FOIA Number: 2012-0769-F

FOIA MARKER

This is not a textual record. This is used as an administrative marker by the William J. Clinton Presidential Library Staff.

Collection/Record Group: Clinton Presidential Records

Subgroup/Office of Origin: Council on Environmental Quality

Series/Staff Member: Kathleen (Katie) McGinty

Subseries:

OA/ID Number: 2614

FolderID:

Folder Title:
UNCED [United Nations Conference on Environment and Development]/Renewable Energy/Climate Change

Stack:	Row:	Section:	Shelf:	Position:
S	61	5	6	3

file UNCED/Renewable Energy.

January 27, 1991

The Honorable James A. Baker, III
Secretary of State
Department of State
Washington, D.C. 20520

By Messenger

Dear Secretary Baker,

Beginning February 5, representatives of the United States will attend a meeting in New York to begin the process of preparing a new ~~international~~ plan of action for developing renewable energy sources. The product of this meeting will be incorporated into the UN Conference on Environment and Development (UNCED) process for possible action in Brazil this June.

In August 1990, the United Nations established a high-level working group of experts to prepare a comprehensive and analytical study on new and renewable sources of energy in preparation for the UNCED meeting. This group, the United Nations Solar Energy Group for Environment and Development (UNSEGED), examined the technological status of renewable energy technologies and reviewed the progress which has occurred since the Nairobi Program of Action was adopted in 1981.

Their report, *Solar Energy: A strategy in Support of Environment and Development*, concludes that the technical potential for renewable energy sources is significant. Whether or not renewable resources will make a contribution in the future is largely a political question. As the working group report states:

> "In the long-term, the utilization of renewable energy sources is not likely to be constrained by the availability of resources or cost-effective technologies. Political and administrative decisions are their primary constraints." (Reported of the UN Solar Energy Group for Environment and Development, page 3.)

The UN Solar Energy report makes a series of national and international recommendations for action. These proposals will be the foundations for the discussions which will begin in New York in February.

As strong supporters of the development of renewable energy resources, we wish to encourage the United States delegates to take an active, leadership role in these discussions. We agree with the general conclusions of the UN Solar Energy working group that the potential for these technologies is significant, and that their major constraints are political and institutional.

In addition, we would like to be informed of your intentions regarding the positions to be taken by the United States in these discussions. Specifically,

1) Will the United States delegation support reaching a new agreement on a international solar energy development plan of action at UNCED?

2) What is the United States position on the specific recommendations made in the UN Solar Energy Report for national and international action?

3) What other initiatives to promote the development of renewable energy resources is the United States prepared to advance as part of the UNCED process?

Given the immediacy of the February meeting, we would appreciate your prompt response to this request. If you have any questions about this inquiry, please feel free to contact either of us directly or have your staff contact our respective staff listed below.

Sincerely,

Paul D. Wellstone　　　　Al Gore, Jr.

Staff Contacts:
Sen. Wellstone: Karl Gawell, 224-9694
Sen. Gore: Katie McGinty, 224-4944

Solar Energy: A Strategy in Support of Environment and Development

A comprehensive analytical study on renewable sources of energy

Report of the
United Nations Solar Energy Group for Environment and Development

(UNSEGED)

November 1991

Table of Contents

1. Summary and Recommendations

by the UN Solar Energy Group on Environment and Development[1,2]
(UNSEGED)

I. Impetus

1. Development, economic growth and population increase lead to ever greater energy-service requirements. These growing requirements must be met in a sustainable way. Current patterns of energy production, transportation and use do not meet these requirements. They do not lead to a sustainable world.

2. Energy production, transformation, transportation, and utilization account for at least as much of all manmade environmental problems of a global or regional nature as all other human activities. They also cause major national and local environmental damage.

3. Energy issues are central, therefore, to discussions regarding the environment and development.

4. The energy sector represents a large fraction of national and international economies. Globally, energy accounts for 25 to 30 percent of present investments in development and economic growth. Energy-sector investments, therefore, are important determinants of the direction of societal development.

5. Maintaining current patterns of fossil-fuel use will cause unprecedented rates of global surface-temperature increase, resulting in the disruption of the Earth's climate. The scientists on the Intergovernmental Panel on Climate Change concluded that, in order to stabilize atmospheric concentrations of carbon-dioxide (CO_2) at today's levels, an immediate reduction of anthropogenic CO_2 emissions by more than 60 percent would be necessary. Fossil-fuel use is the main source of anthropogenic CO_2 emissions. Such a reduction implies, therefore, a profound change in the commercial energy system, about 88 percent of which is currently

---

[1] The term solar energy is used broadly here to mean all renewable energy sources.

[2] This high-level group of experts, designated in their personal capacity and selected on a geographical basis, was established in August 1990 by the Director-General for Development and the International Economic Cooperation of the United Nations, New York. The group is working under recommendation of UN General Assembly resolution A/45/208 of 21 December 1990. The group's mandate is to prepare a comprehensive and analytical study on new and renewable sources of energy with a view to providing a significant contribution to the 1992 United Nations Conference on Environment and Development (UNCED) to consider appropriate action, including funding and technology transfer, within its area of competence and within the existing financial resources, not excluding voluntary contributions.

The members of the group, chaired by Professor Thomas B. Johansson (Sweden), are listed in Appendix A.

The UNSEGED has held meetings in New York, (USA), Sophia Antipolis (France), Rome (Italy), Snekkersten (Denmark), Munich (Germany), and Oslo (Norway). The work has been supported in cash and in kind by the governments of Austria, Canada, Denmark, France, Germany, Italy, the Netherlands, Norway, and Sweden. In support of the UNSEGED work, the government of Denmark organized a Conference (Meyer, N.I. and Nielsen, P.S. (eds), "Conference Proceedings: Global Collaboration on a Sustainable Energy Development," Technical University of Denmark, April 1991) and the government of Norway a "Symposium on Hydropower — Its Role in an Environmentally Sensitive World." The reports from these meetings are available from the respective governments. The government of France has supported an evaluation of the accessible potential of renewable energy sources for the work (Dessus *et. al.*, "Renewable Energies: Actually Accessible Regional Potentials and Environmental Impacts Analysis for the Ninties," La Houille Blanche, no. 1, January 1992). A scientific state-of-the-art review of technologies to utilize renewable sources of energy has been prepared for the United Nations in support of the UNSEGED work, and is published separately (Johansson, *et. al.* (eds), "Fuels and Electricity from Renewable Sources of Energy," Island Press, 1992).

supplied with fossil fuels.

