reading, the U.S. proposal seems moderate. We're encouraged by the call for voluntary, market-based steps. But we're wary of incentives, which are usually subsidies in disguise.

What is not moderate is the call to lower emissions to 1990 levels. A cutback of that size would inflict considerable economic pain.

The Energy Information Agency projects that energy demand in industrialized nations over the 1990–2010 period will grow about 30 percent. Committing to binding targets and timetables now will alter today's lifestyles and tomorrow's living standards. Flexibility will be constrained. Carpooling in; sport utility vehicles out. High fuel and electric bills. Factory closures. Job displacement. And could businesses and consumers cut their energy consumption by 30 percent without some form of tax or carbon rationing? Probably not.

Let's face it: The science of climate change is too uncertain to mandate a plan of action that could plunge economies into turmoil. Yet, that's what nations seem prepared to do.

Scientists cannot predict with certainty if temperatures will increase, by how much and where changes will occur. We still don't know what role man-made greenhouse gases might play in warming the planet.

We're not impugning the existing science or suggesting that "our science is better than your science." Current science isn't bad; it just doesn't go far enough. Better science is emerging on what factors affect global warming. No need to wait 20 or 50 years; big breakthroughs that will dramatically inform our decision-making are expected in the next five to 10 years. Scientists are getting more precise in calculating temperature variations; they're probing the role of clouds and oceans on climate. Such information can take much of the guesswork out of what and where actions will be needed.

In the meantime, businesses, individuals and governments can take precautionary, voluntary steps to reduce their emissions. And we can begin to work more closely with developing nations to help them grow their economies in energy efficient ways.

Let's not rush to a decision at Kyoto. Climate change is complex; the science is not conclusive; the economics could be devastating. And the world's not ready for it. Reset the alarm and take the time to get it right.

Mobil The energy to make a difference.

http://www.mobil.com/climatechange

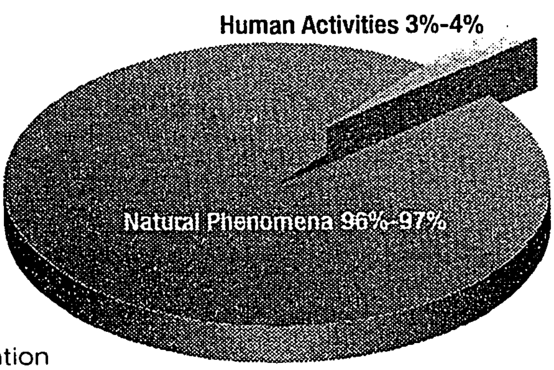
Display Ad 26 -- No Title
New York Times (1923-Current file); Nov 6, 1997;
ProQuest Historical Newspapers: The New York Times (1851-2008) with Index (1851-1993)
pg. A31

Science: what we know and don't know

As the debate over climate change heats up, science is being upstaged by the call for solutions. At stake is a complex issue with many questions. Some things we know for certain. Others are far from certain.

First, we know greenhouse gases account for less than one percent of Earth's atmosphere. The ability of these gases to trap heat and warm Earth is an important part of the climate system because it makes our planet habitable. Greenhouse gases consist largely of water vapor, with smaller amounts of carbon dioxide (CO_2), methane and nitrous oxide and traces of chlorofluorocarbons (CFCs).

The focus of concern is CO_2. While most of the CO_2 emitted by far is the result of natural phenomena—namely respiration and decomposition, most attention has centered on the three to four percent related to human activities—burning of fossil fuels, deforestation. The amount of carbon dioxide in the atmosphere has risen in the last 100 years, leading scientists to conclude that the increase is a result of man-made activities.



Although the linkage between the greenhouse gases and global warming is one factor, other variables could be much more important in the climate system than emissions produced by man.

The UN-sponsored Intergovernmental Panel on Climate Change (IPCC) thought it had found the magic bullet when it concluded that the one-degree Fahrenheit rise in global temperatures over the past century may bear a "fingerprint" of human activity. The fingerprint soon blurred when an IPCC lead author conceded to the "uncertainty inherent in computer climate modeling."

Nonetheless, nations at Kyoto are being asked to embrace proposals that could have potentially huge impacts on economies and lifestyles. Nations are being urged to cut emissions without knowing either the severity of the problem—that is, will Earth's temperature increase over the next 50–100 years?—or the efficacy of the solution—will cutting CO_2 emissions reduce the problem?

Within a decade, science is likely to provide more answers on what factors affect global warming, thereby improving our decision-making. We just don't have this information today.

Answers to questions on climate change will require more reliable measurements of temperature at many places on Earth, better understanding of clouds and ocean currents along with greater computer power.

This process shouldn't be short-circuited to satisfy an artificial deadline, like the conference in Kyoto. Whatever effect increased concentrations of man-made gases may have, it will develop slowly over decades. Thus, there is time for scientists to refine their understanding of the climate system, while governments, industry and the public work to find practical means to control greenhouse gases, if such measures are called for. Adopting quick-fix measures at this point could pose grave economic risks for the world.

Mobil The energy to make a difference.

http://www.mobil.com/climatechange

Display Ad 24 -- No Title
New York Times (1923-Current file); Nov 13, 1997;
ProQuest Historical Newspapers: The New York Times (1851-2008) with Index (1851-1993)
pg. A27

Climate change: a prudent approach

Ask the wrong questions and you may be stuck with the wrong answers. This could occur next month in Kyoto, Japan, as government negotiators weigh questions on how to reduce greenhouse gas emissions <u>now</u> and who should bear the burden of these cuts.

These questions, we believe, are premature. We don't know enough about the factors that affect global warming and the degree to which—if any—that man-made emissions (namely, carbon dioxide) contribute to increases in Earth's temperature.

Instead, we should be asking: What precautionary, voluntary steps can be taken now to reduce greenhouse gases while science is developing answers that will improve our decision-making?

Governments, industry and individuals can all contribute. Mobil is stepping up efforts on two fronts—reducing emissions at the source and removing carbon dioxide from the atmosphere. We're supporting research and technology efforts, curtailing our own greenhouse gas emissions and helping customers scale back their emissions of carbon dioxide.

Technology/R&D. We continue to sponsor research at universities and other institutions. At Battelle Pacific Northwest Laboratory and the Massachusetts Institute of Technology, for example, we're supporting research to identify technology strategies that promise the greatest potential for reducing greenhouse gas emissions.

At Columbia's Lamont-Doherty Geophysical Observatory, we supported work on the role that oceans play in the climate system. Though more than 90 percent of the energy in the climate system is stored in the top layer of the oceans, scientists currently have a poor understanding of how to predict sea surface temperatures. Improved understanding of this system could lead to better predictions of future climate change.

More is on tap for the future. More to understand the greenhouse gas implications of our investment decisions as we develop new hydrocarbon resources. More to investigate technologies that can reduce energy consumption and greenhouse gases. And more to support changes in transportation power sources and fuel technologies, including fuels for hybrid and fuel-cell vehicles.

Internal efforts. Inside Mobil, we've cut emissions by more than one million tons of carbon over the past three years. To put this in context, the average U.S. automobile emits about two tons of carbon annually. We've used manufacturing process improvements to cut the energy needed to refine a barrel of oil. Without compromising safety, we've eliminated gas-flaring from many offshore operations. And participating in a U.S. government program, we've eliminated leaks of methane, which is six times more potent than carbon dioxide, from our natural gas production and distribution systems. Upgraded lighting systems and more energy-efficient offices have helped, too.

Products. Mobil's synthetic lubricants help customers use energy more efficiently. Use of these products helped cut carbon emissions by one million tons since 1990. For tomorrow, we're designing more stable lubricants that promise longer life and greater energy efficiency.

Reforestation. We intend to sponsor several projects to plant and protect trees in the U.S. and internationally. Such activities absorb significant amounts of carbon dioxide and sustain the environment.

And that's just what one company—Mobil—is doing. Working together, government, industry and individuals can achieve major progress in reducing greenhouse gas emissions while scientists work to provide more definitive answers on the impact that these gases and other factors may have on our climate system. Let's wait for more answers before taking on obligations that could jeopardize better living standards for all.

Mobil The energy to make a difference.™

http://www.mobil.com/climatechange

Display Ad 26 -- No Title
New York Times (1923-Current file); Nov 20, 1997;
ProQuest Historical Newspapers: The New York Times (1851-2008) with Index (1851-1993)
pg. A31

Climate change: where we come out

The government representatives who will meet in Kyoto, Japan, have a weighty task. They must consider several proposals for cutting emissions of carbon dioxide and other greenhouse gases, knowing that each carries a large price tag for the global economy.

We share the widespread concern over the possibility that human activity may contribute to global warming, and we have used this platform to participate in the climate change debate. On the eve of the Kyoto conference, we take this opportunity to sum up our position.

Each of the proposals being weighed in Kyoto would require dramatic emissions cuts over the next 10 to 15 years. The most moderate plan calls for nations to stabilize emissions at 1990 levels by the year 2010. Why is that a problem? There is simply no easy way to get back to that level given the current and projected rates of growth in energy demand. Agreeing to mandatory targets will stunt economic growth.

Two questions, we believe, must be asked: Is it necessary? And is there a better way to do it?

As to its necessity, the best answer to date is a resounding "maybe." Even after two decades of progress, climatologists are still uncertain how—or even _if_—the buildup of man-made greenhouse gases is linked to global warming. It could be at least a decade before climate models will be able to link greenhouse warming unambiguously to human actions. Important answers on the science lie ahead.

Credible economic studies, including those by Charles River Associates and Wharton Economic Forecasting Associates, point out the enormous, cumulative costs that these proposals could have. Just stabilizing greenhouse gas emissions at 1990 levels and assuming the benefits of ongoing technology will compel industrialized nations to cut their consumption of fossil fuels by nearly 30 percent.

Energy producers and energy-intensive industries will suffer most, but everyone will feel the pinch. Even if developing nations are exempted from emissions cuts (as many nations have proposed), they would also feel the impact, for they would face reduced markets for their goods.

There is a better way—one that doesn't commit nations to targets that may be scientifically overblown and financially crippling. The first steps are already being taken. There is much that governments and industry can do to reduce emissions and to foster research that will help us understand the global climate and devise technologies to protect it.

Mobil has already begun. We are promoting energy savings throughout our operations. We are funding research into the scientific and economic consequences of climate change. And we're supporting research focused on technology solutions. We intend to do more. Our efforts multiplied a thousandfold by governments and industry around the world can do much to alleviate the potential problem—without the pain that must ensue if emissions are cut without a clearer sense of the consequences.

We urge the delegates at Kyoto to resist a "quick fix"—but instead to ponder what will truly benefit our planet. Any solution must be long term and truly global, requiring commitments from _all_ nations. We are counting on their wisdom and their prudence.

Mobil The energy to make a difference.

http://www.mobil.com/climatechange

Display Ad 28 -- No Title
New York Times (1923-Current file); Dec 4, 1997;
ProQuest Historical Newspapers: The New York Times (1851-2007) with Index (1851-1993)
pg. A31

Climate change: a degree of uncertainty

The debate on climate change has been long, complex and intense. Governments, corporations, scientists, economists and private citizens have all helped to frame this debate. Today, we respectfully submit our message to the officials who are gathered in Kyoto to consider actions to reduce emissions of carbon dioxide and other greenhouse gases.

Mobil shares the widespread concern about the potential impact of these emissions on the global climate. At the same time, we are concerned that mandated emission cutbacks now will produce grave economic consequences for all nations.

Fossil fuels dominate the world's energy picture today. For at least several decades, they will continue to be the major source of the world's energy needs. Government and the private sector should begin now to expand the array of technology options that can help reduce our emission of greenhouse gases in the future.

The mission of the delegates at the Kyoto conference should not be driven by the politics of an artificial deadline, nor should it be constrained by only the several proposals under consideration.

Two factors argue for nations to move prudently. First, there is a high degree of uncertainty over the timing and magnitude of the potential impacts that man-made emissions of greenhouse gases have on climate. Second, the emission-reduction policies being considered carry with them very large economic risks. Objectives and actions to deal with climate change can only be determined as additional knowledge is gained and uncertainties minimized. Nations should commit themselves to meaningful actions, including:

- Governments should encourage and accelerate cooperative research on climate change while harnessing free markets and voluntary measures to deliver optimum emission reductions while preserving sustained economic growth.
- To address the scientific uncertainty, governments, universities and industry should form global research partnerships to fill in the knowledge gap, with the goal of achieving a consensus view on critical issues within a defined time frame.
- During the fact-finding period, governments should encourage and promote voluntary actions by industry and citizens that reduce emissions and use energy wisely. Governments can do much to raise public awareness of the importance of energy conservation.

Mobil is already participating in such efforts. Through cooperative endeavors, we are funding research on technologies that promise greater energy savings or lower greenhouse gas emissions. We are continuing to create energy-saving products, reducing our own emissions and undertaking forestation projects to remove carbon dioxide from the atmosphere.

In proposing these recommendations, we ask the Kyoto delegates to avoid mandates based on uncertain science and to resist agreements that could inflict great economic pain. Take steps to curtail emissions, develop more energy-efficient technologies and improve scientific understanding: These are the challenges nations should lay before their citizens. Collectively, we can accomplish a lot.

The Kyoto delegates should know that there is time to make it right. Advances in climate science can remove a degree of uncertainty from decisions on how best to protect our planet and its inhabitants.

Mobil The energy to make a difference.

http://www.mobil.com/climatechange

1997 speech by Exxon CEO, Lee Raymond,
Energy—key to growth and a better environment for Asia-Pacific nations

Energy — key to growth and a better environment for Asia-Pacific nations

By Lee R. Raymond
Chairman and Chief Executive Officer
Exxon Corporation

World Petroleum Congress
Beijing, People's Republic of China

October 13, 1997

Remarks by Lee R. Raymond
Chairman and Chief Executive Officer, Exxon Corporation
World Petroleum Congress
Beijing, People's Republic of China
October 13, 1997 – As Given

It's a pleasure to be back in Beijing and an honor to address the World Petroleum Congress.

It's entirely fitting that we meet in this seat of ancient civilization and source of world culture. For centuries, people from far parts of the Earth have come to China seeking commercial and other opportunities.

The Romans came here seeking silk – traveling along a network of trails that became known as the Silk Road. In the 13th century, history's most famous traveling salesman, Marco Polo, took this road to Cathay, returning to Venice with treasures and tales that astonished all of Europe.

More than a century ago, William Herbert Libby, representing Jersey Standard, the predecessor to Exxon, came here to persuade Chinese families to try Esso's kerosene in their lamps and cooking stoves.

The odorless oil and its clear white light proved an instant success, and by 1910 China had become Exxon's largest customer in the Far East.

To build sales, Libby gave away small, inexpensive kerosene lamps that became widely popular. The company was known by the name "Keepers of Light."

Today, Exxon and the world petroleum industry are still "Keepers of Light." We earn that title by providing energy to light the way to economic progress, higher standards of living and hope for a brighter future for people around the world.

Nowhere is that progress more evident than in the Asia-Pacific region.

I've traveled to this part of the world often in recent years, and I'm constantly impressed by the commitment to economic growth that's prevalent throughout the region.

All across this region -- from Bangkok to Beijing, Jakarta to Shanghai, Singapore to Seoul -- the signs of growth are unmistakable.

Homes, apartments and office buildings going up. Factories, refineries and power plants under construction. More cars, trains and airplanes on the move than ever before. In 15 years, this region's economy should almost double, shifting the global economic center of gravity toward the East.

The people of this region, representing some 40 percent of the world's population, have a lot to smile about: new and better-paying jobs, more and better consumer goods and services, and greater opportunities for the next generation. Their smiles and looks of hope and optimism are the human face on the economic transformation that's gaining force in Asia.

I know all of us here today want to see this transformation continue. But we have to remember that progress is not automatic. As recent economic difficulties in the region demonstrate, there is no guarantee when it comes to economic growth.

In fact, some argue that the easy growth from increasing capital and labor inputs has already occurred. They say that the road ahead will be more difficult and will require strong boosts in productivity to keep Asian economies growing.

I see no reason why economic growth can't continue strongly in this region in the future. But I do agree that sustained growth is only possible when it is built on sound fundamentals -- education and training, a strong work ethic, sound regulatory policies, incentives to invest, and many other factors that don't come easily or cheaply.

We might also remind ourselves that this region's growth depends on strong economic ties with other parts of the world. Today, the world is much more economically interdependent than it was a few years ago.

Advances such as fiber optic cable, communications satellites and the computer have created better tools for communicating and conducting business. As a result, opportunities and challenges flow more quickly from one area of the world to another.

Political change has also played an important role in laying a foundation for growth. As more and more governments have turned to market principles, trade barriers have fallen, fostering a rising tide of international investment and commerce.

One result of these changes is that the area of the world open for energy development has increased by more than one-third.

That's very good news indeed because, as we all know, economic growth and higher standards of living require energy. Energy use and economic growth are inextricably linked. The countries with the highest economic growth and the highest standards of living are also those with the highest energy use per capita.

Today, most of that energy, both in Asia and in the world as a whole, comes from fossil fuels – about 85 percent. Of these, oil and natural gas supply the majority, with coal also being a major player. That's especially true here in China, where coal remains the dominant fuel source.

I know there are some people who argue that we should drastically curtail our use of fossil fuels for environmental reasons, and I'll have more to say about that in a moment. But let me state at this point my belief that such proposals are neither prudent nor practical.

With no readily available economic alternatives on the horizon, fossil fuels will continue to supply most of the world's and this region's energy for the foreseeable future. Their use is essential both for economic growth and for the elimination of poverty, which is itself the worst polluter.

In recognition of this, we must continue to develop and apply technology and expertise that enable us to use fossil fuels in ways that are efficient and environmentally sound. Doing that will require a great deal, from both government and the petroleum industry.

Looking specifically at oil, demand in the region has grown vigorously, increasing reliance on imports, despite efforts to develop indigenous supplies.

China itself, with growth rates among the highest in the world, became a net importer in 1995.

I do expect some moderation in the rate of oil demand growth in all of the region as economies become larger, more sophisticated and efficient. But with the volume increase that is expected, I do not see how growing import dependence can be avoided.

In anticipation of this, it appears that supply strategies are changing, with Chinese and other Asian companies becoming more active in exploration in other parts of the world. But this change should not cause us to lose sight of the need to maintain and, if possible, increase local production and reserves.

Asia still has numerous areas with hydrocarbon potential. But it will take a major effort to unlock these resources for the benefit of consumers.

Increasingly, this is a difficult task, often involving seismic and drilling in deep waters or harsh terrain, with complex geological formations. Examples include the Sakhalin islands off Russia and the Tarim Basin in China.

Developing such resources at an affordable cost is going to require the application of the very best technology and practices known to the industry. Private petroleum companies have those tools. And so, an essential step to achieve further progress is for governments to accelerate the opening up of prospective resources for development by private industry.

One resource with great potential for Asia is natural gas. But producing and using it will require some visionary thinking and the application of new and as yet unproved technology.

Vast resources of gas exist off Natuna Island in Indonesia, in Papua New Guinea, and along the Northwest Shelf of Australia, to name a few.

Others may develop along the Asia-Pacific coast as far north as Russia. And, of course, there are major gas deposits west of the region as well. The key issues are how to get this gas to markets, and how to develop markets once it is determined that the gas can be produced at reasonable cost.

Today, most gas is transported to this region as liquefied natural gas, LNG. In the United States and Europe, most gas moves through pipelines – as it will in South America in the years ahead. Could the same not take place in Asia?

The distances are greater here, the markets less developed, but technology may yet lead the way to a pipeline grid serving the countries of this region. New high-strength steel and other technology may make pipelines feasible from Sakhalin, Natuna or as far away as Turkmenistan.

On the demand side, we estimate that oil for transportation and industrial use in the region will grow by nearly 10 million barrels per day by 2010. That's equivalent to about 40 new large refineries over that period – 3 per year.

Of course, along with demand comes the need for improved products, new chemicals and better processes. Increasingly, refineries and chemical plants are integrated into single sites as we're seeing in Singapore, for instance.

Finding new and better ways to produce, refine and market oil in the midst of change is not new to the petroleum business. What is new is the remarkable pace at which the need for petroleum fuels and products is accelerating in Asia.

Such conditions are creating opportunities for a synergy between governments of the region and private petroleum companies, with the potential to speed and strengthen the whole process of economic development.

Clearly, private companies such as Exxon have a lot to offer. Developing energy resources in new and difficult areas, building safe, reliable, and efficient refineries and chemical plants, and bringing new and better products to market are just a few of the contributions we can make.

We also bring hard-won technological expertise tested and proven in other areas of the world. This can make it practical to develop resources that would not have been economic just a few years ago. It can also lead to significant employment and educational opportunities. Time will not have to be spent in developing technology or training from scratch – they're already available without the growing pains.

Of course, all of this will require massive outlays of capital – financial, intellectual and technical. Projects will likely be large and complex, requiring multiple management skills. Familiarity with challenging environments, flexibility, and strong technological support will be key elements of a successful venture.

Private petroleum companies offer all of these essentials. But to draw on them, countries must be willing to provide incentives that cause companies to want to invest.

This is particularly true now, with so many new opportunities throughout the world. Competition among countries eager to develop petroleum reserves is at an all-time high. Resources are being stretched to the limit. To attract companies to make the huge investments needed, nations need to offer tax-and-take provisions that will encourage businesses to bring their best people and technology.

Governments also need to provide a stable investment climate, one that vigorously protects physical and intellectual property rights. They should avoid the temptation to intervene in energy markets in ways that give advantage to one competitor over another – or one fuel over another. Governments' goal should be to promote a fair contest on a level playing field.

Another key contribution governments can make to economic development is in setting rational environmental standards. People the world over want a clean environment, and some are concerned that fossil fuel use – especially oil use – is incompatible with that objective.

Today, concern about the environment focuses on the issue of global climate change. In December, representatives from some 160 nations will meet in the beautiful city of Kyoto, Japan, to decide on legally binding agreements that would have the effect of cutting the use of oil and other fossil fuels. Clearly, all of us here today have a big stake in the decisions that will be made.

Proponents of the agreements say they are necessary because burning fossil fuels causes global warming. Many people – politicians and the public alike – believe that global warming is a rock-solid certainty. But it's not.

Let me briefly address three key questions: Is the Earth really warming? Does burning fossil fuels cause global warming? And do we now have a reasonable scientific basis for predicting future temperature?

In answer to the first question, we know that natural fluctuations in the Earth's temperature have occurred throughout history – with wide temperature swings. The ice ages are a good example.

In fact, one period of cooling occurred from 1940 to 1975. In the 1970s, some of today's prophets of doom from global warming were predicting the coming of a new ice age.

Some measurements suggest that the Earth's average temperature has risen about half a degree centigrade since the late 19th century. Yet sensitive satellite measurements have shown no warming trend since the late 1970s. In fact, the earth is cooler today than it was 20 years ago.

We also have to keep in mind that most of the greenhouse effect comes from natural sources, especially water vapor. Less than a quarter is from carbon dioxide, and, of this, only four percent of the carbon dioxide entering the atmosphere is due to human activities – 96 percent comes from nature.

Leaping to radically cut this tiny sliver of the greenhouse pie on the premise that it will affect climate defies common sense and lacks foundation in our current understanding of the climate system.

Forecasts of future warming come from computer models that try to replicate Earth's past climate and predict the future. They are notoriously inaccurate. None can do it without significant overriding adjustments.

Even then, 1990's models were predicting temperature increases of two to five degrees Celsius by the year 2100. Last year's models say one to three degrees. Where to next year?

As one climate modeling researcher said in the May issue of the prestigious magazine, *Science*, "The more you learn, the more you understand that you don't understand very much."

So the case for so called global warming is far from air tight. You would think that all the uncertainty would give political leaders pause. Unfortunately, it hasn't, and officials continue to insist that agreement is needed in Kyoto.

To achieve the kind of reduction in carbon dioxide emissions most advocates are talking about, governments would have to resort to energy rationing administered by a vast international bureaucracy responsible to no one. This could include the imposition of punishing, high energy taxes.

This heavy burden of taxes and regulation would take its toll in many ways – in slower economic growth, lost jobs and a profound and unpleasant impact on the way we live. Companies in industrialized nations that compete in world markets would be seriously handicapped.

Currently, most proposals exclude developing nations, including China, Indonesia and many other countries here in the Far East. The rationale is that these countries are trying to grow economically and need to consume fossil fuels to do so.

Of course, this is true. But excluding developing countries from the reductions will not prevent them from being hurt. Their exports will suffer as the economies of industrialized nations slow.

So all of us would suffer from these proposals. The U.S. Senate recognized that fact this summer when it voted 95-0 in favor of a resolution expressing its concern about the proposals under consideration.

What should we do? First, let's agree there's a lot we really don't know about how climate will change in the 21st century and beyond. That means we need to understand the issue better, and fortunately, we have time. It is highly unlikely that the temperature in the middle of the next century will be significantly affected whether policies are enacted now or 20 years from now.

It also means it's bad public policy to impose very costly regulations and restrictions when their need has yet to be proven, their total impact undefined, and when nations are not prepared to act in concert.

In fact, in the U.S. the administration says it is futile to attempt to determine the impact on the economy in 2010 of reducing CO_2 emissions – although many studies indicate the impact will be vast.

Before we make choices about global climate policies, we need an open debate on the science, an analysis of the risks, and a careful consideration of the costs and benefits. So far, this has not taken place, and until it has, I hope that the governments of this region will work with us to resist policies that could strangle economic growth.

Fostering economic growth will require a broader understanding of the environment than many environmental activists seem to appreciate. The most pressing environmental problems of the developing nations are related to poverty, not global climate change. Addressing these problems will require economic growth, and that will necessitate increasing, not curtailing, the use of fossil fuels.

Such use does not mean inevitable environmental degradation. New technologies have allowed industrialized countries to enjoy both economic growth and environmental progress.

Studies in the economic community support this idea. A recent study at Princeton University found "no evidence that environmental quality deteriorates steadily with economic growth." Instead, it found that after an initial decline, a nation's environment improved as its economy grew.

So the real secret to environmental improvement is economic growth. And as this growth continues, the economies of this region will need to import more oil, and, to a lesser extent, gas.

This growing reliance on petroleum imports will cause a major eastward shift in the politics of energy. Nations may form new alliances, some based on commercial interests, others on geo-political considerations. The temptation may be strong to make these exclusive or restrictive, reversing recent trends toward more openness and harmony.

I hope that such factionalism will not be the case. We need the smooth functioning of an increasingly interdependent world economic and energy system. And this requires that barriers to trade and to the free movement of goods, services and people be dismantled, not raised.

It also requires that nations practice energy cooperation, not selfishness – and that they do so both in times of prosperity and of crisis.

Finally, some people say that, in pursuing economic development, Asia must follow a western model. I believe that the region must find its own way.

But I also believe that the most direct path is the one many countries in the region and around the world have chosen over the past 20 years – the free market approach. This approach has many antecedents, including the Chinese philosopher Lao-Tzu.

He wrote in the sixth century B.C.: "Govern a great nation as you would cook a small fish – do not overdo it."

It would be tragic indeed if the people of this region were deprived of the opportunity for continued prosperity by misguided restrictions and regulations.

It is up to all of us – the petroleum industry, the governments of this great region, and the international community – to ensure that this does not happen. By working together, we can lay a solid foundation for continued prosperity and rising standards of living that will benefit not only the people of Asia, but also people around the world. And the petroleum industry, convened at this Congress, will play a key role.

1998 draft *Global Climate Science Communications Plan* by the API

Joe Walker

To: Global Climate Science Team
Cc: Michelle Ross; Susan Moya
Subject: Draft Global Climate Science Communications Plan

As promised, attached is the draft Global Climate Science Communications Plan that we developed during our workshop last Friday. Thanks especially to those of you who participated in the workshop, and in particular to John Adams for his very helpful thoughts following up our meeting, and Alan Caudill for turning around the notes from our workshop so quickly.

Please review the plan and get back to me with your comments as soon as possible.

As those of you who were at the workshop know, we have scheduled a follow-up team meeting to review the plan in person on Friday, April 17, from 1 to 3 p.m. at the API headquarters. After that, we hope to have a "plan champion" help us move it forward to potential funding sources, perhaps starting with the global climate "Coordinating Council." That will be an item for discussion on April 17.

Again, thanks for your hard work on this project. Please e-mail, call or fax me with your comments. Thanks.

Regards,
Joe Walker

Global Climate Science Communications

Action Plan

Project Goal

A majority of the American public, including industry leadership, recognizes that significant uncertainties exist in climate science, and therefore raises questions among those (e.g. Congress) who chart the future U.S. course on global climate change.

Progress will be measured toward the goal. A measurement of the public's perspective on climate science will be taken before the plan is launched, and the same measurement will be taken at one or more as-yet-to-be-determined intervals as the plan is implemented.

Victory Will Be Achieved When

- Average citizens "understand" (recognize) uncertainties in climate science; recognition of uncertainties becomes part of the "conventional wisdom"
- Media "understands" (recognizes) uncertainties in climate science.
- Media coverage reflects balance on climate science and recognition of the validity of viewpoints that challenge the current "conventional wisdom"
- Industry senior leadership understands uncertainties in climate science, making them stronger ambassadors to those who shape climate policy
- Those promoting the Kyoto treaty on the basis of extant science appear to be out of touch with reality.

Current Reality

Unless "climate change" becomes a non-issue, meaning that the Kyoto proposal is defeated and there are no further initiatives to thwart the threat of climate change, there may be no moment when we can declare victory for our efforts. It will be necessary to establish measurements for the science effort to track progress toward achieving the goal and strategic success.

Because the science underpinning the global climate change theory has not been challenged effectively in the media or through other vehicles reaching the American public, there is widespread ignorance, which works in favor of the Kyoto treaty and against the best interests of the United States. Indeed, the public has been highly receptive to the Clinton Administration's plans. There has been little, if any, public resistance or pressure applied to Congress to reject the treaty, except by those "inside the Beltway" with vested interests.

Moreover, from the political viewpoint, it is difficult for the United States to oppose the treaty solely on economic grounds, valid as the economic issues are. It makes it too easy for others to portray the United States as putting preservation of its own lifestyle above the greater concerns of mankind. This argument, in turn, forces our negotiators to make concessions that have not been well thought through, and in the end may do far more harm than good. This is the process that unfolded at Kyoto, and is very likely to be repeated in Buenos Aires in November 1998.

The advocates of global warming have been successful on the basis of skillfully misrepresenting the science and the extent of agreement on the science, while industry and its partners ceded the science and fought on the economic issues. Yet if we can show that science does not support the Kyoto treaty -- which most true climate scientists believe to be the case -- this puts the United States in a stronger moral position and frees its negotiators from the need to make concessions as a defense against perceived selfish economic concerns.

Upon this tableau, the Global Climate Science Communications Team (GCSCT) developed an action plan to inform the American public that science does not support the precipitous actions Kyoto would dictate, thereby providing a climate for the right policy decisions to be made. The team considered results from a new public opinion survey in developing the plan.

Charlton Research's survey of 1,100 "informed Americans" suggests that while Americans currently perceive climate change to be a great threat, public opinion is open to change on climate science. When informed that "some scientists believe there is not enough evidence to suggest that [what is called global climate change] is a long-term change due to human behavior and activities," 58 percent of those surveyed said they were more likely to oppose the Kyoto treaty. Moreover, half the respondents harbored doubts about climate science.

GCSCT members who contributed to the development of the plan are A. John Adams, John Adams Associates; Candace Crandall, Science and Environmental Policy Project; David Rothbard, Committee For A Constructive Tomorrow; Jeffrey Salmon, The Marshall Institute; Lee Garrigan, Environmental Issues Council; Lynn Bouchey and Myron Ebell, Frontiers of Freedom; Peter Cleary, Americans for Tax Reform; Randy Randol, Exxon Corp.; Robert Gehri, The Southern Company; Sharon Kneiss, Chevron Corp; Steve Milloy, The Advancement of Sound Science Coalition; and Joseph Walker, American Petroleum Institute.

The action plan is detailed on the following pages.

April 3, 1998

Global Climate Science Communications

Action Plan

Situation Analysis

In December 1997, the Clinton Administration agreed in Kyoto, Japan, to a treaty to reduce greenhouse gas emissions to prevent what it purports to be changes in the global climate caused by the continuing release of such emissions. The so-called greenhouse gases have many sources. For example, water vapor is a greenhouse gas. But the Clinton Administration's action, if eventually approved by the U.S. Senate, will mainly affect emissions from fossil fuel (gasoline, coal, natural gas, etc.) combustion.

As the climate change debate has evolved, those who oppose action have argued mainly that signing such a treaty will place the U.S. at a competitive disadvantage with most other nations, and will be extremely expensive to implement. Much of the cost will be borne by American consumers who will pay higher prices for most energy and transportation.

The climate change theory being advanced by the treaty supporters is based primarily on forecasting models with a very high degree of uncertainty. In fact, it not known for sure whether (a) climate change actually is occurring, or (b) if it is, whether humans really have any influence on it.

Despite these weaknesses in scientific understanding, those who oppose the treaty have done little to build a case against precipitous action on climate change based on the scientific uncertainty. As a result, the Clinton Administration and environmental groups essentially have had the field to themselves. They have conducted an effective public relations program to convince the American public that the climate is changing, we humans are at fault, and we must do something about it before calamity strikes.

The environmental groups know they have been successful. Commenting after the Kyoto negotiations about recent media coverage of climate change, Tom Wathen, executive vice president of the National Environmental Trust, wrote:

"...As important as the extent of the coverage was the tone and tenor of it. In a change from just six months ago, most media stories no longer presented global warming as just a theory over which reasonable scientists could differ. Most stories described predictions of global warming as the position of the overwhelming number of mainstream scientists. That the environmental community had, to a great extent, settled the scientific issue with the U.S. media is the other great success that began perhaps several months earlier but became apparent during Kyoto."

Strategies and Tactics

I. National Media Relations Program: Develop and implement a national media relations program to inform the media about uncertainties in climate science; to generate national, regional and local media coverage on the scientific uncertainties, and thereby educate and inform the public, stimulating them to raise questions with policy makers.

Tactics: These tactics will be undertaken between now and the next climate meeting in Buenos Aires, Argentina, in November 1998, and will be continued thereafter, as appropriate. Activities will be launched as soon as the plan is approved, funding obtained, and the necessary resources (e.g., public relations counsel) arranged and deployed. In all cases, tactical implementation will be fully integrated with other elements of this action plan, most especially Strategy II (National Climate Science Data Center).

- Identify, recruit and train a team of five independent scientists to participate in media outreach. These will be individuals who do not have a long history of visibility and/or participation in the climate change debate. Rather, this team will consist of new faces who will add their voices to those recognized scientists who already are vocal.

- Develop a global climate science information kit for media including peer-reviewed papers that undercut the "conventional wisdom" on climate science. This kit also will include understandable communications, including simple fact sheets that present scientific uncertainties in language that the media and public can understand.

- Conduct briefings by media-trained scientists for science writers in the top 20 media markets, using the information kits. Distribute the information kits to daily newspapers nationwide with offer of scientists to brief reporters at each paper. Develop, disseminate radio news releases featuring scientists nationwide, and offer scientists to appear on radio talk shows across the country.

- Produce, distribute a steady stream of climate science information via facsimile and e-mail to science writers around the country.

- Produce, distribute via syndicate and directly to newspapers nationwide a steady stream of op-ed columns and letters to the editor authored by scientists.

- Convince one of the major news national TV journalists (e.g., John Stossel) to produce a report examining the scientific underpinnings of the Kyoto treaty.

- Organize, promote and conduct through grassroots organizations a series of campus/community workshops/debates on climate science in 10 most important states during the period mid-August through October, 1998.

- Consider advertising the scientific uncertainties in select markets to support national, regional and local (e.g., workshops/debates), as appropriate.

National Media Program Budget — $600,000 plus paid advertising

II. Global Climate Science Information Source: Develop and implement a program to inject credible science and scientific accountability into the global climate debate, thereby raising questions about and undercutting the "prevailing scientific wisdom." The strategy will have the added benefit of providing a platform for credible, constructive criticism of the opposition's position on the science.

Tactics: As with the National Media Relations Program, these activities will be undertaken between now and the next climate meeting in Buenos Aires, Argentina, in November 1998, and will continue thereafter. Initiatives will be launched as soon as the plan is approved, funding obtained, and the necessary resources arranged and deployed.

- Establish a Global Climate Science Data Center. The GCSDC will be established in Washington as a non-profit educational foundation with an advisory board of respected climate scientists. It will be staffed initially with professionals on loan from various companies and associations with a major interest in the climate issue. These executives will bring with them knowledge and experience in the following areas:
  - Overall history of climate research and the IPCC process;
  - Congressional relations and knowledge of where individual Senators stand on the climate issue;
  - Knowledge of key climate scientists and where they stand;
  - Ability to identify and recruit as many as 20 respected climate scientists to serve on the science advisory board;
  - Knowledge and expertise in media relations and with established relationships with science and energy writers, columnists and editorial writers;
  - Expertise in grassroots organization; and
  - Campaign organization and administration.

  The GCSDC will be led by a dynamic senior executive with a major personal commitment to the goals of the campaign and easy access to business leaders at the CEO level. The Center will be run on a day-to-day basis by an executive director with responsibility for ensuring targets are met. The Center will be funded at a level that will permit it to succeed, including funding for research contracts that may be deemed appropriate to fill gaps in climate science (e.g., a complete scientific critique of the IPCC research and its conclusions).

- The GCSDC will become a one-stop resource on climate science for members of Congress, the media, industry and all others concerned. It will be in constant contact with the best climate scientists and ensure that their findings and views receive appropriate attention. It will provide them with the logistical and moral support they have been lacking. In short, it will be a sound scientific alternative to the IPCC. Its functions will include:
  - Providing as an easily accessible database (including a website) of all mainstream climate science information.
  - Identifying and establishing cooperative relationships with all major scientists whose research in this field supports our position.
  - Establishing cooperative relationships with other mainstream scientific organizations (e.g., meteorologists, geophysicists) to bring their perspectives to bear on the debate, as appropriate.
  - Developing opportunities to maximize the impact of scientific views consistent with ours with Congress, the media and other key audiences.
  - Monitoring and serving as and early warning system for scientific developments with the potential to impact on the climate science debate, pro and con.
  - Responding to claims from the scientific alarmists and media.
  - Providing grants for advocacy on climate science, as deemed appropriate.

Global Climate Science Data Center Budget — $5,000,000 (spread over two years minimum)

III. **National Direct Outreach and Education: Develop and implement a direct outreach program to inform and educate members of Congress, state officials, industry leadership, and school teachers/students about uncertainties in climate science.** This strategy will enable Congress, state officials and industry leaders will be able to raise such serious questions about the Kyoto treaty's scientific underpinnings that American policy-makers not only will refuse to endorse it, they will seek to prevent progress toward implementation at the Buenos Aires meeting in November or through other ways. Informing teachers/students about uncertainties in climate science will begin to erect a barrier against further efforts to impose Kyoto-like measures in the future.

Tactics: Informing and educating members of Congress, state officials and industry leaders will be undertaken as soon as the plan is approved, funding is obtained, and the necessary resources are arrayed and will continue through Buenos Aires and for the foreseeable future. The teachers/students outreach program will be developed and launched in early 1999. In all cases, tactical implementation will be fully integrated with other elements of this action plan.

- Develop and conduct through the Global Climate Science Data Center science briefings for Congress, governors, state legislators, and industry leaders by August 1998.

- Develop information kits on climate science targeted specifically at the needs of government officials and industry leaders, to be used in conjunction with and separately from the in-person briefings to further disseminate information on climate science uncertainties and thereby arm these influentials to raise serious questions on the science issue.

- Organize under the GCSDC a "Science Education Task Group" that will serve as the point of outreach to the National Science Teachers Association (NSTA) and other influential science education organizations. Work with NSTA to develop school materials that present a credible, balanced picture of climate science for use in classrooms nationwide.

- Distribute educational materials directly to schools and through grassroots organizations of climate science partners (companies, organizations that participate in this effort).

National Direct Outreach Program Budget — $300,000

IV. Funding/Fund Allocation: Develop and implement program to obtain funding, and to allocate funds to ensure that the program it is carried out effectively.

