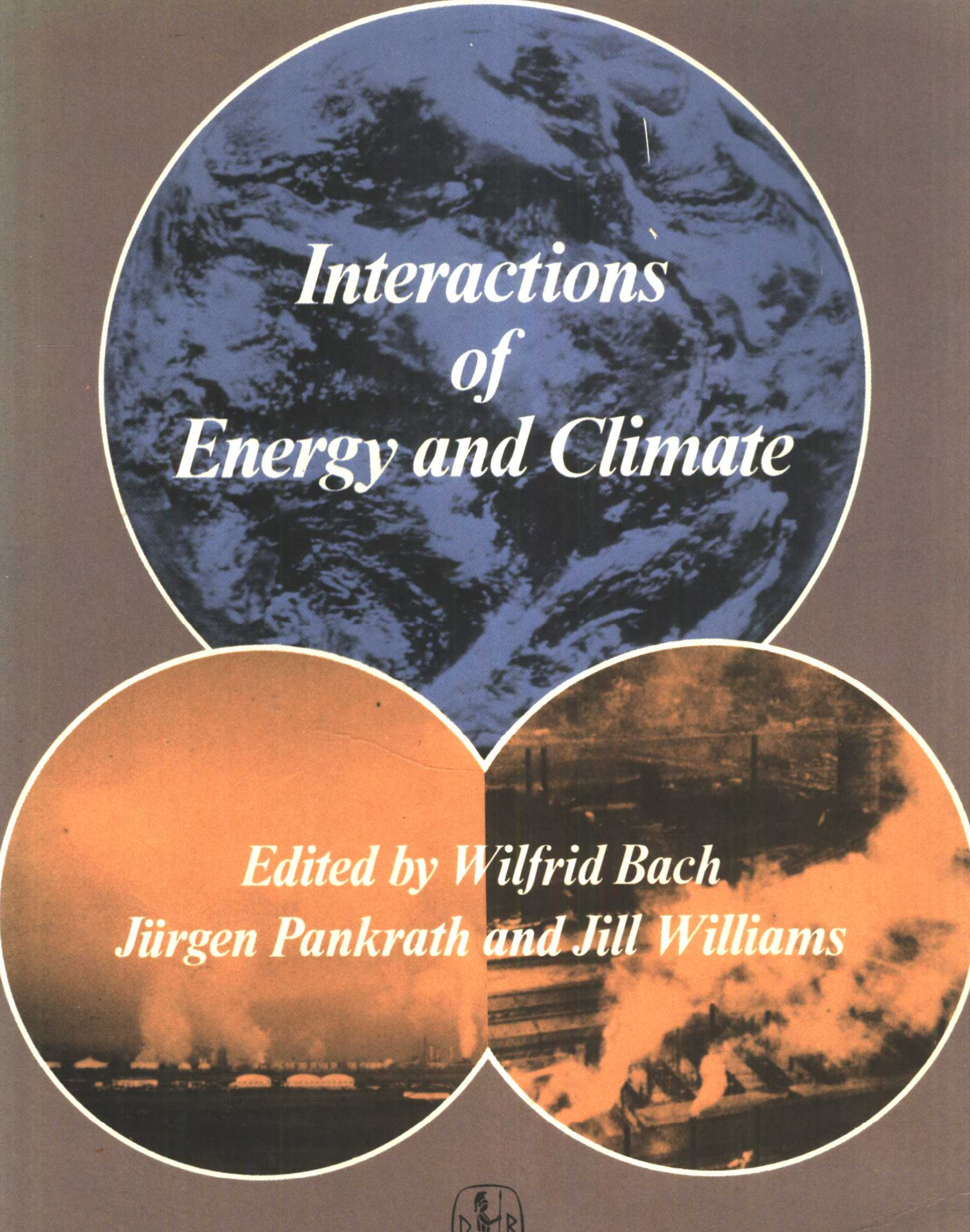

Interactions of Energy and Climate

Edited by Wilfrid Bach
Jürgen Pankrath and Jill Williams

D. Reidel Publishing Company
Dordrecht : Holland / Boston : U.S.A. / London : England

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Proceedings of an International Workshop held in Münster, Germany, March 3-6, 1980

Edited by

W. BACH

Center for Applied Climatology and Environmental Studies, The University of Münster, Germany

J. PANKRATH

Umweltbundesamt, Berlin (West), Germany

and

J. WILLIAMS

Climatological Consultant, Karlsruhe, Germany

D. Reidel Publishing Company

Dordrecht : Holland / Boston : U.S.A. / London : England

Library of Congress Cataloging in Publication Data

CIP

Main entry under title:

Interactions of energy and climate.