6. Energy strategies should be used as instruments for sustainable development and preserving the environment. Increasing the share of renewable energy sources in total world energy supply and improving energy efficiency are the essential elements of a strategy for making this happen. Public concern about nuclear power has increased and investments have slowed considerably, reducing the potential role nuclear power might play in such a strategy. This report deals solely with renewable energy sources.

II. Background on Renewable Energy Sources in the United Nations System

7. Concern in the 1970s over uncertainties of fuel supply and future depletion of fossil fuels led to increased interest within the international community in expanding the utilization of new and renewable energy sources. The Nairobi Programme of Action (NPA) was established in 1981 as a comprehensive international effort for developing and utilizing new and renewable energy sources.

8. The decade since the adoption of the NPA has, essentially, been lost. This is not because of lack of technical progress or failure of individual projects, but because the political resolve expressed in the NPA was not supported by:

- agreed upon targets quantifying the objectives of the NPA, and, correspondingly,
- financial commitments, and
- adequate institutional support,

especially in the industrialized countries.

9. The absence of these fundamental structure-forming mechanisms left room for the continuation of national policies that inhibited the promotion of renewable energy sources. Such policies included:

- lack of support, policy development and legislation for broad dissemination of new technologies,

- small and declining support for research and development (R&D) on renewable energy sources at the national level in most OECD countries (after a buildup period, International Energy Agency (IEA) governments' expenditures on energy research and development were reduced by more than 70 percent between 1980 and 1987. Only seven percent of the 1990 expenditures was directed to renewable energy sources).

- exclusion of external costs and non-monetary benefits in economic evaluations of energy technologies and systems, and

- large subsidies provided in many countries for conventional energy sources. Some of these subsidies were made directly in the form of large state-run development programs or tax relief while others were indirect and manifest in ignored environmental costs and government responsibility for insurance, waste disposal, etc.

10. The government signals reflected in the above four points, along with new discoveries of fossil-fuel resources, changing economic conditions and falling oil prices, led to small and declining private investments in renewable energy.

III. Renewable Energy Resources

11. The flow of renewable energy to the Earth's land surface is thousands of times greater than mankind's present rate of total energy use. Utilizing only a small fraction of this resource would provide humanity with an alternative and environmentally-sound path toward meeting future energy needs.

12. Present total commercial world energy supply is about eight gigatonnes of oil equivalent (Gtoe) per year. Of this, renewable energy sources contribute about seven percent, most of which is large-scale hydropower. Including non-commercial energy sources, renewable energy sources contribute 14 to 20 percent of total primary energy supply.

IV. Technologies

13. Renewable energy sources can be used to produce a variety of energy carriers, such as liquid fuels and electricity, which can be utilized within the existing transmission, distribution and end-use infrastructure in both industrialized and developing countries.

14. Several technologies for utilizing renewable energy sources are mature and economically competitive. They are diffusing on the market even under present conditions. Electricity generation in biomass-fuelled plants in the U.S. has increased from about 250 to 9000 megawatts (MW) during the 1980s. Three hundred and fifty MW of installed capacity in solar thermal plants are selling electricity to the grid at competitive prices in California and 350MW more are being built. Worldwide geothermal power capacity has increased from 2000MW in 1980 to 5830MW in 1990. Wind farms provide 1900MW of electricity to the grid (in locations such as California, Denmark, India, and the Netherlands) and, after a more than 60 percent cost reduction in the 1980s, are now economically competitive with coal-based plants on sites with favorable wind regimes. Ethanol from biomass is used in Brazil as an automotive fuel in approximately four million automobiles. It is also used as an octane enhancer. Current production volumes exceed 200,000 barrels per day. About 110 thousand small wind generators and 1600 wind pumps are operating in China. Several million household anaerobic digestors are operating in China and India, and several million household solar water heaters are in use. Passive-solar technologies for heating and cooling, if introduced at the design stage, are paid back in three to five years.

15. Some renewable-energy technologies and energy carriers show great promise. The two most important examples are photovoltaics and new advanced uses of biomass for gasification/power generation and producing liquid fuels. The photovoltaics market has grown steadily to present sales of 50MW of power per year, doubling its size about every four years. Photovoltaic electricity-generating costs have decreased markedly, making some applications economically feasible and, with adequate research, development and demonstration (RD&D) efforts, are expected to be competitive with central-station generation after year 2000. Many advanced biomass production and conversion technologies are being developed. Large-scale RD&D efforts would greatly improve and accelerate the economic potentials of such technologies.

16. A renewable-energy system will, by nature, include a wide variety of technologies that harness a range of energy forms. Such a system will be decentralized, with components of different scales designed to meet local and regional needs. The energy flows into the system will vary spatially and fluctuate over time. The supply technologies used in a renewable-energy system and the end-use technologies used to meet the demand for energy services, must, therefore, be well integrated. The technologies needed for providing such integration are already available.

V. Potentials

17. The near-term (1990-2000) global economic potential to supply energy based on renewable sources is about 3.3 Gtoe per year (i.e., 2.5 times the 1985 contribution), taking into account the availability of cost-effective technologies and levels of energy end-use in different climate zones. The major quantitative increments of the near-term renewable potential are expected to derive from the sustainable use of biomass and large-scale hydropower. The rate at which emerging technologies develop indicates a minimum potential contribution of five Gtoe per year in 2020 (i.e., 3.5 Gtoe more than the present contribution). Emerging energy technologies, such as photovoltaics and new biomass technologies, can come to play a dominant role in the early 21st century. In the long-term, the utilization of renewable energy sources is not likely to be constrained by the availability of resources or cost-effective technologies. Political and administrative decisions are their primary constraints. The opportunity exists now to start the transition to an energy system

for a sustainable world.

VI. Advantages

18. Replacing conventional energy sources with renewable ones would reduce many environmental impacts caused by the current energy system, including greenhouse-gas emissions, land degradation, air and water pollution, acid precipitation, and emissions of radioactive substances.