Tactics: This strategy will be implemented as soon as we have the go-ahead to proceed.

- Potential funding sources were identified as American Petroleum Institute (API) and its members; Business Round Table (BRT) and its members, Edison Electric Institute (EEI) and its members; Independent Petroleum Association of America (IPAA) and its members; and the National Mining Association (NMA) and its members.

- Potential fund allocators were identified as the American Legislative Exchange Council (ALEC), Committee For A Constructive Tomorrow (CFACT), Competitive Enterprise Institute, Frontiers of Freedom and The Marshall Institute.

Total Funds Required to Implement Program through November 1998 — $2,000,000 (A significant portion of funding for the GCSDC will be deferred until 1999 and beyond)

Measurements

Various metrics will be used to track progress. These measurements will have to be determined in fleshing out the action plan and may include:

- Baseline public/government official opinion surveys and periodic follow-up surveys on the percentage of Americans and government officials who recognize significant uncertainties in climate science.

- Tracking the percent of media articles that raise questions about climate science.

- Number of Members of Congress exposed to our materials on climate science.

- Number of communications on climate science received by Members of Congress from their constituents.

- Number of radio talk show appearances by scientists questioning the "prevailing

- Number of school teachers/students reached with our information on climate science.
- Number of science writers briefed and who report upon climate science uncertainties.
- Total audience exposed to newspaper, radio, television coverage of science uncertainties.

1998 article by Robert Peterson, CEO of Imperial Oil, in the Imperial Oil Review, *A Cleaner Canada*

A Cleaner Canada

Imperial Oil's chairman examines the state of the environment and finds much to applaud. The fact is, he says, substantial progress has been made

BY ROBERT PETERSON

IT WILL COME AS A SURPRISE TO MANY PEOPLE TO LEARN THAT THE QUALITY OF the environment in Canada has been steadily improving for a long time and continues to do so. Surveys indicate that a majority of Canadians believe that the environment in this country is deteriorating rapidly. In fact, the historical record shows just the contrary. During the past three decades, air quality, water purity and other important indicators of environmental health have all improved – some of them very substantially.

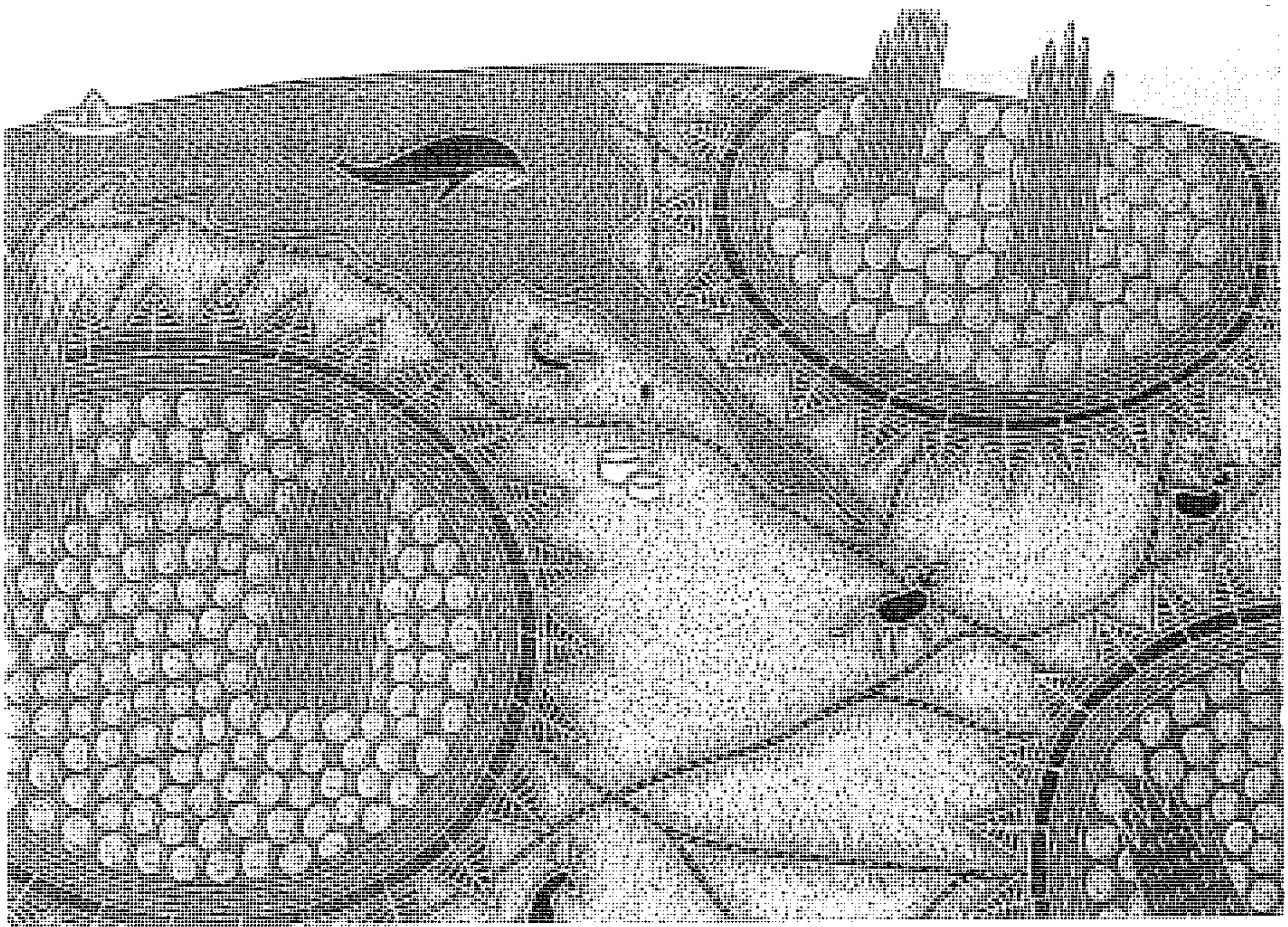
Personally, I would have been very surprised if this had not been the case. Whenever I visit the various sectors of Imperial Oil's operations, I see evidence all around me of what our company is doing to eliminate or minimize pollution and to improve efficiency in its use of resources. In Western Canada, our crude oil and natural gas production operations now generate less waste. Our refineries, which process crude oil into gasoline and many other oil-based products, have substantially improved the quality of the water discharged from operations into sewers as well as their energy efficiency (energy use per unit of output at Imperial refineries has been reduced by more than 20 percent since the mid-seventies). They have also reduced waste. As for the gasoline we manufacture, that too has been changed considerably to minimize atmospheric emissions while, at the same time, providing the motorist with the best possible product.

Over the past 10 years, Imperial has invested $472 million in new processes and procedures designed to be more efficient, use fewer resources and have less effect on the ecology than those used previously. This year alone, Imperial has earmarked $30 million for capital investment directed towards improving the environment. Like any other investment we make, we expect these expenditures to produce measurable results.

And here, of course, I'm speaking of only one company. In total, Canada's petroleum industry spent more than $600 million between 1993 and 1995 on environmental protection. The country's resource industries as a whole committed a total of $3.4 billion over the same period. If this kind of spending hadn't resulted in an improved environment, we'd have been squandering an awful lot of our shareholders' money.

But this considerable investment on the part of Canadian industry *has* produced results. Let's take a quick look at what has happened in some of the more important sectors of the environment.

Among all the environment categories, air quality shows the clearest trend of improvement. The air we breathe today in this country is, without a doubt, cleaner than it was 25 years ago. According to a 1997 study produced by the Fraser Institute, an independent Canadian economic and social research organization, five of the six major contributors to atmos



STEPHAN DAIGLE/SIS

pheric pollution, measured in terms of "ambient pollution" (that is, the actual concentration of a pollutant in the air), have shown decreases over the years. For example, levels of sulphur dioxide, a major contributor to acid rain, decreased by 54 percent from 1975 to 1993, while ambient levels of lead in the air decreased by no less than 97 percent between 1975 and 1992, mainly as a result of the phasing out of leaded gasoline. Ground-level ozone, which contributes to urban summer smog, was the only identified substance to show an increase in ambient levels, but even these levels are lower than those indicated as acceptable in federal guidelines. (Ground-level ozone is formed partly as a result of emissions associated with gasoline use.)

In recent years, Imperial and other companies have worked actively to help governments find practical, cost-effective answers to Canadian air-quality concerns. To help reduce smog, Imperial and other Canadian refiners have progressively lowered the volatility of gasoline sold during the summer. In addition, systems have been installed at fuel distribution facilities to capture emissions caused by evaporation. Refiners have also invested heavily in equipment to produce low-sulphur diesel fuel and to reduce the benzene content of gasoline. All these actions have contributed to the measured improvement in Canadian air quality.

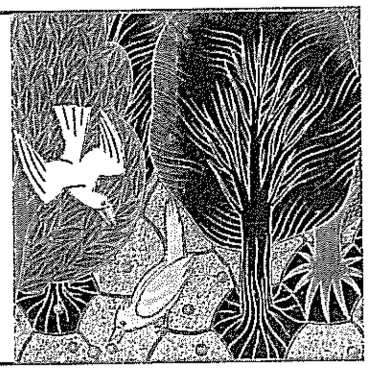
Of course, car manufacturers have also made significant improvements to their products to improve air quality. Since 1970, tailpipe emissions of hydrocarbons and nitrogen oxides – both contributors to ground-level ozone – from new vehicles have been reduced by more than 90 percent. In fact, the situation today is that half of all exhaust pollution comes from 10 percent of vehicles – those that were made in 1988 and before or are poorly tuned. The Ontario government, with the support of the petroleum industry, recently announced the introduction of a motor vehicle inspection and maintenance program, while British Columbia has been operating a pilot program since 1996 to provide financial incentives to get high-polluting vehicles off the road.

Progress in improving water quality is more difficult to measure. While comprehensive statistics for all provinces are unavailable, a 1996 federal government report states that water quality in Canada in general, compared with most countries, remains relatively high. This is particularly true of drinking water – about 87 percent of all Canadians receive treated municipal tap water. (Most problems arise from human consumption of water from untreated sources, such as private wells.)

In recent years, there has also been a greater awareness of the polluting effect of human activities on large bodies of water. The Great Lakes are a case in point. The International Joint Commission, which administers water treaties between Canada and the United States, believes that there is still much work to be done in improving water quality in the lakes. Nevertheless, there are some encouraging trends. While levels of nitrogen have increased in the Great Lakes, they are still well below the threshold for safe drinking water. Levels of phosphorus (which generally enters the water in detergents and fertilizers) have declined by one-third in Lake Ontario and have remained static in Lake Huron and Lake Superior. In fact, I read recently that some people are complaining that Lake Erie has become too clean and that fish stocks are diminishing as a result (phosphorus and nitrogen promote the growth of algae and other plant life, an important link in the Great Lakes food chain).

One important area in which we have seen a major improvement in water quality is that associated with industrial activities. For example, the petroleum and chemical plants that stretch along the St. Clair River (which connects Lake Huron to the Lower Great Lakes) near Sarnia, Ont., constitute one of the largest industrial concentrations in Canada. A key reason they are located there is so they can draw their water supplies from the river. Imperial's refinery at Sarnia is one such plant, and the workforce there takes great pride in the fact that the water returned to the river after being used is actually cleaner than when it was taken out. In fact, despite all this industrial activity, the water of the St. Clair is today among the cleanest river water in the Great Lakes system, and to keep it that way, industry spends millions of dollars a year on pollution control. Scott Munro, the general manager of the Lambton Industrial Society, which constantly monitors the quality of the water in the St. Clair, says that the river water has shown a steady improvement over the years.

SINCE 1970, TAILPIPE EMISSIONS OF HYDROCARBONS AND NITROGEN OXIDES FROM NEW CARS HAVE BEEN REDUCED BY MORE THAN 90 PERCENT



In other key environmental areas, the news is also encouraging. A 1997 joint study by the Fraser Institute and the Pacific Research Institute for Public Policy in the United States found that "in most instances objectives for protecting human health and the environment are being met, pollution and wastes are being controlled, and resources and land are being sustainably and effectively managed. Environmental quality in both Canada and the United States is *improving*, not deteriorating."

The overall conclusion of this comprehensive study was that "fears about increasing environmental degradation in Canada and the United States are unfounded."

Does this kind of report card provide us with any room for complacency? Of course not; there is still much to be done. But I *do* think that we can, as Canadians, take the time to recognize what has been achieved so far. In fact, I think we need to do this so that we can arrive at a realistic assessment of where we stand.

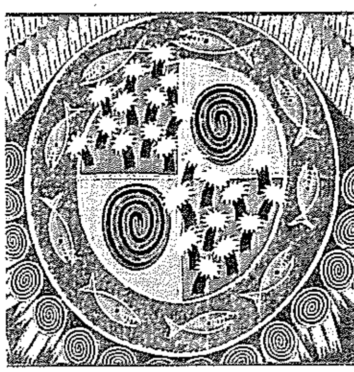
Unfortunately, Canadians rarely get the opportunity to hear the good news. Human nature being what it is, the fact that Canada's air quality has been steadily improving is unlikely to make front-page news. Nor are we likely to hear that kind of good news from those individuals who are convinced that no aspect of the environment is improving and for whom every pronouncement on the subject must be couched in terms of a doomsday scenario. Despite the substantial progress that has been achieved in such key areas as air and water pollution, toxic discharges, acid rain emissions, waste reduction and the recycling of many kinds of material, nearly every statement on the state of the environment appears to be wrapped in gloom and doom. It seems to be politically incorrect to say anything good about it. Little wonder that most Canadians think that things are getting worse even though they are getting better.

This is not meant to be an attack on environmentalists. I respect many of their beliefs and salute their achievements. I think the world as a whole would be in a much sorrier state today if it were not for the efforts of a group of dedicated people who have devoted their time and energy to increasing public awareness of ecological matters and to pushing governments to give priority to the protection of the environment. They have had some notable successes.

I do, however, regret the polarization that has come to characterize relations between the business community and some segments of the environmental movement. Too often, it seems to me, they resemble islands shouting across a sea of misunderstanding, unable – or, perhaps, unwilling – to see each other's point of view.

I believe there is a clear and positive connection between strong economic growth and a healthy environment. Indeed, I view economic growth as a prerequisite for fulfilling the aspirations of all Canadians by providing a better standard of living, advances in education and improved public health, and by generating the funds for the protection of the environment. Some environmental activists, on the other hand, are more inclined to view continuing economic growth as a destructive force, resulting in the depletion of our country's natural resources and damage to the environment.

The link between economic growth – driven largely by fossil fuel consumption – and environmental quality continues to be a subject of great debate. Recently, a major study conducted at Princeton University in the United States attempted to define the link between these two factors. The study found that initially environmental quality declines as a result of economic growth. But as people's incomes rise, a turnaround occurs. At a certain level of per capita income, the quality of the environment improves and continues to improve as incomes rise. This suggests that economic growth and environmental improvement are compatible.



In fact, despite all this industrial activity, the water of the St. Clair is today among the cleanest river water in the Great Lakes system

Finally, I would like to turn to a topic that many people think is related to air quality and pollution. I refer to global warming. The debate over this controversial issue centres around whether the burning of fossil fuels, by emitting so-called heat-trapping "greenhouse" gases (primarily carbon dioxide), will cause temperatures around the world to rise to the point where we will be faced with a planetary disaster.

It is important to understand that this issue has absolutely nothing to do with pollution and air quality. Carbon dioxide is not a pollutant but an essential ingredient of life on this planet – the plant world cannot live without it. Furthermore, the question of whether or not the trapping of "greenhouse" gases will result in the planet's getting warmer – and I will comment on this shortly – has no connection whatsoever with our day-to-day weather.

Nevertheless, it seems to have become fashionable for some media and environmental groups to lay the blame for every unusual variation in normal weather patterns – whether it be floods in California, tornadoes in Florida or ice storms in eastern Ontario and Quebec – on global warming. This is, quite simply, a fallacy. In fact, the Intergovernmental Panel on Climate Change, which is made up of a group of international scientists, has found no indications that instances of extreme weather have increased in a global sense through the 20th century.

One thing is clear in this debate. There is absolutely no agreement among climatologists on whether or not the planet is getting warmer or, if it is, on whether the warming is the result of man-made factors or natural variations in the climate. As an article in the May 1998 issue of *National Geographic* stated: "If the [warming] trend continues, it could alter climate patterns worldwide....

"Or it might not. Global climate depends on combinations of factors interacting in subtle and complex ways that we do not yet fully understand. It is possible that the warming observed during this century may have resulted from natural variations...."

Nor is there any agreement on whether or not the impact – if the planet does get warmer – will be serious and what should be done about it. There has been no shortage of experts willing to testify for either side in this debate. Space does not allow me to summarize the various scientific arguments that have been marshalled for and against the case for global warming. I will say that given the amount of money and scientific resources that are being allocated to this matter in many countries, I believe that, over time, an answer will emerge that will meet with general consensus among the international scientific community. However, we are a long way from that answer today and, at this stage, I feel very safe in saying that the view that burning fossil fuels will result in global climate change remains an unproved hypothesis.

This thought, however, is not shared by the government of Canada. At an international conference on climate change held in Kyoto, Japan, at the end of last year, the federal government undertook to reduce Canadian emissions of carbon dioxide and

CHAPTER SIX

Undermining their own Science
1998—2006

Despite the oil industry's decade-long media campaign against the scientific consensus on climate change, public desire for action was growing at the turn of the millennium. No longer able to simply outright deny the existence, causes, or consequences of climate change, oil companies were forced to adopt a more nuanced strategy built on duplicity and disinformation, feigning concern for the issue while continuing to fund denier groups and scientists-for-hire to sow doubt about climate science.

Shell's 1998 Group Scenario report, **Document 27**, acknowledges their role in causing the problem and their failure to heed dire warnings from their own scientists, while making a few eerily prescient predictions in scenarios describing a possible future: "In 2010, a series of violent storms cause extensive damage to the eastern coast of the U.S. Although it is not clear whether the storms are caused by climate change, people are not willing to take further chances. The insurance industry refuses to accept liability, setting off a fierce debate over who is liable… Following the storm, a coalition of NGOs brings a class action suit against the U.S. government and fossil fuel companies on the grounds of neglecting what scientists (including their own) had been saying for years: that something must be done."

"The scientific debate is closing [against us] but is not yet closed. There is still a window of opportunity to challenge the science."

Frank Luntz, Pollster, memo to Bush White House, 2002

The oil industry's political allies were no less cognizant of the growing public consensus, yet they too understood that creating doubt about the science was key to their success. In a 2002 messaging memo to the Bush White House, **Document 28**, pollster Frank Luntz, advises, "The scientific debate is closing [against us] but is not yet closed. There is still a window of opportunity to challenge the science." He added, "Should the public come to believe that the scientific issues are settled, their views about global warming will change accordingly. Therefore, you need to continue to make the lack of scientific certainty a primary issue in the debate."

A 2006 report by ExxonMobil titled *Tomorrow's Energy: A Perspective on Energy Trends, Greenhouse Gas Emissions and Future Energy Options*, **Document 29**, strikes this carefully crafted balance between projecting concern about climate change while still effectively undermining the science. In it, ExxonMobil writes, "While assessments such as those of the IPCC have expressed growing confidence that recent warming can be attributed to increases in greenhouse gases, these conclusions rely on expert judgement rather than objective, reproducible statistical models. Taken together, gaps in the scientific basis for theoretical climate models and the interplay of significant natural variability make it very difficult to determine objectively the extent to which recent climate changes might be the result of human actions."

In reaction, the Royal Society, the premier scientific academy in the UK dating back to the 1600's, called out ExxonMobil, **Document 30**, for a persistent pattern of misrepresenting climate science and funding denialist groups. In its 400-year history, the group had never before commented on a company's activities, but now was so disturbed by ExxonMobil's repeated and ongoing "inaccurate and misleading view of the science of climate change," including the above *Tomorrow's Energy* report, that it went public with these concerns. The Society's unprecedented letter breaks down several of ExxonMobil's misleading statements, and points out the inconsistency of Exxon's public statements with its own scientific research. The letter concludes with an analysis of Exxon's Worldwide Giving report, finding that "ExxonMobil last year provided more than $2.9 million to organizations in the United States which misinformed the public about climate change through their websites." Both the Royal Society's letter and ExxonMobil reply received significant press coverage, which would force ExxonMobil to address their funding of denialist groups the next year.

1998 internal Shell report, *Group Scenarios, 1998-2020*

Group Scenarios 1998-2020

Contents

Energy, the Environment, and Consumer's Choice

The Customer is King

In ***People Power***, three forces drive the energy business: sophisticated, diverse, and demanding customers, the widespread use of information technology, and the many experiments in tailored service provision unleashed by the liberalisation of energy markets. In a world of growing diversity, a global energy market does not develop. Within and between markets, customers differ in their energy service needs and expectations.

What Do Customers Want?

A 1998 Survey of US Utility Customers concluded that customers wanted five particular services, in the following order:

1. To have accurate and easily readable bills
2. To talk to a real person when there is a problem
3. To be served on time
4. To have high quality people provide services
5. To be charged the lowest price competitors offer

Some customers, especially industrial and commercial customers, are concerned primarily with *low* cost. Multi-national customers, including large buyers on behalf of groups of retail customers, demand supply contracts with single national or multinational suppliers so as to achieve cost savings. Many of these customers require energy suppliers to absorb some of their business risk through flexible pricing schemes, thereby lowering their overall cost exposure.

Other customers are simply concerned with whether suppliers provide *reliable energy* at a reasonable cost, with minimal hassle, and are available for immediate response to problems. Saving a few cents is of less concern than being able to talk to a real person when there is a problem or having an accurate and easily readable bill. Large remote suppliers must assure such customers that they really understand these desires and can respond to them.

"I'm sick of all the competition, I just want to make a simple phone call and not worry about it."
Bell Atlantic customer

A significant number of customers are intensely concerned with the *environmental or social impacts* of their energy sources. In ***People Power***, many varied supply packages are developed for these consumers – from pure renewable, to low carbon, to locally produced energy. These customers rely on a host of third-party agents to certify and verify the quality and source of their supply.

But no matter what their interests or needs, these customers demand action. If the energy markets or suppliers can't or won't move fast enough, they do it themselves. Some produce their own energy; others adjust their lifestyles and find other technologies, products, or services to meet their needs. Corporate customers with large energy bills simply relocate to regions where markets are more responsive.

Many energy companies, in the habit of telling their customers what they can have rather than discovering what they might want, do not survive. But some 'old dinosaurs' find the shock a stimulus for revolution in their attitudes and behaviour.

PG&E Energy Services	Energy Mix Clean Choice 50™	Energy Mix Clean Choice 100™	Energy Mix Wind for the Future™
New Renewables	13%	25%	10%
Existing Renewables	37%	75%	65%
Non-Renewables	50%	–	25%
Price over current rate	1.6 ¢/kWh	2.3 ¢/kWh	n/a

Reputation Matters

While all energy markets liberalise, the outcomes of liberalisation are often very different. India, for example, is unable to persuade all states to adopt a standard set of rules for their energy sectors. Consequently, India, like many other federations, operates under a patchwork of energy regimes. Region-specific rules and conditions make it difficult for energy firms to gain scale economies in service offerings across the whole country. But this patchwork of rules means that in ***People Power***, reputation really matters. Customers cannot simply rely on authorities to ensure quality standards.

Information Technology and Tailored Services

Energy marketers in ***People Power*** aggressively exploit new information and communication technologies to collate customer preferences and promote a greater range of products and services in order to distinguish themselves. As was seen in the telecommunication industry, the capacity to differentiate according to time and occasion-of-use, demography, location, and even attitude creates an explosion of new bundled energy services. IT also allows a faster response to customers, leading to greater experimentation and volatility in the half-lives of products and services. The increasing ability of financial markets to

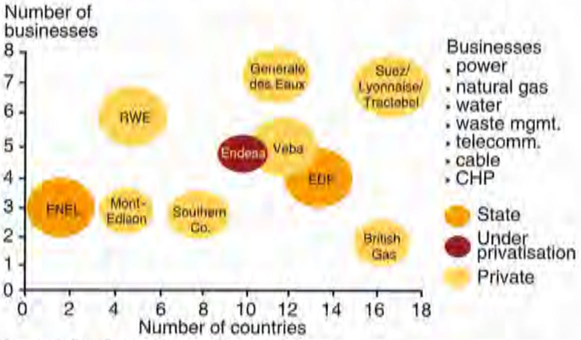
"Think about what happened in telecommunications. Only 20 years ago we didn't have call-waiting, call-forwarding, voicemail, cell phones, modems, and even answering machines were a rarity. I think we'll see a similar evolution in energy, with all sorts of interesting new products."

Scott W. Gebhardt, President and CEO of PG&E Energy Services segment and price specific risks, such as weather, allows further tailoring of service offerings.

Because of the cost savings in providing multiple end-use services over what is in effect a common distribution channel and the desire of many consumers for simplification, some firms offer a wide range of bundled convenience packages of energy and other services: for example, gas, power, water, and security; energy and office equipment management coupled with fuel services; and many others, with new offerings introduced at a dizzying rate.

But some experiments in providing customer service simply fail. Customers carefully weigh whether the bundled service on offer is worth the risk of putting too much power in the hands of one provider. Suppliers are rarely able to meet the needs of all customer segments and have to make choices about what services and products to offer. Some customers, for example, simply will not purchase 'green electricity' from a supplier who also produces 'dirty electricity'. In addition, firms have to spend hundreds of millions of dollars trying to create brand awareness. Loyalty schemes abound as firms try to hold onto customers.

The Largest Aggregators in Europe, 1998



Source: *CERA, The New European Energy Utility, 1998*

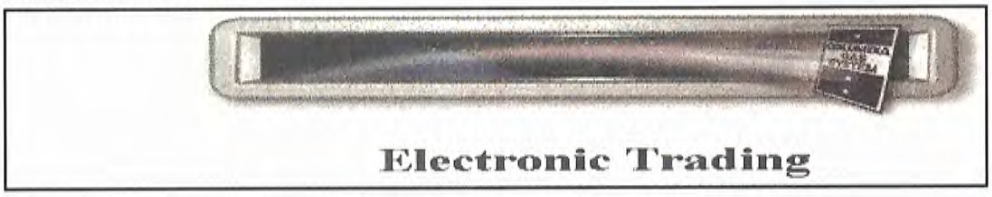
For many customers, however, energy marketers become an irrelevant impediment between themselves and the supplier. Smart appliances decide when to operate and purchase energy, based on real-time market prices. In 2004, Microsoft succeeds in establishing an appliance protocol that allows energy equipment to have direct communication over the internet, thus enabling automated, on-line energy purchases.

People Power: On-line Energy Markets

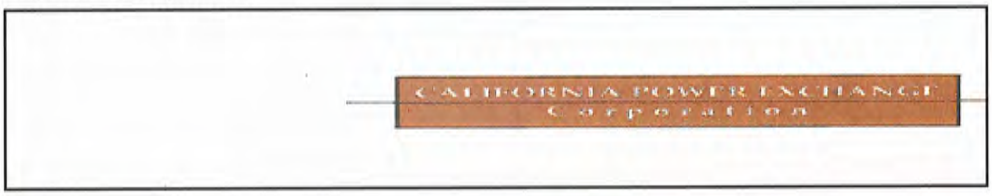
http://www.energyagent.com

http://www.nordpool.com

http://www.columbiaenergy.com



http://www.calpx.com



http://www.ucm.com

Environment – Other Priorities

Following the Millennium Recession, unemployment is high, and concern for the environment recedes. Those opposed to the Kyoto climate-change agreement find it easy to stop things happening – and governments have higher priorities. Taking special care not to affect economic recovery, most OECD countries offer half-hearted policies to meet the Kyoto agreement, usually in the form of higher road transport charges, gasoline taxes, tax incentives for renewable energy (which are rarely taken up), and exhortations to use energy more efficiently. The auto industry vigorously opposes new auto efficiency standards, and, in any event, citizens are far more concerned with local air quality issues than with efficiency.

The US Congress fails to ratify the Kyoto agreement – how could it without the participation of key developing countries, who seem determined to 'steal jobs', while wrecking the very environment the US is being asked to save? The costs are simply too high – carbon mitigation, for example, will cost over $200/tonne, representing a doubling in primary energy costs and unacceptable economic hardship.

Government programmes, such as the US Partnership for a New Generation of Vehicles (PNGV), are scaled back in the face of the difficult economic conditions and as more pressing transport concerns, such as congestion, become apparent. Automakers see little advantage for themselves in strongly supporting the program. The European Car of Tomorrow Programme, without substance to begin with, never gets off the ground. Non-OECD governments, waiting for OECD governments to take the lead in emission reductions, are not interested in taking on actions of their own – even though by 2010 their combined emissions exceed those of the OECD countries.

"There are those who are unwilling to see China progress and who are trying to contain its development by pointing their fingers at the world's environmental problems."

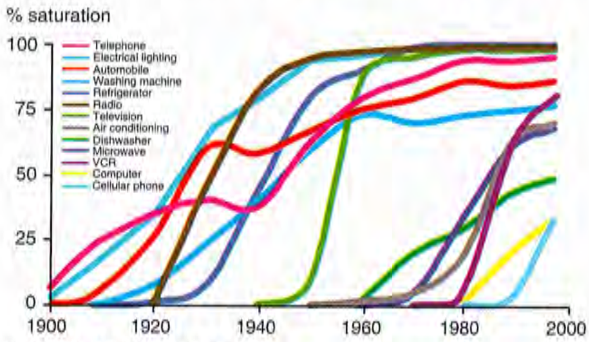
China Daily 1997

Demand Explosion and Saturation

Following the Millennium Bangs of 2002, global energy demand falls for the first time in two decades. Three years later, as economies recover and consumer confidence grows, demand begins to grow strongly, rising by 3% per year from 2005 to 2010, and by over 5% per year in non-OECD countries. In middle-income countries like Brazil, the demand for commercial fuels outpaces economic growth.

In OECD countries, however, energy demand growth does not recover strongly after the recession, increasing only with population growth of just under 1% per year. The on-going economic shifts from industry to services, and efficiency improvements in households and industry both serve to dampen energy growth. But the bigger factor is that major energy needs – heat, light, motors to substitute for physical activities, and mobility – have already been met, and people prefer to spend increases in disposable income on entertainment, health, and personal services rather than on superfluous appliances. Even in developing countries, where end-use penetration proceeds more rapidly than in the countries of origin, basic energy needs for wealthier households are largely met. With no major new energy end-uses introduced in OECD countries in over three decades, and with new electric goods largely substituting for other energy-using goods, the fight for energy market share becomes intense.

US Saturation of Household Energy Uses



Source: *Federal Reserve Bank, Dallas*

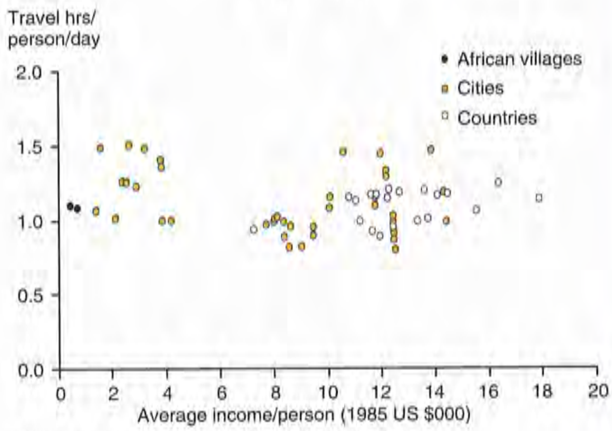
Mobility Services

In ***People Power***, it is customer end-service that really matters. Consumers seek out services that make their hectic lives easier and help save the scarcest resource – time. But as road congestion continues to worsen in major urban centres of North America, Europe, and Asia, and as road infrastructure starts to hit physical

Transport Time and Zahavi's Constant

Research indicates that people allocate a constant share of their time for travelling. While there is substantial individual variability, on average, people everywhere, regardless of social or economic status, are unwilling to spend more than about 1.0 to 1.5 hours a day for travel – 'Zahavi's Constant'. People in African villages spend the same 1.0 to 1.5 hours of time travelling per day as people in Japan, Singapore, Western Europe, and North America. Historic studies have found similar results – while people today travel much further, they still devote the same share of their day to travel as their grandparents did.

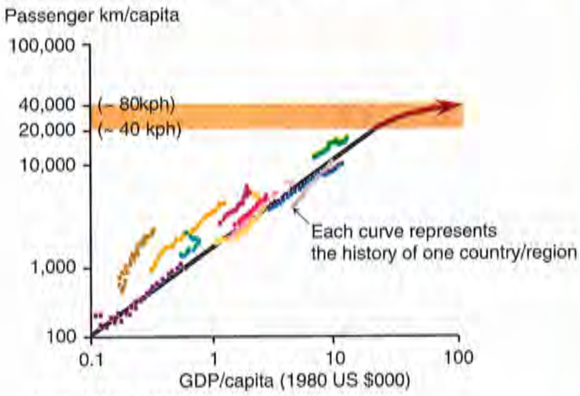
Travel Time



Source: *Schafer and Victor, The Past and Future of Global Mobility*

Given Zahavi's Constant, increased mobility can come about only through higher speed or more efficient forms of transport. But competing uses for land and resources are making expansion of roads and mass transport systems more difficult. Congestion may soon start to hinder further increases in mobility, especially in urban centres in Asia, Europe, and North America, where traffic has slowed to almost 'turtle-pace' speeds, and where average travel time is beginning to exceed Zahavi's Constant.

Mobility Saturation



Source: *Schafer, IIASA*

In a world of congestion, people will try to reserve their available travel time for 'quality' travel, such as leisure, and will look for alternate ways of meeting more basic needs, such as shopping and commuting. Zahavi's Constant seems to point to an inevitable increase in such substitutes for physical travel as tele-shopping and tele-commuting.

limits, drivers have to give up more of their time in daily travel. While there is strong public clamour for governments to address congestion issues, land constraints limit road expansion, and government budget constraints make it difficult to develop alternatives such as efficient mass transport systems.

In London, citizen groups like 'Reclaim Our Streets' succeed in their campaigns to increase the number of 'car-free zones' in the city. Flexible working hours and tele-commuting become pervasive in New York. In Bangkok, the public responds to road space limitations through the use of ingenious car pooling schemes. But overall, these measures have marginal impacts. By 2010, travel time in major urban centres becomes unacceptable, averaging over three hours a day. This is well above what people are willing to allocate to daily travel, regardless of the mode of transport.

Patag Cybershop, Manila 2005

A young electronics company executive visiting Manila for the first time is astonished that the ten-mile trip from the airport to his hotel takes three hours even though it is Sunday, when most offices and shops are closed. He wonders how people cope with such congestion.

While stuck in traffic, he notices people of all ages entering a small shop and coming out empty-handed. He also notices that most people coming out of the shop are on foot.

After checking his luggage at the hotel, he visits the nearby 'Patag Cybershop'. Inside, in one corner, a small group of men are chatting over a bottle of 'San Miguel' beer, while at another table, teenagers are having a *balut* (duck-egg)-eating contest. In another corner, kids play in a mini-children's playground. The atmosphere is very festive, and the *lechon* (roasted suckling pig) smells great.

Towards the other wall of the shop, people are sitting around a dozen computers. He approaches an elderly lady at one of the computers to see what she is doing. With the help of her four-year old granddaughter, she is clicking icons on a screen grocery list. When she is finished, she simply enters her password to complete the transaction and leaves the computer for the next person in line.

Curious, the executive sits down and sees that the cybershop lists more than 100,000 items, from bath soaps to wallpapers to bread. Taking advantage of the opportunity, he orders toothpaste, shaving cream, a box of floppy disks, and a souvenir for his wife—all at very reasonable prices, and all guaranteed for delivery to his hotel before breakfast the next morning.

As a result, consumers seek alternatives to enhance mobility and productivity. On corners in most major cities, cybershops pop up, where consumers can buy a wide range of day-to-day household items and groceries using the internet. Rather than waste hours driving to shops, consumers turn to information technology for solutions.

With the commercialisation of high bandwidth video-conferencing in 2006, companies increasingly require strong justification for physical travel, given the overwhelming cost savings from virtual meetings. In the world of ***People Power*** anything that can be digitised, generally is.

The Supercar – False Promises

In 2004, to meet the PNGV target date, automakers bring a variety of supercars to the market, with claims of dramatic improvement in fuel efficiency and, in some cases, radical new fuel and engine systems. Because costs are high, manufacturers have hedged their bets, often producing uneasy compromises. While many consumers are excited, most are confused by the wide variety of new vehicles, some of which require special fuelling facilities. Many of the vehicles also perform badly, having been rushed to market in order to meet the PNGV timetable. Like diesel cars in the US, which were introduced with great fanfare in the 1980s, but then sank without trace, the new vehicles have a negligible overall impact on fleet efficiency.

Nonetheless, the California Air Resources Board (CARB) maintains its tough stance against vehicle emissions and continues its program to require near zero emission vehicles. Links between fuel suppliers and 'green' car manufacturers increase to meet these demands for improved local air quality and to establish premium niche markets through supply of special 'designer fuels'.

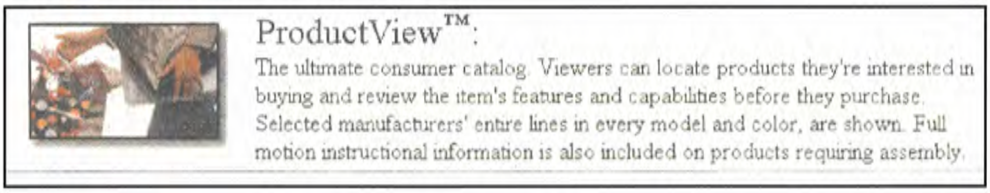
People Power: On-line Shopping

http://www.tesco.co.uk

http://www.vh.org

http://www.traderonline.com

http://www.vdat.com



http://www.auctionfloor.com

Energy Supply

Until 2010, the focus for OECD power and gas suppliers is simply on survival. Stagnant demand following the recession in 2002, and intense competition to establish shares in newly liberalised markets, leave most incumbents in difficult financial shape.

"Gas is difficult to sell because it's one of the most boring things on earth. You can't see it. You can't touch it."

Caroline Harper, Managing Director of Gas at Amerada Hess

Because little new electricity capacity is required, development of renewable energy is slow. Renewable energy niches reach 5% market share by 2010, although in a growing number of wealthy regions, such as California, where customers are willing to pay a premium for a clean environment, the share reaches 10%.

Following the recession, many non-OECD governments move to a hasty liberalisation of markets, creating a complex and fluid patchwork of regimes. Foreign companies flood into these energy markets, but only those with the capacity to withstand a high degree of volatility can succeed. Companies find, for example, that contracts are cancelled and then reinstated with surprising frequency. Consumers in these volatile markets look for those companies that can hold on for the ride, and so select their energy providers on the basis of reputation and resilience.

Concerns in Asia about energy security and on-going disputes over regional resource ownership periodically threaten to escalate into conflict. After the financial shocks of 1997 and the recession of 2002, Asian governments and those in Russia and Central Asia are pre-occupied with local matters, and despite the signing of numerous protocols to develop energy trade between Central Asia, Russia, and Asia, no natural gas pipelines or electricity supply projects are completed by 2010. The political will to complete the complex negotiations needed to support these projects is lacking. Only LNG imports provide any serious competition to domestic energy sources. Not until 2015 are the first major gas and electricity export projects to Asia completed.

Distributed Energy

The only growth area for electricity supply in OECD countries is distributed power supply. While sales of fuel-cell vehicles find limited success, due to consumer concerns about fuel supply, sales of natural gas-based fuel cells for buildings grow rapidly. Many consumers want greater control over the quality of their heat and power supply; others simply want to lower costs. The largest uptake of distributed power occurs in commercial establishments such as office towers and schools, which are able to sell surplus power to the grid during peak periods. Growth in distributed energy supply exacerbates excess capacity problems for grid-based power suppliers.