Proceedings of an international conference held at Münster, Germany, in March 1980.
Includes index.
1. Climatology–Congresses. 2. Energy development–Environmental aspects–Congresses. I. Bach, Wilfrid. II. Pankrath, Jürgen. III. Williams, Jill, 1949–
QC980.I56 551.5 80–23220
ISBN 90–277–1179–8
ISBN 90–277–1177–1 (pbk.)

Published by D. Reidel Publishing Company,
P.O. Box 17, 3300 AA Dordrecht, Holland.

Sold and distributed in the U.S.A. and Canada
by Kluwer Boston Inc.,
190 Old Derby Street, Hingham, MA 02043, U.S.A.

In all other countries, sold and distributed
by Kluwer Academic Publishers Group,
P.O. Box 322, 3300 AH Dordrecht, Holland.

D. Reidel Publishing Company is a member of the Kluwer Group.

Printed in The Netherlands

INTERACTIONS OF ENERGY AND CLIMATE

FOREWORD

Since the beginning of industrialization in the last century, a steady increase in energy consumption can be observed. At the same time, energy generation switched from wood and coal to predominantly oil, coal and natural gas.

Soon, many countries became aware of the fact that the resources of fossil fuels, especially of oil and natural gas are finite. Diversification of energy sources became a requirement for the future.

Governments expressed their concern by setting up natural energy programmes while international organisations undertook assessments of the global energy resources and possible rates of supply and substitution.

When it comes to setting up energy policies, the following factors must be taken into consideration: population growth, level and nature of socio-economic activity, the costs of energy, the adequacy and reliability of supply, the availability of technology and supporting infrastructure, the success of energy conservation programmes and concern about the environment, safety aspects of production and use of energy as well as educational efforts toward a rational use of energy.

When we express our most urgent concern, the long-term global energy provision, experts offer four interrelated partial strategies:

- the strategy of rational use and conservation of energy
- the strategy of using renewable energy sources
- the coal strategy including coal gasification and liquefaction
- the nuclear power strategy.

Any strategy, however, for securing future energy supply has, from my point of view, to be thoroughly examined as to its impact on the environment.

In the past, the environment discussion tended to focus more attention on short-term aspects than on long-term environmental, climatic and socio-economic consequences. But long-term developments, because of their irreversibility, need even more attention.

One important part of this risk assessment process is the attempt to quantify the impact of the various energy generation options

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on global and regional climate. And I am glad that the workshop, the proceedings of which I am pleased to introduce herewith, comes to scientific recommendations regarding energy use and production causing the least impact on climate and environment.

The outcome of this workshop is a fruitful contribution to the interdisciplinary Governmental Research Programme on Climatology of the Federal Republic of Germany. With this programme we are joining the relevant multinational activities of the WMO and the Commission of the European Community, which is to give the basis for political decisions to protect man and his environment from harmful effects.

Main points of interest are

- Research on the climate system
- Acquisition, management and availability of climate data
- Research on sources and sinks of air pollutants potentially affecting climate
- Research on the impact of climatic changes on socio-economic conditions
- Research on the impact of biospheric changes as well as impacts of air pollutants on the regional climate.

Within this programme it is one of the particular concerns of my agency, which on behalf of the Federal Minister of the Interior sponsored this workshop, to investigate the interactions between energy and climate. We therefore set up a research and development programme on the environmental compatability of specific developments and options in future energy generation. And, in this respect, I am grateful for the contribution of the workshop on energy/climate interactions to our programme.

The Federal Environmental Agency acknowledges, with gratitude, the efforts of Professor Wilfrid Bach in developing and organizing, and of the University of Münster, in hosting this workshop.

Dr. Heinrich von Lersner

President

Umweltbundesamt

PREFACE

Over the past decades climatic events in many regions of the world have made us aware of our vulnerability to climatic change and variability. We increasingly realise that not only is man vulnerable to variations in climate but also that climate is vulnerable to the actions of man. This is of particular concern in view of the continued world population growth and the world's increasing appetite for energy and food.