19. The scale of facilities for manufacturing devices for utilizing renewable energy sources can be comparatively modest. With access to some of these technologies, developing nations will be able to reduce foreign capital outlays by developing endogenous manufacturing capabilities. Such industries can contribute to local economic growth. Producing alternative fuels can also reduce foreign capital expenditures in many countries.

20. Utilizing renewable energy sources can provide training and employment opportunities that would not otherwise be available, thereby supporting development based on self reliance.

21. Locally-available primary energy resources are, in essence, free from control outside national boundaries. They therefore provide secure, independent energy supply, an important element of sustainable and autonomous development.

22. The time period required from planning through implementing renewable energy-supply projects is often much shorter than that for conventional, large-scale supply projects. This characteristic offers flexibility and reduces investment and, thereby, delivered-energy costs.

23. Most renewable-energy technologies are designed in modules, simplifying installation and maintenance and offering the added advantage of flexibility in increasing supply capacity.

24. The opportunity exists for establishing rational and efficient energy systems based on technologies that utilize renewable energy sources. For environmental and developmental reasons, doing so must be a goal for the first part of the next century.

VII. Constraints on the Rate of Expansion

25. The technological limits to the diffusion of existing competitive technologies for utilizing renewable energy sources derive mainly from the time needed to increase global capacities for producing them.

26. Because financial resources are scarce, the setting of priorities for energy-sector investments will determine the penetration rate of technologies that utilize renewable energy sources. A transition to a global energy system based on renewable energy sources will not take place unless the *share* of energy-sector investments devoted to renewable-energy technologies is greatly increased.

27. Current practices for distributing development aid favor large-scale projects. Project orientation must be replaced by program orientation in order to make funds available for small-scale decentralized technologies that utilize renewable energy sources.

28. Global renewable energy resources are more than sufficient for meeting the demand for energy services. However, conflicting demands for natural resources, such as food versus energy-production demands for arable land, must be addressed in evaluating the accessible potential for utilizing biomass resources within individual countries.

29. Within the limitations posed by technological, financial and natural resources, the extent to which renewable energy sources will contribute to future world energy supply will depend on energy-policy decisions made by governments and coordinated international cooperation.

VIII. Recommendations

30. Seizing the opportunity to develop a sustainable global energy system based on renewable energy sources will require fundamental structural, economic, and institutional changes in industrialized and developing countries. None of these can be achieved without unyielding political will, international cooperation, and active public and private involvement.

31. Adopting a long-term approach is vital for the development of the physical as well as policy and institutional infrastructure needed for utilizing renewable energy sources.

32. Implementing such an approach will require both transitional and foundation-building policies. Toward those ends, we make the following recommendations.

33. At the national level, it is essential to formulate integrated energy policies and programs, compatible with sustainable development, and to promote increased investments in renewable energy supplies. We therefore recommend that governments:

(a) adopt and implement an integrated national action program on the development and utilization of renewable energy sources, within the framework of strategies and policies for the transition to energy systems compatible with sustainable development.

(b) establish targets for contributions of the different renewable energy sources to their energy supply, commensurate with the time frames of technical feasibility outlined above. Such targets should be linked to environmental as well as social and developmental objectives.

(c) establish and strengthen institutional arrangements that facilitate the implementation of the national program, including policies and programs for achieving the set targets. Appropriate governmental institutions should be given the mandate of promoting the utilization of renewable energy sources through: education, training and information programs; energy/environment planning and policy coordination; and research, development and demonstration.

(d) enlarge markets for renewable-energy applications by adopting new regulatory and fiscal legislation which, *inter alia*, ensure that all costs and benefits (environmental, social, etc.) are included in the market price and in economic comparisons of public and private energy-sector investment options, and public procurement policies.

(e) increase public funding of research into the utilization of renewable energy sources by at least a factor of three, on average, within five years.

(f) ensure that the share of public energy investments devoted to promoting research, development, demonstrations and training related to renewable energy sources is commensurate with their potential to meet national energy needs and global responsibilities.

(g) ensure that renewable energy sources are not discriminated against in domestic energy markets by subsidizing other energy sources directly or indirectly, and that small or independently-owned producers are not discriminated against by utilities or denied access to transmission and distribution systems.

(h) establish and implement procedures for recording statistical data on renewable-energy applications in their country. Such data should be collected in a harmonized form, so that it can be useful at the international level.

(i) report on their national programs of action for promoting renewable energy sources in order to facilitate an international dialogue (see 34a and 35).

34. At the international level, arrangements must be made, in close collaboration with national and international institutions and non-governmental organizations, to strengthen international cooperation for promoting the utilization of renewable energy sources. Such arrangements should intensify renewable-energy-technology RD&D, stimulate broad dissemination and application of available renewable-energy technologies, and provide for exchange of information and manpower training for using such technologies. Toward those ends, it is necessary to:

(a) promote and support policy planning, *inter alia*, by organizing a dialogue with each nation based on national renewable-energy policy and program reports (see 33i).

(b) promote rapid implementation of systems based on renewable energy sources, especially in industrial countries because of their dominant use of fossil fuels.

(c) restructure energy-sector expenditures so that renewable energy sources and technologies for their utilization, together with energy-efficiency improvements, are given first priority.

(d) promote increased funding, *inter alia*, from new and additional financial resources, in support of the implementation of national action programs on renewable energy sources, in particular in the developing countries.

(e) promote rapid and effective transfer of environmentally-sound technologies for utilizing renewable energy sources amongst countries in general and, in particular, on favorable and concessional terms to developing countries. In this regard, action should be taken to adapt currently-available technologies to local conditions, promote the build-up of the endogenous expertise and infrastructure needed to enable the implementation of renewable energy programs, and to promote local production of technologies in order to enhance national self-reliance.

(f) prepare and disseminate studies on new technological developments, techniques and strategies for identifying, locating and evaluating new and renewable energy sources.

(g) allocate a minimum of 20 percent of all aid funds from bilateral, multilateral and international agencies devoted to the energy sector in the coming years to viable renewable-energy projects (in addition to large-scale hydro). The same should apply to grants and loans from international development banks. This percentage should increase over time.

(h) increase capacity-building efforts, particularly in developing countries, to ensure increased development and implementation of renewable-energy programs.

(i) coordinate international activities aimed at promoting the utilization of renewable energy sources.

(j) promote research, development, and demonstration programs in developing countries for technologies that utilize renewable energy sources.

(k) coordinate the exchange of information and experience on research, development and applications of renewable-energy technologies.