2010 – Environment Back on the Front Pages

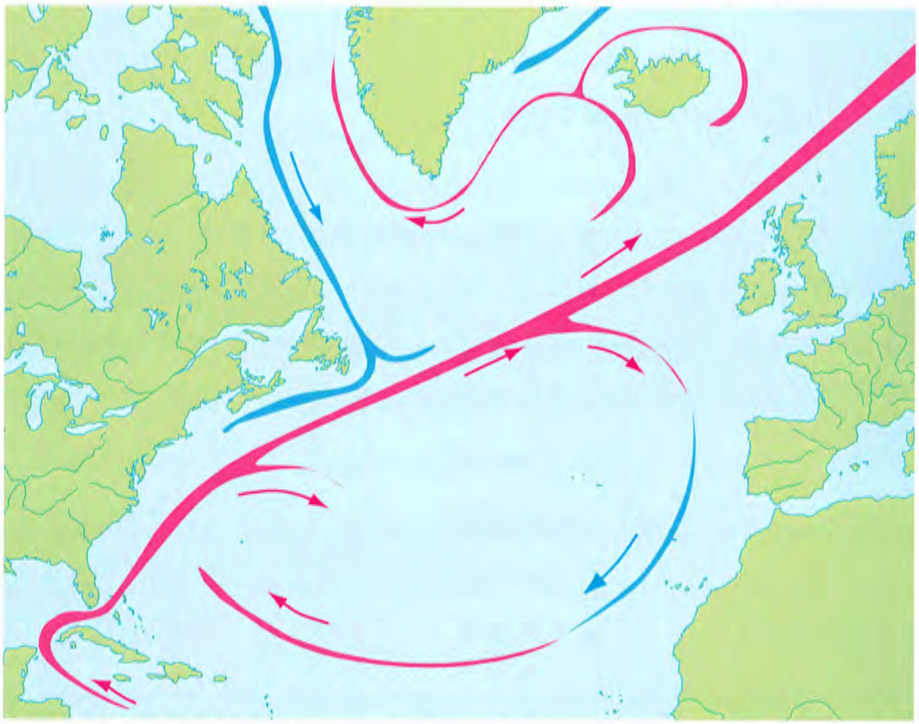
While climate change is not a high priority for most people early in the century, NGOs continue to lobby against inaction on the Kyoto protocol. The original commitment period ends in 2010, and OECD countries are clearly not meeting their targets.

In 2010, a series of violent storms causes extensive damage to the eastern coast of the US. Although it is not clear whether the storms are caused by climate change, people are not willing to take further chances. The insurance industry refuses to accept liability, setting off a fierce debate over who is liable: the insurance industry, or the government. After all, two successive IPCC reports since 1995 have reinforced the human connection to climate change.

Further evidence has also grown on the health impacts of particulates, partly due to the knowledge gained from completion of the Human Genome Project. More people are aware of the impact of particulates as they experience the rapidly worsening congestion on the roads. Although cybershops have helped ease congestion by eliminating the need to drive for mundane activities such as buying groceries, local air pollution resulting from growing numbers of cars continues unabated, particularly in Asian cities, where cases of respiratory ailments and eye and skin diseases increase. By the time the great storms hit the US east coast, public sentiment in many parts of the world has been growing in favour of doing something about the environment.

Shock Box*: A New Ice Age?

The temperature of the surface of the sea has a profound and complex effect on the weather. This temperature is itself strongly influenced by the ocean currents that mix cold and warm water together. The slow wrestling amongst the different ocean currents, a wrestling that determines the El Niño phenomenon, is linked to features as subtle as the 22-year sunspot cycle and as coarse as the temperature differences between the equator and the pole.



The North Atlantic Current

One area of particular concern is the northern loop of the North Atlantic Current. In the 19th century, the relative warmth of the Eastern Atlantic countries was noted: Norway, on the same latitude as Alaska, is around 10°C warmer. Indeed, people in Europe can live 15° further north than people in North America or Asia, because the North Atlantic Current bears warm water north from the tropics and around the European coastline. As it cools, this water sinks into the sea before sweeping

southwards as a deep, silent, salty torrent. This gigantic conveyor has shut down many times in the past, with far-reaching effects: Europe became colder, as did the rest of the world, for reasons which are not fully understood. The most recent occurrence came when humans were carving their first monuments: Scotland was glaciated, the North Sea was frozen, and Finland laboured under an estimated eight kilometres of ice.

For most of the past 250,000 years, average temperatures around the earth have been substantially cooler than they are now. There was a warm 'bubble' of 13,000 years, which occurred around 130,000 years ago and which was, perhaps co-incidentally, associated with the appearance of homo sapiens. The world then plunged into a period of cold, unstable climate, which continued until around 8,000 years ago, when a second period of exceptional stable warmth began. This period coincided with the development of settled agriculture, urbanisation, and complex societies. The oceans themselves warmed and expanded, rising around a hundred feet, and creating islands, such as Britain, while also flooding dry basins – to form the Black Sea, for example. Perhaps this period of rising oceans contributed to the many legends of gigantic floods and dry-land passage across seas.

The warming that brought civilisation came abruptly. Ice core records show a 13°C increase that occurred within 50 years: roughly the difference that exists today between Britain and Borneo. Before this increase, abrupt warmings were succeeded by cool periods which lasted centuries or millennia. As we are now discovering from ice cores, sea bed sediment, and pollen records, changes in temperature of at least this scale had occurred hundreds of times in the preceding quarter of a million years. Studies on glaciers in the Andes and in Antarctica show that these 'flickerings' of the Northern European climate were mirrored by events around the planet.

We now understand something of the mechanism by which these catastrophes occurred, but we can only guess whether our own warm contemporary bubble is likely to be pricked by it. Ocean currents – and, in particular, the North Atlantic Current – are the key agencies. One theory is that such a failure of the North Atlantic Current could be triggered by increased volumes of fresh water – whose density and freezing point differ from those of salty water. And global warming might bring additional fresh water through the melting of glaciers around Greenland, for example.

Thus, paradoxically, global warming could lead to a sudden and catastrophic return of an ice age.

**Unlike ordinary scenario 'boxes', which focus more deeply on a particular subject, or offer historical background, a 'shock box' describes relatively improbable events which, if they happened, would have a high impact.*

Following the storms, a coalition of environmental NGOs brings a class-action suit against the US government and fossil-fuel companies on the grounds of neglecting what scientists (including their own) have been saying for years: that something must be done. A social reaction to the use of fossil fuels grows, and individuals become 'vigilante environmentalists' in the same way, a generation earlier, they had become fiercely anti-tobacco. Direct-action campaigns against companies escalate. Young consumers, especially, demand action.

OECD governments, under intense pressure from citizens, decide they must also act. Accelerated development of renewable energy commences, along with plans to develop a new generation of nuclear power stations in Europe. Strong new CAFE type legislation is hastily drawn up in 2011. The power, auto, and oil industries see billions wiped off their market value overnight.

Consumers react in a variety of ways. In many areas, small, efficient luxury vehicles become fashionable, like the VW Beetle II, fifteen years before. In some European cities, only 'small and compact' cars are allowed to enter within city limits, while in some Asian cities, private cars and light trucks are totally banned from entering the city at certain times of the day. The new generation of vehicles, brought out badly by the auto industry in 2005, but now vastly improved, finds an interested market, particularly in developing countries. Global oil demand starts to level off.

Oil Volatility

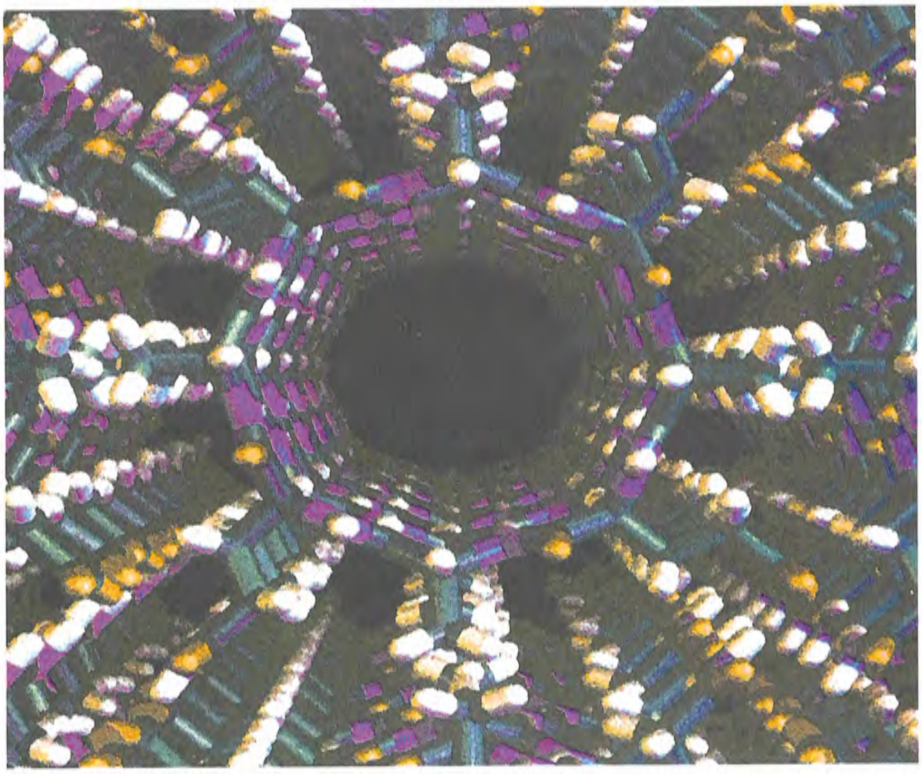
Oil price volatility is characteristic of ***People Power***. OPEC enjoys periods of cohesion followed by disagreement and unexpected interruptions to production – and all of these factors contribute to oil prices that fluctuate within a broad band of $10/bbl to $30/bbl.

Because OPEC members cannot take concerted action to limit production, oil prices remain weak through to 2000, hovering in the $12/bbl to $16/bbl range. Stagnant demand during the 2000-2002 Millennium Recession further weakens prices.

Shock Box*: Energy Storage

By 2015, the late 1990s discovery that massive amounts of hydrogen could be stored utilising nano-technologies fundamentally changes the structure of the energy supply and distribution system. Solid fuel cartridges, capable of powering a fuel-cell vehicle 1200 miles between replacements, or of providing heat and power to a household for one year, eliminate the need for fuel-filling stations and gas and power distribution systems. Retailers simply monitor fuel cartridge sensors and deliver replacements to homes and businesses when necessary.

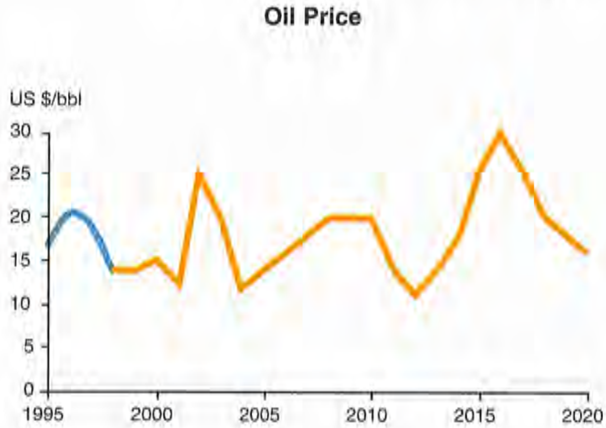
Hydrogen production costs also fall dramatically as the full range of renewable energy sources start to be utilised: solar, wind, wave, biomass, and run of river hydroelectric. These developments, combined with ubiquitous satellite communications, also break the bounds of centralised energy supply and distribution systems, allowing much wider dispersion of human settlements.



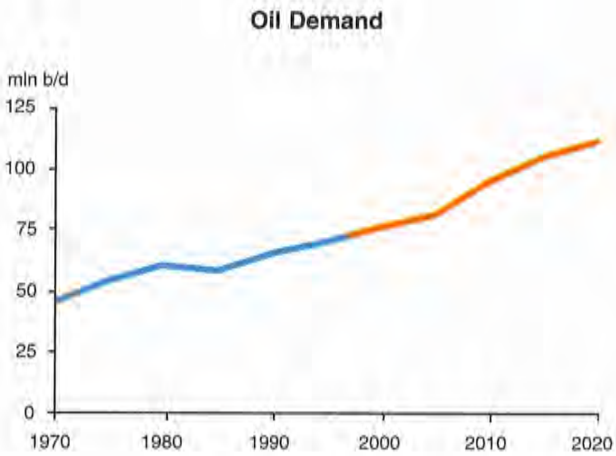
Nano-tube storage

**Unlike ordinary scenario 'boxes', which focus more deeply on a particular subject, or offer historical background, a 'shock box' describes relatively improbable events which, if they happened, would have a high impact.*

In Nigeria, reduced national income as a result of lower oil prices in 2002 has exacerbated unrest. Following riots and looting in Port Harcourt, the military again seizes power, despite warnings of sanctions from the US. The EU and US immediately place an embargo on the import of Nigerian crude. In Algeria, unrest and rioting cause the temporary closure of export terminals. The sudden loss of 3 mb/d production from world markets causes prices to shoot up to $26/bbl in 2002. In this volatile environment, National Oil Companies look for partners with proven track records in rapid project realisation and in enhancement of recovery through advanced skills and technology.



With economic recovery following the global recession, demand picks up strongly, and by 2008, growth rates are approaching 4% per year. Although demand growth is high, it is not sufficient to absorb rapidly increasing production from Central Asia and other parts of the world. Again, prices fall, but stabilise when OPEC members manage to come together to restrain production. Russia, although not a member of OPEC, also agrees to a quota limit.



Shortly after 2010, as concerns over the environment spread, growth in oil demand moderates to 1.5% per year. In spite of relative OPEC cohesion at this point, over-capacity weakens prices. However, after a decade in which oil prices have averaged some $18/bbl, non-OPEC production is at a maximum of 45 mb/d, with a gradual decline in resources now clearly seen. Similarly, non-Gulf OPEC countries are either nearing their peak production potential or, as in the case of Indonesia, are in decline. The Gulf States, with a 35% share of production and over 50% of remaining conventional oil resources, see an opportunity to achieve high prices through limiting production, as other producers would be unable to respond by raising production. They co-ordinate production, achieving prices of over $30/bbl for the next two or three years.

However, improved technology over the past decade has reduced the cost of exploiting unconventional oil resources to the $10/bbl to $15/bbl range, effectively increasing remaining oil resources from 1 trillion barrels to 2 trillion barrels. Bio-fuels are also widely available at under $13/boe. As these new sources of energy are commercialised, oil prices are gradually pushed to below a new ceiling of $15/bbl. By 2020, total demand for liquid hydrocarbons has plateaued at just over 110 mb/d.

2002 memo by pollster Frank Luntz,
Winning the Global Warming Debate

THE ENVIRONMENT: A CLEANER, SAFER, HEALTHIER AMERICA

The core of the Democrat argument depends on the belief that ***"Washington regulations"*** represent the best way to preserve the environment. We don't agree.

1) ***First, assure your audience that you are committed to "preserving and protecting" the environment, but that "it can be done more wisely and effectively."*** (Absolutely do not raise economic arguments first.) Tell them a personal story from your life. Since many Americans believe Republicans do not care about the environment, ***you will never convince people to accept your ideas until you confront this suspicion and put it to rest.***

2) ***Provide specific examples of federal bureaucrats failing to meet their responsibilities to protect the environment.*** Do not attack the ***principles*** behind existing legislation. Focus instead on the way it is enforced or carried out, and use rhetorical questions.

3) ***Your plan must be put in terms of the future, not the past or present.*** We are carrying forward a legacy, yes, but we are trying to make things ***even better*** for the future. ***The environment is an area in which people expect progress,*** and when they do not see progress being made, they get frustrated.

4) ***The three words Americans are looking for in an environmental policy, they are "safer," "cleaner," and "healthier."*** Two words that summarize what Americans are expecting from regulators and agencies are "***accountability***" and "***responsibility***."

5) ***Stay away from "risk assessment," "cost-benefit analysis," and the other traditional environmental terminology used by industry and corporations.*** Your constituents don't know what those terms mean, and they will then assume that you are pro-business.

6) ***If you must use the economic argument, stress that you are seeking "a fair balance" between the environment and the economy.*** Be prepared to specify and quantify the jobs lost because of needless, excessive or redundant regulations.

7) ***Describe the limited role for Washington.*** We must ***thoroughly review*** the environmental regulations already in place, decide which ones we still need, identify those which no longer make sense, and make sure we don't add any unnecessary rules. Washington should disclose the ***expected cost*** of current and all new environmental regulations. ***The public has a right to know.***

8) ***Emphasize common sense.*** In making regulatory decisions, we should use best estimates and ***realistic assumptions***, not the worst-case scenarios advanced by environmental extremists.

OVERVIEW

The environment is probably the single issue on which Republicans in general – and President Bush in particular – are most vulnerable. A caricature has taken hold in the public imagination: Republicans seemingly in the pockets of corporate fat cats who rub their hands together and chuckle manically as they plot to pollute America for fun and profit. And only the Democrats and their good-hearted friends from Washington can save America from these sinister companies drooling at the prospect of strip mining every picturesque mountain range, drilling for oil on every white sand beach, and clear cutting every green forest.

The fundamental problem for Republicans when it comes to the environment is that whatever you say is viewed through the prism of suspicion. As with education, Social Security and so many other issues, the Democrats have been expert at constructing a narrative in which Republicans and conservatives are the bad guys. And if Americans swallow that story, then whatever comes later is mere detail.

Indeed, it can be helpful to think of environmental (and other) issues in terms of "story." A compelling story, even if factually inaccurate, can be more emotionally compelling than a dry recitation of the truth. The popular movie *Erin Brockovich* presented a courageous woman fighting against an impersonal corporation that poisoned the public with cancerous chemicals with impunity. *The Wall Street Journal* and investigative journalist Michael Fumento later conclusively demonstrated that the real-life Erin Brockovich's legal case was full of holes and contradictions, but no matter the public had it's emotional story, and no number of exposes will ever come close to matching the power of that story.

As with those other issues, the first (and most important) step to neutralizing the problem and eventually bringing people around to your point of view on environmental issues is to convince them of your ***sincerity*** and ***concern***. You may come up with the most subtle, nuanced, brilliant, ironclad and indisputable argument as to why President Bush's approach to the "arsenic in the water" issue was responsible and correct, but it will fall on deaf ears unless the public is willing to give *you* the benefit of the doubt at the beginning.

I don't have to remind you how often Republicans are depicted as cold, uncaring, ruthless, even downright anti-social. These attacks appeal to resentment and fear. Because they are primarily emotional in nature, they cannot be blunted with logic or statistics. Therefore, ***any discussion of the environment has to be grounded in an effort to reassure a skeptical public that you care about the environment for its own sake*** – that your intentions are strictly honorable. Otherwise, all the rational arguments in the world won't be enough for you to prevail.

The good news, amidst all this doom and gloom, is that once you *are* able to establish your environmental *bona fides*, once you show people that your heart is in the right place and make them comfortable listening to what you have to say, then the conservative, free market approach to the environment actually has the potential to be quite popular.

ON THE MATTER OF ARSENIC IN THE WATER

I start here because this is where we almost snatched defeat from the jaws of victory. As you know, the incoming Bush administration's judicious, prudent approach to the numerous "midnight" regulations imposed by Bill Clinton on his way out the door ended up backfiring in a big way. The *"arsenic in the water"* imbroglio of spring 2001 was the biggest public relations misfire of President Bush's first year in office.

What was the chaos all about? The Bush Administration's suspension of Clinton's last-minute executive order toughening the federal standard for arsenic in drinking water from 50 parts per billion to 10 parts per billion.

The Democrats' message came through loud and clear: Bush and the Republicans put business interests above public health. The fact that the new administration was only delaying a change that hadn't been considered urgent enough for the Clinton administration to do anything about it for eight long years got lost in the hubbub.

Indeed, the story was not that Bush was delaying a hastily imposed regulation, but rather that he was actively ***putting in more*** arsenic in the water. Republicans pointing out that the Democrats were distorting the facts…and pointed this out…and pointed this out…and pointed this out again… but the facts didn't matter. The hit had been scored, the political damage done, and that was the first chink in President Bush's approval ratings.

Again, let me emphasize: The facts were beside the point. ***Facts only become relevant when the public is receptive and willing to listen to them.*** The decision to suspend the regulation wouldn't be troubling to someone educated on the issue, to someone who knew that there already was arsenic in the water and the only thing being debated was whether it was necessary to reduce it, and by how much. But Americans didn't know that. They heard *"arsenic in the water,"* and it was news to them. No wonder that they reacted in horror.

How do we avoid such debacles in the future?

It's all in how you frame your argument, and the order in which you present your facts. Don't allow yourself to become bogged down in minutiae when you should be presenting the big picture. You should have the details at hand to back you up, to be sure, but don't be afraid to begin by painting in broad strokes.

A more effective, step-by-step approach to ***educating*** the public about the arsenic issue would have been:

THE "ARSENIC" COMMUNICATION LADDER

1. Every American has the right to clean, healthy and safe drinking water.

2. Republicans are dedicated to the continued improvement of our nation's water supply, and to ensuring that Americans have the best quality water available. We all drink water. We all want it safe and clean.

3. Today, there are minute, tiny amounts of arsenic in our drinking water. It has always been this way. It will always be this way.

4. Based on sound science, the government's standard is that there should be no more than 50 parts of arsenic per billion.

5. In the last weeks before Bill Clinton left office, he issued an executive order reducing the standard from 50 to 10 parts of arsenic per billion – but he did not act for eight years because it was neither a priority nor a health risk.

6. Before this new standard takes effect, we would like to make sure that it is necessary to make this change. The decision was reached quickly, without public debate, and without evidence that this change will make our water appreciably safer.

Points one and two above may sound like boilerplate to you, but they are the ***most important element*** in arguing about this and similar issues. Talking about the environment is no different than explaining your position on taxes, Social Security, or the war on terrorism: Begin with your fundamental, guiding principles, explain where you are coming from and what your ultimate ends and intentions are, and only then delve into the particulars of your case.

Although President Bush ultimately adopted the Clinton administration standard of 10 parts per billion in November 2001, the arsenic issue should be a lesson to all Republicans. Remember, ***the burden of proof is on you to prove your good intentions and your sincerity.*** Reassure the public on those counts, and ***only then*** will they see the Democrats' demagoguery for what it is.

> *Note: The day President Bush made his subsequent announcement accepting the new regulation, the Democrats immediately began harping on the Clinton standard, claiming that 10 parts per billion was too high, and that the new arsenic standard should actually be changed to three parts per billion.*

No one wants polluted air and water, yet that's what a majority of Americans think Republicans stand for. ***When we talk about "rolling back regulations" involving the environment, we are sending a signal Americans don't support.*** If we suggest that the choice is between environmental protection and deregulation, the environment will win consistently.

GETTING BACK TO NATURE

> **"I'm usually the one running around the house shutting off lights, making sure the water is turned off. Still, when I think environmentalist – I'm sorry if someone is offended by this – I think of somebody chaining themselves to a tree."**
>
> **– Pittsburgh woman**

The most popular federal programs today are those that preserve and protect our natural heritage through ***conservation of public lands and waters through parks and open spaces.***

Americans love the outdoors. Becoming a champion of national parks and forests – and protecting American culture and history with sound policies for carrying these legacies to the next generations of Americans – is the best way to show our citizens that Republicans can be ***FOR*** something positive on the environment. Being ***AGAINST*** existing laws or regulations has been translated into being ***AGAINST*** the environment.

Preserving parks and open spaces is a winner because it doesn't need to be explained to everyday Americans. We need more issues like this. No matter how many experts know that Superfund law or the Clean Water Act or Clean Air rules don't work as they should, the public doesn't perceive them as broken. There is not a public outcry to fix them.

That is not to say that it is unreasonable to try to "update" Superfund or to "modernize" the Clean Water Act. But you can't do that kind of heavy lifting until you win the public's trust on the basics: protecting and maintaining what we have. [Avoid terms and concepts like "providing stewardship" (passive and unclear) in favor of "preserving and protecting" (active and clear).] ***And the number one hot button to most voters is water quality*** – including both infrastructure and pollution protection.

People ***don't*** understand the technicalities of environmental law – but they ***do*** understand the benefits of conservation of water, land, and open spaces. Republicans need to focus more on the ***benefits*** the public expects and spend less time debating ***process***, which the public really doesn't care to follow.

Public support for a trust fund for conservation of land, water and open spaces is both widespread and deep. We should not pass up the opportunity to talk about an ***"open space conservation trust fund"*** as a better response to chatter about ***"urban sprawl."*** Remember, few want the growth and development of their community determined by Washington.

But don't reject a federal role altogether. The environment knows no state or local boundaries, and the public demands at least some federal guidelines. However, people don't want an intrusive federal bureaucracy dictating local enforcement. They want the federal government to take care of the "big picture" and leave the details to the states and localities.

UPDATING WASHINGTON'S RULES ON THE ENVIRONMENT

> ***"Do you want some pencil-pushing Washington bureaucrat to tell you what to do and how to do it, someone who gets all his knowledge of the Everglades, the Rocky Mountains, and every environmental issue from the pages of* National Geographic?"**

While we may have lost the environmental communications battle in the past, the war is not over. When we explain our environmental proposals ***correctly***, more than 70 percent of the nation prefers our positions to those of our opponents. Let me emphasize, however, that when our environmental policies are explained ineffectively, not only do we risk losing the swing vote, but our suburban female base could abandon us as well.

The Democratic message could best be characterized as the ***"Protection Racket"*** of politics – protection of the environment, protection of education, protection of workers, protection of health care, protection of Social Security, protection of Medicare and Medicaid. "Protecting" those programs has become the Democratic mantra, and their ability to remain ***on message*** in all of their communications has reaped great rewards. And who could disagree? Having those things given to you and protected is an offer that's difficult to refuse.

As Republicans, we have the moral and rhetorical high ground when we talk about values, like ***freedom, responsibility, and accountability.*** The same values apply to the environment as to other examples of government-knows-best solutions. ***But when we talk about "rolling back regulations" involving the environment, we are sending a signal Americans don't support.*** If we suggest that the choice is between environmental protection and deregulation, the environment will win consistently.

You cannot allow yourself to be labeled "anti-environment" simply because you are opposed to the current regulatory configuration (your opponents will almost certainly try to label you that way). The public does not approve of the current regulatory process, and Americans certainly don't want an increased regulatory burden, but they will put a higher priority on environmental protection and public health than on cutting regulations. Even Republicans prioritize protecting the environment.

That is why you must explain how it is possible to pursue a ***common sense*** or ***sensible*** environmental policy that ***"preserves all the gains of the past two decades"*** without going to extremes, and allows for new science and technologies to carry us even further. Give citizens the idea that ***progress is being frustrated by over-reaching government***, and you will hit a very strong strain in the American psyche.

If there must be regulation, Americans are most comfortable with local oversight. Participants respond favorably to proposals that included communities and more common sense approaches. This is important. We can uphold the environmental priorities of the American people, while at the same time moving control to the state and local level and removing needless bureaucratic meddling. People believe they know better than do nameless, faceless federal bureaucrats how to preserve and protect ***their*** local environment.

WINNING THE GLOBAL WARMING DEBATE – AN OVERVIEW

Please keep in mind the following communication recommendations as you address global warming in general, particularly as Democrats and opinion leaders attack President Bush over Kyoto.

1.	***The scientific debate remains open.*** Voters believe that there is ***no consensus*** about global warming within the scientific community. Should the public come to believe that the scientific issues are settled, their views about global warming will change accordingly. Therefore, ***you need to continue to make the lack of scientific certainty a primary issue in the debate***, and defer to scientists and other experts in the field.

2.	***Americans want a free and open discussion.*** Even though Democrats savaged President Bush for formally withdrawing from the Kyoto accord, the truth is that none of them would have actually voted to ratify the treaty, and they were all glad to see it die. Emphasize the importance of ***"acting only with all the facts in hand"*** and ***"making the right decision, not the quick decision."***

3.	***Technology and innovation are the key in arguments on both sides.*** Global warming alarmists use American superiority in technology and innovation quite effectively in responding to accusations that international agreements such as the Kyoto accord could cost the United States billions. Rather than condemning corporate America the way most environmentalists have done in the past, they attack their us for lacking faith in our collective ability to meet any economic challenges presented by environmental changes we make. This should be our argument. ***We*** need to emphasize how ***voluntary*** innovation and experimentation are preferable to bureaucratic or international intervention and regulation.

4.	***The "international fairness" issue is the emotional home run.*** Given the chance, Americans will demand that all nations be part of any international global warming treaty. Nations such as China, Mexico and India would have to sign such an agreement for the majority of Americans to support it.

5.	***The economic argument should be secondary.*** Many of you will want to focus on the higher prices and lost jobs that would result from complying with Kyoto, but you can do better. Yes, when put in specific terms (food and fuel prices, for example) on an individual-by-individual basis, this argument does resonate. Yes, the fact that Kyoto would hurt the economic well being of seniors and the poor is of particular concern. However, the economic argument is less effective than each of the arguments listed above.

The most important principle in any discussion of global warming is your commitment to sound science. Americans unanimously believe all environmental rules and regulations should be based on sound science and common sense. Similarly, our confidence in the ability of science and technology to solve our nation's ills is second to none. Both perceptions will work in your favor if properly cultivated.

The scientific debate is closing [against us] but not yet closed. There is still a window of opportunity to challenge the science. Americans believe that all the strange weather that was associated with El Nino had something to do with global warming, and there is little you can do to convince them otherwise. However, only a handful of people believes the science of global warming is a closed question. Most Americans want more information so that they can make an informed decision. It is our job to provide that information.

> **LANGUAGE THAT WORKS**
>
> ***"We must not rush to judgment before all the facts are in. We need to ask more questions. We deserve more answers. And until we learn more, we should not commit America to any international document that handcuffs us either now or into the future."***

You need to be even more active in recruiting experts who are sympathetic to your view, and much more active in making them part of your message. People are willing to trust scientists, engineers, and other leading research professionals, and less willing to trust politicians. If you wish to challenge the prevailing wisdom about global warming, it is more effective to have professionals making the case than politicians. When you do enter the fray, keep your message short, concise, and refer to the source of the material you use. Back up your points with a limited number of facts and figures – but then explain why they matter.

One final science note: Americans have little trust in arguments relying on short-term data, such as mentioning that year *X* was the hottest on record or year *Y* was the coldest on record, etc. Even 15 years of satellite records, or modeling that shows rising sea levels is not enough.

> **WORDS THAT WORK**
>
> ***"Scientists can extrapolate all kinds of things from today's data, but that doesn't tell us anything about tomorrow's world. You can't look back a million years and say that proves that we're heating the globe now hotter than it's ever been. After all, just 20 years ago scientists were worried about a new Ice Age."***

The Kyoto camp is divided into two categories: ***America Besters*** and ***Calamity Janes***. The American Besters, led by Sen. John Kerry, will argue that we have the most innovative, technically advanced business community that can easily adapt to stricter anti-global warming regulations. The Calamity Janes, on the other hand, use scare tactics to convince audiences that global warming will lead to doom and gloom. Both have one common argument: The future will be a better place if we take the necessary actions today.

Let me warn you that both arguments do resonate with some people when they make the case that short-term pain will yield long term gain. Americans are still forward thinking and are likely to respond favorably to sacrifice if they can see a light at the end of the tunnel.

That's what you must offer. The fact that people take a long-term view gives you an opportunity to construct a "zero-regrets" argument. For example, you should argue that America should invest more in research and development to find ways to burn fuel more efficiently.

The traditional economic approach taken by Republicans to oppose many environmental rules and regulations simply does not move Democrats and has only limited appeal among independents. If you must raise economic concerns, the best way to reach swing voters is to take a practical, down-to-earth approach. Talk about the real world day-to-day effects that proposed environmental remedies would have on their everyday lives.

1. ***<u>Put the costs of regulation in human terms.</u>*** Stringent environmental regulations hit the most vulnerable among us – the elderly, the poor and those on fixed incomes – the hardest. Say it. Taxes on fuel and other products will be highly regressive, and new regulations will contribute to higher prices for necessities like food and utilities.

> **LANGUAGE THAT WORKS**
>
> ***"Unnecessary environmental regulations hurt moms and dads, grandmas and grandpas. They hurt senior citizens on fixed incomes. They take an enormous swipe at miners, loggers, truckers, farmers – anyone who has any work in energy intensive professions. They mean less income for families struggling to survive and educate their children."***

This is most effective when you actually describe how specific activities and items will cost more, from "pumping gas to turning on the light." Remember, Americans already think they are an overtaxed people. Treaties such as Kyoto would have been yet another tax on an already overburdened population.

2. ***Job losses.*** Every year, excessive environmental regulations cost the United States thousands of jobs. Independents and swing voters can really relate to concrete effects such as this. The prospect of losing so many jobs may upset Americans more than any hypothetical effects of global warming, but you have to be careful to use specifics – generalities will be rejected. Talk about the professions and industries that will be most hurt.

3. ***Major lifestyle changes.*** Talking generically about higher taxes and greater costs will not persuade those who are truly undecided of the dangers of the Kyoto protocol and similar regulation regimes. But they will listen if you point out that the unintended consequences of such well-intended regulations may make American life ***less*** safe, not more safe.

Let me emphasize that while the economic arguments may receive the most applause at the Chamber of Commerce meeting, it is the least effective approach among the people you most want to reach – average Americans. The assertion that there are better ways to address environmental threats such as global warming is a superior argument.

Nothing scores better than a "We're Number One" theme, and in the arena of scientific breakthroughs, we really are Number One. Therefore, if supporters of drastic environmental regulations tell you that "we can do anything we set our sights on," and that ***"American corporations and industry can meet any challenge,"*** immediately agree, but then add the following:

WORDS THAT WORK

"Don't confuse my opposition to excessive regulation with a desire for inaction. We don't need an international treaty with rules and regulations that will handcuff the American economy or our ability to make our environment cleaner, safer and healthier.

"On the contrary, what we need to do is to put American creativity and American innovation to work. It's time to call on the leaders of science and technology to find new forms of fuel that burn cleaner and more efficiently. We need to invest in research and development that will restore polluted air and water to pristine conditions – just as we have done for Lake Erie. We should take an active role in helping other nations save their forests and build safer energy sources."

That puts you back on offense, but don't stop there. Proponents will criticize America for causing a majority of the world's pollution and being the biggest contributor to the greenhouse effect. Excuse the pun, but this is garbage. We do so much more and pollute so much less than anyone else. ***You must set the record straight.***

WORDS THAT WORK

"As a nation, we should be proud. We produce a majority of the world's food, a large majority of the world's technology, and virtually all of the world's health and scientific breakthroughs, yet we produce a fraction of the world's pollution. America has the best scientists, the best engineers, the best researchers, and the best technicians in the world. That is why we must assume a leadership role in conservation and preservation, but we cannot do it alone. Every nation must do its part."

We should dominate the technology and innovation argument, but you will still fall short unless you emphasize the voluntary actions and environmental progress already underway. Remember, Democrats have nothing to offer but more bureaucrats and bureaucratic solutions to the challenges we face. They are simply attempting to involve bureaucrats in areas in which the private sector is already making tremendous progress.

MORE WORDS THAT WORK

"In the last 20 years, America has made significant progress in environmental research without any foreign treaty. These breakthroughs have already been put to work to help the global environment, and we didn't need any foreign body to tell us how it do it."

CONCLUSION: REDEFINING LABELS

The mainstream, centrist American now sees the excesses of so-called "environmentalists," and prefers the label "conservationist" instead. These individuals are still clearly "pro-environment," but not at the expense of everything else in life. They are the kind of voters who consider the environment as one of a variety of factors in their decision for whom to vote, but not the overriding factor. If we win these people over, we win the debate. It's that simple. The rest is commentary.

Most people now recognize that some self-described environmentalists are – in their words – "extremists." Thanks to some pretty bizarre behavior, there are some negative connotations that attach themselves to those who promote environmentalism. In particular, Greenpeace and Ralph Nader have an extremist image that turns off many voters.

We have spent the last seven years examining how best to communicate complicated ideas and controversial subjects. The terminology in the upcoming environmental debate needs refinement, starting with "global warming" and ending with "environmentalism." ***It's time for us to start talking about "climate change" instead of global warming and "conservation" instead of preservation.***

1. ***<u>"Climate change" is less frightening than "global warming."</u>*** As one focus group participant noted, climate change "sounds like you're going from Pittsburgh to Fort Lauderdale." While global warming has catastrophic connotations attached to it, climate change suggests a more controllable and less emotional challenge.

2. ***<u>We should be "conservationists," not "preservationists" or "environmentalists."</u>*** The term "conservationist" has far more positive connotations than either of the other two terms. It conveys a moderate, reasoned, common sense position between replenishing the earth's natural resources and the human need to make use of those resources.

   "Environmentalist" can have the connotation of extremism to many Americans, particularly those outside the Northeast. "Preservationist" suggests someone who believes nature should remain untouched – preserving exactly what we have. By comparison, Americans see a "conservationist" as someone who believes we should use our natural resources efficiently and replenish what we can when we can.

Republicans ***can*** redefine the environmental debate and make inroads on what conventional wisdom calls a traditionally Democratic constituency, because we offer better policy choices to the Washington-run bureaucracy. But we have to get the talk right to capture that segment of the public that is willing to give President Bush the benefit of the doubt on the environment – and they are out there waiting.

The words on these pages are tested – they work! But the ideas behind them – translated into actions – will speak louder than words. Once Republicans show the public that we are ***for*** something positive, not just against existing environmental regulations, we can start to close that credibility gap.

THE NINE PRINCIPLES OF ENVIRONMENTAL POLICY AND GLOBAL WARMING

1. Sound science must be our guide in choosing which problems to tackle and how to approach them.

2. We should identify the real risks to human health and safety ***before*** we decide how to address a problem.

3. Punishing real polluters must be a higher priority than creating more rules and regulations.

4. Local problems require local solutions. National standards may be necessary, but enforcement should be local. People in the community have the greatest incentive to keep their local environment clean.

5. Technology, innovation and discovery should play a major role in preserving a clean and healthy environment.

6. Environmental policies should take into account the economic impact on senior citizens, the poor and those with fixed incomes.

7. The best solutions to environmental challenges are common sense solutions.

8. All nations must share responsibility for the environment. No nation should be excluded from doing its part to improve climate conditions and the health and safety of its population.

9. All changes in national environmental policy should be fully discussed in an open forum. Laws, agreements and treaties should not be signed without public input.

PROTECTING OUR ENVIRONMENT
(Democrats in their own words)

One of the most important responsibilities of government and elected officials is the protection of our air, our water, and our land. Making rules against polluting our natural environment and investments in restoring it are part of a Democratic tradition that extends back almost 100 years. From the founding of our national parks early in this century, to the landmark laws of the past three decades, one of America's greatest achievements has been conserving and cleaning our natural environment. This is one area where citizen initiative and government regulation of corporate behavior has been a demonstrable success.

Americans are proud of the achievements that have been made – and understand the urgency of the work that still needs to be done. Yet Republicans have opposed efforts to reform the massive government subsidies for new logging roads that will benefit private logging companies in national forests. They have blocked efforts to charge market prices for range-land grazing on federal land. And they even refused to re-authorize the "crown jewel" of American environmental laws – the Endangered Species Act.

When the law that restored the bald eagle to vibrant populations can't be preserved, we must call the Republicans what they are – anti-environment. Similarly, Republican support for corporate subsidies for polluters represents hypocrisy at its worst. It's bad enough that conservatives condone the exploitation of the environment. It's even worse when they want the taxpayers to pick up the tab.

Simply stated, we want to protect our natural resources for our children and future generations. The Republicans want to protect the deep pockets of those who seek to exploit our national parks and forests and waterways.

Democratic environmental legislation of past years made tremendous gains toward restoring our pristine natural resources. We no longer have rivers catching fire from pollution. Once dead rivers, lakes and estuaries are now pulsating with life. People are returning to these areas to swim, fish and enjoy the great outdoors as wildlife thrives. Republicans want to remove the stiff fines and penalties levied on polluters. We won't let them.

Today our skies are cleaner. In virtually every city in this country, the air is cleaner than it was 25 years ago. Smog is down. Carbon monoxide in the air is down. Parents can now breathe easier knowing their children are breathing cleaner air.