This concern is shared by a number of international organizations as well as a growing number of national governments. The Federal Republic of Germany, through the Department of the Interior and its Federal Environmental Agency, is sponsoring a pilot program of the effects of man's activities on the global climate. An important part of the overall program involves the organization of a series of international conferences. The first meeting, entitled "Man's Impact on Climate", which was held at the Federal Environmental Agency's headquarters in Berlin in 1978, was designed to give a technical review of the various aspects of climatic change. The second meeting, entitled "Energy/Climate Interactions" was held at Münster, Germany, in March 1980, and is documented in this book. This conference dealt with both the effects of energy systems on climate and with the effects of climate on energy use. A third meeting will be held at the Aspen Institute of Berlin in December 1980 to deal with the climate/food interactions and their implications for world food security. All of these conferences are planned and organized by the Center for Applied Climatology and Environmental Studies at the University of Münster.

The "Energy/Climate Interactions" meeting included 29 formal presentations to an audience of about 100 participants, representing 10 different nations. The lectures were grouped into 7 different sessions and are reflected by the sections of this book. Some of the important questions addressed at this meeting were:

- What climatic impacts can be expected from the various energy, economic and population growth policies?

- What energy strategies are feasible that would cause acceptable climatic impacts?

- What are the relative contributions of the various forcing functions to climatic change?

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- What are the relative risks, costs and/or benefits of climatic impacts?

- What possible countervailing measures could reduce or even avert impacts on climate?

An edited version of the conference discussions follows each group of papers.

The last two days of the meeting were devoted to three simultaneous working group sessions. Statements prepared by the working group chairmen were discussed with emphasis on the topics: 'Energy demand and supply - the preferred energy strategy causing the least impact on climate', 'Identification and assessment of the various climatic impacts', and 'Objectives of a climatic impact study program'.

Based on the papers, the discussions and the working group reports the following observations can be made. In the decades ahead decisions have to be made to reduce or avert the impacts of climatic change before all the answers have been obtained. Although a climatic impact assessment program is faced with many uncertainties, it nevertheless has to be started now, because society cannot afford to wait until all variables are quantified to the satisfaction of all the parties involved. Additionally, as a precautionary measure, society should follow a low risk-climate-energy-land use policy, which would

- promote the more efficient end use of energy,

- secure the expeditious introduction of energy sources that release little or no carbon dioxide to the atmosphere, and

- discourage deforestation and encourage reforestation and soil conservation.

The major advantage of such a low risk policy is that in the best case it may prevent climatic impacts altogether, and that in the worst case valuable time would be gained to obtain better information to redirect policy decisions. Since this policy is based on measures that make sense for other than climatic reasons, it is worthy of consideration in any case.

In conclusion, the convenors of this meeting wish to thank all colleagues who gave valuable advice during the planning stage of the conference and who contributed their papers to this book. Additionally, we are grateful to all conference participants who shared their ideas with us.

We further wish to acknowledge the financial support from our sponsor, the Department of the Interior, who through the Federal Environmental Agency, made available a grant to carry out this climate/energy project. We are also grateful to the Commission for the European Communities and the United Nations University for co-sponsoring this meeting. The conference host, the University of Münster, deserves special thanks for supplying the facilities which helped to make this a successful conference. The reception given by the City of Münster is also gratefully acknowledged.

Finally, we especially wish to recognise the assistance given by the staff of the Center for Applied Climatology and Environmental Studies at the University of Münster in the preparation of both the conference and the conference publication.

Wilfrid Bach
Jürgen Pankrath
Jill Williams

WORKING GROUP I:

ENERGY DEMAND AND SUPPLY – THE PREFERRED ENERGY STRATEGY CAUSING THE LEAST IMPACT ON CLIMATE

Chairman/Co-Chairman: F. Niehaus/A. Voss

W. Bach, P. Biscain, U. Hampicke
G. Hekstra, C. Keeling, F. Krause
H. Oeschger, W. Quirk, T. Waltz,
G. Zimmermeyer

1. THE ISSUE

Provided energy growth continues at the current rate and with the present mix of sources, there is a definite prospect of a significant climatic change. Along with the expected overall warming of the lower atmosphere there will be shifts in the atmospheric circulation patterns resulting in regional and seasonal temperature and precipitation anomalies. The major effect will not be the creation of a new type of climate, but rather a different distribution of climate. This can have an impact on energy requirements, food production, fisheries, water resources, forestry, land use, transportation, tourism, and human health and well-being. In short, the total global socio-economic structure is vulnerable in varying degrees to a naturally and/or anthropogenically induced climate change and variability.

The influence of energy use on climate and the environment, and thus on society, therefore cannot be evaluated in isolation, but has to be viewed together with economic, ecological and social developments. Thus the minimization of the influence on climate and environment can only be a sub-set of the overall objectives of policy decisions which need to be defined carefully. A broad systems approach is required that considers all aspects including those which are difficult to quantify.