(l) gather statistics from individual countries on, and perform evaluations of applications of, renewable energy sources.

(m) implement the proposal by the Colloquium of High Level Experts on New and Renewable Sources of Energy (the Castel Gandolfo Group) to establish a global Network of International Research Centers of Excellence in the field of renewable energy sources.

35. We believe that a strong international institutional arrangement is needed to carry out such tasks, and give renewable energy necessary visibility and weight in relevant international negotiations (i.e., the climate convention). The creation of an International Renewable Energy Agency responsible for promoting renewable energy sources is therefore recommended. This agency should be responsible for points 34(a, b, d, e, f, h, i, j, k, l and m) and should act as a network focal point for national and international institutions, stimulating and supporting two-way communication between them.

2. The Nairobi Programme of Action: Lessons Learned

I. The Nairobi Programme of Action: Objectives and Rationale

a) Energy transition

36. The Nairobi Programme of Action (NPA) was adopted by consensus at the United Nations Conference on New and Renewable Sources of Energy, held in Nairobi in August of 1981. At that time, the general perception was that the world was facing an energy transition from the international economy based primarily on hydrocarbons (fossil fuels) to one based increasingly on a more diversified resource base. This perception stemmed from the recognition a few years earlier that fossil fuels were depletable. The international economy could not, therefore, continue to rely predominantly on fossil fuels. This situation was compounded by the inefficient and wasteful use of fossil fuels, that had reached unsustainable levels.

37. There was no question of whether an energy transition would take place. The NPA, conceived as a major undertaking of international cooperation for supporting and assisting action at the national level, was intended to help ensure that the transition would take place in a manner which, consistent with the needs and options of individual countries, is socially equitable, economically and technically viable, and environmentally sustainable.

38. The NPA conveyed a sense of urgency for the development and utilization of 14 new and renewable sources of energy (NRSE),[3] consistent with the need to keep up with the pace of the energy transition. The emphasis of the NPA was on the contribution of NRSE to meeting the energy needs of the developing countries.

39. In developing countries, NRSE had the double advantage of representing both an option for developing indigenous resources and for contributing to meeting energy needs in rural areas with decentralized energy supplies. The prevailing and projected future energy prices at the time of the Nairobi Conference represented another incentive for undertaking major efforts to develop NRSE in developing countries. Such efforts were seen as a means of reducing the balance-of-payments burden caused by importing energy.

b) Structure of the NPA

40. The NPA provides a comprehensive description of specific technical measures for developing and utilizing each of the 14 NRSE in five broad policy areas: energy assessment and planning; research, development and demonstration; transfer, adaptation and application of mature technologies; information flows; and education and training. Furthermore, the NPA identifies a number of areas for priority action, covering all five policy areas, where action is needed on an urgent basis.

41. The NPA calls for both financial and technical actions for the development and utilization of NRSE. Specific measures contained in the NPA concentrate on supporting actions and pre-investment activities

[3] The fourteen sources of energy included in the NPA definition of NRSE were: hydropower, solar, wind, wave, geothermal energy, biomass, fuelwood, charcoal, peat, tidal, ocean thermal energy, draught animal power, oil shale and tar sands. See: "Report of the United Nations Conference on New and Renewable Sources of Energy," United Nations, New York, 1981, (doc. A/CONF.100/11).

aimed at providing a strong impetus to the development and utilization of NRSE.[4] At the time of the conference, it was perceived that development of NRSE at the commercial level — even though it required significant capital outlays — would attract funding from already-existing international and other financial institutions.

c) Impact of energy prices

42. Falling energy prices in the years that followed the Nairobi Conference led many to believe that the NPA had lost, at least, its sense of urgency, if not its very purpose. In addition, short-term gluts in the oil market were instrumental in bringing about a collective loss of sight of the depletable nature of fossil fuels on the part of decision makers considering energy options and policies. As a result, there was a definite loss of interest by some governments in supporting the NPA. This resulted in a loss of momentum in its implementation, in spite of the repeated warnings by the United Nations and many governments that the need to develop NRSE should be seen from a long-term perspective.

43. In addition, implementation of the NPA was adversely affected by developments such as a general de-emphasis on large-scale demonstration projects in industrialized countries, and the discovery of natural-gas resources in some developing countries as a result of oil exploration.

II. Assessing the Implementation of the NPA

a) Basis for an assessment

44. The NPA is a complex effort involving numerous energy sources, a wide range of specific technical and financial measures, decentralized implementation, and participation of a number of actors, both national and international, public and private. Because of this the implementation of the NPA must be assessed from a variety of viewpoints. In particular, a comprehensive assessment should examine:

- the changing share of NRSE in energy supply on a global basis. The rate of change of that share should be measured, including and excluding large-scale hydropower, the relative weight of which, in NRSE, is extremely high.
- the contribution of NRSE at the local level, since its significance would have to be judged in terms of widespread rather than massive applications, such as energy services, in particular for small and remote communities.
- the progress or lack thereof in each of the various action areas called for in the NPA, e.g., specific measures, areas for priority action, and institutional and financial arrangements.
- changes in the rate of progress over time, as compared to energy price changes.
- resources allocated to NRSE programs within the budgets of the major institutions involved: national institutions, United Nations entities, international financial institutions, other international institutions, and bilateral cooperation organizations.

b) Concrete goal setting

45. During the Nairobi Conference it was agreed that financial resources for the development and utilization of NRSE should be additional and adequate, i.e., not at the expense of other existing or planned programs of international cooperation. It was not possible, however, to reach an agreement on the financial

---

[4] Supporting actions include: energy assessment and planning; establishment and strengthening of relevant national institutional infrastructure; research, development and demonstration; data collection; training and education; etc. Pre-investment activities include: feasibility studies; design and engineering; etc.

commitment of the international community to the NPA, e.g., a financial target or a mechanism for annual or multi-annual contribution pledges. The NPA only contains a description of avenues for mobilizing financial resources, with emphasis on consultative meetings.

46. In addition, the magnitude of the financial needs was not stipulated in the NPA. Thus, no common yardstick was provided for measuring the progress. However, two documents prepared in 1982 provide a reference for making an assessment, at least in general terms.