Yet today, there are those who want to turn back the clock on people who want to fish in the rivers and drink safe, clean water from the tap….on parents who want to be sure the park down the block is safe for their children to play in….on people who want to breathe clean, healthy air. We won't let them. Democrats will continue to fight Republicans and their corporate allies that would risk our children's long-term health, the air they breathe and the water they drink for the sake of short-term profits.

A CLEANER, SAFER, HEALTHIER FUTURE

(A Republican speech about the air we breath)

It is possible to achieve better protection of human health and the environment by regulating smarter, but you can't regulate smarter unless we all demand it from the regulators in Washington. The fact is, businesses -- big and small -- spend too much time trying to comply with too much paperwork and too many regulations from too many Washington bureaucrats.

If we are to move forward to a safer, cleaner, healthier future, we have to change the way Washington regulates. States and communities should be allowed -- even encouraged -- to take a greater role in environmental regulations and oversight. After all, who knows better about what each community needs, a local leader or a Washington bureaucrat? There are national environmental standards that must be set, and the federal government must make that determination, but federal resources must be targeted and allocated more effectively, and that's why we must have greater involvement by state and local officials.

But the improvements we need in Washington go beyond state and local involvement. ***We need to plan for the future, not just for today.*** Science and technology are constantly changing and improving. Too often, the federal government doesn't keep up with these improvements, and old regulations become out-dated and don't do the best job they can. That is why I want to see four immediate changes to the way we regulate the environment:

1. We must do a thorough review of the environmental regulations already in place, decide what works and what doesn't, and then make sure we don't add any more unnecessary or unproductive rules. There should be a mandatory requirement that obligates the federal government to determine whether current regulations should be reformed, consolidated or discontinued.

2. Washington should also be required to disclose the expected cost of current and all new environmental regulations. The public has a right to know what these laws and regulations cost.

3. In making regulatory decisions involving the environment, the federal government should use best estimates and realistic assumptions rather than worst-case scenarios advanced by environmental extremists.

4. New regulations should be based on the most advanced and credible scientific knowledge available.

Finally, to promote the ***accountability*** and ***responsibility*** of federal regulatory agency decisions, the entire process should be open to public scrutiny. It's time to restore common sense to environmental laws. This is how we move forward to a safer, cleaner, healthier future.

THE VALUE OF GREEN AND OPEN SPACES

(A Republican speech about protecting the earth)

William Shakespeare wrote, "One touch of nature makes the whole world kin." I'm joining you today to share a little bit of my personal family history and why I think we all as Americans share a common interest in protecting our common legacy – the environment.

We would do well to take stock of what it is that has made this country great – and what has made us truly unique as Americans – so that we carry the finest traditions of America into the new century. Our rugged individualism, sense of adventure, and pioneer spirit are all embodied in our collective love of the outdoors. I want to join you today in a pledge to preserve and protect the special places God gave us.

Our public lands and waters, and all the private habitats and nature preserves, remind me of times spent with my family – as a child, discovering a love of the outdoors my parents and grandparents instilled in me; as a young adult, taking walks in the park with a special someone; and now as a parent, teaching my own kids to identify species of animals and plants, having a picnic, or just throwing or kicking a ball around in an open field. I want those places to still exist when my children grow older and teach their own kids the values of our family for another generation.

But if we fail to act now, many of those special places won't be preserved, and what is lost or destroyed cannot be replaced. We must take ***responsibility*** and show ***accountability*** for protecting these sacred places for generations to come.

More than half of us plan our annual vacations around some aspect of the outdoors. But in the new century, as we focus more than ever on the future and confront rapid change – we need to keep touch with those places that remind us of those defining ideas and principles that have made America the great pioneer nation.

Whether we want a place to get away for some solitude … or to vacation with our loved ones … or whether we just enjoy the peace of mind that comes with knowing that those places will still exist for future generations … we Americans see a value in conserving places vastly different than our own backyards. North Dakota does not look like North Carolina, nor does New Mexico look like New Jersey. America's diversity accounts for a great measure of her beauty.

Whether or not you believe as I do that ***conserving the environment is its own reward***, there is no doubt that green and open spaces will benefit all of us in the long run.

Man's discoveries from nature may provide the cure for diseases like cancer. Today, programs that take place in our national, state, and local parks and forests provide a place for children to learn new skills and values like teamwork and respect for nature, which helps prevent juvenile crime and delinquency. Having buffers of open spaces contributes to property values and the economic stability of neighborhoods.

Washington is rarely known for its display of common sense. But just this once, why not do what makes the most sense to most Americans and support policies for parks and open spaces that conserve nature and the environment as a legacy for the next generation of Americans? If we work together, there is no reason we can't make these areas cleaner, safer, and healthier for us all.

2006 ExxonMobil report, *Tomorrow's Energy*

Tomorrow's Energy

A Perspective on Energy Trends, Greenhouse Gas Emissions and Future Energy Options

February 2006

ExxonMobil

Taking on the world's toughest energy challenges.™

CONTENTS

Projections, targets, expectations, estimates and business plans in this report are forward-looking statements. Actual future results, including energy demand growth and mix; economic development patterns; efficiency gains; resource recoveries; capital expenditures; technological developments; emission reductions; and project plans and schedules could differ materially due to a number of factors. These include changes in market conditions affecting the energy industry; changes in law or government regulation; unexpected technological developments; and other factors discussed in this report and under the heading "Factors Affecting Future Results" on our Web site at www.exxonmobil.com. References to resources in this report include quantities of oil and gas that are not yet classified as proved reserves but that, in the case of ExxonMobil figures, we believe will ultimately be produced. Additional information on terms used in this report, including our calculation of Return on Capital Employed, is available through our Web site under the heading "Frequently Used Terms."

Introduction: Energy for a Growing World

Energy is essential to our way of life, to economic progress and to raising and maintaining living standards. The pursuit of economic growth and a better quality of life in developing countries is driving global energy demand. New supplies of reliable, affordable energy are needed.

At the same time, concerns about future energy supply and climate change have heightened interest in energy supply options, energy prices and the effect of energy use on the environment.

We believe it is essential that industry plays an active role in the ongoing dialogue about the future of energy – one which is grounded in reality, focused on the long term and intent on finding viable solutions.

In this document, we explain our views on future energy trends, the risks of climate change, the prospects for promising new energy technologies and ExxonMobil's activities in these areas.

In particular, we highlight the important relationship between rising energy demand, economic progress and greenhouse gas emissions. As policymakers seek to ensure future energy supplies while addressing the risks associated with global climate change, it is critical that the economic and social consequences – in the developed and the developing world – are taken into account.

Equally critical is a recognition that huge investments will be needed to meet the world's growing energy needs. Energy is a massive business. Even as the largest non-government energy company, ExxonMobil produces just two percent of the energy the world consumes every day. Projects take years to develop, cost billions of dollars to bring on stream and operate for decades.

To be justified in making these large investments, companies need stable, consistent government policies to help projects remain robust over the long term.

In a world featuring both geopolitical and regulatory uncertainty, we believe ExxonMobil will be served well by continuing to focus on operational and technical excellence, prudent risk management and responsible business behavior. ExxonMobil stands ready to meet the many challenges of delivering energy for a growing world.

Section 1: The Next Quarter-Century of Energy

Energy is a long-term, capital-intensive business. As a major participant in the global energy industry, we must anticipate and adapt to trends and changes in our industry so that we can make sound business decisions and invest our shareholders' money wisely in projects that remain attractive over the long term.

Every year, we prepare a long-range outlook of global energy trends. The 2005 outlook covers the period to the year 2030 and provides a strategic framework to aid evaluation of potential business opportunities.

Economic growth and expanding populations drive global energy needs

Energy is critical to economic progress. The global economy is expected to double in size by 2030 – mainly driven by the developing nations that today account for just over 20% of the world's economic output. By 2030, this share will grow to 30%, led by rapidly expanding economies such as China, India, Indonesia and Malaysia.

World population is also expanding. Today, there are nearly 6.5 billion people, about 20% of whom live in developed countries (member nations of the Organization for Economic Cooperation and Development – OECD) and the remainder in developing (non-OECD) countries. By 2030, population is expected to reach 8 billion people, with close to 95% of this growth occurring in the developing world.[1]

Yet there are still about 1.6 billion people today without access to electricity and about 2.4 billion who rely on basic fuels such as wood and dung for heating and cooking.[2]

Economic growth in the developed and developing world over the next quarter-century will have a dramatic impact on global energy demand and trade patterns.

A vast and growing need for energy

Every day, the world consumes about 230 million barrels of energy (expressed in terms of "oil equivalent" or MBDOE), with demand split about equally between developed and developing nations.

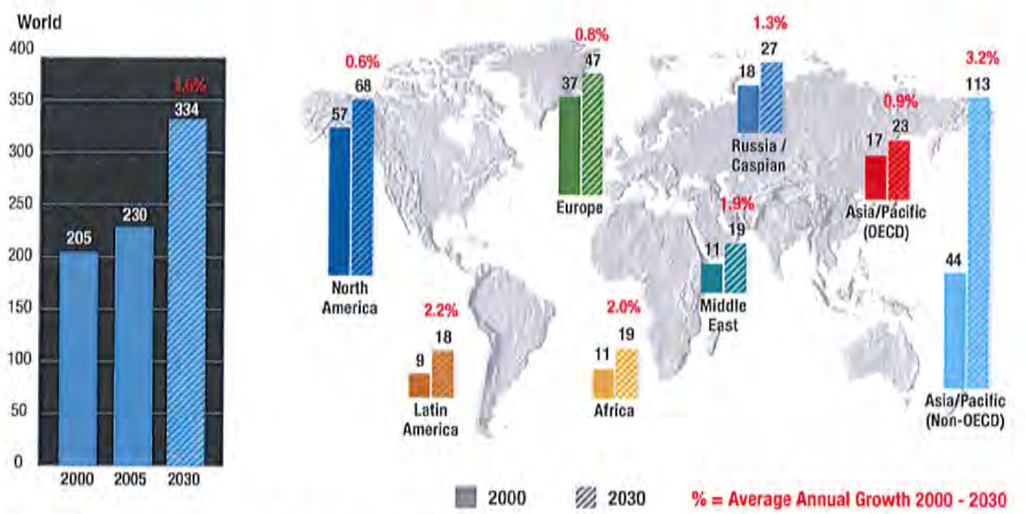
By 2030, we expect the world's energy needs to be almost 50% greater than in 2005, with growth most pronounced in the rapidly expanding developing countries (See Fig. 1). Perhaps most significant, we anticipate energy demand in developing Asia/Pacific to grow at 3.2% annually, increasing to one-third of the world's total – an amount equivalent to the energy demand of North America and Europe combined.

Continuing progress in energy efficiency

Continued rapid improvement in energy efficiency, mainly driven by the development and use of new technology in the transportation and power generation sectors, is expected to temper the growth in global energy demand.

Fig. 1

Growing World Energy Demand
Millions of Barrels per Day of Oil Equivalent (MBDOE)



Note: For the purposes of this report, the phrases "developing countries" and "non-OECD countries" are interchangeable. OECD countries are: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Republic of Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, the UK and the United States.

Energy intensity improves globally

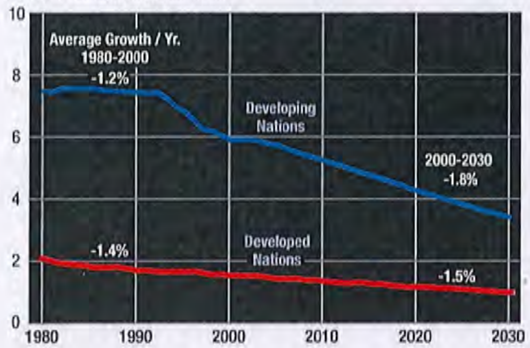
We expect the rate of "energy intensity" (the energy used per $1,000 of GDP) to improve 1.8% annually in developing countries and 1.5% annually in developed countries from 2000 through 2030, compared with 1.2% and 1.4% per year respectively between 1980 and 2000.

The developing nations are particularly important, given that the energy intensity of their economies is about 3-4 times greater than that of the developed countries. There was a steep drop in the energy intensity of the developing countries during the 1990s, reflecting the collapse of the former Soviet Union (FSU), but today a dramatic level of disparity remains (See Fig.2). There are significant opportunities for efficiency gains as these nations develop.

Fig. 2

Energy Intensity - Declining trend accelerates most notably in developing (non-OECD) countries

Barrels of oil equivalent per $K GDP



Fossil fuels remain the predominant energy sources

Over time, an increasingly diverse range of energy sources and technologies will be needed. But at least through 2030, fossil fuels will continue to satisfy the vast majority of global demand (See Fig. 3 on page 4). These are the only fuels with the scale and flexibility to meet the bulk of the world's vast energy needs over this period.

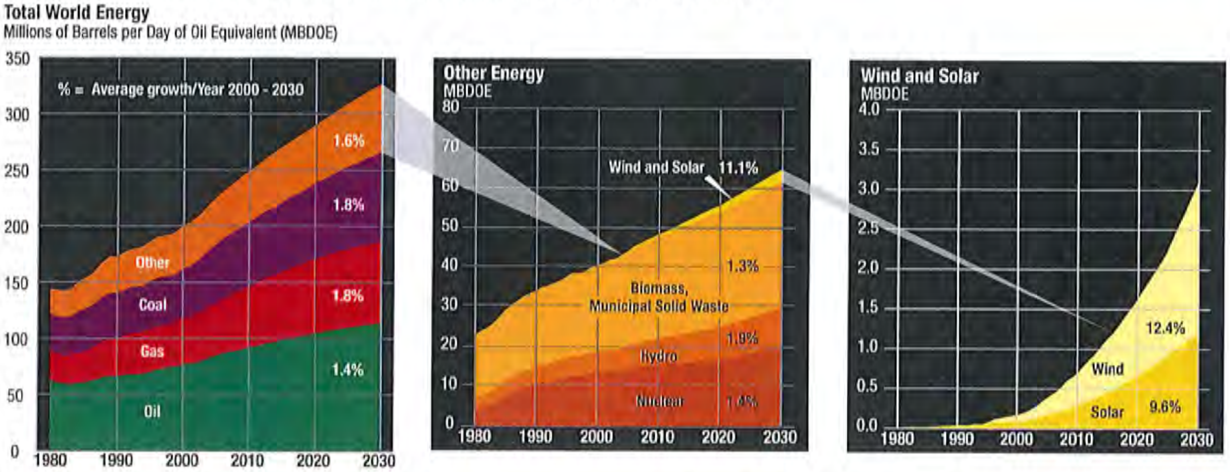
- Oil and gas combined will represent close to 60% of overall energy in 2030, a similar share to today.
- Oil use is expected to grow at 1.4% annually. Significant improvements in vehicle fuel economy will dampen demand growth.
- Gas is expected to grow at 1.8% annually, driven largely by strong growth in global electricity demand.
- Coal, like gas, is expected to grow at 1.8% annually, driven by expanding power generation. Despite higher CO_2 intensity, large indigenous supplies will give coal economic advantages in many nations, particularly in Asia.

ExxonMobil's 2005 Energy Outlook: Highlights

- By 2030, global energy demand will increase almost 50% from the 2005 level, driven by economic progress and population growth.
- About 80% of growing energy demand will occur in developing countries.
- Improvements in energy efficiency and intensity will accelerate, due to advancing technologies.
- Oil, gas and coal remain the predominant energy sources, maintaining about an 80% share of total energy demand through 2030.
- Global resources are sufficient to meet demand. Access to resources and timely investments are vital to developing adequate energy supplies.
- Natural gas will grow rapidly in importance, mainly due to its environmental benefits and efficiency in electricity generation.
- Biofuels, wind and solar will grow rapidly as sources of energy, contributing about 2% of total energy supply by 2030.
- Increased use of fossil fuels will increase global carbon dioxide (CO_2) emissions, with close to 85% of the increase in developing countries (See section 2).
- Advances in technology are critical to successfully meeting future energy supply-and-demand challenges.

Fig. 3

Energy Demand Grows: Fossil fuels remain predominant; renewables grow rapidly from small base



Non-fossil energy supplies will expand

- Nuclear will grow on average at 1.4% per year, with the largest growth in Asia, although we expect North America and Europe to add new plants late in the outlook period.
- Hydro power is expected to grow at just under 2% per year, with increases likely in China, India and other developing countries.
- The use of biomass, including traditional fuels (wood, dung) used in developing countries, and solid waste will grow about 1.3% per year.
- Wind and solar energy combined will likely average about 11% growth per year, supported by subsidies and related mandates. Even with this rapid projected growth, wind and solar will contribute only 1% of total energy by 2030, illustrating the vast scale of the global energy sector.
- Biofuels, including ethanol and biodiesel, will grow from less than one million barrels per day (MBD) in 2005 to about 3 MBD in 2030.

The prospects for wind, solar, biofuels, nuclear and other longer-term energy technologies are discussed further in Section 3.

Oil: Increased transportation demand and improved engine technology

Growth in oil demand will be driven by increasing transportation needs, especially in developing countries. Widely available, most affordable and supported by a global infrastructure, oil is uniquely suited as a transport fuel. There is no large-scale alternative to oil as a transport fuel in the near term.

Critical to transportation demand will be the size and nature of the personal vehicle fleet. By 2030, we expect the size of the U.S. and European fleets to plateau, while the number of vehicles in Asia will nearly quadruple (See Fig. 4). Working to offset demand growth from the larger vehicle fleet will be continuing improvements in fuel and engine system technology and efficiency.

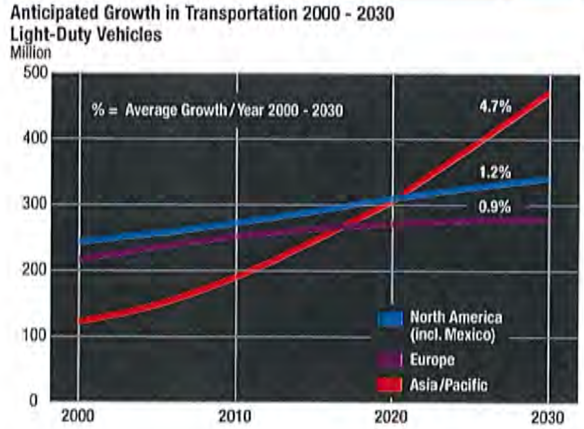
Over the next 25 years, we expect the average fuel economy of new vehicles worldwide to improve by over 25% as a result of both the evolution of technology as well as shifts in the kinds of vehicles that people drive. While the rate of increase (about 1% annually) may seem small, it is more than double the rate of global improvement that we have seen in the past 10 years.

Hybrid vehicle technology, which couples the internal combustion engine with an electric motor, will play an increasingly important role as costs come down and it becomes available on a broader range of vehicles. In cities, where this technology has its greatest advantages, hybrid vehicles could deliver fuel economy improvements in excess of 50%.[3]

We also anticipate significant efficiency improvements to the basic internal combustion engine. One promising

Fig. 4

Anticipated Growth in Transportation 2000 - 2030



development that ExxonMobil is working on is known as Homogeneous Charge Compression Ignition, or HCCI. This technology combines aspects of gasoline and diesel engines. HCCI has the potential to improve vehicle fuel economy by 30% and be applicable to a broad range of vehicle types, including hybrids.

In addition to technology enhancements in vehicle power trains, we believe that technologies such as lighter-weight materials and improved lubricants will play an important role in delivering valuable efficiency improvements to the transportation sector.

Natural Gas: Power generation, emissions benefits and LNG technology drive growth

Natural gas demand continues to rise with growing electricity needs, aided by inherent advantages in efficiency and lower emissions. Growth will be most rapid in Asia/Pacific.

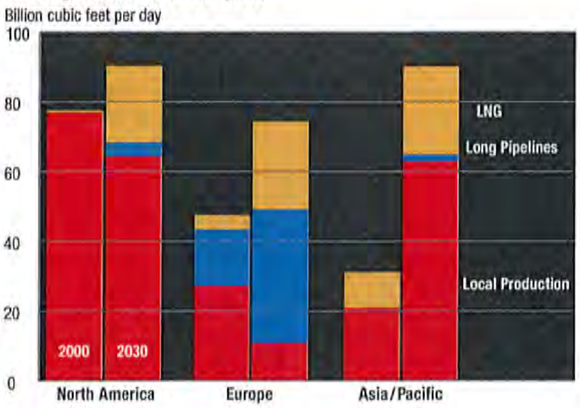
We anticipate that the efficiency of electricity production and distribution will continue to improve, through deployment of more advanced power generation technology and transmission infrastructure.

An important outcome of this growing gas demand is the increasing role of natural gas imports, particularly in the mature regions of North America and Europe, where local production is expected to decline (See Fig. 5). To balance supply and demand, the distance between the major natural gas-consuming nations and their sources of supply will grow. While pipelines will remain an efficient means to transport the majority of natural gas, the world will increasingly rely on liquefied natural gas (LNG), transported in large volumes across oceans via LNG tankers:

- In North America, LNG imports are expected to increase to about 25% of supply by 2030 (versus about 3% today), even with additional supplies via northern pipelines and tight gas developments.

Fig. 5

Growing Reliance on Gas Imports



- In Europe, natural gas imports are expected to increase from about 40% to about 85% of supply by 2030. In addition to LNG, pipeline imports will increase from Russia and the Caspian region.
- Natural gas demand in Asia/Pacific will triple over the next 25 years. Local production will meet a large part of this increased demand, but pipeline imports and increased volumes of LNG are expected in the future.

LNG's dramatic growth

By 2030, the LNG market will change dramatically, with a fivefold increase in volume to nearly 75 billion cubic feet per day (BCFD). That represents about 15% of the total gas market, up from about 5% in 2000. The center of global LNG supply will shift from Asia/Pacific to the Middle East and West Africa. Supplies from the Middle East are expected to be roughly double the supplies from either Africa or Asia/Pacific by 2030. Africa's supply contribution will grow, as LNG supplies there quadruple.

Global oil resources are adequate to meet demand

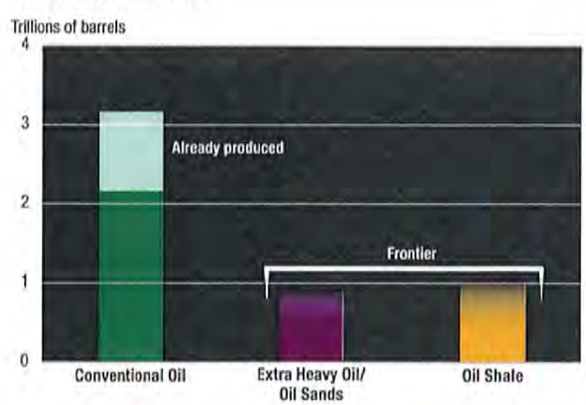
An important factor in predicting future supply trends is the scale of the worldwide oil resource base.

By today's estimates, the world was endowed with *recoverable* conventional oil resources of over three trillion barrels worldwide. Additional frontier resources (extra-heavy oil, oil sands, oil shale) bring this recoverable total to 4 – 5 trillion barrels. Of this amount, approximately 1 trillion barrels have been produced since oil was first discovered (See Fig. 6)

This global resource base will support production growth through the 2030 time horizon, with growing contributions from the Middle East, Africa and the Russia/Caspian region.

Fig. 6

Recoverable Oil Resources



Meeting Future Energy Needs: Technology, investment and supportive governments are critical

To meet the anticipated 190 MBDOE of oil and gas demand in 2030, the industry will need to find new supplies as well as extend and expand existing production sources.

Continued technology advances will be needed to increase supplies while protecting the environment. Technology has continually expanded the industry's ability to find, develop, produce and transport energy supplies while reducing environmental impact. These advances evolve over time and are expected to continue to assist in meeting growing global energy demand.

Fig. 7

The Move to Deeper Water: Exploration depths

Sophisticated reservoir imaging, facilitated by the growth in computing power, allows the identification of previously unknown oil and gas deposits. Deepwater exploration technology and extended-reach drilling allow the industry to pinpoint and access previously inaccessible resources (See Fig. 7). Continued success in challenging environments, from arctic locations to water depths approaching two miles, demonstrate the industry's capacity for technical innovation.

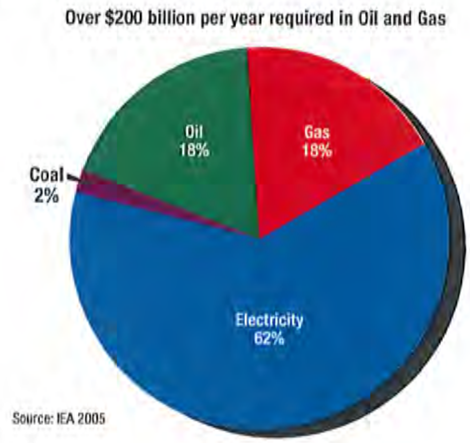
Technology not only expands the geological range of where we produce, but it also extends the types of supplies that contribute to meeting global demand. As we move toward 2030, we anticipate an increasing contribution from "frontier" hydrocarbon resources such as oil sands and extra-heavy oil. While the technology needed to produce these resources economically is available today, continued R&D will ensure that the required growth in production can be realized in an efficient, cost-effective and environmentally responsible manner.

Increasing supplies to meet demand will require substantial investment. The International Energy Agency estimates that the investment required to meet global energy demand for 2004-2030 will be $17 trillion, of which over $10 trillion is required for electricity and $6 trillion (over $200 billion annually) for oil and gas (See Fig. 8)[4]. Financing will be a critical challenge, with funding dependent on attractive, competitive investment conditions.

Fig. 8

Total World Energy Investment Requirement: $17 Trillion

World Energy Investment, 2004-2030



Source: IEA 2005

But more than investment dollars and technology advances will be needed. Governments have a vital role to play in providing access to acreage, opening markets, reducing barriers to trade and avoiding harmful policies, such as subsidies and regulations that can weaken or distort energy markets. Given the enormous investments involved, potential investors need to be confident of the sanctity of contracts, the recognition of intellectual property and support for the rule of law.

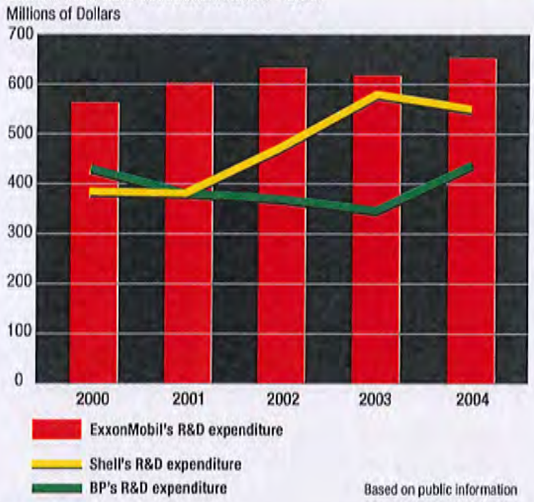
ExxonMobil's Technology Advantage

ExxonMobil has long been the industry leader in research and technology, with a history of invention, including 3-D seismic, digital reservoir simulation and industry 'firsts' in such areas as deepwater drilling, refining technology, chemicals and synthetic lubricants.

Today we invest over $600 million per year in research and development, balancing our investment between technology extensions, which can be rapidly deployed to our existing operations, and breakthrough research in areas that can have a lasting impact on the company and the industry.

Fig. 9

ExxonMobil R&D Investment 2000 - 2004



Examples of our recent achievements in technologies that help unlock the potential in some of the world's hydrocarbon basins include:

- A promising new technology known as R3M (Remote Reservoir Resistivity Mapping) uses electromagnetic energy to directly detect reservoirs of oil and gas before drilling, substantially reducing exploration risk.
- Our proprietary tool EMpower™ is the industry's only next-generation reservoir simulator, allowing engineers to study reservoirs more comprehensively than ever before.
- Proprietary well-bore technology used on Sakhalin Island in Russia's Far East enables us to reach oil reservoirs five miles offshore via extended-reach, horizontal drilling from an onshore location.

With LNG playing an increasingly critical role in meeting demand for natural gas, ExxonMobil engineers have recently developed technology that can double the capacity of liquefaction plants and increase by 80% the LNG carried by a single ship, dramatically reducing LNG costs.

At the same time we have developed unique high-strength steel to lower the cost of transporting natural gas by pipeline.

In the area of vehicle engine and fuel efficiency, ExxonMobil scientists are involved in projects including:

- Partnerships with Toyota and Caterpillar to research improvements to internal combustion fuel and engine systems that could result in a 30% improvement in fuel economy and reduced emissions
- A partnership with DaimlerChrysler to develop new lubricants to improve fuel economy, extend oil change intervals and lower emissions
- Development of new recyclable plastics to enable lighter-weight vehicles
- Groundbreaking research in hydrogen generation (see "hydrogen" - Section 3)

In an effort to apply the combined resources of industry and academia to the challenge of identifying technologies that meet growing energy demand while dramatically reducing greenhouse gas emissions, we launched the Global Climate and Energy Project (GCEP) at Stanford University in 2002. The GCEP research areas are covered in Section 2, and at gcep.stanford.edu.

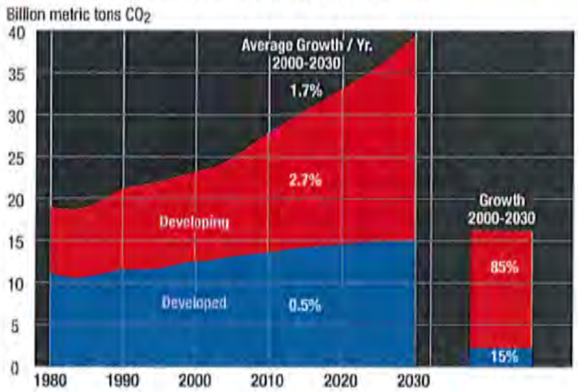
Managing the risks from increases in global greenhouse gas emissions is an important concern for ExxonMobil, industry and governments around the world.

Economic growth and emissions reduction

Section 1 described how increasing population and prosperity, especially in developing countries, will drive up global energy demand. This will result in substantial increases in greenhouse gas emissions, particularly from developing countries, which will account for about 85% of the growth in CO_2 emissions from 2000 through 2030 (See Fig.10).

Fig. 10

CO_2 Emissions Growth Driven by Developing Countries



This poses a challenge. To deliver the benefits of continued economic progress, fossil fuels are expected to remain the predominant source of world energy supply over this period. At the same time, governments at all levels are responding to growing concern about climate change by taking policy actions to reduce greenhouse gas emissions. Policymakers face a difficult task: where these policies restrict fossil fuel use or add cost to their use, they can also retard economic development.

It is therefore vital that policymakers and society take into account the wider social and economic impacts of energy and climate policies.

ExxonMobil is involved in this process through direct participation in scientific, technical, economic and policy forums and by working through trade associations to engage in public policy discussions. We are also taking actions in our own operations.

Climate Policy: Path forward is unclear

Until recently, the policy debate focused primarily on near-term emissions reductions in the framework of targets and timetables set by the Kyoto Protocol. The first compliance period under the Protocol is 2008-2012.

Among those nations ratifying the Protocol, the European Union (EU) has been most active in seeking to implement it. An emissions trading scheme (ETS) has been established, which will limit emissions of CO_2 from certain industrial activities, including power production and refining. Other nations, such as Japan and Canada, are still considering policies and regulations they may adopt.

Most nations are not on track today to meet their 2008-2012 Kyoto targets with domestic actions. The total shortfall could be several hundred million metric tons of CO_2 per year.

That shortfall may be eliminated if international emissions trading enables countries to purchase sufficient allowances from those countries with surpluses, particularly Russia and the Ukraine. These two countries have substantial excess emissions allowances due to the decline and restructuring of their economies since 1990. No further actual emission reduction steps are required to create the surplus, which is large enough to compensate for missed targets among other industrialized nations.

The international debate on what policy actions to take beyond 2012 is now under way, but the outcome is uncertain. The debate is complicated by the following concerns:

- The developing world has indicated it will not accept greenhouse gas emissions reduction targets, leaving the vast majority of the global growth in greenhouse gas emissions outside the reach of the Kyoto Protocol targets.
- Differing targets in developed countries can increase domestic energy costs and accelerate the shift of new investment abroad, including to developing countries, which already enjoy lower labor costs.

The Business Impact: Regulatory uncertainty threatens investment

The current uncertainty poses challenges for global businesses. Major energy investments usually have long lives. Uncertainty about regulations, both for 2008-2012 and beyond 2012, creates a higher level of risk for companies. In Europe and Canada, for example, concerns are growing regarding companies' willingness to invest in energy-intensive activities, such as new chemical production and heavy oil production. The uncertainty about future regulations raises questions about the longer-term viability of such investments.

Increasing recognition of technology's vital role

As nations have begun to consider other options for reducing GHG emissions, there is a growing interest in the role technology can play in emissions reduction. For example, the recently announced Asia Pacific Partnership for Clean

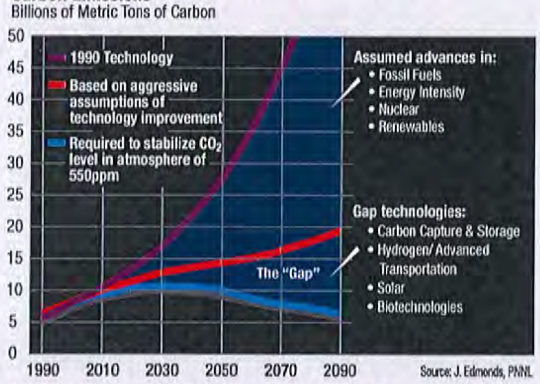
Development and Climate aims to promote the use of clean, efficient technology. The latest G8 statement and the EU-China Climate Partnership also highlight the importance of using and developing innovative technologies. The focus on technology development and deployment is supported by the recognition that:

- The more widespread application of existing energy-efficient technologies could significantly reduce the growth in greenhouse gas emissions from economic progress in both the industrialized and the developing world (See Fig. 12).
- Development and deployment of new, energy-efficient technologies can enable lower energy consumption without damage to economic growth.
- New breakthrough technologies offer the possibility of substantial long-term reductions in greenhouse gas emissions at lower costs than current technology options.

Fig. 11

The Need for Innovative Technology[5]

Carbon Emissions
Billions of Metric Tons of Carbon



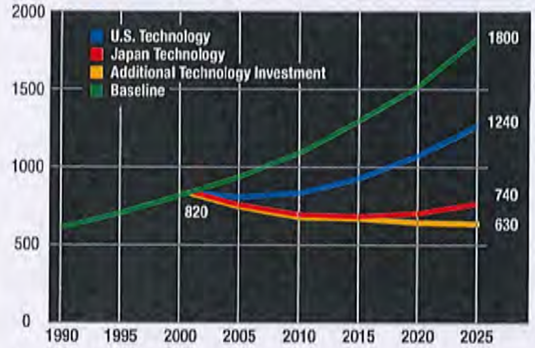
Source: J. Edmonds, PNNL

Worldwide carbon emissions are expected to grow rapidly over the next century, even with significant technology advances. The middle curve (red line: from the Intergovernmental Panel on Climate Change 1992) shows projected growth in greenhouse gas emissions over the coming century. The IPCC projection assumes major ongoing improvements in the efficiency with which energy is supplied and used from oil, coal and gas, as well as enhanced penetration of nuclear and renewable energy. Without technological improvements, emissions would be much higher, as shown in the top curve (purple line) where energy is supplied and used with efficiency at 1990 levels. The lowest (blue) curve illustrates one emissions trend corresponding to stabilizing CO_2 concentrations at 550 parts per million (ppm). Reducing emissions to the lowest trend line would require widespread introduction of innovative, currently non-commercial technologies to fill the remaining gap. In this study these 'gap' technologies include carbon capture and storage, hydrogen production and use, solar and biotechnologies, all of which require fundamental breakthroughs in research to overcome current barriers to cost, performance, safety and public acceptance before they could enter into widespread use.

Fig. 12

Existing Technologies Offer Significant Potential

Projected Chinese Emissions with Enhanced Technology[6]
MMTCE



Source: Bernstein, Tuladhar, Montgomery

Applying OECD country technology to developing economies could dramatically reduce carbon emissions. In China, for example, investments today have, on average, significantly poorer energy efficiency and higher greenhouse gas emissions than investments being made today in OECD countries. A recent study showed that adopting today's U.S. or Japanese-level technology in future investments in China could reduce China's anticipated 2025 carbon emissions by over 30% and over 50% respectively (see graph). Furthermore, if policies to increase R&D investment could increase the rate of improvement in energy efficiency to twice today's levels, then emissions could decrease to around 35% of anticipated 2025 emissions and result in a continuous decrease in China's future emissions. In fact, the study concluded that "the potential for reducing emissions through changing technology in developing countries over the next 15 years is estimated to be of similar magnitude to the reductions in emissions that would be achieved if all Annex B countries were to achieve their Kyoto Protocol emission caps."

ExxonMobil Recommendations: Key Objectives for Long-Term Climate Policy

- Promote global participation
- Encourage more rapid use of existing efficient technologies (in both developed and developing countries)
- Stimulate research and development to create innovative, affordable, lower GHG technologies sooner
- Address climate risks in the context of developing country priorities: development, poverty eradication, access to energy
- Continue scientific research to assess risks and pace policy response

Climate Science: What we know

ExxonMobil has undertaken climate science research for 25 years. Our work has produced more than 40 papers in peer-reviewed literature, and our scientists serve on the Intergovernmental Panel on Climate Change (IPCC) and numerous related scientific bodies. Contributed papers on climate science are listed on our web site.[7]

Based on this experience, we recognize that the accumulation of greenhouse gases in the Earth's atmosphere poses risks that may prove significant for society and ecosystems. We believe that these risks justify actions now, but the selection of actions must consider the uncertainties that remain. Notwithstanding these uncertainties, ExxonMobil is taking action to address these risks.

Our world has changed

Since the 1800s, concentrations of carbon dioxide (CO_2) in the atmosphere have increased by roughly 30% (from 280 to 380 parts per million today).[8] Concentrations of other greenhouse gases have also increased – including a doubling of methane levels. Human activities have contributed to these increased concentrations, mainly through the combustion of fossil fuels for energy use; land use changes (especially deforestation); and agricultural, animal husbandry and waste-disposal practices.

Surface temperature measurements have shown that the average global temperature has risen by about 0.6 °C since the mid-1800s. Other changes, consistent with the surface temperature rise, have also been observed. For example, scientists have documented a decrease in the volume of mountain glaciers and an increase in the length of growing seasons. These observations have fueled concern about the potential longer-term consequences of climate change.

Climate is a complex science

The complexity of the climate system makes it difficult to understand past and future consequences of greenhouse gas increases. As a result, the extent to which recent temperature changes can be attributed to greenhouse gas increases remains uncertain.

Limits in climate knowledge – for example in describing the behavior of clouds, hydrology, sea ice and ocean circulation – are well known and continue to be researched.[9] Climate observations display significant natural variability that cannot be explained with existing models and knowledge. In the recent and ancient geological past, for example, climate has been both warmer and cooler than today for reasons that are not yet understood.[10]

Projections of climate change require estimates of future emissions from energy use and other sources over the 21st century. In our own Energy Outlook it is difficult to predict how technology will develop even over the next 25 years. Longer-term economic and climate forecasts face even more uncertainty about how new technologies and changes in human behavior may affect greenhouse gas emissions.

As a result, researchers must rely on scenarios based on various assumptions, which deliver results ranging from significant emissions growth (a threefold increase in emissions over the 21st century) to a drop in global emissions, even without policy interventions.[11]

When climate models are used to analyze the implications of these emissions scenarios, they project more severe consequences at the high end – including sea level rises, droughts and polar ice melting – and relatively benign climate changes at the low end.

Uncertainty and risk

While assessments such as those of the IPCC have expressed growing confidence that recent warming can be attributed to increases in greenhouse gases, these conclusions rely on expert judgment rather than objective, reproducible statistical methods. Taken together, gaps in the scientific basis for theoretical climate models and the interplay of significant natural variability make it very difficult to determine objectively the extent to which recent climate change might be the result of human actions. These gaps also make it difficult to predict the timing, extent and consequences of future climate change.