The overall objective of policy decisions guiding energy strategies is the improvement of the well-being of all mankind now and in the future. Such decisions have a subjective component so that different conclusions can be reached by different individuals and different nations with different value systems. It is, therefore, important that an assessment of the various national and global energy scenarios takes fully into consideration both the technical potential and the economic, social and political realities.

It is also important to recognise that any optimization procedure

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regarding a desirable energy mix may lead to very different conclusions depending on the spatial and temporal scales considered. Thus it is necessary to consider not only what is desirable on a local and regional basis but also what is desirable on a global scale. Attention must also be paid to the short-term as well as the long-term solutions and their consequences.

Considering the problems of future energy demand and supply, it is desirable to have a wide variety of energy options at our disposal in order to increase the resilience of the energy economy. This can best be achieved by a more efficient use of the traditional energy sources and by the more expeditious development of alternative energy resources.

All options must be carefully scrutinized for their inherent risks, costs and benefits prior to their adoption. Such comparisons should consider the total fuel cycle of the various systems including construction and dismantling of plants as well as waste disposal. Moreover, comparisons must be made among systems that provide the same product to the end-user. Current risk-cost-benefit analyses require considerable improvement. Finally, it is important that the short-term benefits be carefully weighed against the medium-to long-term risks.

2. CLIMATIC INFLUENCE OF ENERGY USE

All energy use results in the emission of heat into the atmosphere. Model studies show that there are apparently no effects on global climate from heat emission when energy scenarios of less than 100 TW of primary energy consumption as compared to the present 9 TW are considered. Heat emission may, however, pose problems on a local or regional scale. The results of model and analogue studies and comparisons with natural phenomena suggest that the major effects of power plants clustered in energy centers of 10,000-50,000 MWe capacity could produce significant changes in cloudiness and precipitation with an increase in the probability of severe weather. Research on effects of heat emission should therefore concentrate on local-scale meteorological models and on the investigation of the impacts of large power centers.

Human activities, especially those related to industrial processes and the practice of agricultural burning and soil management, result in the release of particles into the atmosphere. In addition to direct particle emission, aerosols are also formed from the gaseous products of combustion. All aerosols scatter and absorb both solar and infrared radiation, and, by influencing the atmospheric heat balance, may also change the climate. There may be warming in some regions and cooling in others. The net global effect will probably be one of atmospheric warming.

The increase of atmospheric CO_2 poses a problem of major concern. This increase which is worldwide has to be studied in international co-operation and given high priority.

If energy consumption follows current projections it seems probable, based on present knowledge of the carbon cycle, that atmospheric CO_2 will increase to a level of about 380 ppm by volume by the end of the century and reach twice the preindustrial level around 2050 A.D. Still further increases could occur before limitations in fossil fuel supply will force a decline in production, so that a peak concentration 4 to 8 times the preindustrial level may occur within 2 or 3 centuries. High levels once reached will only slowly decline so that a level over twice the preindustrial is likely to persist for over 1,000 years.

Since the beginning of the industrial era, the atmospheric CO_2 level has increased by about 15%. The present rise in atmospheric CO_2 is equivalent to 50 to 60% of the CO_2 from fossil fuels remaining airborne. The year to year fraction is, however, variable. Accurate measurements of atmospheric CO_2 are therefore desirable to furnish a more reliable baseline for projecting the airborne fraction into the future.

Although present knowledge of the carbon cycle is adequate to predict future CO_2 fractions remaining airborne, efforts must continue and be expanded to determine more accurately the uptake by the oceans, and to assess both the contribution and the response of the biosphere to atmospheric CO_2 increases. These factors influence the airborne fraction and should be established to the highest possible accuracy.

Present estimates center around a global average value of 2-3°C surface air temperature increase per doubling of atmospheric CO_2 concentration with a 3-4 fold temperature increase in northern polar regions. Due to the inertia of the oceanic response, temperature increases are expected to follow the CO_2 increase with a lag of 10-20 years. Based on studies of the exploitable oil, gas and coal resources, carbon cycle models suggest a maximum possible atmospheric CO_2 increase by a factor of about 8. Since the temperature increases approximately logarithmically with increases in atmospheric CO_2 concentration (see Working Group Report No. II), the maximum global average rise could be as high as 8°C.