47. A joint study by the World Bank and the UNDP addressed the problem of estimating the financial resources needed for the supporting actions and pre-investment activities related to the implementation of the NPA for the 1980s, on the basis of a conservative assessment of projects and programs that could be carried out in the developing countries.[5]

48. In the study, national financial requirements for each NRSE were derived on the basis of country data where available and estimates where detailed data was lacking. The resource base as well as national plans and programs according to national priorities were basic inputs for the study. The national calculations were aggregated to estimate global financial requirements. It was assumed that energy demand would grow in developing countries at a rate of five to six percent per annum. Prices of liquid fossils would tend to rise in the long term from their 1982 levels, despite the short-run prospects of a decline in real terms. Developing countries were expected to have a firm commitment to developing their indigenous NRSE. Supporting actions and pre-investment activities would be concentrated in areas where development of NRSE was perceived to be both technically and economically feasible.

49. The results of the study indicated that implementation of such supporting actions and pre-investment activities would require $3.6 billion[6] and $10.6 billion respectively, i.e., a total of some $14 billion for the period 1982-1990. On an annual basis, financial requirements were estimated at $1 billion for the period 1982-1986 and $2 billion for the period 1986-1990.

50. Supporting actions and pre-investment activities normally represent between five and ten percent of the total financial resources needed for the development of NRSE at the commercial level. The total financial requirement for implementing the NPA was estimated, therefore, to be between $140 billion and $280 billion ($15 billion to $30 billion annually).

51. A report prepared by the Administrative Committee on Coordination in 1982[7] contains a number of projects and programs aimed at providing a framework for action by the United Nations system in implementing the NPA. It represented the collective judgement of the interested entities within the United Nations system on the activities necessary for the immediate launching of the program.

c) Institutional arrangements

52. Institutional arrangements at the United Nations level for implementing the NPA were completed as a result of a General Assembly resolution (37/250), adopted in 1982. These included the establishment of an open-ended intergovernmental committee and secretariat arrangements. During the process of preparations for the Nairobi conference, the idea of creating an agency for promoting NRSE was considered but not taken further.

---

[5] "Joint study by the World Bank and the UNDP on financial requirements of the supporting actions and pre-investment activities for the development and utilization of NRSE in the developing countries in the 1980s," United Nations, General Assembly, Interim Committee on new and renewable sources of energy, 1982 (doc. A/AC. 215/4).

[6] All monetary values are given in current U.S. dollars except where otherwise noted.

[7] "Report of the Administrative Committee on Co-ordination: proposals of action-oriented plans and programs for carrying out the Nairobi Programme of Action," United Nations, General Assembly, Interim Committee on New and Renewable Sources of Energy, 1982 (doc. A/AC. 215/5).

53. The **intergovernmental Committee** on the Development and Utilization of New and Renewable Sources of Energy meets every two years, on even years, and has a wide range of responsibilities for implementing the NPA, including monitoring and follow-up of the implementation and activities of the entities within the United Nations system with regard to NRSE; recommendation of policy guidelines to such entities; formulation and recommendation of action-oriented plans and programs; promotion of the mobilization of financial resources and recommendation of guidelines to the financial organs within the United Nations system. The Committee launched its activities at its first session, held in 1983. Four additional sessions have been held in 1984, 1986, 1988 and 1990.

54. The first meeting was devoted to finalizing and adopting the various arrangements needed for implementing the NPA, whereas the other four were aimed at adopting the necessary decisions to ensure an effective contribution of the United Nations system to the implementation of the NPA and, in a broader sense, to maintain interest and support within the international community for promoting NRSE.

55. A number of criticisms have been made regarding the effectiveness of the Committee's work, in particular with regard to the lack of in-depth technical discussions and the limited participation of member countries in the meetings. At each of its sessions, however, the Committee has executed its responsibilities with regard to the monitoring and follow-up of the implementation of the NPA.

56. In its third session (in 1986), the Committee decided to concentrate its deliberations on a limited number of specific subjects. This initiative has proved to be successful: it has provided focus to the inter-sessional work of the secretariat and allowed for more substantive discussions during the Committee meetings.

57. The **Secretariat arrangements** include a Special Coordinator for NRSE in the office of the Director-General for Development and International Economic Cooperation (DIEC) and a secretariat unit. The secretariat unit was established in 1982 as a small separate unit of the Department of International Economic and Social Affairs (DIESA). The unit is responsible for providing secretarial support to the meetings as well as for gathering and disseminating information regarding NRSE in general, and the NPA in particular. In 1989 the unit was merged with the DIESA unit in charge of conventional energy resources.

58. Experience thus far shows that the secretariat arrangements have been inadequate and have impeded the provision of the full range of secretarial services and support required by the Intergovernmental Committee to carry out its mandate.

d) <u>Inter-agency coordination</u>

59. Because a number of entities within the United Nations system had been undertaking activities related to various NRSE, it was agreed at the Nairobi Conference that the NPA would be implemented in a decentralized manner. This arrangement called for strong coordination of activities within the United Nations system in order to avoid duplication of work and inefficient use of resources. The Director-General for Development and International Economic Cooperation was entrusted with the task of ensuring that such coordination took place. Although exchange of information between UN agencies has improved slightly, experience thus far shows that interagency coordination has been completely inadequate.

60. Timely availability of accurate information is essential for the successful coordination of activities within and outside the United Nations system. To that end, governments were requested to designate focal points for NRSE at the national level. Entities within the United Nations system were also requested to designate focal points for NRSE.

61. So far, 120 countries and United Nations entities involved in NRSE activities have designated their focal points for NRSE. Even though there has been no formal assessment of the role and effectiveness of such focal points in the implementation of NPA, there is a general concern that the flow of information needs to be improved.

e) Mobilizing financial resources

62. As acknowledged in the Nairobi Conference, implementing the NPA requires the mobilization of additional and adequate financial resources. A clear-cut assessment of progress made in this regard would require a common yardstick for measuring progress as well as a consistent way of reporting on mobilized resources.

63. A report submitted by the United Nations Secretary-General in 1988[8] stated that resources mobilized for utilizing NRSE, as well as energy planning and energy conservation, in developing countries totaled about $35.9 billion for the period 1980-1987. It should be noted, however, that 74 percent of this amount was allocated to large-scale hydropower and that only $9.4 billion were mobilized for all other NRSE. A meaningful assessment must, therefore, consider large-scale hydropower and other NRSE separately.