Consequently, the National Research Council[12] cautioned after the most recent IPCC report:[13] "Because of the large and still uncertain level of natural variability inherent in the climate record and the uncertainties in the time histories of the various forcing agents (and particularly aerosols), a causal linkage between the buildup of greenhouse gases in the atmosphere and the observed climate changes during the 20th century cannot be unequivocally established. The fact that the magnitude of the observed warming is large in comparison to natural variability as simulated in climate models is suggestive of such a linkage, but it does not constitute proof of one because the model simulations could be deficient in natural variability on the decadal to century time scale."

Even with many scientific uncertainties, the risk that greenhouse gas emissions may have serious impacts justifies taking action. ExxonMobil's actions to reduce greenhouse gas emissions are described in the next section.

ExxonMobil Actions to Reduce GHG Emissions

Recognizing the risk of climate change, we are taking actions to improve efficiency and reduce greenhouse gas emissions in our operations.

We are also working with the scientific and business communities to undertake research to identify and develop economically competitive and affordable technologies to reduce long-term global greenhouse gas emissions while meeting the world's growing demand for energy.

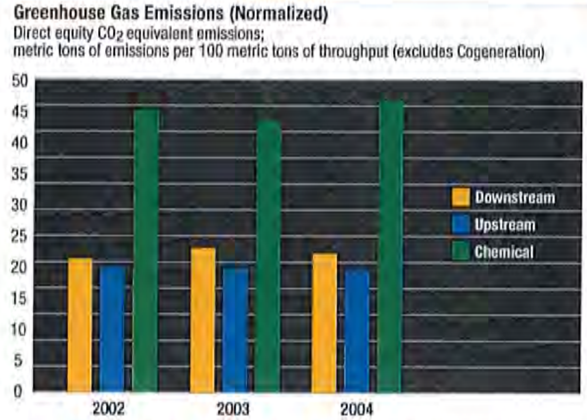
Examples of our efforts include:

- **Reporting:** ExxonMobil is committed to consistent, comprehensive reporting of greenhouse gas emissions. We have publicly reported greenhouse gas emissions[14] as they relate to our operations since 1998. Starting in 2003, we report direct greenhouse gas emissions, based on our equity share of ownership, both from facilities we operate and those in which we share ownership. We believe that direct, equity-based accounting best reflects shareholder interests in this area.
  In 2004 our greenhouse gas emissions rose by 1% compared to 2003 due to throughput increases and more intense processing to meet clean fuels demand. Energy efficiency steps helped to offset the impact of more intense operations and prevented further increases in emissions per barrel (See Fig. 13).

- **Research:** We have conducted and supported scientific, economic and technological research on climate change for more than two decades. Overall, our research has been designed to improve scientific understanding, assess policy options and achieve technological breakthroughs that reduce GHG emissions in both industrial and developing countries. Major projects have been supported at institutions including the Australian Bureau of Agricultural Resource Economics, Battelle Pacific Northwest Laboratory, Carnegie Mellon, Charles River Associates, The Hadley Centre for Climate Prediction, International Energy Agency Greenhouse Gas R&D Programme, Lamont Doherty Earth Observatory at Columbia University, Massachusetts Institute of Technology, Princeton, Stanford, University of Texas and Yale.

- **Advanced vehicle technology:** Because the majority of GHG emissions associated with the production and use of oil arises from consumer use of fuels (87%), with the remainder from our industry's operations (13%), we partner with automobile manufacturers to help develop advanced vehicles and fuels. The internal combustion engine is expected to power more than 95% of vehicles in 2030,[15] so technologies that improve fuel efficiency and the emissions performance of the internal combustion engine could substantially reduce environmental impacts for decades to come. Examples of ExxonMobil's work in this area include:
  - Working with Toyota and Caterpillar on separate programs to design high-efficiency, low-emission gasoline and diesel fuel/engine systems. This has already produced groundbreaking research in combustion science.
  - Developing a novel technique for hydrogen production, potentially compatible with both on-board vehicle and larger-scale applications.

Fig. 13



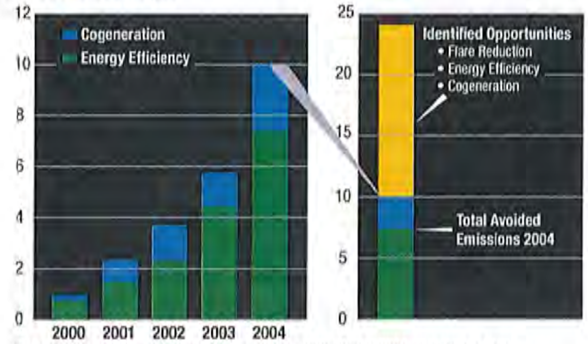
Note: Adding cogeneration of power and steam increases ExxonMobil's emissions but reduces those of others that would have produced the power. The overall impact is a reduction by as much as half in emissions for the same amount of energy produced.

- **Global energy management system (GEMS):** Improving energy efficiency in our operations helps us to reduce costs as well as reduce emissions. ExxonMobil's proprietary GEMS system focuses on opportunities to reduce energy consumed at our refineries and chemical complexes. Since its launch in 2000, the GEMS system has helped us identify opportunities for more than one billion dollars in pre-tax savings, and our energy-conservation efforts have saved enough energy to supply over one million European households each year. The greenhouse gas emission effect has been equivalent to taking more than one million cars off the road (See Fig. 14).

- **Cogeneration** is the simultaneous production of electricity and steam, typically using clean-burning natural gas. With the latest technology, cogeneration is up to twice as efficient as traditional methods of producing steam and power separately. ExxonMobil has interests in 85 cogeneration facilities at some 30 locations worldwide, representing a capacity of about 3,700MW, enough to power nearly 3 million U.S. homes. These facilities, which represent decades of investment, enable a reduction in carbon dioxide emissions by 9 million metric tons a year versus traditional methods

Fig. 14

Avoided Greenhouse Gas Emissions from ExxonMobil actions since 1999
Million metric tons per year



Since 1999, our energy-saving initiatives have had a GHG effect in 2004 equivalent to taking over 1.5 million U.S. cars off the road. We have identified opportunities for avoiding GHG emissions equivalent to taking another two million U.S. cars off the road.

of separate power and steam generation. Our cogeneration capacity has increased by 800MW in the last two years, representing an investment of $1 billion. In 2005 the cogeneration system at our refinery in Beaumont, Texas, was awarded a Certificate of Recognition from the U.S. Environmental Protection Agency. The EPA commended ExxonMobil for "exceptional leadership in energy use and management" and estimated that the system at Beaumont alone reduced CO_2 emissions by more than two million tons.

- **Reduction in flaring:** Flaring is the burning of natural gas that is produced along with oil during oil production. In parts of the world where gas has no market outlet, gas production beyond that needed for fuel and other operational needs is often flared. In Africa, the region where flaring is most significant, we are undertaking major projects to reduce flaring. When fully implemented, we expect these projects to reduce greenhouse gas emissions by about seven million metric tons per year, the equivalent of removing approximately one million cars from U.S. roads. We are also working to reduce flaring at our refineries and chemical plants. For example, flaring at our Baytown refinery in Texas has been reduced by more than 70% since 2002.

- **The Global Climate and Energy Project (GCEP):** ExxonMobil worked to establish and is providing $100 million to Stanford University's Global Climate and Energy Project – the largest-ever independent climate and energy research effort. GCEP is a major long-term research program designed to accelerate development of commercially viable energy technologies that can lower GHG emissions on a worldwide scale. Current GCEP research areas include hydrogen, solar energy, biomass, advanced combustion, CO_2 sequestration and advanced materials. A full list of ongoing projects is available on the GCEP web site (gcep.stanford.edu).

GCEP
Global Climate & Energy Project
STANFORD UNIVERSITY

In 2005 GCEP announced new research grants totaling approximately $20 million to Stanford faculty and collaborating researchers at several U.S. and international institutions.[16] Other participating institutions include the Energy Research Centre of the Netherlands, the Delft University of Technology in the Netherlands, the Swiss Federal Institute of Technology in Zurich, the Carnegie Institution of Washington, D.C., University of Montana, University of New South Wales in Australia and the Research Institution of Innovative Technology for the Earth in Japan.

GCEP Research Programs

At the end of 2005, 27 GCEP research programs were under way at Stanford and other institutions, comprising:

7 hydrogen
6 advanced combustion
5 solar energy
4 CO_2 storage
2 CO_2 capture and separation
2 biomass
1 advanced materials and catalysts

Building capacity to address climate change risks – through research results and by training a new generation of scientists and engineers – is an important GCEP deliverable. GCEP research programs involve contributions from more than 30 faculty and from more than 80 students and postdoctorate fellows.

Responding to Greenhouse Gas Regulations

We actively engage with government authorities seeking to implement regulations regarding greenhouse gas emissions accounting and trading.

We believe that reliable inventories of emissions are an essential component of emissions control procedures and trading. As a result, we played a leading role in developing reliable, consistent tools to estimate and report greenhouse gas emissions in the oil and gas industry, namely:

- API Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry, April 2001. (available at http://api-ec.api.org/policy/)[17]
- IPIECA Petroleum Industry GHG Reporting Guidelines, December 2003. (available at www.ipieca.org)[18]

These procedures now form the basis for our own internal measurement and reporting. Building on these guidelines, our Rotterdam refinery developed a monitoring and reporting protocol that was recognized by the Dutch government as a best practice and recommended for use throughout the European Union.

Climate Policy: Assessing risks to investors

ExxonMobil continually considers risks to operations and investments from a wide variety of perspectives. In the case of climate change, market and technological considerations are important, as well as policy and regulatory developments. In our view, it is impossible today to assess the potential implications for shareholder value from initiatives to address climate change. No governments have established definitive regulations for the 2008-2012 Kyoto Protocol compliance period, and there is currently no consensus on plans for the post-2012 period.

There has been some recent effort to quantify the potential implications of climate-related policies for oil and gas industry shareholders.[19] However, in light of trends in climate negotiations, the regulatory assumptions made are speculative and unlikely. The analyses also fail to take into account adjustments to investments and other business decisions that companies may make in the context of evolving regulatory frameworks or, indeed, how OPEC and other producing nations may react to regulations affecting demand for oil.

Technological, political and regulatory risks have been inherent in the oil industry since its earliest beginnings. Shareholder value will depend, as it always has, on how companies manage operations and investments in a changing business environment. Those best able to manage investment risks and operate efficiently will achieve competitive advantage.

Against this background we believe that the same strengths that have generated industry-leading returns for ExxonMobil in the past position us well to succeed in an uncertain future:

- Our strong financial position enables us to evolve in new directions when attractive opportunities appear.
- We manage business operations and investments with disciplined efficiency based on strong management and management systems.
- We utilize industry-leading technical capacity both to develop proprietary technologies that provide a competitive advantage and to maintain a window on external research developments that might affect our business.

Assessing the Impact on ExxonMobil of Europe's Emissions Trading Scheme (EU-ETS) for 2005-2007

In Europe ExxonMobil operates approximately 40 facilities and shares ownership in another 40 facilities that are covered under the EU-ETS. In total, ExxonMobil's equity share of covered emissions amounts to approximately 20 million metric tons of CO_2 annually.

As a result of internal actions, we expect to meet our obligations for the period 2005-2007 without acquiring allowances through emissions trading.

The overall impact of the EU-ETS for 2005-2007 includes the cost of monitoring and reporting efforts, third-party verification and the increased cost of purchased electricity due to EU-ETS restrictions on power generation. These costs will be offset in some part by the revenue from sales of surplus emissions allowances. While the net impact of these factors is unknown, it is not expected to be material to the Corporation.

The impact of the EU-ETS for 2008-2012 is unknown, as the member governments have not yet determined what emissions will be covered or how emissions allowances will be allocated.

To comply with the EU-ETS, we have established management systems to:

- monitor, report and verify emissions
- control and manage disposition of greenhouse gas allowances
- participate in emissions trading
- plan future emission reduction steps

Required system changes have been fully implemented and are in place at all covered ExxonMobil facilities.

Section 3: Technology Options for the Longer Term

Meeting future energy needs will require a diverse range of energy technologies. Looking to the long term, concern about energy security and rising greenhouse gas emissions has brought a number of new or enhanced technologies to the forefront of public discussion.

Among these, wind, solar and biofuels are growing rapidly, albeit from a small base. Other technologies, such as hydrogen, are considered to hold promise, but face substantial challenges in terms of cost and large-scale implementation.

Over and above the technical hurdles, the scale of the global energy business means that widespread global deployment of new technologies, however promising, will take decades before the cumulative effect of investments makes a substantive contribution to overall energy supply.

Energy companies are involved in a wide range of new technology options, whether through research or the manufacture and marketing of products.

Our own approach is based on the belief that technological breakthroughs, and not simply expanded scale, are key to unlocking the potential of alternative energy technologies. We closely analyze the potential of emerging technologies. Based on these assessments, we determine our approach, and – if appropriate – a level of involvement consistent with our business needs and strengths. This may involve proprietary research, shared knowledge through participation in industry groups or the funding of external research in those areas where fundamental breakthroughs are needed for a technology to reach its potential.

In this section, we highlight some of the most prominent technology options, the challenges that need to be overcome and – where relevant – ExxonMobil's involvement.

Carbon Capture and Storage

Fossil fuels are expected to dominate the world's energy supply portfolio for some decades to come. A technology option that could play a significant role in helping reduce CO_2 emissions from the use of fossil fuels is carbon capture and storage (CCS). CCS technology separates CO_2 from a gas stream, compresses it to reduce volume and transports it by pipeline to a storage site (See Fig. 15).

This technology could have a major impact, as it is applicable to any large-emission source of CO_2. The IPCC estimates that these large facilities account for nearly 60% of global man-made CO_2 emissions.[20]

All of the important components of CCS systems are practiced commercially today at industrial scale by ExxonMobil. For example, ExxonMobil recovers CO_2 at LaBarge, Wyoming, which is used for enhanced oil recovery. As part of that activity, a gas stream including CO_2 is removed and geologically sequestered. Commercial-scale CCS is practiced today only in a few niche applications and pilot demonstration studies. One of the best-known and longest-running CCS projects is in the Sleipner Field in the North Sea[21] – in which ExxonMobil shares ownership. Before CCS can be widely deployed on a global scale, it must overcome important challenges. In particular,

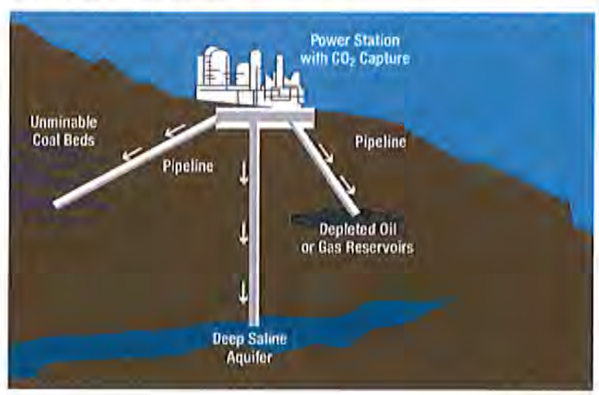
- CO_2 capture from power plants and most other large combustion facilities remains expensive.
- CO_2 storage presents technical and regulatory issues associated with ensuring safe operations and the integrity of the site over the long term.

Recognizing these challenges, ExxonMobil believes that CCS represents an important option to address global CO_2 emissions.

We have conducted research relevant to CCS for many years and have supported external research and other activities to understand scientific, economic, technical and policy aspects of carbon capture and storage. In addition to the CCS studies as part of GCEP, ExxonMobil has supported the IEA's Greenhouse Gas R&D Programme and the Geological CO_2 Storage Research Program at the University of Texas. The research that we conduct and support is aimed at improving the performance, lowering the cost and assuring the integrity of CCS systems and their component technologies.

Fig. 15

Carbon Capture and Storage



Hydrogen

Hydrogen is widely considered to hold promise as an energy carrier, particularly as it offers the potential for fuel-efficient, emissions-free vehicles and can be produced from multiple primary energy sources.

It is important to remember that hydrogen, while abundant, does not occur naturally in pure form and must first be produced from water or hydrocarbons. This requires the use of energy generated from primary sources: oil, gas, coal, nuclear or renewables. So any evaluation of hydrogen needs to recognize the costs and the greenhouse gas emissions associated not only with its consumption, but also its production and distribution.

For hydrogen to become a viable transportation fuel, a number of formidable challenges must be met, including its safe handling and the high cost of production and distribution. While hydrogen has been used safely for decades by highly trained technicians in industrial settings, its characteristics pose unique challenges for use in consumer markets such as self-service vehicle fueling.

The high cost of producing and distributing hydrogen results in a fuel cost that is higher than gasoline on a cents-per-mile-driven basis. Based on an analysis by the National Academy of Engineering (NAE), the cost of fueling a hydrogen fuel cell vehicle is 1.9 to about 15 times greater than that of fueling a gasoline hybrid, depending on how the hydrogen is produced[22] (See Fig. 16). Significant R&D effort will be required to lower these costs to a competitive level.

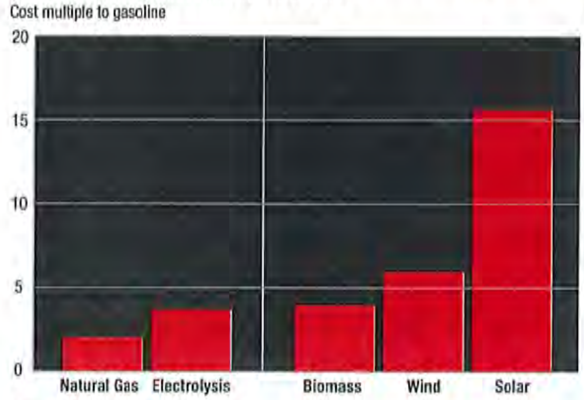
A number of studies conducted by different sponsors in different regions have assessed the potential for reducing CO_2 emissions via the use of hydrogen. All have concluded that there is some reduction in full-cycle CO_2 emissions for hydrogen fuel cell vehicles compared with hybrid technology (approximately 11% to 35%).[23]

Interest in the use of renewable energy to make hydrogen is high, as this is the only option that would result in a "zero emissions" transportation fuel system on a total supply-chain basis. There are, however, a number of additional challenges associated with the manufacture of hydrogen from renewable energy. The NAE estimated that hydrogen is five times more expensive than gasoline when produced from wind and 15 times more expensive when produced from solar energy.[22]

With limited supplies of renewables in the coming decades, it is reasonable to ask whether the use of renewables to produce hydrogen for transportation would be the best use of those resources. A unit of wind or solar energy that is used to displace coal in power generation saves 2.5 times more carbon dioxide than using the same unit of wind or solar energy to replace gasoline with hydrogen.[24]

Fig. 16

Cost of fueling a vehicle with hydrogen from different energy sources relative to fueling a gasoline hybrid engine



Source: National Academy of Engineering

ExxonMobil is currently pursuing groundbreaking research in hydrogen generation. Our unique skills in catalysis and process technologies have enabled us to identify a new approach to hydrogen production from hydrocarbon fuels that overcomes many of the challenges faced by alternative approaches.

If successfully developed, this technology would be scalable for applications ranging from on-board a vehicle to use at either retail stations or large centralized production facilities to produce hydrogen for fleets of fuel cell vehicles. We are also active members of the U.S. Department of Energy's FreedomCAR and Fuel Partnership.

Biofuels

The use of biofuels in transportation is another way that CO_2 emissions could be reduced. Today ethanol and biodiesel, liquid fuels derived from organic matter, are receiving a lot of attention.

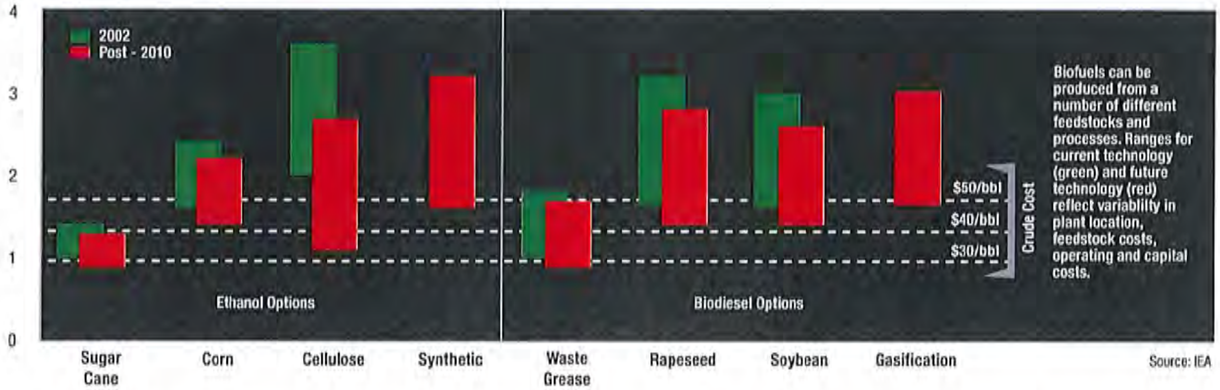
The current generation of biofuels, however, has scale limitations due to their cost and large land requirements. With continued research, a new generation of processes capable of using a more diverse set of biomass feedstocks may be able to overcome these challenges. A recent study by the International Energy Agency examined the economics of both current and potential future technologies (See Fig. 17).[25]

When considering the potential of biofuels, a number of factors must be analyzed, including land use impacts, fertilizer requirements and water use. The last is particularly important, as studies indicate that by 2015 half the world's population will live in countries where availability of sufficient fresh water is a concern.[26]

Most current biofuels production processes convert only a small portion of the plant. In the future, however, processes involving cellulosic conversion hold the promise of being able

Fig. 17

Cost of Production for Biofuels Options
2004 $ per gallon gasoline equivalent



to utilize a much larger portion of the feed biomass. This would result in full-cycle CO_2 savings of about 90% versus up to 50% with current processes.[27]

Important, too, is the question of which biomass applications yield the greatest benefit. A recent study in Europe involving the energy and auto industries, as well as the Joint Research Commission of the European Union, concluded that greater energy and GHG savings can be achieved if biomass is used in heat and power generation rather than in transportation, especially if efficient cogeneration schemes can be used.[28]

Wind and Solar

Currently, the most competitive renewable energy source is wind power (See Fig. 18). While growing rapidly, its impact on the overall energy supply mix is limited. In some applications, wind-generated electricity can be cost-competitive with that generated from natural gas, but it generally relies on government subsidies to be economical.

A key challenge for wind power is that the areas best able to produce electricity at low cost from wind are also located far from where the electricity is needed. New technology will be required to allow either the capture of wind energy in areas with low average wind speeds or to enable transmission of electricity over long distances at lower cost and with lower losses than is currently possible.

Solar energy remains far more costly, except in limited applications. Existing solar photovoltaic technology is significantly more costly than conventional electricity generation. Breakthrough technology is needed to enable fundamentally new photovoltaic materials that will allow power generation at competitive costs.

A key issue in the ability of wind and solar technologies to contribute to electric power supply is intermittence. Stable electric grids require traditional generating facilities or costly backup systems to ensure uninterrupted supply to consumers on cloudy days, at night or at times the winds fail.

Without a breakthrough in energy storage technology, intermittency limits the ability of wind and solar energy to contribute to electricity supplies and increases the overall costs of integrated power supply systems.

Research into solar energy is a core research area of the ExxonMobil-sponsored Global Climate and Energy Project at Stanford University.

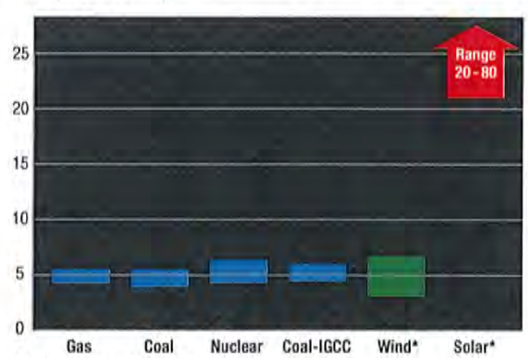
Gasification

Gasification, a technology that was developed decades ago, may see increased use in the future.

Gasification can process any carbon containing feedstock – such as coal, biomass or heavy oil – and convert it into a "synthesis gas" that can be used to produce electricity, liquid fuels, hydrogen or chemicals. Gasification is also better suited to use with carbon capture and sequestration than other processes that can use the same feeds.

Fig. 18

Cost of Electricity from Traditional and Emerging Sources
Cents per kWh (2005 $)



* Site limited and excludes intermittency costs

While gasification has many attractive properties, it is still more costly relative to alternative ways of producing the same products. For example, electricity produced by the gasification of coal (without CO_2 capture) is about 13%[29] more costly than that from a conventional coal power plant. By comparison, if CO_2 capture were included, then a coal gasification plant could produce electricity at a cost 20% lower than a conventional coal-powered plant retrofitted for carbon capture and storage (CCS).[30] Clearly there are synergies between gasification and CCS technologies.

Further work is needed to both lower the costs and improve the reliability of gasification technology, and ExxonMobil researchers are evaluating the opportunities in this area. If successful, studies could result in a technology option that provides a level of both feed and product flexibility that no current process is able to offer.

Advanced Nuclear

Nuclear energy has the potential to become an increasingly important option for meeting a growing portion of our long-term energy needs, specifically in the power generation sector.

Key barriers to increased use of nuclear today are cost, perceived safety risks and the lack of an acceptable solution to the long-term management of radioactive waste.

Research is continuing into advanced nuclear systems that are passively safe and offer the potential of significantly lower cost than current reactors. Systems with these safety features will have a very low likelihood of reactor core damage and address the problems that occurred at Three Mile Island and Chernobyl.[31]

Designs include advanced third-generation versions of conventional reactors, as well as fundamentally new designs such as the "pebble bed modular reactor." If successful, these designs could reduce the capital cost of nuclear power plants by 15% to 20% and thereby add another economically competitive option to our long-term energy supply portfolio. Addressing the long-term waste storage issue is largely a matter that will require extensive dialogue between governments, communities and industry to resolve.

Technology Choice and CO_2 Emissions

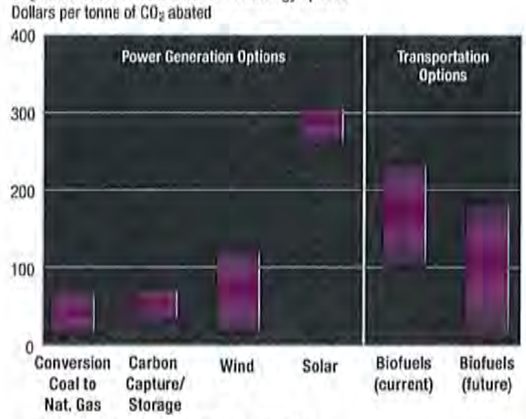
If new technologies are to be applied to realize reductions in CO_2 emissions, then it is important to understand the cost of various options in terms of dollars per tonne of CO_2 abated. Applying the lowest abatement cost options first will maximize impact while minimizing costs. European researchers in both the power and transportation industries have been working to quantify the abatement cost of technologies, and their work is helpful in understanding the relative attractiveness of different options.[32]

The chart in Fig. 19 illustrates ranges of abatement costs for various power generation and transportation technologies. The lowest cost reductions in CO_2 are likely to be realized in the power generation sector. This is due in part to the fact that it is easier to deal with a few large point sources of CO_2 than millions of individual sources, such as vehicles. It is also important to note that continued R&D can have a significant impact on lowering the cost of CO_2 abatement as illustrated by the current and future biofuels ranges.

ExxonMobil is well positioned to participate in the implementation of the lowest cost options through our focus on natural gas resource development, our experience with carbon capture and storage and our support of breakthrough research.

Fig. 19

The Cost of Reducing CO_2
CO_2 abatement costs for different technology options
Dollars per tonne of CO_2 abated



Source: CONCAWE, European Climate Change Project

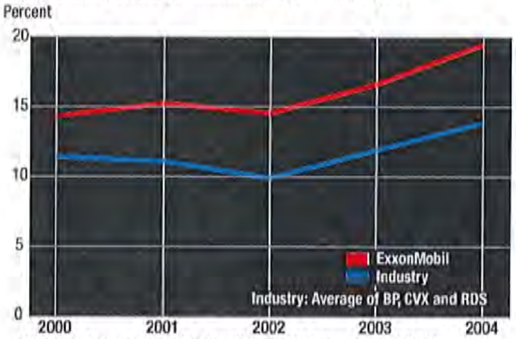
Although wind, solar, biofuels and nuclear all compete with fossil fuels as sources of primary energy, their contribution to the world's total energy demand is limited because they are more expensive than fossil fuels – and in the case of nuclear, limited by waste and disposal concerns. Technology advances and government policy will support rapid growth in alternative fuels, but they start from such a small base that their contribution to total energy supply will be modest well into the future. Their limited but growing contribution should be used in ways that make the greatest possible difference in CO_2 emissions.

While we recognize the risks of climate change, we also conclude that the world will continue to demand oil and gas for a majority of its primary energy supplies for many decades to come. This will be true even if governments continue to support alternative energy sources and limit greenhouse gas emissions. ExxonMobil is well positioned across a range of possible futures to conduct our operations competitively in a responsible and profitable manner.

ExxonMobil's long-term perspective, disciplined approach to investment and focus on world-class operational performance explain why the company has continually delivered industry-leading returns, even through times of dramatic and unforeseen change.

Fig. 20

Sustained Competitive Advantage
5-year Rolling Average Return on Capital Employed**



**Calculated on a consistent basis with ExxonMobil, based on public information.

In addition, our scale, geographic diversity and range of businesses provide a hedge that reduces sensitivity to changes in commodity prices, business cycles and local market conditions. Our financial and technology strength enables us to invest in any opportunity that meets our rigorous investment criteria.

These attributes, which we believe set us apart from our competitors, position us well to respond successfully to change, whether driven by markets, competitors or governments.

In response to rising environmental concerns, we anticipate more regulatory requirements than we face today. Uncertainty and risk are familiar territory in our industry, but we believe the way we manage our business puts us at an advantage over the competition in meeting new expectations.

Investment discipline and long-term perspective

The $200 billion industry investment required annually to meet growing demand for oil and gas through 2030 reflects not just the scale of demand, but also the fact that significant new resources are increasingly found in more remote areas and difficult environments.

Investment decisions can have long-term consequences. So we adopt a highly selective and disciplined approach to investment, which considers:

- political and technical risks, along with potential regulatory changes
- business and societal trends
- the resilience of investment opportunities over a range of economic scenarios

Regular, formal reviews enable us to evaluate emerging issues and plan accordingly.
Our objective is to seek out projects that:

- are profitable and sustainable over the long term
- are not reliant on government subsidies
- are consistent with our own scale and capabilities
- yield a well-balanced and diversified business
- do not compromise our high safety and environmental standards

Fig. 21

Business Model
ExxonMobil Approach

We believe that the world's energy needs will be met through consistent investment strategies that are not driven by periodic swings in commodity prices. Our capital investments over the period 1995 through 2004 averaged $14 billion a year, although our annual earnings ranged from $8 billion to $25 billion over that period.

A focus on operational excellence

We apply the same rigor to our operations as we apply to our investments, via a wide range of proven management systems, including:

- **Standards of Business Conduct:** These 16 foundation policies and related procedures form the framework by which we operate around the globe – providing employees with principles for managing compliance with company standards.

- **Financial Controls:** Sound financial control is fundamental to our business model. Authority to approve business arrangements on behalf of our company is clearly assigned and delegated. Our System of Management Control (SMC) defines the principles, concepts and standards, and our Control Integrity Management System (CIMS) provides common processes and tools for compliance with the SMC.

- **Project execution and appraisal:** Our disciplined approach continues from concept through start-up and ongoing operations. All projects are rigorously appraised after completion, and learnings are incorporated into future planning. These processes have earned ExxonMobil a reputation for excellence in project management and distinguish us from the competition. For example, in Africa and the Gulf of Mexico, ExxonMobil-operated projects have consistently started up on or ahead of schedule.

- **Operating Reliability:** Safely increasing plant reliability and availability while lowering total maintenance costs is the objective of our Reliability and Maintenance Management System. This program has been applied to all our refineries worldwide and has reduced the amount of time that units are down for maintenance by 40% and reduced maintenance costs by 30%.

- **Safety, Health and Environment:** At the core of our approach to safety, health, security and environment management is our Operations Integrity Management System (OIMS). This system fully meets the requirements of the International Standards Organization (ISO) 14001 benchmark and is used at every ExxonMobil facility. It is a disciplined management framework that enables us to track experiences, measure progress, plan future improvements and ensure management accountability. OIMS covers the collection and reporting of emissions data, including greenhouse gas emissions for all facilities.

Fig. 22

OIMS' 11 Elements

2004 OIMS assessment by Lloyd's

"It is the opinion of Lloyd's Register Quality Assurance that the environmental management components of ExxonMobil's Operations Integrity Management System are consistent with the intent and meet the requirements of the ISO 14001 Environmental Management Systems Standard."

"Deployment of the Operations Integrity Management System has contributed toward the overall improvement in the Corporation's environmental performance. At the locations visited, individuals at all levels demonstrated a high degree of personal commitment to OIMS implementation and environmental care. The integration of Environmental Business Plans into the annual planning cycle has strengthened the process for continual improvement of the Corporation's environmental performance."

- **Energy Efficiency:** As a major consumer of energy, energy efficiency is important to us. Our Global Energy Management System (GEMS), developed in the late 1990s, uses international best practices and benchmarking techniques to identify energy efficiency opportunities at all our facilities and promote continuous improvement. In 2004, we achieved record energy efficiency performance across our worldwide refining and chemicals businesses, improving by more than 3% over 2003. In fact, our rate of improvement in refining is significantly better than the historical industry average.

- **Environmental Business Planning:** Continuous improvement of environmental performance is the objective of our Environmental Business Planning (EBP) process, which integrates environmental improvement activities into annual operating plans at each of our facilities and businesses. This process includes assessment of potential regulatory changes affecting environmental aspects of our operations and systematic management of any consequent business impacts.

The management systems that underpin our business enable us to consistently deliver superior results in terms of financial, safety and environmental performance, while playing our part in meeting the world's growing energy needs.

Summary

Summary

- Energy is vital to economic growth and progress.
- Global energy demand is expected to grow by almost 50% by 2030, driven mainly by rapidly growing economies in the developing world.
- Fossil fuels will remain predominant, with a growing role for natural gas.
- Greenhouse gas emissions will rise substantially, particularly as developing economies grow.
- ExxonMobil recognizes that the risk from climate change requires action, and we are taking action both to address our operational emissions and to promote more efficient use of our products.
- Policies to address climate change need to consider consequences not only for environmental risks but also for social and economic development, especially in developing countries.
- More widespread use now of existing efficient technologies in industrialized and developing countries offers significant potential to reduce greenhouse gas emissions growth.
- Over the next 25 years, technologies that enable expanded energy supplies, along with those that moderate energy demand via improved energy efficiency, will be critical to meeting the world's growing need for energy while managing greenhouse gas emissions.
- New energy sources, while they hold promise, require substantial technological advances to enable them to compete for a significant share of global energy supply – and the vast scale of the global energy business means that penetration of new technologies on a meaningful, global scale will take decades.
- Fundamental research is necessary to identify and develop viable technologies for the long term that allow energy demand to be met while dramatically reducing greenhouse gas emissions.
- Uncertainties about future climate-related policies will create issues for investors in global energy provision. However, we believe that ExxonMobil's well-proven, disciplined approach to investment and operational risk positions the company well to successfully manage this uncertainty, maintain our position as the technology leader in our industry and take advantage of attractive business opportunities that may emerge.

References

1. World Bank, World Development Indicators, 2004

2. International Energy Agency (IEA), World Energy Outlook, 2004

3. EPA Fuel Economy Data: www.fueleconomy.gov

4. IEA, World Energy Outlook, 2005

5. Battelle Memorial Institute. 2001. A Global Energy Technology Strategy Project Addressing Climate Change: An Initial Report on International Public-Private Collaboration. Joint Global Change Research Institute, College Park, MD.

6. P. Bernstein, S. Tuladhar, and W. D. Montgomery, "Potential for Reducing Carbon Emissions from Non-Annex B Countries through Changes in Technology", forthcoming in Energy Economics

7. http://exxonmobil.com/corporate/Citizenship/Corp_citizenship_enviro_publications.asp

8. Carbon Dioxide Information Analysis Center: Trends Online: A Compendium of Data on Global Change. Oak Ridge National Laboratory, U. S. Department of Energy, Oak Ridge TN. See http://cdiac.esd.ornl.gov/trends/trends.htm

9. Strategic Plan for the U.S. Climate Change Science Program, (U.S. Climate Change Science Program: Washington, DC, 2003)

10. Moberg, A., Sonechkin, D. M., Holmgren, K., Datsenko, N. M., and Karlen, W.: 2005, 'Highly variable Northern Hemisphere temperatures reconstructed from low- and high-resolution proxy data', Nature 433, 613-617; and Zachos, J., Pagani, M., Sloan, L., Thomas, E., and Billups, K.: 2001, 'Trends, rhythms, and aberrations in global climate 65 Ma to present', Science 292, 686-693.

11. Emission Scenarios, Intergovernmental Panel on Climate Change (Cambridge University Press, Cambridge, UK, 2000)

12. Climate Change 2001: The Scientific Basis, Intergovernmental Panel on Climate Change (Cambridge University Press, Cambridge, UK, 2001)

13. Climate Change Science: an Analysis of Some Key Questions, Committee on the Science of Climate Change, National Research Council, (National Academy Press: Washington, DC, 2001)

14. ExxonMobil Corporate Citizenship Report, 2001

15. EUCAR (European Council for Automotive R&D) predictions

16. http://gcep.stanford.edu/news/pressreleases.html

17. IPIECA Petroleum Industry GHG Reporting Guidelines, International Petroleum Industry Environmental Conservation Association, London, UK, December 2003 (www.ipieca.org: see Climate Change Publications)

18. API Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry, American Petroleum Industry Institute, Washington, DC, April 2001 (http://ghg.api.org)

19. Austin, D., and Sauer, A., Changing Oil; Emerging Environmental Risks and Shareholder Value in the Oil & Gas Industry, World Resources Institute, Washington, DC, 2002.

20. Carbon Dioxide Capture and Storage, Intergovernmental Panel on Climate Change (Cambridge University Press, Cambridge, UK, 2005)

21. Herzog, H., Eliasson, B., and Kaarstad, O.: 2000, 'Capturing Greenhouse Gases', Scientific American 72-79.

22. The Hydrogen Economy: Opportunities, Costs, Barriers and R&D Needs, The National Academies Press, 2004

23. General Motors/Argonne National Laboratory: Well-to-Wheel Study, June 2001; General Motors/LBST: Well-to-Wheel Study, September 2002; Concawe/EUCAR, EU Joint Research Centre, December 2003

24. Transport Fuels for the Future, CONCAWE presentation to the Inland Transport Committee Round Table, Geneva, February 2002

25. Biofuels for Transport – An International Perspective, International Energy Agency, 2004

26. Global Trends, 2015: A Dialogue about the Future with Non-government Experts, National Intelligence Council, 2000

27. The Energy Balance of Corn Ethanol: An Update, U.S. Department of Agriculture,Office of the Chief Economist, Office of Energy Policy and New Uses, Agricultural Economic Report No. 813

28. Well-to-Wheel Analysis of Future Automotive Fuels and Powertrains in the European Context, CONCAWE, EUCAR, EC Joint Research Commission, 2005

29. CO_2 Emissions Control and Mitigation, Technical Business Analysis, SFA Pacific, Inc. 2001

30. Ibid

31. Technology Roadmap for Generation IV Nuclear Energy Systems, U.S. Department of Energy, 2002

32. Well-to-Wheel Analysis of Future Automotive Fuels and Powertrains in the European Context, CONCAWE, EUCAR, EC Joint Research Commission, 2005. European Climate Change Program – Long Report, 2001

ExxonMobil

5959 Las Colinas Boulevard • Irving, Texas 75039-2298
Internet Web site: http://www.exxonmobil.com
February 2006
Printed entirely on recycled paper
SP-116

2006 letter from the Royal Society to ExxonMobil and Exxon's reply

THE ROYAL SOCIETY

Nick Thomas
Director, Corporate Affairs
Esso UK Limited
UK Public Affairs
ExxonMobil House, Mailpoint 8
Ermyn Bay
Leatherhead
Surrey
KT22 8UX

6–9 Carlton House Terrace
London SW1Y 5AG
tel +44 020 7451 2516
fax +44 020 7451 2615
mob +44 07811 320346
www.royalsoc.ac.uk

4 September 2006
Our ref: BW/NT/CC

Dear Nick

Thank-you for your recent letter and accompanying copies of the 2005 ExxonMobil 'Corporate Citizenship Report' and the 'UK and Ireland Corporate Citizenship' brochure. I have read both with interest, but I am writing to express my disappointment at the inaccurate and misleading view of the science of climate change that these documents present.