The most likely ultimate temperature increase, based on present knowledge, is considerably lower than this but nevertheless higher than that predicted by a single doubling of the preindustrial CO_2 level. If the exploitation of fossil fuels is not restrained and no large storage of carbon in the biosphere occurs, the most likely global average temperature rise could be of the order of 4 to 6°C.

If, on the other hand, the fossil fuel CO_2 production could be kept at the present level, a 50% CO_2 increase, corresponding to an average temperature increase of 1 to 1.5°C, would result in 2100 A.D. Over such a long time period this global average temperature increase is perhaps tolerable. If not tolerable, time is gained to take further remedial action.

In this context it is well to recall that there are other gases and probably also aerosols that will reinforce the CO_2-greenhouse effect making an eventual remedial action more difficult. At any rate scrubbing CO_2 from the stack gases or taking it out of the atmosphere and disposing of it somewhere are considered to be last resort measures in the prevention of a CO_2 build-up in the atmosphere because they are very expensive and require large additional energy expenditure.

The Panel looked also into the possibility of whether coal gasification or liquefaction would aggravate the CO_2 problem. These processes require both heat and hydrogen. If tnese are supplied by burning part of the coal (autothermal gasification) the total CO_2 emissions are some 40% higher than using coal directly. If, on the other hand, the energy is provided by a non-fossil energy source (allothermal gasification), the total CO_2 emissions are still some 6% higher than burning coal directly, because carbon is still needed to split the water for making hydrogen. Moreover, if the energy is supplied by an external energy source and the hydrogen production does not involve carbon (e.g. electrolysis, thermal water splitting) the total CO_2 emissions could be reduced by about 40%. Of course, CO_2 emissions would be prevented altogether, if hydrogen was produced from a non fossil fuel source and used as a direct energy carrier.

3. EVALUATION OF ENERGY SCENARIOS AND RECOMMENDATIONS

In the following emphasis is placed on the increasing atmospheric CO_2 levels due to fossil fuel use because they were identified as the most likely contributing cause to a global climatic change. Projections of CO_2 emission levels into the future are based on aggregated regional energy scenarios. A number of such scenarios were considered notably those developed at the International Institute for Applied Systems Analysis (IIASA) in Laxenburg in Austria, the International Energy Agency in Paris, France, the Institute for Energy Analysis (IEA) in Oak Ridge, USA, and the Massachusetts Institute of Technology in Boston, USA.

It was seen that all scenarios considered a continued growth in energy demand of between 20 and 40 TW by 2030 A.D., mainly because of the continued population growth and the obligation to reduce the gross inequities in energy consumption between the developed and the developing nations. The fossil fuel share in 1980 is about 90% of the total primary energy supply. Both the IEA scenario for 2025 and the IIASA high and low scenarios for 2030 project a fossil fuel share of 65-70%. It was also noted and taken into consideration that the increase in energy demand may not be as large as the above figures suggest in view of the fact that primary energy demand forecasts have been scaled down continually in recent years.

Based on this information the following strategies can be envisaged:

- to let fossil fuel use, and hence CO_2 emission, continue to grow at the historical exponential growth rate of 4.3%/yr.;
- to let fossil fuel use grow at a reduced rate;
- to keep fossil fuel use at the present level, or
- to reduce fossil fuel consumption.

Considering the fact that the world economy will continue to be strongly dependent upon fossil fuel use for at least a transitional period of several decades, the panel does not recommend a reduction in fossil fuel use at this time. However, the panel wants to make it equally clear that a continued growth of fossil fuel use at the historical rate is highly undesirable in the light of the magnitude and irreversibility of the potential effects.

After much deliberation, out of the remaining two strategies, the panel opted to recommend that the global fossil fuel consumption not be increased above the present level. We felt justified in making such a recommendation on account of recent energy studies prepared for a number of nations in the developed world and data presented at this and other workshops suggesting that

- the more efficient use of energy can result in substantial savings (initially as much as 30-50%) in several energy sectors without in any way jeopardizing prosperity; and that
- non-fossil energy sources have the technical potential to make a significant contribution given sufficient time and appropriate institutional support.

These strategies used in a complementary fashion could ensure growth of end use energy over a few decades until primary energy consumption equilibrium is reached. They can be viewed as a prudent insurance policy with a built-in flexibility sufficient to react to the potential impact of CO_2 and other agents on climate and environment. Further arguments which were put forth in support of our recommendation included

- the necessity of developed nations to curtail drastically their strong dependence on imported fossil fuels, thereby avoiding an imbalance of payments;

- the fact that the recovery and processing of unconventional fossil fuel resources will exert an extremely high strain both on the economy and on the environment; and

- the argument that the rapid combustion of fossil fuels to produce energy may be hard to justify to our progeny since fossil fuels represent non-renewable substances of high chemical value.