64. As indicated in the report, data were compiled on the basis of information provided to the secretariat. There appeared to be an understatement of the efforts made by the developing countries themselves, i.e., the national sources of financing. National efforts represented the largest single source of financing for developing and utilizing NRSE if large-scale hydropower is included and the second largest single source after the United Nations system if large-scale hydro is excluded. A breakdown by source of financing is given in Table 1.

Table 1[9]

Funding Sources for Promoting and Utilizing NRSE in Developing Countries (1980-1987)

Source of Financing	All NRSE (excl. large-scale hydro)		Large-scale Hydropower	
	million USD	%	million USD	%
National	2,300	25	7,000	27
Bilateral	2,200	23	4,400	17
Intergovernmental	1,200	13	4,800	18
United Nations System	3,500	37	5,300	20
Private	neg.	-	2,500	9
Other	200	2	2,500	9
Total	9,400	100	26,500	100

65. When considering contributions by energy source, a number of activities cannot be allocated to a specific NRSE, such as energy planning or conservation that encompasses conventional energy sources as well as

[8] "Report of the Secretary-General: Mobilization of financial resources and inter-agency co-ordination for the development and utilization of new and renewable sources of energy," United Nations, General Assembly, Committee on the Development and Utilization of New and Renewable Sources of Energy, fourth session, 1988 (doc. A/AC. 218/16).

[9] *Op. cit.* ref. 7.

NRSE. Bearing this in mind and considering large-scale hydropower separately, a breakdown of total developing-country financing by energy source is given in Table 2.

66. Global mobilization of financial resources for NRSE, including large-scale hydropower, averaged $4.5 billion per annum over the period 1980-1987. This represents only 15 to 30 percent of the $15 billion to $30 billion per annum identified as necessary in the UNDP-World Bank joint study.

Table 2[10]

Main Areas of Activity in Promoting the Utilization of NRSE in Developing Countries (1980-1987)

Energy Source	Allocation (million USD)	%
Fuelwood and charcoal	1,900	20
General NRSE	1,800	19
Conservation (conventional and NRSE)	1,400	15
Geothermal	1,200	13
Energy planning	1,200	13
Solar	600	6
Small-scale hydropower	600	6
Other	700	8
Total	9,400	100

67. The report submitted by the United Nations Secretary-General in 1990[11] only provides data on financial resources mobilized by the United Nations system. Total U.N. resources committed for the period 1980-1989 amounted to $13.4 billion, the largest part of which (67%) was allocated to conventional large-scale hydropower projects.

68. Although this figure seems to compare favorably with the one submitted in the 1988 report, there has been a continuous decline in resources mobilized by the United Nations system since 1987, when commitments peaked at $1.9 billion. In 1988, the figure was reduced to under $1.5 billion and in 1989 it was further reduced to under $1.4 billion.

69. Both the 1988 and the 1990 reports clearly indicate an unfavorable and undesirable trend in the mobilization of financial resources for developing and utilizing NRSE. This trend was consistent with the loss of the sense of urgency in implementing the NPA that was experienced in the years following the Nairobi Conference.

---

[10] *ibid.*

[11] "Report of the Secretary-General: Progress achieved in resource mobilization, including consultative meetings, and inter-agency co-ordination," United Nations, General Assembly, Committee on the Development and Utilization of New and Renewable Sources of Energy, fifth session, 1990 (doc. A/AC 218/1990/8).

70. The reduced effort was not limited to cooperation at the international level: significant reductions of effort occurred at the national level in industrialized countries. One indication of this was the steady decline in government research, development and demonstration (RD&D) budgets for NRSE in industrialized countries since the adoption of the NPA, as illustrated in Table 3, derived from an International Energy Agency report[12]:

Table 3[13]

IEA Governments' Energy[14] RD&D Budgets[15]
(million 1990 USD)

Year	Total Energy Sector	NRSE Allocation	NRSE as % of Total
1979	10,760	1,430	13
1980	11,610	1,670	14
1981	11,810	1,660	14
1982	10,730	1,130	11
1983	9,770	980	10
1984	9,430	930	10
1985	9,120	740	8
1986	8,200	580	7
1987	6,830	540	8
1988	7,270	540	7
1989	7,550	500	7
1990	7,200	490	7

71. The UNDP Energy Account has been another major casualty of the declining trend in resource mobilization. This account was considered to be one of the major mechanisms for mobilizing financial resources for developing and utilizing NRSE. At the 1988 session of the UNDP Governing Council, it was decided to close the Energy Office, while the Energy Account was maintained as a sub-account of the United Nations Fund for Science and Technology. This decision was taken as a result of the lack of resources channeled through the Energy Account.

72. In addition to the overall trend toward reduced funding, a number of shortcomings in the mechanisms for mobilizing financial resources may have contributed to the lack of success in fund raising. Consultative meetings provide a good illustration in this regard.

---

[12] "Energy Policies of IEA Countries, 1990 Review," Organization for Economic Cooperation and Development (OECD), Paris, 1991.

[13] *Op. cit.* ref. 9.

[14] The International Energy Agency includes solar (heating, thermal, photovoltaic, etc.), wind, biomass, ocean and geothermal energy sources in these data.

[15] The figures for 1979 through 1987 do not include expenditures on electric power transmission, energy storage, and "other" as is the case for the 1988 through 1990 data. The NRSE share of total expenditures is probably overestimated, therefore, for the 1979 through 1987 period.

73. Consultative meetings were presented as a useful and effective means of mobilizing financial resources for developing NRSE, since they provided a forum for donors and recipients to consider a limited number of concrete projects. The first consultative meetings were organized in 1982. Experience thus far leads to the following conclusions:

- There is no common understanding of the purpose of consultative meetings. Some donors perceive them as a forum for holding general discussions on projects unrelated to financial commitments to support them. Recipients expect these meetings to result in actual mobilization of resources. In other words, donors consider such meetings as the beginning of a process, while recipients consider them to be conclusive.

- Attempts to measure the effectiveness of the consultative meetings, in terms of mobilization of resources for the projects presented at such meetings, have been unsuccessful thus far. No relationship between the discussions held at the consultative meetings and the actual contributions has been clearly established and assessments undertaken by the United Nations secretariat are inconclusive in this regard.