In particular, I was very surprised to read the following passage from the section on Environmental performance under the sub-heading of 'Uncertainty and risk' (p.23) in the 'Corporate Citizenship Report':

"While assessments such as those of the IPCC have expressed growing confidence that recent warming can be attributed to increases in greenhouse gases, these conclusions rely on expert judgment rather than objective, reproducible statistical methods. Taken together, gaps in the scientific basis for theoretical climate models and the interplay of significant natural variability make it very difficult to determine objectively the extent to which recent climate changes might be the result of human actions."

These statements also appear, of course, in the ExxonMobil document on 'Tomorrow's Energy', which was published in February. As I mentioned during our meeting in July, these statements are very misleading. The "expert judgment" of the Intergovernmental Panel on Climate Change was actually based on objective and quantitative analyses and methods, including advanced statistical appraisals, which carefully accounted for the interplay of natural variability, and which have been independently reproduced.

Furthermore, these statements in your documents are not consistent with the scientific literature that has been published on this issue. For instance, Chapter 12 of the contribution of IPCC working group 1 to the Third Assessment Report provided an overview of scientific papers relating to the 'Detection of climate change and attribution of causes' that had been published up to the end of 2000. The chapter concluded: "In the light of new evidence and taking into account the remaining uncertainties, most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations". The chapter gives a detailed overview of the evidence, citing 167 references, and points out that "The warming over the last 50 years due to anthropogenic greenhouse gases can be identified despite uncertainties in forcing due to anthropogenic sulphate aerosol and natural factors (volcanoes and solar irradiance)".

What is even more surprising about your documents' lack of consistency with the IPCC's assessment is that one of ExxonMobil's employees, Haroon Kheshgi, was one of the contributing authors on Chapter 12.

Since the publication of the IPCC Third Assessment Report in 2001, many other papers have been published which record new evidence about the causes of climate change. For instance, a major review article by the International Ad Hoc Detection and Attribution Group ('Detecting and attributing external influences on the climate system: a review of recent advances', published in the 1 May 2005 issue of the *Journal of Climate* – copy enclosed) concluded that "the recent research supports and strengthens the IPCC Third Assessment Report conclusion that 'most of the global warming over the past 50 years is likely due to the increase in greenhouse gases'". This review paper cites 147 references.

The IPCC's conclusions have been endorsed by the world's other leading scientific organisations. For example, the science academies of the G8 nations plus Brazil, China and India, in June 2005 published a joint statement on 'Global response to climate change'. This statement pointed out that "it is likely that most of the warming in recent decades can be attributed to human activities".

It is very disappointing that the ExxonMobil 2005 Corporate Citizenship Report, like 'Tomorrow's Energy', leaves readers with such an inaccurate and misleading impression of the evidence on the causes of climate change that is documented in the scientific literature. It is very difficult to reconcile the misrepresentations of climate change science in these documents with ExxonMobil's claim to be an industry leader.

At our meeting in July, I also told you of my concerns about the support that ExxonMobil has been giving to organisations that have been misinforming the public about the science of climate change. You indicated that ExxonMobil would not be providing any further funding to these organisations. I would be grateful if you could let me know when ExxonMobil plans to carry out this pledge, and if you could provide me with a list of which organisations will no longer be receiving funding.

I have carried out an *ad hoc* survey on the websites of organisations that are listed in the ExxonMobil 2005 Worldwide Giving Report for 'public information and policy research', which is published on your website. Of those organisations whose websites feature information about climate change, I found that 25 offered views that are consistent with the scientific literature. However, some 39 organisations were featuring information on their websites that misrepresented the science of climate change, by outright denial of the evidence that greenhouse gases are driving climate change, or by overstating the amount and significance of uncertainty in knowledge, or by conveying a misleading impression of the potential impacts of anthropogenic climate change. My analysis indicates that ExxonMobil last year provided more than $2.9 million to organisations in the United States which misinformed the public about climate change through their websites.

As you know, the Worldwide Giving Report only lists organisations in the United States which have received support from ExxonMobil. I would be grateful if you could let me know which organisations in the UK and other European countries have been receiving funding from ExxonMobil so that I can work out which of these have been similarly providing inaccurate and misleading information to the public.

I appreciate that I have raised some substantial issues in this letter, but I would be grateful to receive a prompt response from you – I have shared the contents of your documents with some climate researchers who are Fellows of the Royal Society and it would be useful to update them about whether ExxonMobil will be continuing to express views that are inconsistent with the findings of their work.

Yours sincerely

Bob Ward

Bob Ward
Senior Manager, Policy Communication
email bob.ward@royalsoc.ac.uk

Exxon Mobil Corporation
5959 Las Colinas Boulevard
Irving, Texas 75039-2298

Kenneth P. Cohen
Vice President
Public Affairs

ExxonMobil

September 25, 2006

Lord Rees of Ludlow Kt PRS
President
The Royal Society
6-9 Carlton House Terrace
London SW1Y 5AG

Dear Lord Rees:

Recent actions and public statements by one or more representatives of the Royal Society have incorrectly and unfairly described our company and our approach to climate change.

The issues relating to anthropogenic greenhouse gas emissions, energy use and climate change are complex and varying points of view exist on how to address the difficult, long-term technological and policy challenges.

The use of fossil fuels is a major source of carbon dioxide emissions. Given the important role that fossil fuels play in providing energy for the global economy, the issues of global economic development, future energy supply, and climate change are closely linked. In light of the interests that governments, our shareholders and customers, and the public at large have in these issues, we recently published the enclosed report entitled "*Tomorrow's Energy: A Perspective on Energy Trends, Greenhouse Gas Emissions and Future Energy Options*."

Section 2 of that report covers the topic of global climate change. This section briefly reviews what we know about the science of global climate change, including observations of the world's warming since the mid-1800s and a 30 percent increase in the atmospheric concentration of carbon dioxide and a doubling of methane levels. Our report states:

> We recognize that the accumulation of greenhouse gases in the Earth's atmosphere poses risks that may prove significant for society and ecosystems....Human activities have contributed to these increased concentrations [of greenhouse gases], mainly through the combustion of fossil fuels for energy use; land use changes (especially deforestation); and agricultural, animal husbandry and waste-disposal practices....Even with many scientific uncertainties, the risk that greenhouse gas emissions may have serious impacts justifies taking action.

ExxonMobil has undertaken climate change research for 25 years and our work has produced more than 40 papers in peer-reviewed literature (as listed on our web site: ExxonMobil.com). Our scientists serve on the United Nations Intergovernmental Panel on Climate Change (IPCC) and numerous related scientific bodies. In addition, we have conducted and supported scientific, economic and technological research on climate change for more than two decades. ExxonMobil has supported major projects at such institutions as the Massachusetts Institute of Technology, Stanford University, the Australian Bureau of Agricultural Resource Economics, Batelle Pacific Northwest Laboratory, Princeton University, Charles River Associates, the Hadley Centre for Climate Prediction, the International Energy Agency Greenhouse Gas R & D Programme, Yale University, The University of Texas, Carnegie Mellon University, and the Lamont Doherty Earth Observatory at Columbia University.

ExxonMobil is taking action to address global climate change, including among others:

- *Reporting.* ExxonMobil is committed to consistent, comprehensive annual reporting of our greenhouse gas emissions, which we began in 1998 with respect to our own operations and have since expanded to include our equity interests in operations in which we share ownership. ExxonMobil encouraged and supported the development of cost-effective, reliable, industry endorsed methods to measure and report greenhouse gas emissions from the petroleum industry (through the American Petroleum Institute and International Petroleum Industry Environmental Conservation Association). We also support the enactment of federal legislation to mandate the reporting of annual greenhouse gas inventories to the U. S. Department of Energy.

- *Global Climate Energy Project at Stanford University.* In an effort to apply the combined resources of industry and academia to the challenge of identifying fundamental new leads for innovative technologies that meet growing energy demand while dramatically reducing greenhouse gas emissions, ExxonMobil, along with Toyota, General Electric and Schlumberger, launched the $225 million Global Climate and Energy Project (GCEP) at Stanford University in December 2002. GCEP is the largest privately-funded, long term research program of its type in the world, with a charge to accelerate the development of commercially viable energy technologies that can lower greenhouse gas emissions on a worldwide scale. Its stated mission is "to conduct fundamental research on technologies that will permit the development of global energy systems with significantly lower greenhouse gas emissions." GCEP's current technology focus is on hydrogen production, storage and use; biomass and solar energy; carbon dioxide capture and storage; and advanced transportation and coal technologies. I have also enclosed a copy of the latest report of the important work being done by GCEP. A full list of ongoing projects is available on the GCEP web site at http://gcep.stanford.edu. A symposium was held this month to share progress in all these areas with the wider scientific community.

- *Advanced Vehicle Technology Research.* ExxonMobil is undertaking joint research on advanced vehicle technologies with Toyota and Caterpillar, to develop high efficiency, low-emission gasoline and diesel fuel engine systems.

- *Mitigating Greenhouse Gas Emissions Through Efficiency Systems and Best Practices.* ExxonMobil has reduced emissions in our own operations through improved efficiencies that have resulted from our Global Energy Management System (GEMS); reduced flaring of natural gas at production sites; and investing to expand cogeneration capacity at our refineries (at a cost of $1 billion in 2004 - 2005). These and other actions implemented since 1999 enabled our company in 2005 to avoid 11 million metric tons of greenhouse gas emissions, or the equivalent of taking about 2 million cars off the road. We are working now to identify and implement additional measures to more than double these reductions in the near future.

At ExxonMobil, we believe that good governance is based on good ideas - and that good ideas are based on a respect for facts, rigor in thinking, rationality in debate and civility in discourse. As the largest non-government petroleum and petrochemicals company, we seek to play a positive role in the on-going dialogue about the future of energy - one which is grounded in fact, focused on the long term and intent on finding viable solutions. Selecting appropriate policies that balance economic growth, human development and the risks of climate change is a daunting task. Managing those risks will require sequential, ongoing actions and policy decisions over many decades that will be informed by what we know and what we do not know at each period. Scientific and technical research should play a critical role in the debate by forthrightly addressing and improving our understanding of the well-known scientific and technical uncertainties inherent in climate change.

The Royal Society should welcome the diversity of opinions on all scientific issues. Taking the position that any person or organization that disagrees with the Royal Society on an important scientific issue should be publicly vilified is surely counterproductive for the development of scientific theory, ignores freedom of expression and is hardly consistent with the Society's stated objective of promoting excellence in science.

Lord Rees, when you took over as Chairman you said that the Royal Society's work should lead to a better quality of life and an increase in prosperity. Our own objective, as it relates to climate change, is to seek solutions that protect the environment but do not threaten the aspirations of the billions of people who desire and deserve a better quality of life. Is that not a worthwhile road to be on?

We have a role to play in the policy discussions on these subjects. It is disappointing that representatives of the Royal Society find it appropriate to intentionally misstate our actions and positions relating to these important topics.

Sincerely,

Enclosures

CHAPTER SEVEN

Deception Never Sleeps
2007—2017

Following the Royal Society's 2006 letter, Exxon seemed to agree to stop funding some denier groups. In their 2007 *Corporate Citizenship Report*, **Document 31**, the company pledged, "In 2008, we will discontinue contributions to several public policy research groups whose position on climate change could divert attention from the important discussion on how the world will secure the energy required for economic growth in an environmentally responsible manner." In 2015, Exxon again claimed in a statement to The Guardian that they do not fund climate deniers. Despite this pledge, Exxon continued to support scientists and front groups specifically to promote debunked theories for global warming.

In perhaps the most notorious example, Exxon and other industry giants provided $1.25 million to climate denier Dr. Wei-Hock Soon's research from 2008 through at least 2015. As a series of emails and receipts from Exxon and the Harvard-Smithsonian Center for Astrophysics on behalf of Dr. Soon, **Document 32**, show, Exxon's support for Dr. Soon was directed towards his research into solar disturbances as an alternate theory for global warming—notably, one of the very theories previously debunked in the 1996 GCC primer. Soon was far from their only beneficiary. An accounting by the Union of Concerned Scientists, **Document 33**, reveals that between 1999 and 2017, Exxon gave at least $36 million to 69 organizations that deny, undermine the science, misinform, and obstruct climate action. Over $13 million was given after their 2007 pledge.

"...we have no immediate plans to move to a net-zero emissions portfolio over our investment horizon of 10—20 years"

Shell, 2016

Even today, deception is at the core of the oil and gas industry's climate positions. While most companies publicly support the Paris Agreement, they are simultaneously making investment and business decisions that if realized, will ensure the climate catastrophe that their scientists predicted 40 years ago. Exxon's 2019 Energy Outlook touts to investors a 25% increase in global oil and gas production by 2035, which would be game-over for the climate and is certainly not in line with the Paris Agreement.

In 2012, ConocoPhillips released a Sustainable Development report, **Document 34**, in which they declared developing renewable energy to be a focus of their work, in line with their position on climate change. But their 10-K filing with the US Securities and Exchange Commission from the same year, **Document 35**, states "As an independent E&P company, we are solely focused on our core business of exploring for, developing and producing crude oil and natural gas globally."

In 2016, Shell released a report on pathways to net-zero emissions, *A Better Life with a Healthy Planet*, **Document 36**, accompanied by a large media and advertising plan to push this new narrative. However, a small disclaimer inside the report lays bare the fraudulent nature of the claim: "While we seek to enhance our operations' average energy intensity through both the development of new projects and divestments, we have no immediate plans to move to a net-zero emissions portfolio over our investment horizon of 10—20 years."

Beginning in the late 1980's and continuing to this day, the oil and gas industry's campaign of climate denial and deception has been extraordinarily successful, blocking climate action in the U.S. and thus the world, while even now fostering the illusion that the industry is sincere in its support for modest steps like the Paris Agreement.

But they are not. As they continue to expand production capacity and foment global demand, it is difficult to imagine that the oil and gas majors are now, or will ever be, truthful actors in the fight for climate safety – a fight upon which the fate of humanity quite literally depends

2007 ExxonMobil report, *Corporate Citizenship Report*

ExxonMobil

Taking on the world's toughest energy challenges.™

2007 Corporate Citizenship Report

table of contents

LRQA Assurance Summary Statement. Lloyd's Register Quality Assurance, Inc. (LRQA) believes the ExxonMobil reporting system is effective in delivering safety, health, and environmental indicators, which are useful for assessing corporate performance and for reporting information consistent with the IPIECA/API *Guidance*. For the full assurance statement, see the inside back cover.

about this report

This report was produced in accordance with the reporting guidelines and indicators of the International Petroleum Industry Environmental Conservation Association (IPIECA) and the American Petroleum Institute (API) *Oil and Gas Industry Guidance on Voluntary Sustainability Reporting* (April 2005). The majority of these indicators are also consistent with the indicators used by the Global Reporting Initiative (GRI) in the *Sustainability Reporting Guidelines* Version 3.0 (G3).

Our *2007 Corporate Citizenship Report* describes our efforts in a range of areas relating to the financial, environmental, and social performance of the Corporation. The report is intended for anyone interested in learning more about our corporate citizenship.

We address our corporate citizenship accomplishments, the challenges we face, and our future plans to meet these challenges. In addition to describing our approach to corporate citizenship, including our engagement activities and performance in the most material issues to our business operations, the report also provides an overview of our energy outlook to 2030, which shapes our corporate citizenship challenges. In this year's report, we are interpreting trends in our citizenship performance data in terms of our company operations. Additional information about our company, our operations, and our management systems can be found on our Web site (*exxonmobil.com*).

We value your feedback on this report and our performance in addressing financial, environmental, and social issues. Comments for improvement received for the *2006 Corporate Citizenship Report* were incorporated into this report. We solicited feedback through a variety of mechanisms, including our corporate reporting Web site (*exxonmobil.com/citizenship*), online surveys, business-reply cards, and interviews with opinion leaders from nongovernmental organizations (NGOs), academia, and financial institutions. Business for Social Responsibility (BSR), an advisory organization on corporate social responsibility of which we are a member, also provided a detailed review of our 2006 report.

For additional information and to provide comments, please contact:
Ms. Noa Gimelli
Corporate Citizenship
ExxonMobil
3225 Gallows Road
Fairfax, VA 22037
E-mail: noa.gimelli@exxonmobil.com

On the cover: The design represents the five material areas discussed within the report (see our materiality analysis on page 6).

Note: This report covers ExxonMobil and all of its corporate subsidiaries under the brands ExxonMobil, Exxon, Mobil, *and* Esso. *The report reviews our corporate citizenship performance as of December 31, 2007. Most environmental data are reported in metric units. Financial information is reported in U.S. dollars.*

handled by a Hotline Steering Committee, comprised of security, audit, law, and human resources personnel, and reported to the Audit Committee on a quarterly basis. We expect persons responding to employee questions, concerns, complaints, and suggestions to use discretion to maintain confidentiality and protect anonymity to the greatest extent possible. No action can be taken or threatened against any employee for asking questions, voicing concerns, or making complaints in conformance with company procedures.

priority issue

political involvement

ExxonMobil makes political contributions to candidate committees, political parties, associations, and other political organizations, where permitted by applicable laws and as authorized by the Board of Directors. According to our policy, ExxonMobil employees, including directors and officers, individually engaging in political activities are expected to do so as private citizens and not as company representatives. Personal, lawful, political decisions do not influence compensation, job security, or opportunities for advancement. Also, like many corporations, trade associations, labor unions, and special interest groups, ExxonMobil tracks proposed legislation.

Political Contributions. The Board of Directors regularly reviews political contributions made by ExxonMobil and our Canadian affiliate, Imperial Oil Limited. Where required by law, these contributions are reported to governing agencies. In 2006, ExxonMobil began posting information about our corporate political contributions on our Web site. In 2007, we started publishing an itemized list of political contributions made by the Corporation, which we update annually. We also posted our policy and guidelines for political activities on the Web site. Information about our contributions to political organizations at the national and state level in 2007 is available on our Web site (*exxonmobil.com/political*).

In the United States, ExxonMobil contributes to political candidates in certain states where applicable laws allow. Exxon Mobil Corporation contributed a total of $132,100 to legislative and gubernatorial candidates and caucuses in seven states in 2007.

Canada is the only other country where an ExxonMobil affiliate makes political contributions. Imperial Oil Limited, a majority-owned Canadian affiliate of Exxon Mobil Corporation, adheres to strict guidelines and legal limits when making political contributions to registered political parties. In Canada, contributions are published by the Chief Electoral Officer. Additional information is available on the Elections Canada Web site (*www.elections.ca*).

Political Lobbying and Advocacy. We engage with governments around the world to effectively advocate the company's position when necessary. Lobbying is highly regulated in the United States. ExxonMobil fully complies with regulations by reporting federal lobbying to the U.S. Congress in a semiannual lobbying disclosure report. In 2007, ExxonMobil incurred lobbying expenses—including direct and indirect lobbying expenses as well as salaries, benefits, and overhead costs such as building rental and utilities—totaling $16.9 million under the Internal Revenue Code 162(e) reporting definition. A complete list of federal issues lobbied by ExxonMobil in the United States in 2007 can be found online in our lobbying reports to Congress (search for "Exxon Mobil" as registrant on *sopr.senate.gov*).

In addition to corporate lobbying efforts, ExxonMobil has a grassroots advocacy program called the Citizen Action Team (CAT). Employees and retirees receive periodic e-mail communications from the CAT about important pending legislation and energy issues. CAT e-tools enable members to contact their elected officials to express their views on issues of concern to them. In 2007, 24 CAT messages were sent to employees and retirees, and more than 20,000 messages were sent to elected officials using CAT e-tools.

a closer look

ExxonMobil Political Action Committee

The ExxonMobil Political Action Committee (PAC) restricts solicitation for voluntary contributions to eligible executive retirees and senior-level managers and professionals. PAC funds are designated for candidates who favor the strengthening of the free enterprise system and hold views consistent with the best interests of Exxon Mobil Corporation. In 2007, the first year of the 2007 to 2008 election cycle, the ExxonMobil PAC recorded total receipts of $450,625 from individual participants, and disbursed a total of $296,129, mostly to federal candidates. In 2007, according to *CQMoneyline.com*, the ExxonMobil PAC ranked approximately 225th in disbursements in their listing of the top 500 PACs. Reports on how PAC funds are used can be viewed on the Federal Election Commission Web site (*www.fec.gov*).

public policy research contributions

ExxonMobil promotes discussion on issues of direct relevance to the company. We contribute to a wide range of academic and policy organizations that research and promote dialogue on significant domestic and foreign policy issues, including the Brookings Institution, the American Enterprise Institute, the Council on Foreign Relations, the Center for Strategic and International Studies, and Resources for the Future. In 2008, we will discontinue contributions to several public policy research groups whose position on climate change could divert attention from the important discussion on how the world will secure the energy required for economic growth in an environmentally responsible manner. Additional information about our U.S. contributions can be found on our Web site (*exxonmobil.com/contributions*).

2010 emails, proposals and payments documenting Exxon's grants to Dr. Wei-Hock Soon

Margaret Carroll <mcarroll@cfa.harvard.edu>

From:	Amanda Preston <apreston@cfa.harvard.edu>
Sent:	Thursday, January 21, 2010 1:55 PM
To:	Karen McLaine <kmiminos@cfa.harvard.edu>; Marci Miller <mmiller@cfa.harvard.edu>; Lynne Nee <lnee@cfa.harvard.edu>; Nayla Rathle <nrathle@cfa.harvard.edu>
Cc:	Nancy Brickhouse <nbrickhouse@cfa.harvard.edu>; Robert Palleschi <rpalleschi@cfa.harvard.edu>; Margaret Carroll <mcarroll@cfa.harvard.edu>
Subject:	2009 ExxonMobil Gift of $76,106
Attachments:	2009-12-31_3011 ExxonMobil_$76106 00_00001.pdf; Re: Unrestricted gift to Smithsonian Astrophysical Observatory

Dear Karen, Marci, Lynne, and Nayla:

I received an email from Judith Batty at ExxonMobil about the $76,106 contribution for Dr. Willie Soon's research. I have attached the 3011 Transmittal Form from 4/2/09. You will see that $22,181.00 was allocated to task 40301770IS50AP. This amount is equivalent to the indirect costs that would have been charged if the gift had been a grant. On instructions from Charles Alcock, I asked ExxonMobil to allow us to reclassify that amount as an unrestricted contribution. Judith Batty assented to our request (see attached email).

I have the following questions and comments:

Charles Alcock agrees that this money should be used to defray any shortfall in development funding.

Do we move it from 301770 to 101600? Or to the DDF?

How does it get moved?

Do I need to file an amended 3011 or does a journal entry take care of it?

Please let me know your thoughts and any decisions you make about this.

Thank you,

Amanda

Amanda Preston
Advancement and External Affairs Officer Harvard-Smithsonian Center for Astrophysics 60 Garden Street, MS-45 Cambridge, MA 02138-1516

Voice: 617-495-7321
Fax: 617-495-7105
Blackberry: 617-285-4829
Cell: Exemption 6 [redacted]
Email: apreston@cfa.harvard.edu

Margaret Carroll <mcarroll@cfa.harvard.edu>

From:	[redacted]
Sent:	Monday, January 11, 2010 2:50 PM
To:	Amanda Preston <apreston@cfa.harvard.edu>
Subject:	Re: Unrestricted gift to Smithsonian Astrophysical Observatory

Hi Amanda, I have discussed lifting the restriction on the portion of our donation designated for indirect costs, and you can consider the restriction lifted. Judith

Judith N. Batty
Senior Director, Federal Relations
Exxon Mobil Corporation
2000 K Street NW, Suite 710
Washington, DC 20006
Telephone: [redacted] Fax: [redacted] [redacted]

apreston@cfa.harvard.edu

12/29/2009
12:44 PM

To
<[redacted]>

cc

Subject
Unrestricted gift to Smithsonian Astrophysical Observatory

Dear Judith,

This is to follow up on our telephone conversation in early December. I hope you received my letter highlighting our current research areas. I would very much like to learn if there are any avenues of support that we might explore. I expect to be in Washington in the last week of January. Perhaps we could meet then. I will call you in the next week or so.

I write also about another matter. You may recall that we discussed utilizing the portion of ExxonMobil's March contribution of $76,106 that was designated for indirect costs instead for unrestricted purposes.

You thought you would have a chance to discuss this with others in your office and get back to me. I'm hoping you'll have some thoughts on that soon.

With best wishes for the New Year,

Amanda

Amanda Preston
Advancement and External Affairs Officer Harvard-Smithsonian Center for Astrophysics 60 Garden Street, MS-45 Cambridge, MA 02138-1516

Voice: 617-495-7321
Fax: 617-495-7105
Blackberry: 617-285-4829
Cell: Exemption 6 [redacted]
Email: apreston@cfa.harvard.edu

2009-400000-00016

SMITHSONIAN INSTITUTION

Tracking # 200X-XX0000-00016

TRANSMITTAL FORM FOR GIFTS & PROMISES (PLEDGES) TO GIVE

[Note: All payments from external sources deposited to 802/803 grant and contract funds must be routed on a CRV through OSP.]

DATE OF GIFT	CASH	CHECK	CREDIT CARD		OTHER		
3-17-09	$	$76,106.00	$	DISCOVER / VISA/MASTERCARD / AMERICAN EXPRESS	$		PLEDGES / WIRES / STOCK (PROCEEDS) / GIFT IN KIND
		#2500407776	CREDIT CARD MERCHANT #				

GIFT CHARTFIELD: SPLIT FUNDED

Fund	Budget Ref	Designated Code	Dept. ID		Account	Class	Program	Project ID	Activity ID	Amount
					Unrestricted Designated(5804)					
801	0000	301770	404S50		Permanently Restricted (5803)	0302	4210	40301770IS5000	DEFAULT	$53,925.00
				x	Temporarily Restricted (5802)					
801	0000	301770	404S50		Unrestricted (5801)	0302	8700	40301770IS50AP	DEFAULT	$22,181.00
					Endowment Pig Pymts (1315)					

QUID PRO QUO CHARTFIELD (Complete ONLY for Non Tax Deductible Benefits associated with a GIFT)

Fund	Budget Ref	Designated Code	Dept. ID		Account	Class	Program	Project ID	Activity ID	Amount

DONOR INFORMATION

DONOR NAME	SI UNIT / PROJECT CONTACT NAME AND TELEPHONE NUMBER
EXXON MOBIL CORPORATION	SAO

MAILING ADDRESS

HOME

x WORK P.O. BOX 2518, HOUSTON, TEXAS 77252-2519

PURPOSE/PROJECT TO SUPPORT: UNDERSTANDING SOLAR VARIABILITY AND CLIMATE CHANGE", DR. WILLIE SOON, PI

NAME OF PERSON WHO RECEIVED FUNDS AMANDA PRESTON

DATE SI RECEIVED GIFT/PROMISE 4/2/09

SECURITIES INFORMATION

STOCK/BOND NAME

UNIT PRICE ON DATE SI RECEIVED OWNERSHIP	NUMBER OF SHARES / BONDS	TOTAL MEAN VALUE OF GIFT	DATE SI RECEIVED OWNERSHIP
$ (Mean Value per Share of Stock /Face Value of Bond)		$ (Number X Mean per Share for Stocks/Face for Bonds)	

GIFT IN KIND INFORMATION

NEW GIK?		DESCRIPTION
PAYMENT ON GIK?		

PLEDGE AND PAYMENT SCHEDULE INFORMATION

		PAYMENT SCHEDULE		
NEW PLEDGE?		SCHEDULED PAYMENT	PAYMENT AMOUNT	DISCOUNT AMOUNT
PLEDGE PYMT?				

Remarks:

4/7/09

PLEASE NOTE IN REMARKS IF PLEDGE IS CONDITIONAL. SUBMIT 3011 TO NOTIFY IF CONDITION IS NOT MET

PREPARED BY	TELEPHONE NUMBER	UNIT AND MRC NUMBER	DATE PREPARED
Amanda Preston [signature]	617-496-7321	80 Garden Street, MS 43 Cambridge, MA 02138	4-3/09

Comments

PLEASE NOTE IN COMMENTS IF SOFT CREDIT SHOULD BE APPLIED: IF SO, LIST TO WHAT OTHER DONOR RECORDS

REQUIRED DONOR DOCUMENTATION ATTACHED: YES / NO

SI-3011 (06/07)

Exxon Mobil Corporation
Washington Office
2000 K Street, N.W.
Suite 710
Washington, DC 20006
202 862 0200 Telephone
202 862 0267 Facsimile

Mark D. Boudreaux
Senior Director, Federal Relations

ExxonMobil

March 30, 2009

Ms. Amanda Preston
Smithsonian Astrophysical Observatory
60 Garden Street, MS-45
Cambridge, MA 02138-1516

Dear Ms. Preston:

ExxonMobil is pleased to provide the enclosed contribution to the Smithsonian Astrophysical Observatory in the amount of $76,106.00 for General Support.

We ask that you please complete the enclosed form and return it to the Community Relations Group at the address indicated.

We are pleased to support the Smithsonian Astrophysical Observatory and wish you continued success.

Sincerely,

Mark Boudreaux

Enclosure

this is the request from 12/08.

Smithsonian Astrophysical Observatory

c/o Amanda Preston
60 Garden Street
MS-45
Cambridge, MA 02138-1516

Phone: 617-495-7321
Fax: 617-495-7105
E-mail:
apreston@cfa.harvard.edu

Request for Payment

To:

Attention: Mark Boudreaux
ExxonMobil Corporation
2000 K. Street, NW
Suite 710
Washington, DC 20006

Please make check payable to:
Smithsonian Astrophysical Observatory

Mail check to:
Amanda Preston
Advancement and External Affairs Officer
Smithsonian Astrophysical Observatory
60 Garden Street, MS 45
Cambridge, MA 02138-1516

December 2, 2008

Request for contribution to support Year Two of the research project: *"Understanding Solar Variability and Climate Change: Signals from Temperature Records of the United States"*, Dr. Willie Soon, Principal Investigator

Project Costs	
Salary and Benefits:	
Dr. Willie Soon (75 days)	$49,305
Administrator (1 day)	617
Secretarial (1.5 days)	953
Indirect Costs	21,876
Total Salary and Benefits:	$72,751
Other Costs:	
Travel	$2,000
Publications	1,050
Indirect Costs	305
Total Other Costs:	$3,355
Total All Costs:	$76,106

Thank you very much.

Questions: Please contact Amanda Preston, 617-495-7321, apreston@cfa.harvard.edu.

SMITHSONIAN INSTITUTION

Tracking # 2008 - 400000 – 00032

TRANSMITTAL FORM FOR GIFTS & PROMISES TO GIVE

DATE OF GIFT	CASH	CHECK	CREDIT CARD	DISCOVER / VISA/MC / AMEX	OTHER	PLEDGES / WIRES / LAST 4 DIGITS OF C.C. MERCHANT #	STOCK SALE / GIK
6-11-08	$	$76,106.00	$				

CHARTFIELDS: SPLIT FUNDED SEE BELOW

Fund	Budget Ref	Designated Code	Dept. ID	Account	Class	Program	Project ID	Activity ID
				Unrestricted Designated(5604) Permanently Restricted (5603) Temporarily Restricted (5602) Unrestricted (5601) Endowment Pledge Payments (1315)				

DONOR INFORMATION

DONOR NAME: EXXON MOBIL CORPORATION

SI UNIT / PROJECT CONTACT: SAO/Preston

MAILING ADDRESS

x HOME: P.O. BOX 2519, HOUSTON, TX 77252-2519

WORK:

PURPOSE/PROJECT: TO SUPPORT "UNDERSTANDING SOLAR VARIABILITY AND CLIMATE CHANGE". DR. WILLIE SOON, P.I.

NAME OF PERSON WHO RECEIVED FUNDS: AMANDA PRESTON

DATE SI RECEIVED GIFT/PROMISE: 7-1-08

SECURITIES INFORMATION

STOCK/BOND NAME:

DATE OF TRANSFER TO SI OWNERSHIP: | NUMBER OF SHARES / FACE VALUE OF BONDS: | UNIT PRICE:

GIFT IN KIND INFORMATION

NEW GIK? | DESCRIPTION

PAYMENT ON GIK?

PLEDGE AND PAYMENT SCHEDULE INFORMATION

NEW PLEDGE?

PAYMENT ON PLEDGE?

REMARKS:

NOTE IN REMARKS IF PLEDGE IS CONDITIONAL. SUBMIT 3011 TO NOTIFY IF CONDITION IS NOT MET

PAYMENT SCHEDULE

SCHEDULED PAYMENT	PAYMENT AMOUNT	DISCOUNT AMOUNT

PREPARED BY	TELEPHONE NUMBER	UNIT AND MRC NUMBER	DATE PREPARED
Amanda Preston	617-495-7321	Smithsonian Astrophysical Observatory 60 Garden Street, MS 45 Cambridge, MA 02138-1516	7-2-08

Comments: SPLIT GIFT AS FOLLOWS
$53,876 to:
501 0000 301770 404550 8302 4210
40301770IS5000 DEFAULT

$22,230 to:
501 0000 301770 404550 0302
5700 40301770IS50AP
DEFAULT

REQUIRED DONOR DOCUMENTATION ATTACHED: YES | NO

From the last gift from Mobil Exxon

SI-3011 (04/05) All payments from external sources deposited to 502/503 grant and contract funds must be approved by OSP.

SI-000007

EXXON MOBIL CORPORATION OR AN AFFILIATED COMPANY

CODE	OUR REFERENCE	DATE	YOUR REFERENCE	NET AMOUNT
PAY4	1900006183	03/09/09	78171	76,106.00

Payment made per agreement with ExxonMobil contracting entity.
REFER ANY INQUIRIES TO 1-800-833-1510 OR CHECK THE PAYMENT STATUS AT HTTP://PAYMENT-ADVICE.COM

* INCLUDE WITH EACH INQUIRY	PAYEE ID NUMBER	CHECK NUMBER	CHECK DATE	CHECK AMOUNT
	6357421	2500407776	03/17/09	76,106.00

EXXON MOBIL CORPORATION OR AN AFFILIATED COMPANY

62-20/311

P O BOX 2519
HOUSTON TX 77252-2519

CHECK NUMBER 2500407776

6357421

DATE 03/17/09

********$76,106.00*

PAY TO THE ORDER OF

SMITHSONIAN ASTROPHYSICAL
OBSERVATORY
60 GARDEN ST MS 45
CAMBRIDGE MA 02138-1516

VOID AFTER
SIX MONTHS

CITIBANK NA
NEW CASTLE, DE 19720 2405

Amanda Preston <apreston@cfa.harvard.edu>

From: Amanda Preston <apreston@cfa.harvard.edu>
Sent: Thursday, January 21, 2010 11:41 AM
To: [redacted]
Subject: Acknowledgment Form
Attachments: 2010-01-21_Exxon Mobil_Acknowledgement_00002.PDF

Dear Ms. Ceja:

Attached please find the signed Acknowledgment Form for ExxonMobil's contribution of $76 106.00 to the Smithsonian Astrophysical Observatory. I regret that this is so late coming to you. In actual fact, I was in discussions with Mr. Boudreaux and with Ms. Batty about this contribution until just last week and so we delayed this final acknowledgment until we were in agreement.

I hope you forgive our delay.

With best regards

Amanda Preston

Amanda Preston
Advancement and External Affairs Officer
Harvard-Smithsonian Center for Astrophysics
60 Garden Street, MS-45
Cambridge, MA 02138-1516

Voice: 617-495-7321
Fax: 617-495-7105
Blackberry: 617-285-4829
Cell: [redacted]
Email: apreston@cfa.harvard.edu

Facsimile

ExxonMobil

To **Ms. Rachel**

Re Acknowledgement Form

Fax 617-495-7105

Pages 2 pages + cover

From **Victoria Ceja**

Date January 15, 2010

Please have someone fill out the form attached and return via fax to my attention. Thank you.

Victoria Ceja
Exxon Mobil Corporation - Public Affairs
Corporate Citizenship & Community Investments
5959 Las Colinas Blvd.
Irving, TX 75039
Phone: [redacted]
Fax: [redacted]
[redacted]

EXXON MOBIL CORPORATION OR AN AFFILIATED COMPANY

CODE	OUR REFERENCE	DATE	YOUR REFERENCE	NET AMOUNT
PAY4	1900006183	03/09/09	78171	76,106.00

Payment made per agreement with ExxonMobil contracting entity.
REFER ANY INQUIRIES TO 1-800-833-1510 OR CHECK THE PAYMENT STATUS AT HTTP://PAYMENT-ADVICE.COM

* INCLUDE WITH EACH INQUIRY	PAYEE ID NUMBER	CHECK NUMBER	CHECK DATE	CHECK AMOUNT
	6357421	2500407776	03/17/09	76,106.00

EXXON MOBIL CORPORATION OR AN AFFILIATED COMPANY

62-20/311

P O BOX 2519
HOUSTON TX 77252-2519

CHECK NUMBER 2500407776

6357421

DATE 03/17/09

********$76,106.00*

PAY TO THE ORDER OF
SMITHSONIAN ASTROPHYSICAL OBSERVATORY
60 GARDEN ST MS 45
CAMBRIDGE MA 02138-1516

VOID AFTER SIX MONTHS

CITIBANK NA
NEW CASTLE, DE 19720 8409

[redacted]

SMITHSONIAN INSTITUTION

Tracking # 200X-XX0000-00016

TRANSMITTAL FORM FOR GIFTS & PROMISES (PLEDGES) TO GIVE

[Note: All payments from external sources deposited to 802/803 grant and contract funds must be routed on a CRV through OSP.]

DATE OF GIFT	CASH	CHECK	CREDIT CARD		DISCOVER VISA/MASTERCARD AMERICAN EXPRESS	OTHER		PLEDGES WIRES STOCK (PROCEEDS) GIFT IN KIND
3-17-09	$	$76,106.00 #2500407776	$ CREDIT CARD MERCHANT #			$		

GIFT CHARTFIELD: SPLIT FUNDED

Fund	Budget Ref	Designated Code	Dept. ID		Account	Class	Program	Project ID	Activity ID	Amount
					Unrestricted Designated(5604)					
801	0000	301770	404S50		Permanently Restricted (5603)	0302	4210	40301770IS5000	DEFAULT	$53,925.00
				X	Temporarily Restricted (5602)					
801	0000	301770	404S50		Unrestricted (5601)	0302	8700	40301770IS50AP	DEFAULT	$22,181.00
					Endowment Plg Paymts (1315)					

QUID PRO QUO CHARTFIELD (Complete ONLY for Non Tax Deductible Benefits associated with a GIFT)

Fund	Budget Ref	Designated Code	Dept. ID	Account	Class	Program	Project ID	Activity ID	Amount

DONOR INFORMATION

DONOR NAME	SI UNIT / PROJECT CONTACT NAME AND TELEPHONE NUMBER
EXXON MOBIL CORPORATION	SAO

MAILING ADDRESS:

	HOME
x	WORK P.O. BOX 2519, HOUSTON, TEXAS 77252-2519
	PURPOSE/PROJECT TO SUPPORT: UNDERSTANDING SOLAR VARIABILITY AND CLIMATE CHANGE", DR. WILLIE SOON, PI
	NAME OF PERSON WHO RECEIVED FUNDS AMANDA PRESTON — DATE SI RECEIVED GIFT/PROMISE 4/2/09

SECURITIES INFORMATION

STOCK/BOND NAME

UNIT PRICE ON DATE SI RECEIVED OWNERSHIP	NUMBER OF SHARES / BONDS	TOTAL MEAN VALUE OF GIFT	DATE SI RECEIVED OWNERSHIP
$ (Mean Value per Share of Stock /Face Value of Bond)		$ (Number X Mean per Share for Stocks/Face for Bonds)	

GIFT IN KIND INFORMATION

NEW GIK?		DESCRIPTION
PAYMENT ON GIK?		