In making the recommendation to keep the global CO_2 emission from fossil fuel use at the present level the panel was fully aware that appropriate allowances must be made for the disparate fossil fuel needs of different countries on an equitable basis. Special care must be exercised that developed countries do not export their energy problems to developing nations i.e. by making available energy-intensive technologies that are unsuitable for their infrastructure. This could well lead to a situation where developing countries produce goods for the developed countries just for the purpose of paying for their energy bill (especially for crude oil imports and capital investments) and without much benefit to their own countries (such as raising their standard of living). In order to reduce North-South tensions it seems therefore highly desirable that developed nations use their high technological potential to reduce their share of global fossil fuel consumption (notably crude oil and natural gas) so that the developing nations can attain a correspondingly larger share. Developing countries will be especially sensitive toward climatic change since they often operate on a minimum of natural resources. These less resilient regions of the world need therefore particular attention and help.

All these actions may, however, be nullified if global population growth continues. Population increase in large regions of the world threatens to outweigh any material improvements. Clearly, the gap in energy use and prosperity between the developing and developed world can only be narrowed by a voluntary change of attitude. This requires an atmosphere of mutual trust and the realization that the problems of energy and population growth both in the developed and the developing nations are inseparably linked.

4. CONCLUSIONS

There is clear evidence of an impact of energy use on local climate. There may already be some perturbation of the global climate, but this may not be detectable in our measurements before the end of this century. Moreover, the interactive mechanisms involved are so complex and presently still so poorly understood that the impacts on climate, which may be quite serious and potentially irreversible, cannot be predicted with confidence at this time. The danger is that energy decisions based on such poor information may lock us into an energy development where we may lose flexibility once energy systems with long market penetration have been adopted.

In the face of present uncertainties prudence dictates a cautious and flexible energy strategy. We therefore recommend the following low climate-risk-energy policy, which would

- promote the more efficient end use of energy,
- secure the expeditious development of energy sources that add little or no CO_2 to the atmosphere, and
- keep global fossil fuel use, and hence CO_2 emission, at the present level.

This energy policy which should be followed anyway - CO_2 risk or not - has the advantage of both permitting energy growth and promoting energy quality. The major bonus is, however, that in the best case such a policy may prevent an impact of energy use on global climate altogether, and that in the worst case valuable time is gained to obtain better information to redirect our energy policy. The time gained can be used to reduce the uncertainties about the future CO_2 emissions, their climatic effects and their socio-economic implications.

WORKING GROUP II:

IDENTIFICATION AND ASSESSMENT OF THE VARIOUS CLIMATIC IMPACTS

Chairman/Co-Chairman: H. Flohn/R. Rotty

R. Chervin, D. Ehhalt, W. L. Gates,
J. Hofmann, H.-J. Jung, H. Lieth,
G. McKay, T. Oke, G. Potter,
V. Ramanathan, G. Schlesser,
C. C. Wallen

It is imperative that the climatological community provide guidance on the environmental consequences of growing global energy demand and the evolving mix of energy supply possibilities. The full understanding is very complex, involving physical, social and economic understanding of the entire global system.

There are fundamental techniques that can be employed in assessing the climatic impacts of anthropogenic uses of energy:

- analytical (numerical) models of varying degrees of complexity and resolution based on physical principles and,
- past climates that may have features similar to those that may come from increased CO_2 can be reconstructed using geological and historical evidence.

We believe that the state of development of each of these techniques is at present inadequate to give a picture of future climate with sufficient resolution and clarity to enable us to identify the specific changes necessary for a full assessment. We recommend that at present both techniques be used to complement each other - models to determine the large scale sensitivity of climate to man's activities and historical and geological reconstructions to obtain information with more detail and regional resolution.

Although the effects of atmospheric carbon dioxide are not the only ones associated with the energy used by man, we believe that they will prove to be the major factors that will give concern to mankind on a global scale within the foreseeable future.

Model studies of climate give general and global average results. History and geological knowledge can be exploited through case studies to acquire understanding of the probable consequences of large scale climatic change for the environment. However, before warm periods of the distant past (as reconstructed, for example, from historical and geological data) can be meaningfully interpreted as possible scenarios of a future CO_2-warmed climate,