- The difficulties in organizing such meetings and the small number of them held thus far indicate that consultative meetings are ineffective as a mechanism for mobilizing financial resources and should not be relied upon as the primary mechanism for doing so.

f) Concrete projects and programs

74. The United Nations Secretary-General has reported on the status of the implementation of projects and programs submitted by the United Nations system since 1982.[16,17] The overall conclusion of those reports is that the rate of progress has varied widely for the different projects and programs, and for the various United Nations entities involved. While some projects and programs have been fully implemented, others remain to be completed.

75. As indicated in the reports, the main cause of non-completion of projects has been lack of financial resources. This, again, is an indication of the loss of interest in supporting NRSE activities that stemmed from falling energy prices in the 1980s.

g) Share of NRSE in global energy supply

76. At the time of the Nairobi Conference, NRSE accounted for 13 percent of world energy supply. In 1985, the share of NRSE remained at approximately the same level (14%). Estimates of current global renewable energy use are in the range of 14 to about 20 percent of total primary energy supply.[18] The bulk of NRSE

---

[16] "Report of the Secretary-General; progress made in implementing projects and programs outlined in the report of the Administrative Committee for Co-ordination A/AC 215/5," United Nations, General Assembly, Committee on the Development and Utilization of New and Renewable Sources of Energy, fourth session, 1988 (doc A/AC 218/11).

[17] "Report of the Secretary-General; project proposals of entities within the United Nations system and status of their implementation," United Nations, General Assembly, Committee on the Development and Utilization of New and Renewable Sources of Energy, fifth session, 1990 (doc. A/AC 218/1990/9).

[18] Presently available statistics are inadequate for providing a precise estimate. A value of 14 percent is reported in, "Report of the Secretary-General: Implementation of resolution 2(III) of the Committee on the Development and Utilization of New and Renewable Sources of Energy at its third session," United Nations, General Assembly, Committee on the Development and Utilization of New and Renewable Sources of Energy, fourth session, 1988 (doc. A/AC.218/15). In "World Energy Horizons: 2000-2020" (14th Congress of the World Energy Conference, Editions Technip, Paris, 1989), a value of 17.5 percent is given. David Hall *et. al.* purport that, in general, estimates of non-commercial use of biomass in developing countries are low (Hall, D., Rosillo-Calle, F., Senelwa, A.K. and Woods, J., "Biomass for Energy: Future Supply Prospects,"

supply comes from three sources: large-scale hydropower, fuelwood and charcoal. These represented over 90 percent of total NRSE production in 1981 and 92 percent in 1985.[19]

77. According to UN statistics, NRSE in the developing countries represented 29 percent of total energy consumption in 1981 and 28 percent in 1985. A breakdown by regions indicates that in 1981 NRSE accounted for 57 percent of total energy consumption in Africa, 34 percent in Latin America and the Caribbean, and 23 percent in Asia and the Pacific. The figures for 1985 were 57, 38 and 21 percent respectively.[20]

78. These figures illustrate the lack of increase in the share of NRSE in global energy production and consumption in the first four years after adoption of the NPA.

III. Lessons Learned from the Implementation of the NPA

79. Since the adoption of the NPA, there has been a big difference in the emphasis attached to NRSE in industrialized and developing countries. Such differences are reflected in institutions, policies and efforts devoted to developing and utilizing NRSE.

80. All countries, developing and industrialized, set up institutions for developing and utilizing NRSE in response to the call for concerted action made at the Nairobi Conference by adopting the NPA. In developing countries, the establishment of institutions and focal points for energy planning and for planning of the development and utilization of NRSE was, in particular, a major achievement. Developing countries, in general, tried to pursue the policies they established regarding NRSE. However, while developing country institutions have, in general, been maintained and strengthened, such institutions have been weakened through reduced budgets and even eliminated in industrialized countries. Member countries of the OECD, in general, reduced the role of NRSE in their energy policies in favor of developing other energy sources during the early 1980s. In recent years, however, environmental concerns have revived interest in NRSE in the OECD.

81. In most developing countries energy planning and policy-making for rural development remains weak and isolated from overall energy policy and planning efforts for the transportation, industrial and commercial sectors.

82. The rural sector is barley affected by competition from commercial sources of energy. Progress in this sector has been hindered by a lack of financial resources for initial energy investments. As a result, there has not been enough progress in the utilization of NRSE for integrated rural development.

83. As the mobilization of financial resources for implementing the NPA indicate, most developing countries have made sustained efforts commensurate with their own capabilities. Efforts to support the implementation of the NPA have been insufficient in most other countries.

84. Although there has been progress in some applications of NRSE, such as hydropower and geothermal energy, there is still a vast potential to be developed where demand for energy in general is not close to centralized energy sources. This is particularly true in many developing countries with limited industrial infrastructure.

---

in Johansson, T.B., Kelly, H., Reddy, A.K.N. and Williams, R.H. (eds), "Fuels and Electricity from Renewable Sources of Energy," Island Press, 1992 (in press)).

[19] "Report of the Secretary-General: Implementation of resolution 2(III) of the Committee on the Development and Utilization of New and Renewable Sources of Energy at its third session," United Nations, General Assembly, Committee on the Development and Utilization of New and Renewable Sources of Energy, fourth session, 1988 (doc. A/AC.218/15).

[20] *ibid.*

IV. Looking forward

85. Environmental concerns have brought a new perspective to the collective perception of the importance of the NPA, in particular since renewable energy sources are more environmentally benign than conventional energy sources. This could contribute to bringing about the political decisions needed to provide a new impetus for developing and utilizing NRSE. Success will only be possible if the issue is approached from a long-term perspective.

3. The New Rationale for Utilizing Renewable Energy Sources

I. Introduction

86. Improving the quality of life of their citizens through, *inter alia*, economic growth and national autonomy are fundamental objectives of all governments. They are particularly acute concerns in developing countries. Fulfilling these objectives and the future needs of growing populations will inevitably require increased quantities of delivered energy services. The quantity of primary energy that will be required to deliver those services depends on the level of energy efficiency of energy conversion, transmission, distribution, and end-use technologies.[21]

87. Current and projected energy production and use have major negative consequences for the global environment, sustainable development, and security. Together these consequences provide a tremendous impetus for change, both in industrialized and developing countries. Most of the energy-related environmental, development and security problems (including climate change) are linked to fossil-fuel use and non-sustainable use of biomass. Two major strategies exist for addressing these problems: 1) increasing energy efficiency in order to reduce the amount of primary energy consumed; 2) replacing fossil-fuel-based energy supply with expanded supplies of non-fossil sources. Special emphasis should be given to the interdependent relationships between the energy sector, economic growth, social development, the environment and security when formulating energy policy.