PLEDGE AND PAYMENT SCHEDULE INFORMATION

		PAYMENT SCHEDULE		
NEW PLEDGE?		SCHEDULED PAYMENT	PAYMENT AMOUNT	DISCOUNT AMOUNT
PLEDGE PYMT?				
Remarks:				
PLEASE NOTE IN REMARKS IF PLEDGE IS CONDITIONAL. SUBMIT 3011 TO NOTIFY IF CONDITION IS NOT MET				

PREPARED BY	TELEPHONE NUMBER	UNIT AND MRC NUMBER	DATE PREPARED
Amanda Preston	617-495-7321	60 Garden Street, MS 45 Cambridge, MA 02138	4/3/09

Comments	REQUIRED DONOR DOCUMENTATION ATTACHED			
PLEASE NOTE IN COMMENTS IF SOFT CREDIT SHOULD BE APPLIED; IF SO, LIST TO WHAT OTHER DONOR RECORDS		YES		NO

SI-3011 (06/07)

SI-000012

Exxon Mobil Corporation
Washington Office
2000 K Street, N.W.
Suite 710
Washington, DC 20006
[redacted] Telephone
[redacted] Facsimile

Mark D. Boudreaux
Senior Director, Federal Relations

ExxonMobil

March 30, 2009

Ms. Amanda Preston
Smithsonian Astrophysical Observatory
60 Garden Street, MS-45
Cambridge, MA 02138-1516

Dear Ms. Preston:

ExxonMobil is pleased to provide the enclosed contribution to the Smithsonian Astrophysical Observatory in the amount of $76,106.00 for General Support.

We ask that you please complete the enclosed form and return it to the Community Relations Group at the address indicated.

We are pleased to support the Smithsonian Astrophysical Observatory and wish you continued success.

Sincerely,

Enclosure

Acknowledgement

Please return this completed form to Exxon Mobil Corporation, Community Relations Group, Public Affairs Department, Room 2423, 5959 Las Colinas Blvd., Irving, TX 75039-2298 or Fax: 972/444-1405.

200901293

Smithsonian Astrophysical Observatory
60 Garden Street, MS 45
Cambridge, MA 02138-1516

Organization Tax ID: 53-0206027

The 1993 Omnibus Budget Reconciliation Act imposes substantiation requirements for charitable contributions. In order to comply with the regulations, ExxonMobil requires each nonprofit organization receiving a grant of $250 or more to provide the following information. ***Acknowledgment must be provided within thirty days after receipt of ExxonMobil contribution***. Failure to respond may result in cancellation of support in the future.

1. Please indicate the date contribution was received: April 2, 2009

2. Please indicate the amount of the check and/or describe any property received: $76,106.00

3. Were any goods and/or services provided to ExxonMobil by your organization in return for this contribution? (meals, entertainment, gifts, etc.) Yes ____ No XX

   If yes, please provide a description and good faith estimate of the value.

   not applicable

Signature: Amanda Preston Date: January 21, 2010

Print Name: Amanda Preston Title: Advancement and External Affairs Officer

Harvard-Smithsonian Center for Astrophysics
60 Garden Street, Cambridge, MA 02138-1516 (617) 495-7000

December 3, 2009

Ms. Judith Batty, Esq.
Exxon Mobil Corporation
2000 K Street, NW, Suite 710.
Washington, DC 20006

Dear Judith:

Thank you very much for meeting with me by phone last week to discuss ExxonMobil's most recent contribution to the Observatory. I hope to hear from you soon that we can use the "indirect cost" portion of the gift for general operating support.

In view of the fact that you will no longer be funding Dr. Soon's research, this letter is a high-level overview of the research efforts pursued here at the Smithsonian Astrophysical Observatory. It would be very helpful to follow up this letter with a meeting to determine which areas of research might merit more discussion and exploration. I am in Washington frequently, and would be happy to visit your office at your convenience.

As you may know, the Smithsonian Astrophysical Observatory (SAO) is a research institute of the Smithsonian Institution headquartered in Cambridge, MA. Its affiliation with the Harvard College Observatory (HCO) is known worldwide as the Harvard-Smithsonian Center for Astrophysics (CfA). The Observatory's primary mission is to advance knowledge of the universe through research in astronomy and astrophysics and in related areas of fundamental physics and geophysics. The secondary mission is to be of service to the national and international astronomical communities, and to society in general, in areas associated with our primary mission. The Observatory has a strong record of achievement in developing and successfully implementing large, complex, and innovative observational and theoretical research projects. SAO also supports the curiosity-driven research carried out by individual researchers and small groups. Research in science education and outreach to many different publics round out our programs.

SAO uses its resources to attack fundamental questions in astronomy and astrophysics. These range from the mysteries of the formation and evolution of planets, stars, black holes, galaxies and larger scale structures in the Universe, to those surrounding the mysterious dark matter and dark energy pervading the Universe. Our own Sun provides a particularly rich laboratory for the study of both fundamental physics and the development of stars and solar systems.

SAO has helped to develop some of the world's most sophisticated astronomical instruments to probe the universe with high resolution at wavelengths across the electromagnetic spectrum. SAO developed and operates telescope facilities in Arizona, Hawaii, Massachusetts, and Chile. The Observatory plays leading roles in several NASA missions (including the currently orbiting Chandra X-ray Observatory, the Spitzer Space Telescope and Hinode (with the Japanese Space Agency), as well as missions organized by the European Space Agency. A widely recognized program that utilizes space-borne technologies to study our Earth has been operating at SAO for many years.

SAO is also a leading center for theoretical and computational astrophysics, utilizing complex numerical simulations calculated on thousands of parallel processors to model the formation of the early universe and the development of galaxies and planets. SAO's strong laboratory astrophysics program uses laboratory experiments to expand our understanding of physical processes and applies these results to processes throughout the Universe.

SAO's current research goals include:

a. To play a lead role in a "next-generation," ground-based optical/infrared telescope, the Giant Magellan Telescope;
b. To develop the next-generation x-ray technology necessary for the follow on missions to the Chandra X-ray Observatory;
c. To play a major role in multi-wavelength observations of star and planet formation, of the formation and evolution of galaxies, of the nature and physics of dark energy and dark matter, and of the "markers" of possibly habitable planets like Earth.
d. To strengthen the synergy between astronomical observatory and laboratory experiments conducted on the Earth to ensure that we are using the best atomic and molecular data to interpret astrophysical observations of the Universe and our own planet.

Enclosed please find the following materials:

- A brief fact sheet on SAO
- A copy of the Executive Summary of our science strategic plan
- Copies of two press releases on important discoveries from the past month

We would be delighted to host you and some of your colleagues at one of our facilities. Our telescope facilities in Arizona and Hawaii are fascinating and make for a wonderful hands-on introduction to the Observatory and to the big questions in contemporary astrophysics. So, too, a visit to our headquarters in Cambridge offers an intriguing glimpse into the engineering and technology development that underlie our observing capabilities.

Please do not hesitate to be in touch if you would like additional information or if we can do anything to arrange some behind-the-scenes visits. I will call you in a few weeks to follow up.

With best regards,

Amanda Preston
Advancement and External Affairs Officer

Enclosures

this is the request from 12/08.

Smithsonian Astrophysical Observatory

c/o Amanda Preston
60 Garden Street
MS-45
Cambridge, MA 02138-1516

Phone: 617-495-7321
Fax: 617-495-7105
E-mail:
apreston@cfa.harvard.edu

Request for Payment

To:

Attention: Mark Boudreaux
ExxonMobil Corporation
2000 K. Street, NW
Suite 710
Washington, DC 20006

Please make check payable to:
Smithsonian Astrophysical Observatory

Mail check to:
Amanda Preston
Advancement and External Affairs Officer
Smithsonian Astrophysical Observatory
60 Garden Street, MS 45
Cambridge, MA 02138-1516

December 2, 2008

Request for contribution to support Year Two of the research project: *"Understanding Solar Variability and Climate Change: Signals from Temperature Records of the United States"*, Dr. Willie Soon, Principal Investigator

Project Costs	
Salary and Benefits:	
Dr. Willie Soon (75 days)	$49,305
Administrator (1 day)	617
Secretarial (1.5 days)	953
Indirect Costs	21,876
Total Salary and Benefits:	$72,751
Other Costs:	
Travel	$2,000
Publications	1,050
Indirect Costs	305
Total Other Costs:	$3,355
Total All Costs:	$76,106

Thank you very much.

Questions: Please contact Amanda Preston, 617-495-7321, apreston@cfa.harvard.edu

Harvard-Smithsonian Center for Astrophysics

60 Garden Street, Cambridge, MA 02138-1516 (617) 495-7000

July 11, 2008

Mark D. Boudreaux
Senior Director, Federal Relations
Exxon Mobil Corporation
2000 K Street, NW
Suite 710
Washington, DC 20006

Dear Mr. Boudreaux:

Thank you very much for Exxon Mobil's contribution of $76,106 to the Smithsonian Astrophysical Observatory to support Dr. Willie Soon's project, "Understanding Solar Variability and Climate Change." Restricted gifts are very important for our science research, particularly the projects that seek to better understand our own Sun.

Please accept my thanks on behalf of the entire Observatory.

With best regards,

Amanda Preston
Advancement and External Affairs Officer

60 Garden Street
MS-45
Cambridge, MA 02138
617-495-7321 (voice)
617-495-7105 (fax)
apreston@cfa.harvard.edu (email)

Smithsonian Astrophysical Observatory

GIFT RECEIPT FOR TAX RECORDS

60 Garden Street, MS 45, Cambridge, MA 02138-1516 Tel: (617) 495-7321 Fax: (617) 495-7105 Email: development@cfa.harvard.edu

To: ***Exxon Mobil Corporation***

This receipt gratefully acknowledges your contribution to the Smithsonian Astrophysical Observatory of:

$76,106.00 (seventy-six thousand one-hundred and six dollars)

For: ***"Understanding Solar Variability and Climate Change" (Dr. Willie Soon)***

Date Received: ***July 1, 2008***

By: Amanda Preston — Date: ***July 11, 2008***

Amanda Preston, Advancement and External Affairs Officer

The Smithsonian Astrophysical Observatory has not provided you with any goods or services in exchange for this contribution.

Exxon Mobil Corporation
Washington Office
2000 K Street, N.W.
Suite 710
Washington, DC 20006
[redacted] Telephone
Facsimile

Mark D. Boudreaux
Senior Director, Federal Relations

ExxonMobil

June 30, 2008

Ms. Amanda Preston
Smithsonian Astrophysical Observatory
60 Garden Street, MS-45
Cambridge, MA 02138-1516

Dear Ms. Preston:

ExxonMobil is pleased to provide the enclosed contribution to the Smithsonian Astrophysical Observatory in the amount of $76,106.00 for General Support.

We ask that you please complete the enclosed form and return it to the Community Relations Group at the address indicated.

We are pleased to support the Smithsonian Astrophysical Observatory and wish you continued success.

Sincerely,

Mark D Boudreaux

Enclosure

SMITHSONIAN INSTITUTION

Tracking # 2008 - 400000 – 00032

TRANSMITTAL FORM FOR GIFTS & PROMISES TO GIVE

DATE OF GIFT	CASH	CHECK	CREDIT CARD			OTHER		PLEDGES		STOCK SALE
6-11-08	$	$76,106.00	$		DISCOVER VISA/MC AMEX			WIRES LAST 4 DIGITS OF C.C. MERCHANT #		GIK

CHARTFIELDS: SPLIT FUNDED SEE BELOW

Fund	Budget Ref	Designated Code	Dept. ID		Account	Class	Program	Project ID	Activity ID
					Unrestricted Designated(5604)				
					Permanently Restricted (5603)				
					Temporarily Restricted (5602)				
					Unrestricted (5601)				
					Endowment Pledge Payments (1315)				

DONOR INFORMATION

DONOR NAME	SI UNIT / PROJECT CONTACT
EXXON MOBIL CORPORATION	SAO/Preston

MAILING ADDRESS:

x HOME P.O. BOX 2519, HOUSTON, TX 77252-2519

WORK

PURPOSE/PROJECT TO SUPPORT "UNDERSTANDING SOLAR VARIABILITY AND CLIMATE CHANGE", DR. WILLIE SOON, P.I.

NAME OF PERSON WHO RECEIVED FUNDS AMANDA PRESTON

DATE SI RECEIVED GIFT/PROMISE 7-1-08

SECURITIES INFORMATION

STOCK/BOND NAME

DATE OF TRANSFER TO SI OWNERSHIP	NUMBER OF SHARES / FACE VALUE OF BONDS	UNIT PRICE

GIFT IN KIND INFORMATION

NEW GIK?		DESCRIPTION
PAYMENT ON GIK?		

PLEDGE AND PAYMENT SCHEDULE INFORMATION

NEW PLEDGE?		
PAYMENT ON PLEDGE?		

REMARKS:

NOTE IN REMARKS IF PLEDGE IS CONDITIONAL
SUBMIT 3011 TO NOTIFY IF CONDITION IS NOT MET

PAYMENT SCHEDULE

SCHEDULED PAYMENT	PAYMENT AMOUNT	DISCOUNT AMOUNT

PREPARED BY	TELEPHONE NUMBER	UNIT AND MRC NUMBER	DATE PREPARED
Amanda Preston Amanda Preston	617-495-7321	Smithsonian Astrophysical Observatory 60 Garden Street, MS 45 Cambridge, MA 02138-1516	7-2-08

Comments: SPLIT GIFT AS FOLLOWS

$53,876 to:
801 0000 ###### 404S50 0302
4210 40######IS50[redacted]

$22,230 to:
402 0000 040201 5601
8700 40040201II9114
DEFAULT

REQUIRED DONOR DOCUMENTATION ATTACHED

YES	NO

SI-000021

EXXON MOBIL CORPORATION OR AN AFFILIATED COMPANY

CODE	OUR REFERENCE	DATE	YOUR REFERENCE	NET AMOUNT
PAY4	1900014331	06/05/08	76244	76,106.00

Payment made per agreement with ExxonMobil contracting entity.
REFER ANY INQUIRIES TO 1-800-833-1510 OR CHECK THE PAYMENT STATUS AT HTTP://PAYMENT-ADVICE.COM

* INCLUDE WITH EACH INQUIRY	PAYEE ID NUMBER	CHECK NUMBER	CHECK DATE	CHECK AMOUNT
	6357421	2500349950	06/11/08	76,106.00

EXXON MOBIL CORPORATION OR AN AFFILIATED COMPANY

62-20/311

P O BOX 2519
HOUSTON TX 77252-2519

CHECK NUMBER 2500349950

DATE 06/11/08

6357421

PAY TO THE ORDER OF

SMITHSONIAN ASTROPHYSICAL
OBSERVATORY
60 GARDEN ST MS 45
CAMBRIDGE MA 02138-1516

********$76,106.00*

VOID AFTER SIX MONTHS

CITIBANK NA
NEW CASTLE, DE 19720 2408

THE BACK OF THIS DOCUMENT CONTAINS AN ARTIFICIAL WATERMARK - HOLD AT AN ANGLE TO VIEW - IF NOT PRESENT DO NOT CASH

Smithsonian Astrophysical Observatory

c/o Amanda Preston
60 Garden Street
MS-45
Cambridge, MA 02138-1516

Phone: 617-495-7321
Fax: 617-495-7105
E-mail:
apreston@cfa.harvard.edu

Request for Payment

To:

Attention: Lauren Kerr
ExxonMobil Corporation
2000 K. Street, NW
Suite 710
Washington, DC 20006

Please make check payable to:
Smithsonian Astrophysical Observatory

Please mail check to:
Amanda Preston
Advancement and External Affairs Officer
Smithsonian Astrophysical Observatory
60 Garden Street, MS 45
Cambridge, MA 02138-1516

Date: February 27, 2008

Request for contribution of $76,106 to support the research project:

"Understanding Solar Variability and Climate Change: Signals from Temperature Records of the United States"
Dr. Willie Soon, Principal Investigator

Thank you very much.

Questions: Please contact Amanda Preston, 617-495-7321, apreston@cfa.harvard.edu.

Amanda Preston <apreston@cfa.harvard.edu>

From:	Amanda Preston <apreston@cfa.harvard.edu>
Sent:	Wednesday, February 27, 2008 2:44 PM
To:	[redacted]
Subject:	Proposal to Support Dr. Willie Soon
Attachments:	Soon Proposal 2008.pdf; Request for Payment (Soon 2008).pdf

Soon Proposal 2008.pdf (87 KB)... Request for ...ayment (Soon 2008.

Dear Lauren,

Thanks very much for getting back to me last week about ExxonMobil's support of Dr. Willie Soon's research. We are very pleased at the outcome of this decision.

I am attaching a proposal for your review and a request for payment. You may recall that I mentioned the adjustment in our indirect costs upwards from the 15% that Walt Buchholtz and I negotiated when he was still in your position. You will see in the attached that the project cost increases to ~$76,000.

I look forward to hearing good news from you soon.

With best regards and thanks,

Amanda

Amanda Preston
Advancement and External Affairs
Harvard-Smithsonian Center for Astrophysics 60 Garden Street, MS 45 Cambridge, MA 02138-1516

Voice: 617-495-7321
Fax: 617-495-7105
Blackberry: 617-285-4829
Cell: [redacted]
Email: apreston@cfa.harvard.edu

Smithsonian Astrophysical Observatory

Understanding Solar Variability and Climate Change: Signals from Temperature Records of the United States

A Proposal to ExxonMobil Corporation

Dr. Willie Soon, Principal Investigator
Smithsonian Astrophysical Observatory
Solar, Stellar and Planetary Sciences Division
(617-495-7488; wsoon@cfa.harvard.edu)
February, 2008

Research Target and Proposal:
This proposal seeks $76,106 from ExxonMobil Corporation for year one of this two-year project, *"Understanding Solar Variability and Climate Change: Signals from Temperature Records of the United States."* Dr. Willie Soon proposes to conduct an intensive up-to-date science review of solar variability and climate change (see e.g., Soon 2007a), with emphasis on the signals from temperature records of the U.S., that will be a clear improvement of previous studies. The goals for the first year are to collect and assess the scientific quality of the available temperature records from the United States, aggregated into four inter-related spatial domains: 1) a rural city (i.e., a city that is minimally disturbed by urban development), 2) an individual state, 3) regional U.S. area, and 4) the whole conterminous U.S. The goals for the second year are to study any plausible connection of these U.S. temperature records with estimated solar irradiance history for the past 112 years from 1895 to 2006.

The previously published research paper by Soon (2005) identifies both the multidecadal variation in total solar irradiance and the 11-year solar UV irradiance forcings to be important in explaining the observed Arctic surface air temperature change over the past 130 years or so. The overall goal for this two-year program is to extend our basic understanding on how the variable solar irradiance outputs could be physically connected to the Earth climate system. The ability to confirm or reject the statistical correlations shown in Figure 1 will be of enormous scientific importance. The ultimate physical understanding will arise from detailed assessments on how the solar irradiance is related to the cloud field as well as how the solar irradiance may systematically and persistently modulate the land surface heat fluxes (i.e., sensible and latent heats) on multidecadal to centennial time scales. A parallel hypothesis regarding the role of rising atmospheric carbon dioxide (see e.g., Soon 2007b) in warming the surface temperatures of the United States on these four spatial scales will also be evaluated.

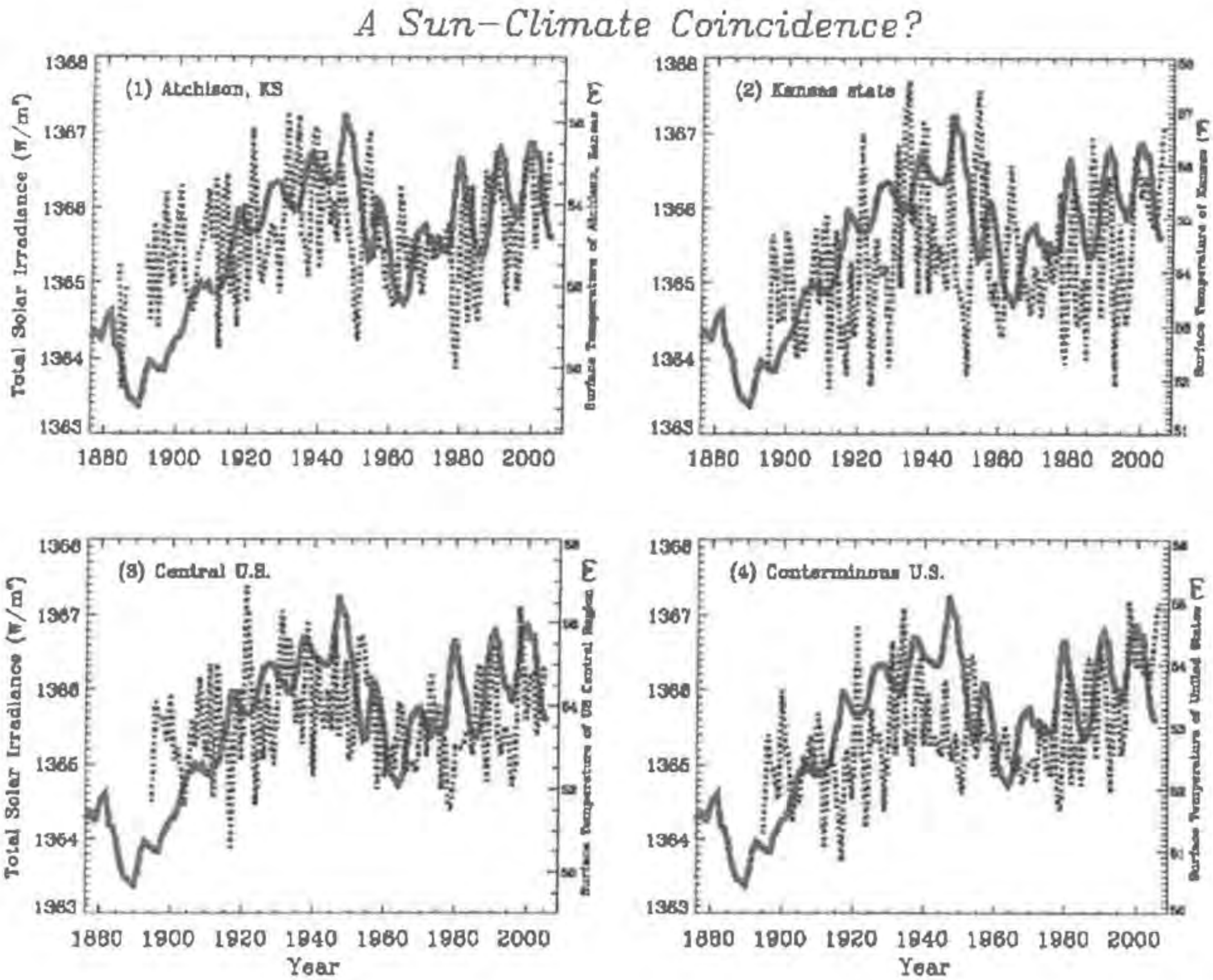


Figure 1: A plausible connection of the solar irradiance (red curves in all four plots; based on Hoyt and Schatten 1993-rescaled to the mean absolute value[1] measured by the ACRIM radiometers) compared with U.S. temperature records in four spatial domains (the blue dotted curves are for 1) Atchinson, KS, 2) State of Kansas, 3) Central region of the U.S., and 4) Conterminous U.S.). These results extend the previous relation found for the Arctic shown in Soon (2005). The scientific hypothesis for this sun-climate relation will be carefully formulated and examined in the proposed project.
[Temperature Data Source: U.S. National Climatic Data Center, http://lwf.ncdc.noaa.gov/oa/climate/research/cag3/cag3.html].

Expected Outcomes:

(1) Publication of both original and review papers on solar variability and climate change and various environmental impacts of that related change in leading scientific journals for the advancement of climate and meteorological sciences.

[1] Soon (2007a) calls for the solar physics community to firmly establish this value emphasizing its great importance in establishing the mean climatology in climate models. The mean climatology in climate models can be subjected to a rather arbitrary tuning given that the absolute level of total solar irradiance is not determined to any level of confidence, with values ranging from 1372 to 1360 W/m².

(2) Development of tools, including power-point presentations and concise scientific essays, for unbiased and more accurate science accounting that will more powerfully serve informed public policy making.

(3) Better public education with active participations by Dr. Soon in all national and international forums interested in promoting the basic understanding of solar variability and climate change.

Research Team:
Dr. Willie Soon at the Smithsonian Astrophysical Observatory, which is a member of the Harvard-Smithsonian Center for Astrophysics, will lead and direct this scientific research program. In addition, the PI *may* solicit interest for collaborative efforts from interested colleagues at no additional cost to the proposal.

Funding Request:
This research proposal requests $76,106 from the Exxon-Mobil Corporation for work to start March, 2008, extending for a duration of about one year. The funding is primarily to support approximately four months of Dr. Soon's full-time research at the Smithsonian Astrophysical Observatory and minimal administrative and clerical support for the project, as well as a small amount of travel to a scientific meeting or publication costs. The Observatory's indirect costs for the project are also included.

Salary and Benefits:	
Dr. Willie Soon (80 days)	$49,370
Administrator (1 day)	749
Secretarial (2.5 days)	917
Indirect costs	21,946
Total Salaries and Benefits:	$72,982
Other Costs:	
Travel	$ 1,790
Publications	1,050
Indirect costs	284
Total Other Costs:	$ 3,124
TOTAL ALL COSTS:	**$76,106**

References

Hoyt D. V. and Schatten K. H. (1993) A discussion of plausible solar irradiance variations, 1700-1992. Journal of Geophysical Research 98 (A11), 18895-18906 [with updates from Dr. Nicola Scafetta, Duke University, private communication May 31, 2007].

Soon W (2005) Variable solar irradiance as a plausible agent for multidecadal variations in the Arctic-wide surface air temperature records of the past 130 years. Geophysical Research Letters 32: L16712.

Soon W (2007a) Some Issues of Solar Irradiance Variability and Climatic Responses: A Brief Review. Invited Talk GC42A-05 at the American Geophysical Union Fall Meeting (December 10-14, 2007).

Soon W (2007b) Implications of the secondary role of carbon dioxide and methane forcing in climate change: Past, present, and future. Physical Geography 28, 97-125.

ESTIMATE OF COST

Period of Performance: January 15, 2008 through December 31, 2008

		Hrs	Dollars
Loaded	Productive Labor:		
	Dr. Willie Soon, PI	494	$25,209
	Program Administration	8	$495
	Secretary	20	$607
	Total Productive Labor	522	26,311
	Leave @ 19.5%		5,131
	Total Direct Labor		31,442
	Fringe Benefits @ 26.5%		8,332
	Direct Operating Overhead Base		39,774
	Direct Operating Overhead @ 30%		11,932
	Travel -see schedule		1,789
	Printing and Reproduction - see schedule		1,050
	G & A Base		54,545
	G & A @ 10%		5,455
	TOTAL ESTIMATED COST		$60,000

ESTIMATE OF COST

Period of Performance: January 15, 2008 through December 31, 2008

	Hrs	Dollars	
Productive Labor:			
Dr. Willie Soon, PI	640	$32,659	
Leave @ 19.5%		6,369	
Total Direct Labor		39,028	
Fringe Benefits @ 26.5%		10,342	
		49,370	
Travel -see schedule		1,789	
Printing and Reproduction - see schedule		1,050	
		52,209	
		7,831	Administrative Charge 15%
TOTAL ESTIMATED COST		$60,040	

Amanda Preston <apreston@cfa.harvard.edu>

From: Amanda Preston <apreston@cfa.harvard.edu>
Sent: Friday, May 02, 2008 11:37 AM
To: Exemption 6 [redacted]
Subject: FW: Proposal to Support Dr. Willie Soon

Attachments: Soon Proposal 2008.pdf; Request for Payment (Soon 2008).pdf

Soon Proposal 2008.pdf (84 KB)... Request for ...ayment (Soon 2008...

Dear Lynn,

Thank you for your call. It was good to speak with you again.

Attached is the proposal and the request for payment I sent to Lauren at the end of February.

Please don't hesitate to call if you have questions.

Thanks much,

Amanda
Amanda Preston
Advancement and External Affairs
Harvard-Smithsonian Center for Astrophysics 60 Garden Street, MS 45 Cambridge, MA 02138-1516

Voice: 617-495-7321
Fax: 617-495-7105
Blackberry: 617-285-4829
Cell: Exemption 6 [redacted]
Email: apreston@cfa.harvard.edu

-----Original Message-----
From: Amanda Preston <apreston@cfa.harvard.edu>
Sent: Wednesday, February 27, 2008 2:44 PM
To: Exemption 6 [redacted]
Subject: Proposal to Support Dr. Willie Soon

Dear Lauren,

Thanks very much for getting back to me last week about ExxonMobil's support of Dr. Willie Soon's research. We are very pleased at the outcome of this decision.

I am attaching a proposal for your review and a request for payment. You may recall that I mentioned the adjustment in our indirect costs upwards from the 15% that Walt Buchholtz and I negotiated when he was still in your position. You will see in the attached that the project cost increases to ~$76,000.

I look forward to hearing good news from you soon.

With best regards and thanks,

Amanda

Amanda Preston
Advancement and External Affairs
Harvard-Smithsonian Center for Astrophysics 60 Garden Street, MS 45 Cambridge, MA 02138-1516

Voice: 617-495-7321
Fax: 617-495-7105
Blackberry: 617-285-4829
Cell: Exemption 6 [redacted]
Email: apreston@cfa.harvard.edu

Amanda Preston <apreston@cfa.harvard.edu>

From: Amanda Preston <apreston@cfa.harvard.edu>
Sent: Tuesday, February 12, 2008 3:57 PM
To: Exemption 6 [redacted]
Subject: Further Word?

Dear Lauren,

Just a quick note to see if you've heard anything about the issue of restricted gifts versus general operating support.

I'm around all week and can move things along quickly once we know it's okay to proceed.

Thanks much,

Amanda

Amanda Preston
Advancement and External Affairs
Harvard-Smithsonian Center for Astrophysics 60 Garden Street, MS 45 Cambridge, MA 02138-1516

Voice: 617-495-7321
Fax: 617-495-7105
Blackberry: 617-285-4829
Cell: Exemption 6 [redacted]
Email: apreston@cfa.harvard.edu

Amanda Preston <apreston@cfa.harvard.edu>

From:	Willie Soon [wsoon@cfa.harvard.edu]
Sent:	Tuesday, January 15, 2008 6:24 AM
To:	Sara Yorke; Amanda Preston <apreston@cfa.harvard.edu>
Subject:	(2) let's submit this proposal for $60K to Exxon-Mobil ...
Attachments:	KerrLauren08-Jan15--Sun-USClimate-Proposal-Exxon-FINAL.doc

KerrLauren08-Ja
15--Sun-USClim.

dear Sara and Amanda,

can you help submit this proposal to

Lauren Kerr
Exxon Mobil Corporation
2000 K Street NW, Suite 710
Washington, D.C. 20006
Ph: [redacted]
F:

Assistant: Lynn Gellner
[redacted]

asap??

Any way you can help me stretch this proposal to maximize my work at SAO would be appreciated ...

Willie

ps: i have answered Lauren's questions

----- Original Message -----
Subject: Re: would it be OK for me to submit my sun-climate research proposal to Exxon-Mobil for 2008 support?
Date: Mon, 14 Jan 2008 14:08:31 -0500
From: [redacted]
To: Willie Soon <wsoon@cfa.harvard.edu>
CC: [redacted]

Hi Willie - the proposal looks fine. Please have the Center send me an invoice for 2008, for General Support for your work. Can you clarify for me, on page two there's a reference to "original" and "review" papers - does that mean not peer reviewed, and peer reviewed?

I'd love to see a copy of the DVD. Who is releasing it - Smithsonian?

Lauren Kerr
Exxon Mobil Corporation

2017 ExxonMobil's Giving to Climate Change Denier & Obstructionist Organizations

ExxonMobil Foundation & Corporate Giving to Climate Change Denier & Obstructionist Organizations

Organization	2017	2008-2017	1998-2007	1998-2017
Acton Institute	-	-	$365,000	$365,000
Advancement of Sound Science Center	-	-	$50,000	$50,000
American Conservative Union Foundation	-	$20,000	$70,000	$90,000
American Council for Capital Formation	-	$145,000	$1,634,523	$1,779,523
American Council on Science and Health	-	$15,000	$150,000	$165,000
American Enterprise Institute (AEI)	$160,000	$2,390,000	$2,100,000	$4,490,000
American Legislative Exchange Council (ALEC)	$60,000	$621,500	$1,306,700	$1,928,200
American Spectator Foundation	-	$50,000	$65,000	$115,000
Annapolis Center	-	$180,000	$973,500	$1,153,500
Atlas Economic Research Foundation	-	$202,500	$880,000	$1,082,500
Capital Research Center/Greenwatch	-	-	$265,000	$265,000
Cato Institute	-	-	$125,000	$125,000
Center for a New Europe-USA	-	-	$170,000	$170,000
Center for American and International Law	$23,000	$293,600	$249,550	$543,150
Center for Defense of Free Enterprise	-	-	$230,000	$230,000
Center for the Study of CO2 and Global Change	-	-	$100,000	$100,000
Chemical Education Foundation	-	-	$155,000	$155,000
Committee for a Constructive Tomorrow (CFACT)	-	-	$582,000	$582,000
Communications Institute	-	$240,000	$275,000	$515,000
Competitive Enterprise Institute (CEI)	-	-	$2,005,000	$2,005,000
Congress of Racial Equality	-	$50,000	$275,000	$325,000
Consumer Alert	-	-	$70,000	$70,000
Environmental Literacy Council	-	-	$100,000	$100,000
Federal Focus	-	-	$125,000	$125,000
Federalist Society	$10,000	$140,000	$120,000	$260,000
Foundation for Research on Economics and the Environment (FREE)	-	$180,000	$270,000	$450,000
Fraser Institute, Canada	-	-	$120,000	$120,000
Free Enterprise Action Institute	-	-	$50,000	$50,000
Free Enterprise Education Institute	-	-	$80,000	$80,000
FreedomWorks	-	-	$380,250	$380,250
Frontiers of Freedom	-	-	$1,272,000	$1,272,000
George C. Marshall Institute	-	$25,000	$840,000	$865,000
George Mason University Law and Economics Center	-	$220,000	$255,000	$475,000
Harvard-Smithsonian Center for Astrophysics	-	$152,212	$265,000	$417,212
Heartland Institute	-	-	$676,500	$676,500
Heritage Foundation	-	$300,000	$530,000	$830,000
Hoover Institution	$15,000	$105,000	$295,000	$400,000
Hudson Institute	-	$15,000	$25,000	$40,000
Independent Institute	-	-	$85,000	$85,000
Independent Women's Forum	-	$15,000	$50,000	$65,000
Institute for Energy Research/American Energy Alliance	-	-	$337,000	$337,000

Institute for Senior Studies	-	-	$30,000	$30,000
Institute for Study of Earth and Man	-	-	$76,500	$76,500
International Policy Network - North America	-	-	$390,000	$390,000
International Republican Institute	-	-	$115,000	$115,000
Landmark Legal Foundation	-	$30,000	$60,000	$90,000
Lexington Institute	-	-	$10,000	$10,000
Lindenwood University	-	$10,000	$30,000	$40,000
Manhattan Institute	$115,200	$895,200	$355,000	$1,250,200
Media Institute	-	-	$120,000	$120,000
Media Research Center/Cybercast News Service	-	$105,000	$257,500	$362,500
Mercatus Center, George Mason University	-	$255,000	$160,000	$415,000
Mountain States Legal Foundation	$5,000	$80,000	-	$80,000
National Association of Neighborhoods	-	$75,000	$150,000	$225,000
National Black Chamber of Commerce	$30,000	$865,000	$300,000	$1,165,000
National Center for Policy Analysis	-	$75,000	$570,900	$645,900
National Center for Public Policy Research	-	$55,000	$390,000	$445,000
National Legal Center for the Public Interest	-	-	$216,500	$216,500
National Taxpayers Union Foundation	$40,000	$670,000	$195,000	$865,000
Pacific Legal Foundation	-	$150,000	$135,000	$285,000
Pacific Research Institute for Public Policy	-	$150,000	$515,000	$665,000
Property and Environment Research Center (PERC)	-	-	$155,000	$155,000
Reason Foundation / Reason Public Policy Institute	-	-	$321,000	$321,000
Regulatory Checkbook	-	-	$50,000	$50,000
Science and Environmental Policy Project	-	-	$20,000	$20,000
Tech Central Science Foundation	-	-	$95,000	$95,000
Texas Public Policy Foundation	-	$50,000	$30,000	$80,000
U.S. Chamber of Commerce	$1,015,000	$4,015,000	-	$4,015,000
Washington Legal Foundation	$40,000	$330,000	$245,000	$575,000
Totals	**$1,513,200**	**$13,170,012**	**$22,964,423**	**$36,134,435**

2012 ConocoPhillips *Sustainable Development report*

ConocoPhillips

Sustainable Development

Introduction

This file contains all of the content related to sustainability found on ConocoPhillips.com. Its purpose is to better communicate our progress on sustainable development issues for stakeholders who choose to download our content. The file is current as of October 31, 2013.

Contents

• Communicate our commitment to this Policy to our employees, contractors, and visitors and engage their support for creating and maintaining an environment that is free of substance abuse.

In those circumstances where government regulations, laws, or local practices impact the implementation of this Policy, business unit leadership will develop and implement a country-specific Substance Abuse Policy that conforms to local requirements, after which the local policy will be included as an addendum to this Policy. Applicants and employees will adhere to the Substance Abuse Policy addendum relevant to their country.

We believe that the successful implementation of this Global Substance Abuse Policy will help ensure a continued safe, healthy and productive work environment.

Our Positions

Sustainable Development Position

For ConocoPhillips, Sustainable Development is about conducting our business to promote economic growth, a healthy environment and vibrant communities, now and into the future. We believe that this approach will enable us to deliver long-term value and satisfaction to our shareholders and our stakeholders.

Sustainable Development is fully aligned with our vision, to be the E&P company of choice for all stakeholders by pioneering a new standard of excellence, and our SPIRIT Values.

Our Focus

To deliver on these commitments, we will prioritize issues, establish plans for action with clear goals and monitor our performance. In addition, we will develop the following company-wide competencies to successfully promote sustainable development:

- Integration – Clearly and completely integrate economic, social and environmental considerations into strategic planning, decision-making and operating processes.
- Stakeholder Engagement – Engage our stakeholders to understand their diverse and evolving expectations and incorporate that understanding into our strategies.

- Life-Cycle Management – Manage the full life-cycle impacts of our operations, assets, and products.
- Knowledge Management – Share our successes and failures to learn from our experiences.
- Innovation – Create a culture that brings new, innovative thinking to the challenges of our evolving business environment.

Our Expectations

Through delivering on our commitments to sustainable development, we will be the best company to have as a supplier, investment, employer, partner and neighbor.

Biodiversity Position

ConocoPhillips will implement mitigation planning processes aimed at reducing the effects of our activities on the environment and conserving biodiversity. We will address biodiversity conservation as part of investment appraisal, and during the planning and development of major capital projects, by conducting environmental impact analyses, collecting key environmental data and implementing mitigation and monitoring programs to reduce impacts and assure results.

Our Focus

We are continuously building our knowledge about the ecosystems in which we work and recently completed an internal study to benchmark our performance compared to other extractive-industry companies. To increase internal awareness about biodiversity, a knowledge-sharing intranet site has been launched to foster employee collaboration within ConocoPhillips in the areas of biodiversity and ecosystems.

We conducted industry benchmarking to explore better ways to collect and manage our biodiversity data. We are using a range of technologies, from improved animal tagging to streamlined databases. Employees are encouraged to ask questions about challenges they encounter in this area, and to share project ideas for technology development in the area of ecosystems and land use. The intranet site also provides such resources as global conferences and contacts to benefit its members.

Our biodiversity strategy will include the following elements:

- Integration of biodiversity conservation principles in our business management systems, considering all stages of the asset life cycle.
- Development of Biodiversity Action Plans for projects located in areas of high conservation value.
- Use of widely available and effective planning tools such as those developed by the International Petroleum Industry Environmental Conservation Association (IPIECA) , Energy and Biodiversity Initiative, and the International Association of Oil and Gas Producers to facilitate biodiversity conservation.
- Adoption of a landscape-scale perspective which promotes habitat integrity and connectivity over a broader area than just our facility sites as important issues in land use decision making.

- Consideration of targeted opportunities for habitat improvement, including projects for rehabilitation. The use of biodiversity offsets will be considered when appropriate.
- Collaboration with key stakeholders to increase capacity for biodiversity protection, internally and in related institutions and communities.
- Linkage of biodiversity protection with GHG emissions reductions, where both goals can be met through integrated planning and action.

Our Expectations

We follow widely accepted guidelines from the IPIECA and the International Association of Oil and Gas Producers (OGP) in our approach to biodiversity conservation. As a member of the IPIECA biodiversity working group, we work to develop tools and materials to help companies across our industry enhance their biodiversity conservation activities. As a founding member of the OGP's Sound and Marine Life program, we support continued research to increase scientific knowledge on the possible impact that sound produced by offshore exploration and production has on marine mammals, fish, turtles, seabirds, invertebrates and other marine life. In the fulfillment of our business strategy, we will serve as a positive example of how natural resource development can occur in harmony with society's need to conserve biodiversity. For more information, see Biodiversity

Climate Change Position

ConocoPhillips recognizes that human activity, including the burning of fossil fuels, is contributing to increased concentrations of greenhouse gases (GHG) in the atmosphere that can lead to adverse changes in global climate.

Our Focus

While uncertainties remain, we continue to manage greenhouse gas emissions in our operations and to integrate climate change related activities and goals into our business planning. Our corporate action plan focuses on the following areas:

- Understanding our GHG footprint
- Reducing our GHG emissions
- Evaluating climate change related risks
- Leveraging technology innovation to explore new business opportunities
- Engaging externally in support of practical, sustainable climate change solutions
- Reviewing progress and updating business unit climate change management plans

Our approach to climate change is designed to advance the company's vision to be the exploration and production company of choice for all stakeholders by pioneering a new standard of excellence.

Climate Change Public Policy

We believe that effective climate change policy must be aligned with the following principles:

- Recognize that climate change is a global issue which requires global solutions – economy-wide governmental GHG management frameworks should be linked to binding international agreements comprising the major GHG contributors
- Result in the stabilization of global GHG atmospheric concentrations at safe levels
- Coordinate with energy policy to ensure a diverse and secure supply of affordable energy
- Utilize market-based mechanisms rather than technology mandates
- Create a level competitive playing field among energy sources and between countries
- Avoid overlapping or duplicating existing energy and climate change programs
- Provide long-term certainty for investment decisions
- Promote government and private sector investment in energy research and development
- Match the pace at which new technology can be developed and deployed
- Encourage efficient use of energy
- Foster resiliency to the impacts of a changing climate
- Avoid undue harm to the economy.

Building balanced energy policies is challenging, and we recognize that no one has all the answers. As economies around the world continue to develop, fossil fuels will play an important role in meeting the growing global demand for energy. Meeting the challenge of taking action on climate change while providing adequate, affordable supplies of reliable energy will require financial investments, skilled people, technical innovation and responsible stewardship from policy makers, energy producers and consumers.

ConocoPhillips is committed to doing our part.

Diversity & Inclusion Position

At ConocoPhillips, we strive to represent and reflect the global communities in which we live and work. To deliver superior performance, we create an environment of inclusion that respects the contributions and differences of every individual (employees, contract workers, suppliers and business partners). Wherever possible, we use these differences to drive competitive business advantage, personal growth and, ultimately, create success for ConocoPhillips globally.

Our Focus

As we pursue opportunities in a dynamic marketplace, we value motivated people who set the standard of excellence by:

- Living our SPIRIT Values.
- Demonstrating a proactive attitude and being culturally capable of doing business globally.
- Using creativity and a variety of approaches to capture opportunities.
- Inspiring and supporting others to reach new heights.

Our Expectations

At ConocoPhillips, our pledge to diversity is a global commitment that reaches across the entire company. Our leadership team, managers and supervisors are accountable for developing and progressing our global inclusion initiatives. Additionally, employees and contractors are responsible for playing a key role in ensuring that their personal behaviors create an inclusive work environment. As a company, we continue to measure our progress toward becoming representative and reflective of the communities in which we live and work.

Economic Transparency and Reporting Position

ConocoPhillips participates in the Extractive Industries Transparency Initiative (EITI), which seeks to ensure that natural resource wealth is an engine for sustainable economic growth that contributes to sustainable development and poverty reduction.

Our Focus & Expectations

We remain actively involved in the EITI process and implementation in participating countries where we operate. Currently, three participating countries where we operate have achieved full EITI compliance – Timor-Leste, Nigeria and Norway. Of the countries that have committed to EITI principles, and therefore are considered candidates for EITI membership, we have resource interests in two: Indonesia and Kazakhstan. Of the EITI compliant or committed countries, only our investments in Indonesia, Nigeria and Norway involve production. We currently cooperate with these governments in their EITI validation efforts. When we have assets in new countries, we will work to promote transparency and accountability with those governments.

EITI requires the public reporting of payments to governments. (See related information on the Dodd-Frank Act). Such reporting requirements take into account host-country laws and the terms of contracts under which such revenues are accrued.

HIV/AIDS Position

ConocoPhillips recognizes that HIV/AIDS is a global pandemic resulting in the death of over 3 million people every year, with potential to grow unless concerted action is taken to check the spread of the disease. There remains a significant stigma associated with this disease, which limits willingness of infected individuals to seek effective diagnosis, which frequently results in social and workplace discrimination. There are now treatments available which make HIV/AIDS a manageable chronic illness for those infected with this disease to live normal and productive lives. Yet economic and technical limitations in much of the developing world have created disparities between developed and developing countries, in their ability to effectively manage spread of the disease and treatment of infected individuals.

Our Focus & Expectations

To the extent that HIV/AIDS affects the health of our employees and their dependents and represents a significant public health risk where our employees live and work, ConocoPhillips will work to identify, use and otherwise support community-based resources and programs that recognize and seek to mitigate the social stigma and adverse impact of HIV/AIDS, emphasize preventive education and provide early intervention and long-term treatment.

Human Rights Position

Governments have the primary responsibility for protecting human rights. ConocoPhillips believes business has a constructive role to play to advance respect for human rights throughout the world as do Non-Government Organizations (NGOs) and other representative groups in civil society.

We recognize the dignity of all human beings and our core values embrace these inalienable rights for all people to live their lives free from social, political, or economic discrimination or abuse.

Our Focus & Expectations

ConocoPhillips will conduct business consistent with the human rights philosophy expressed in the Universal Declaration of Human Rights (UDHR), and the International Labour Organization Declaration on Fundamental Principles and Rights at Work.

Our intent regarding human rights is also reflected in our Purpose and Values and in our business ethics policy and health, safety and environmental policy. These policies address how we conduct our business with respect for people and the environment, accountability and responsibility to communities, and ethical and trustworthy relationships with our stakeholders. We will maintain ongoing discussion with government, NGO and other business stakeholders through our participation in the Voluntary Principles on Human Rights and Security. The company's approach to engagement with indigenous communities, in locations where they are an important stakeholder group for our operations, is consistent with the principles of the International Labour Organization Convention 169, concerning Indigenous and Tribal Peoples, and the United Nations Declaration on the Rights of Indigenous Peoples.

Renewable Energy Position

In alignment with our mission to power civilization, and consistent with our positions on sustainable development and climate change, ConocoPhillips is evaluating and developing technologies for renewable energy. We are leveraging our expertise, intellectual property and physical assets in pursuit of economically viable, renewable energy business opportunities.

Our Focus

We continue to develop technology options with the potential to enable or complement renewable energy use.

Investments in technology development will be disciplined and commensurate with the likely returns, market size, timing of development and technology risk inherent in renewable energy projects. Our criteria for business investment include:

- Business Leveraged. Renewable energy opportunities that complement our existing processes will be prioritized.
- Competency and Asset Leveraged. We plan to focus our efforts on renewable technologies that directly leverage our experience in energy development and markets.
- Ongoing Awareness. We plan to continue to evaluate renewable energy technologies to proactively identify new opportunities and to understand the economic drivers, strengths and weaknesses of the alternative technologies available.
- Sustainable Solutions. We remain open to developing and using renewable energy as a component of our portfolio of energy offerings, as and when these technologies can be deployed in a sustainable manner for our stakeholders.

Our Expectations

Our work will assist in the development of viable, sustainable and environmentally responsible energy for existing and future customers. For more information, go to ConocoPhillips.com→What we do→Creating Innovative Solutions→ Technology Ventures.

Water Sustainability Position

As a responsible global energy company committed to sustainable development, we recognize that fresh water is an essential natural resource for communities, businesses, and ecosystems. Global population growth will increase demand for fresh water and all users – domestic, agriculture, and industry – will need to effectively manage supplies to meet demands.

Our Focus & Expectations

ConocoPhillips produces and utilizes water in its operations. We are committed to the development of water management practices that conserve and protect fresh water resources and enhance the efficiency of water utilization at our facilities. We will assess, measure, and monitor our fresh water usage and based on these assessments we will manage our consumption and strive to reduce the potential impact to the environment from wastewater disposal.

Our initial focus in implementing the strategy can be broken down into four broad categories:

- Focusing on priority assets and developing evaluation and mitigation tools.
- Sharing best-practice water management systems at a local level.
- Developing and implementing technologies to reduce the environmental impact of our water footprint.
- Delivering on sustainable development public commitment.

For more information, see the Integrated Water Management section in this report, or go to ConocoPhillips.com→Sustainable Development→Environment→Water.

2012 ConocoPhillips 10k filings to the US Securities and Exchange Commission

2012

UNITED STATES
SECURITIES AND EXCHANGE COMMISSION
Washington, D.C. 20549

Form 10-K

(Mark One)

[x] ANNUAL REPORT PURSUANT TO SECTION 13 OR 15(d) OF THE SECURITIES EXCHANGE ACT OF 1934
For the fiscal year ended **December 31, 2012**

OR

[ ] TRANSITION REPORT PURSUANT TO SECTION 13 OR 15(d) OF THE SECURITIES EXCHANGE ACT OF 1934
For the transition period from ____________ to ____________

Commission file number: **001-32395**

ConocoPhillips

(Exact name of registrant as specified in its charter)

Delaware	**01-0562944**
(State or other jurisdiction of incorporation or organization)	*(I.R.S. Employer Identification No.)*

600 North Dairy Ashford
Houston, TX 77079
(Address of principal executive offices) (Zip Code)

Registrant's telephone number, including area code: **281-293-1000**

Securities registered pursuant to Section 12(b) of the Act:

Title of each class	**Name of each exchange on which registered**
Common Stock, $.01 Par Value	New York Stock Exchange
6.65% Debentures due July 15, 2018	New York Stock Exchange
7% Debentures due 2029	New York Stock Exchange

Securities registered pursuant to Section 12(g) of the Act: None

Indicate by check mark if the registrant is a well-known seasoned issuer, as defined in Rule 405 of the Securities Act.
[x] Yes [ ] No

Indicate by check mark if the registrant is not required to file reports pursuant to Section 13 or Section 15(d) of the Act.
[ ] Yes [x] No

Indicate by check mark whether the registrant (1) has filed all reports required to be filed by Section 13 or 15(d) of the Securities Exchange Act of 1934 during the preceding 12 months (or for such shorter period that the registrant was required to file such reports), and (2) has been subject to such filing requirements for the past 90 days. [x] Yes [ ] No

Indicate by check mark whether the registrant has submitted electronically and posted on its corporate Web site, if any, every Interactive Data File required to be submitted and posted pursuant to Rule 405 of Regulation S-T during the preceding 12 months (or for such shorter period that the registrant was required to submit and post such files).
[x] Yes [ ] No

Indicate by check mark if disclosure of delinquent filers pursuant to Item 405 of Regulation S-K is not contained herein, and will not be contained, to the best of the registrant's knowledge, in definitive proxy or information statements incorporated by reference in Part III of this Form 10-K or any amendment to this Form 10-K. [ ]

Indicate by check mark whether the registrant is a large accelerated filer, an accelerated filer, a non-accelerated filer, or a smaller reporting company. See the definitions of "large accelerated filer," "accelerated filer" and "smaller reporting company" in Rule 12b-2 of the Exchange Act.

Large accelerated filer [x]   Accelerated filer [ ]   Non-accelerated filer [ ]   Smaller reporting company [ ]

Indicate by check mark whether the registrant is a shell company (as defined in Rule 12b-2 of the Act).[ ] Yes [x] No

The aggregate market value of common stock held by non-affiliates of the registrant on June 30, 2012, the last business day of the registrant's most recently completed second fiscal quarter, based on the closing price on that date of $55.88, was $67.9 billion. The registrant, solely for the purpose of this required presentation, had deemed its Board of Directors to be an affiliate and deducted their stockholdings of 66,914 shares in determining the aggregate market value.

The registrant had 1,220,992,874 shares of common stock outstanding at January 31, 2013.

Documents incorporated by reference:

Portions of the Proxy Statement for the Annual Meeting of Stockholders to be held on May 14, 2013 (Part III)

TABLE OF CONTENTS

Item 7. MANAGEMENT'S DISCUSSION AND ANALYSIS OF FINANCIAL CONDITION AND RESULTS OF OPERATIONS

February 19, 2013

Management's Discussion and Analysis is the Company's analysis of its financial performance and of significant trends that may affect future performance. It should be read in conjunction with the financial statements and notes, and supplemental oil and gas disclosures included elsewhere in this report. It contains forward-looking statements including, without limitation, statements relating to the Company's plans, strategies, objectives, expectations and intentions that are made pursuant to the "safe harbor" provisions of the Private Securities Litigation Reform Act of 1995. The words "anticipate," "estimate," "believe," "budget," "continue," "could," "intend," "may," "plan," "potential," "predict," "seek," "should," "will," "would," "expect," "objective," "projection," "forecast," "goal," "guidance," "outlook," "effort," "target" and similar expressions identify forward-looking statements. The Company does not undertake to update, revise or correct any of the forward-looking information unless required to do so under the federal securities laws. Readers are cautioned that such forward-looking statements should be read in conjunction with the Company's disclosures under the heading: "CAUTIONARY STATEMENT FOR THE PURPOSES OF THE 'SAFE HARBOR' PROVISIONS OF THE PRIVATE SECURITIES LITIGATION REFORM ACT OF 1995," beginning on page 67.

Due to the separation of the downstream businesses and our intention to sell our interest in the North Caspian Sea Production Sharing Agreement (Kashagan) and our Nigerian and Algerian businesses in 2012, which are reported as discontinued operations, income (loss) from continuing operations is more representative of ConocoPhillips as an independent exploration and production company. The terms "earnings" and "loss" as used in Management's Discussion and Analysis refer to income (loss) from continuing operations.

BUSINESS ENVIRONMENT AND EXECUTIVE OVERVIEW

ConocoPhillips is the world's largest independent exploration and production (E&P) company, based on proved reserves and production of liquids and natural gas. Headquartered in Houston, Texas, we have operations and activities in 30 countries. At December 31, 2012, we had approximately 16,900 employees worldwide and total assets of $117 billion. Our stock is listed on the New York Stock Exchange under the symbol "COP."

Discontinued Operations

On April 30, 2012, we completed the separation of our downstream businesses into an independent, publicly traded company, Phillips 66. Our refining, marketing and transportation businesses, most of our Midstream segment, our Chemicals segment, as well as our power generation and certain technology operations included in our Emerging Businesses segment (collectively, our "Downstream business"), were transferred to Phillips 66. As a part of our strategic asset disposition program, in the fourth quarter of 2012, we agreed to sell our interest in Kashagan and our Nigerian and Algerian businesses. Results of operations related to Phillips 66, Kashagan, Nigeria and Algeria have been classified as discontinued operations in all periods presented in this Annual Report on Form 10-K. For additional information, see Note 2—Discontinued Operations, in the Notes to Consolidated Financial Statements.

Overview

As an independent E&P company, we are solely focused on our core business of exploring for, developing and producing crude oil and natural gas globally. Our portfolio primarily includes legacy assets in North America, Europe, Asia and Australia; growing North American shale and oil sands businesses; several major international developments; and a global exploration program. Our value proposition to our shareholders is to deliver

2016 Shell report, *A Better Life with a Healthy Planet: Pathways to Net-Zero Emissions*

A BETTER LIFE WITH A HEALTHY PLANET

PATHWAYS TO NET-ZERO EMISSIONS

A NEW LENS SCENARIOS SUPPLEMENT

ENTER

TO NAVIGATE

CLICK on the on the **RED ARROWS** from the contents below or side menu to navigate page by page.

CLICK on the **MENU ICON** in the side menu to come back to the contents from any page.

CONTENTS

Note: "The New Lens Scenarios" and "A Better Life with a Healthy Planet" are part of an ongoing process – scenario-building – used in Shell for more than 40 years to challenge executives' perspectives on the future business environment. We base them on plausible assumptions and quantification, and they are designed to stretch management thinking and even to consider events that may only be remotely possible. Scenarios, therefore, are not intended to be predictions of likely future events or outcomes, and investors should not rely on them when making an investment decision with regard to Royal Dutch Shell plc securities.

It is important to note that Shell's existing portfolio has been decades in development. While we believe our portfolio is resilient under a wide range of outlooks, including the IEA's 450 scenario, it includes assets across a spectrum of energy intensities, including some with above-average intensity. While we seek to enhance our operations' average energy intensity through both the development of new projects and divestments, we have no immediate plans to move to a net-zero emissions portfolio over our investment horizon of 10–20 years. Net-zero emissions, as discussed in this document, is a collective ambition that is applied in the aggregate, with technical and other considerations determining the net-positive or net-negative emissions for any individual industry sector or company. It must be driven by society, governments and industry through an effective overall policy framework for the energy system as a whole, integrating consumption and production. We believe the Paris Agreement is a start towards creating such a framework, and we look forward to playing a role as society embarks on this very important journey[1].

FOREWORD: FROM THE CEO

WE KNOW OUR LONG-TERM SUCCESS AS A COMPANY DEPENDS ON OUR ABILITY TO ANTICIPATE THE TYPES OF ENERGY THAT PEOPLE WILL NEED IN THE FUTURE IN A WAY THAT IS BOTH COMMERCIALLY COMPETITIVE AND ENVIRONMENTALLY SOUND.

We at Shell have long recognised the importance of the climate challenge along with the ongoing critical role energy plays in enabling a decent quality of life for people across the world. The global energy system is changing, both to meet greater demand and to respond to environmental stresses. The big challenge for society, simply put, is how to provide much more energy with much less carbon dioxide. The recent Paris Agreement was a constructive milestone in this journey and attention now turns to implementation.

Shell aims to play a role in meeting these challenges by exploring solutions in areas of our technical expertise, such as natural gas production, efficient future fuels (for example, biofuels and hydrogen), and carbon capture and storage, and also in emerging energy system technologies. We know our long-term success as a company depends on our ability to anticipate the types of energy that people will need in the future in a way that is both commercially competitive and environmentally sound.

We find the goal of a better life with a healthy planet to be an inspiring ambition. But navigating the necessary transitions will require extraordinary and unprecedented coordination, collaboration and leadership across all sectors of society. We hope this booklet will provide helpful insights for this challenging journey.

Ben van Beurden
CEO, Royal Dutch Shell plc,
May 2016

INTRODUCTION: SCENARIOS AND A NET-ZERO EMISSIONS WORLD

OUR WORK HAS LED US TO CONCLUDE THAT PROVIDING THE NECESSARY ENERGY IN THE CONTEXT OF NET-ZERO CO_2 EMISSIONS IS TECHNICALLY FEASIBLE. BUT IT WILL BE VERY CHALLENGING. WE KNOW THAT SUCH A FUTURE WILL BE BUILT ON A PATCHWORK OF SOLUTIONS, NOT A SINGLE PATHWAY.

This report is a supplement to the Shell *New Lens Scenarios* (NLS) published in 2013. Scenarios offer plausible alternative stories of the long-term future. They do not describe what *will* happen (a forecast) or what *should* happen (a policy prescription), but what *could* happen. The NLS scenarios – *Mountains* and *Oceans* – considered alternative ways influence in society could evolve and described different routes for the future evolution of the global energy system. We continue to learn from these scenarios what is needed, practically, to have a healthy planet while at the same time responding to the natural human striving for a better quality of life.

The energy system responds to the demands of a growing number of people in the world with aspirations to make life materially better for themselves and their children. Meeting this demand will probably require approximately doubling the size of the global energy system over the course of this century. And that means the potential growth of atmospheric CO_2 and other greenhouse gases – unless something is done at the same time to reduce these emissions so that there are no net additions.

It is valuable to recognise, however, that a *net-zero emissions world* is not necessarily a world without any emissions anywhere. It is a world where remaining emissions are offset elsewhere in the system, an outcome that is more rapidly achievable and hence more consistent with limiting the accumulation of greenhouse gases. This means that the world will need "negative" emissions in some sectors to offset remaining emissions in others such that zero additional emissions enter the atmosphere – the so-called "net zero."

Our work has led us to conclude that providing the necessary energy in the context of net-zero CO_2 emissions is technically feasible. But it will be very challenging. We know that such a future will be built on a patchwork of solutions, not a single pathway. Solutions may work in one place even if they aren't necessarily suitable for every situation. And it may be difficult to predict whether a solution that works well in the lab or on a small scale can succeed in deploying globally.

In this booklet, we distil what we have learned so far in an attempt to answer a fundamental question: How could the energy system evolve from now to provide "a better life for all with a healthy planet?"

We begin with "where we are now", recognising the challenges that face society. We then summarise what we mean by "a better life with a healthy planet" and how the energy system may evolve in future to deliver those objectives. The rest of the booklet offers a more detailed study of three key areas: the necessary transformations in both the consumption and production side of the energy system; economic growth pathways in developing countries; and the policies needed to support those transformations. We end with "An Accelerated Net-Zero Emissions Scenario", the story of one possible pathway involving a patchwork of solutions that could result in a better life with a healthy planet on a timescale consistent with global aspirations.

Jeremy Bentham
Vice President Global Business Environment,
Head of Shell Scenarios

EXECUTIVE SUMMARY

A BETTER LIFE WITH A HEALTHY PLANET

EXECUTIVE SUMMARY: A BETTER LIFE WITH A HEALTHY PLANET

The internationally agreed UN Sustainable Development Goals[2] frame some of the great practical issues of our age, including eliminating poverty, providing energy and addressing climate stress.

Governments and the global community are attempting in many ways to address the challenge of poverty, spreading the benefits of a decent standard of living from the minority toward the majority of people – *a better life* for all. But there is a greater force at work than this collective desire from governmental organisations for a better world, and that is the drive of billions of individuals themselves to create a better material life for their families.

These demands for a better life will inevitably increase energy needs. The challenge is how to supply this demand while at the same time halting the accumulation of CO_2 in the atmosphere – ensuring *a healthy planet*. The rising level of CO_2 not only puts pressure on the climate, but also warms and acidifies the oceans, raises sea levels, threatens land-based ecosystems and affects patterns of food production. There is broad scientific consensus that the quality of life for hundreds of millions of people stands to suffer from this second challenge.

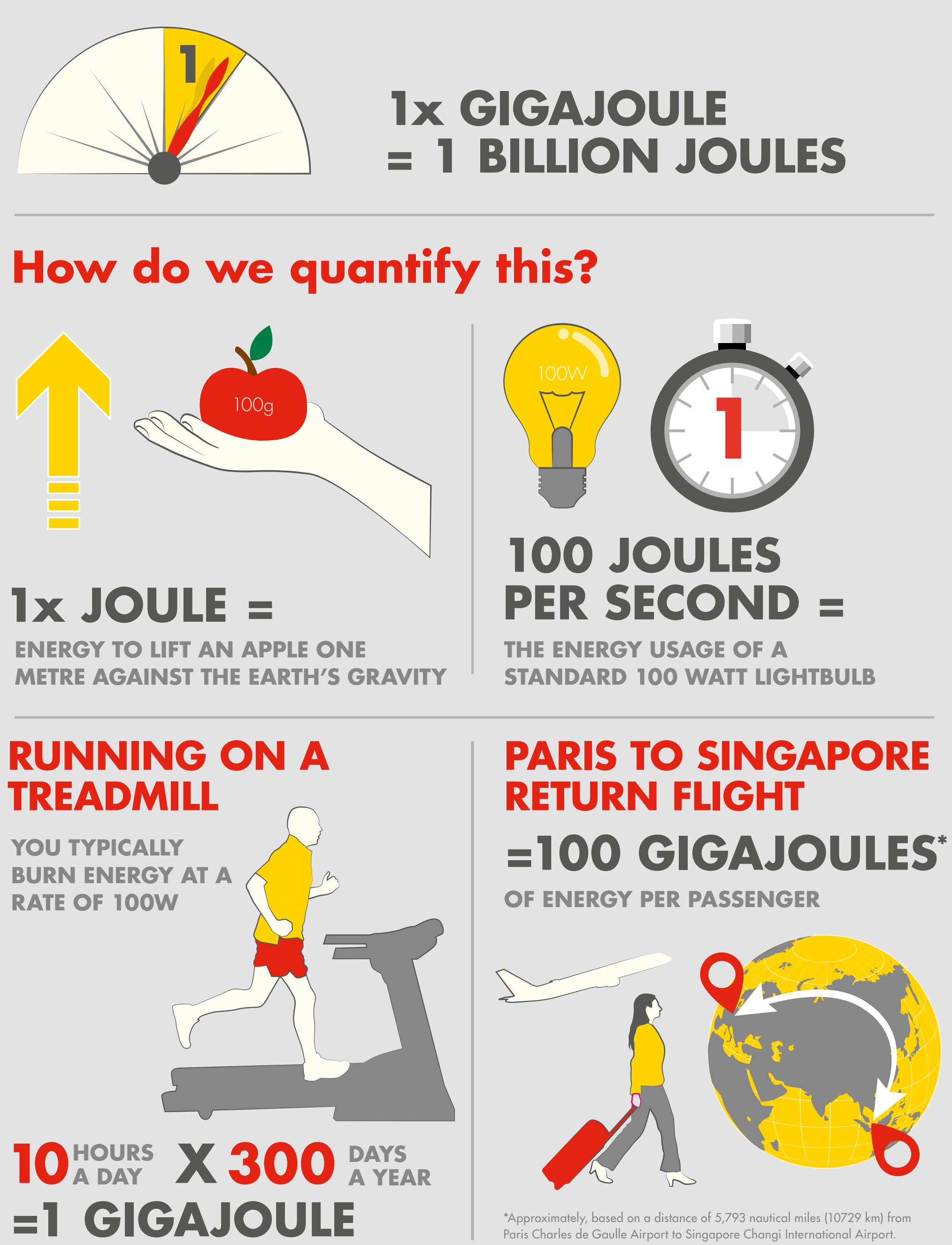
Energy: enabling the material basis for "a better life"

Our understanding and use of "a better life" is quite specific. It refers to a world in which the basic material needs associated with housing, healthcare, adequate sanitation and effective transport are extended to everyone on the planet. It does not mean a TV in every room in the house, a new smartphone every year, three-car families or the "use once and throw away" practices that have become common in much of the rich world in the last 50 years. The question then becomes: how much energy is needed for a better life?

A common measurement of energy is a "gigajoule".[3] A single intercontinental long-haul flight from Cape Town to London requires an average of 40 gigajoules' energy use per passenger. A physical labourer may deliver work that is roughly the equivalent of a gigajoule per year. If we take the United States, the current primary energy consumption is around 300 gigajoules per person per year – roughly similar to 300 physical labourers for every man, woman and child in the country. A more modest and energy-efficient economy, such as Japan or most European countries, averages around 150 gigajoules per person per year.

As we consider the future development of economies, and assume significant energy efficiency improvements, we estimate that an average of about 100 gigajoules of primary energy per person is approximately what is required to fuel the energy-based services that support the decent quality of life to which people naturally aspire. And if we assume a future population of around 10 billion people by the end of the century, and multiply it by a hundred gigajoules per capita, we see that the global energy need would be about 1,000 exajoules (one exajoule is equal to one billion gigajoules) a year – which is roughly twice the size of the current energy system. Such a rough estimate is consistent with much more detailed modelling exercises that have been conducted. It indicates both the scope for efficiency improvements and demand reduction in many already industrialised economies and also the growing need for energy in developing economies.

Gigawhat?



Renewables and hydrocarbons

In order to come close to a net-zero CO_2 emissions sum, societies throughout the world will need to call on an array of carbon-free energy sources, such as wind, solar and nuclear. Because these sources produce electricity, and because new renewable technologies are already becoming established and increasingly cost-effective, in a net-zero emissions world, electricity will likely become the most prominent energy carrier [see page 40, "The Growth of Renewables and New Energy Technologies", for further details].

Renewable energy technologies producing electricity have an indispensable role to play, but on their own they can't address all current energy needs. Renewables vary in availability and in intermittency, and – more importantly – electricity itself is currently the vehicle for less than one-fifth of total end-use energy consumption. While renewables will grow significantly, for the foreseeable future, hydrocarbons will still be required where high process-temperatures and dense energy storage are necessary, such as in iron, steel and cement manufacturing, and in heavy freight and air transport. They will also be required in the production of chemicals (such as solvents) and materials such as plastics. So some economic sectors will inevitably prove more challenging to decarbonise than others.

Similarly, some regions will decarbonise at a slower pace than others, either for political and economic reasons or because they have a particularly high or low population density and hence have either land-use constraints on the availability of renewables or relatively high infrastructure costs and transport needs. So there will be a co-evolution and integration of the fossil fuel and renewable components of the energy system. Inevitably, some level of emissions from certain sectors and regions will remain for the foreseeable future. As a result, the energy system in an emerging net-zero emissions world will be something of a patchwork. Different degrees of decarbonisation and energy efficiency will be achieved at different paces, in different places and in different sectors of the economy. To mop up remaining emissions, CO_2 capture and storage (CCS) will need to be deployed at scale, and selectively combined with sustainable biomass use to provide offsets or "negative emissions".

The four essential policy levers

Specialists know a lot about technical best practice in land use, compact urban development with public transport, integrated infrastructures, high-energy-efficiency with low-emissions transport, reforestation, soil regeneration and many other areas. Although there are costs in moving to this smarter, better world, many economists estimate that these costs are manageable from an economy-wide perspective – a few percentage points of global GDP over the next couple of decades.[4]

The four pillars of the energy system

To achieve net-zero emissions requires the transformation of the entire global economy, especially in four foundational areas where a significant proportion of energy-related emissions of CO_2 occurs: power, buildings, transport and industry.

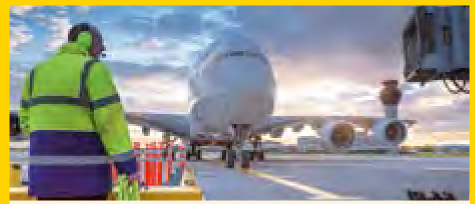
In addition, steps designed to limit emissions from agricultural practices and land-use change will also be essential. Currently, these emissions account for nearly a quarter of all global emissions. [See page 39 "The Key Role of Land Use"].

POWER

Zero-emission technologies, including current and future renewable technologies and nuclear, will need to progressively displace coal and become the largest share of the power sector, with a reduced relative share for hydrocarbons, including gas and biomass combined with CCS.

BUILDINGS

High energy-efficiency standards in building design and operation will need to be implemented and enforced. This greater efficiency is an enabler of full electrification of buildings, which will become much more widespread. The majority of new construction in both developed and emerging economies is already all-electric, driven both by economics and better regulations.



TRANSPORT

Passenger road travel will increasingly need to be electrified or rely on hydrogen, while longer-distance freight, shipping and aviation will continue to rely on energy-dense liquid fuels, including oil, biofuels, liquefied natural gas and hydrogen into the foreseeable future.

INDUSTRY

Certain industrial activities, such as light manufacturing and low-temperature processes, will be able to electrify and therefore decarbonise relatively quickly, while others, particularly in heavy industry, will be more expensive, take longer, or simply lack viable options to transition away from hydrocarbon thermal fuels in the foreseeable future. CCS seems the only viable route to eliminate the bulk of emissions from activities such as steel- and cement-making on a reasonable timescale.

However, because costs are unevenly distributed, the more difficult problem is that such a dramatic transformation will inevitably create relative winners and losers, generating socio-political tensions. Excessive disruption itself can also be extremely costly, impacting not just individual companies and sectors but society as a whole. While the transformation can't be perfectly planned and project-managed top-down, policy needs to be directed at managing these impacts so as to minimise obstacles to change. Almost everyone would suffer in a disorderly transition, so as smooth a transition as possible requires early economy-wide responses rather than late knee-jerk reactions.

Given the urgency and challenging timeframes involved, government policy has a critical role to steer and accelerate the journey in the right direction and provide the certainty required for companies to invest with confidence. Four essential policy levers can help push society from simply knowing the best steps to take to actually taking them:

1. Long-term policy frameworks that support and incentivise the building of necessary infrastructure to enable the take-up of new low-carbon materials and technologies.
2. Economy-wide carbon pricing – whether through carbon trading, carbon taxes or mandated carbon-emissions standards. It provides an efficient and cost-effective way of aligning incentives and motivating action across the economy to reduce carbon emissions.
3. Policies that mitigate the negative effects of the transition on the most vulnerable sectors of the economy and segments of society. Such policies would be time-limited, but are critical for reducing disruptions as the economy goes through the restructuring necessary to become net-zero in its emissions.
4. Other financial support and incentives for low-carbon research and development, particularly for early-stage development and deployment of promising technologies across all key sectors. This support will ensure that technological progress continues apace as carbon pricing ramps up and becomes more effective and widespread in its use.

The human dimension

For global primary energy demands in our net-zero world to remain around 100 gigajoules per year for every person on this planet, while allowing for a decent quality of life, sustained efforts to improve efficiency will be essential. Without such efforts, total energy consumption will not just be double today's level, but could grow to three times greater or more, making the quest for net-zero emissions essentially impossible because the capacity to include biomass in the energy system would be exceeded. There's enough biomass potential to offset double energy use – but not triple.

There is an individual human dimension to these efforts as well. Consumers will need to choose lighter cars with more efficient drives. They will need to employ heat pumps, LED lighting and other energy-efficient appliances as well as increase recycling. Collectively, they can insist on structural efficiencies in their cities with good public transport, integrated waste, water, power and heat management, efficient construction and good building standards. Once built, such major infrastructures stay in place – and shape our energy needs – for decades. So it is critical they are designed and implemented as efficiently as possible from the outset. And by choosing to live in compact cities, consumers lower demand for energy because they don't need to travel as far.

It will also be helpful if concepts such as the sharing economy drive material efficiency – an important factor in keeping in check the growing need for hydrocarbons for chemicals, as well as the demands for products from energy-intensive heavy industry.

> IN SPITE OF THE MANY CHALLENGES, THE PRACTICAL DETAILS OF PROVIDING ENOUGH ENERGY FOR A BETTER LIFE FOR EVERYONE WITH NET-ZERO EMISSIONS CAN BE ENVISAGED – AND THAT IS REASSURING, EVEN INSPIRING.

Can the world do it?

An important and constructive milestone on the journey was the recent Paris climate conference (COP21) in December 2015. At this, 196 countries adopted the Paris Agreement, which will enter into force after 55 countries that account for at least 55% of global greenhouse emissions have deposited their instruments of ratification. The agreement sets out a global action plan intending to put the world on track to avoid dangerous climate change by limiting global warming to well below 2°C.

The architecture of this agreement has been described as a "motorway" to address climate challenges in which there are different lanes, with different economies going along these lanes at different speeds and using different vehicles.[5] But they will all be moving in the same general direction on the same motorway – and this movement, over the course of the century, will bring us towards increasing decarbonisation of our economies and transitions in the way energy is used. Through adopting the Paris Agreement, countries have signalled their intention to enter the motorway, from which, in principle, there are no exits.

This is a valuable platform, differing from the Kyoto Agreement in being a bottom-up, national approach, which is likely to be more politically resilient. The currently identified contributions to reducing emissions are not sufficient and do not look far enough into the future to realise the overall long-term ambition of the Paris Agreement on their own. However, governments agreed to come together every five years to set more ambitious targets, report to each other and the public on how well they are doing to implement their targets and track progress towards the long-term goal.

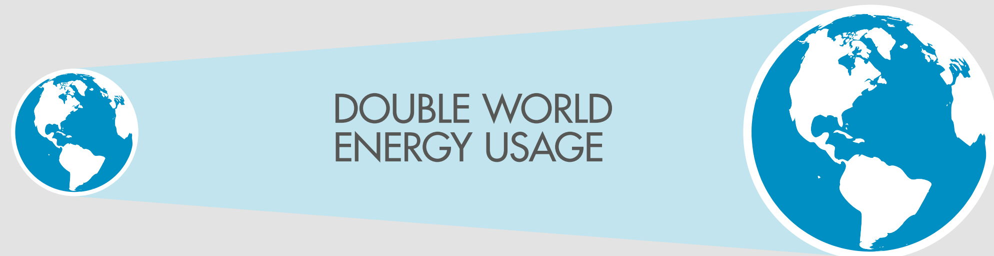
To stabilise the climate requires achieving net-zero emissions globally to arrest the accumulation of CO_2 in the atmosphere and bring down the concentration of other greenhouse gases such as methane. The more quickly this is realised, the lower the risks and impacts of climate change – which is why it is essential to grapple with the practical nitty-gritty realities of what needs to change to achieve net-zero emissions as early as possible. It is also essential to consider the whole pathway to net-zero emissions and not just the first steps. There is a very real danger that policymakers could focus only on the short-term, easier options that can be realised in the next decade or so, and then find that progress runs into a wall because the more technically or socio-politically difficult sectors of the economy have been neglected.

In spite of the many challenges, the practical details of providing enough energy for a better life for everyone with net-zero emissions can be envisaged – and that is reassuring, even inspiring. But getting there will not be easy. The world will need huge and courageous progress in economic restructuring, co-evolution of the emerging and established components of the global energy system and the large-scale implementation of alternative technologies. Above all, we will need the active cooperation of millions of citizens, policymakers, civil society leaders, and businesses across the planet.

How large could the energy system grow?

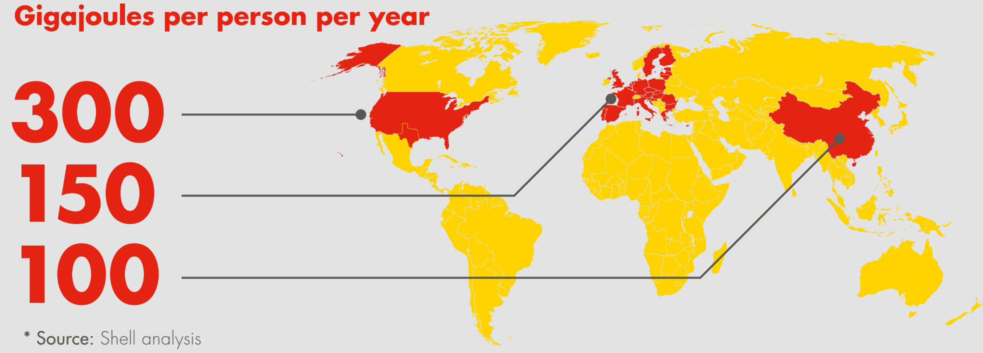
As we consider the future development of economies, and assume significant energy improvements, we estimate that an average of about **100 gigajoules of primary energy per person** is approximately what is required to fuel the energy-based services that support the decent quality of life to which people naturally aspire.

2015	2100
7+bn WORLD POPULATION	**10bn** WORLD POPULATION
~500 EXAJOULES ENERGY CONSUMPTION PER YEAR	**~1000** EXAJOULES ENERGY CONSUMPTION PER YEAR



Average current primary energy use*

Gigajoules per person per year



* Source: Shell analysis