88. The global-warming challenge clearly illustrates that the issues of development and environment are inseparable. The energy system of the industrialized countries has led to a globally unsustainable environmental situation. These countries must implement measures to limit the emissions of pollutants associated with fossil-fuel use. Even a complete restructuring of the energy system in industrialized countries will be insufficient for addressing global warming unless sustainable development is addressed simultaneously. Developing countries must recognize the potential environmental hazards associated with increased energy use and integrate measures for preventing them into their development plans. Although the environmental and developmental problems of industrialized and developing countries are different, the strategies for addressing them are applicable in both. The common objective is a sustainable society; locally, nationally, regionally and globally.

II. Environment

89. Our understanding of both the nature and the magnitude of the environmental impacts of conventional energy systems has grown progressively over the past few decades, even if important areas of uncertainty still remain. Before the 1970s, the perceived hazards of energy use were primarily local and regional in scope, affected distinct populations and were believed to be manageable. With urban air pollution and acid precipitation, the boundaries delineating the zones affected by such hazards expanded, and confidence in our ability to both control and remedy their impacts diminished. The catastrophe at Chernobyl and the discovery of stratospheric ozone depletion brought about the public and political realization that mankind's current actions pose threats of irreversible environmental degradation that respect no borders. Seen within this

---

[21] Goldemberg, J., Johansson, T.B., Reddy, A.K.N. and Williams, R.H., "Energy for a Sustainable World," Wiley Eastern Limited, New Delhi, 1988.

context, the threat of global warming constitutes yet a further step in the conceptual progression of understanding that the energy system that we have become dependent upon is unsustainable.

90. Conventional methods of harnessing and using energy lead to a wide variety of environmental problems. Acid precipitation resulting from emissions of sulphur dioxide and oxides of nitrogen, primarily from burning fossil fuels, has already acidified tens of thousand of lakes and streams and is implicated in damage to a substantial part of the world's forests (in Europe, 60 million hectares of forest is damaged (42% of the european forest) alone),[22] especially in temperate regions. Unsustainable utilization of biomass resources contributes to land degradation. These are just two examples of the many ongoing environmental problems that cannot be totally resolved with technical fixes or add-on measures such as stack-gas scrubbers and catalytic converters. Adequately addressing any of these problems will require a restructuring of our system for utilizing energy and the formulation of new concepts regarding the relationships between quality of life, economic growth and social development within the framework of sustainability.

91. Of all the environmental challenges facing us today, global warming is the most pervasive. It demands, by far, the broadest scope of change. Such change can, however, offer simultaneous solutions to most of the other energy-related environmental problems.

92. The Intergovernmental Panel on Climate Change (IPCC), a group of 170 contributing scientists from 25 countries sponsored by the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP), reached consensus conclusions in June 1990 that increased atmospheric concentrations of the greenhouse gases resulting from human activities will enhance the greenhouse effect, resulting on average in an additional warming of the Earth's surface.[23] In order to stabilize atmospheric concentrations at present-day levels, immediate reductions of global manmade emissions of the long-lived greenhouse gases (carbon dioxide (CO_2), nitrous oxide (N_2O), and the halocarbons (mostly CFCs)) by more than 60 percent, and methane emissions by 15 to 20 percent, would be necessary.[24] This would not stabilize the climate.

93. Approximately half of all anthropogenic greenhouse-gas emissions originate in production, transformation and utilization of fossil fuels (including transportation).[25] It may be possible to reduce fossil-fuel-related greenhouse-gas emissions on the scale called for by the IPCC. In the Alternative Accelerated Policies/Higher and Lower Growth Scenarios developed by the IPCC, emissions of CO_2 from fossil-fuel use begin to decline immediately and continue to do so through 2100, thereby exceeding the emissions reductions necessary for stabilizing atmospheric concentrations of greenhouse gases.[26] These scenarios rely heavily on energy efficiency improvements aimed at reducing total energy demand, and increases in the utilization of renewable sources of energy.

---

[22] Economic Commission for Europe, Executive Body for the Convention on Long-range Transboundary Air Pollution, Working Group on Effects," The 1989 Forest Damage Survey in Europe, Executive Summary," United Nations Economic and Social Council, 30 July 1990.

[23] Intergovernmental Panel on Climate Change, Working Group I, *Policymakers Summary of the Scientific Assessment of Climate Change,* World Meteorological Organization, Geneva, June 1990.

[24] Intergovernmental Panel on Climate Change, Working Group I, *Scientific Assessment of Climate Change*, World Meteorological Organization, Geneva, June 1990.

[25] Intergovernmental Panel on Climate Change, Working Group III, *Policymakers Summary of the Formulation of Response Strategies,* World Meteorological Organization, Geneva, June 1990.

[26] Intergovernmental Panel on Climate Change, Working Group III, Report of the Expert Group on Emissions Scenarios, *Emissions Scenarios*, World Meteorological Organization, Geneva, April 1990.

III. Development

94. Fulfilling fundamental human needs and improving the quality of life are the primary purposes of a development process. These objectives must be understood as the capacity to achieve social and economic growth in an environmentally-sustainable manner, based on a long-term perspective, so that the interests of future generations are not compromised by decisions made today.

95. In the industrialized countries, economic growth has historically been achieved with little recognition of environmental problems. This, together with free access to natural resources, resulted in misuse, overuse and degradation of the environment, with losses for humankind in general. Global sustainable development requires that industrialized countries radically change these practices (this has partially started) and that the developing countries find ways and means of achieving economic growth that are sustainable.

96. Sustainable economic and social growth requires husbanding of non-renewable resources, maintaining renewable resource productivity, and avoiding destructive and irreversible ecological effects. Moving toward a sound and sustainable system will require political, administrative and legislative decisions. These must lead to substantial changes in production and consumption patterns and an immediate re-appraisal of development strategies.

97. Within this framework, the role of renewable energy sources in development is to provide indigenous energy sources that are environmentally benign. Biomass, solar and wind energy comprise a widely distributed resource base that can be used as an instrument for development.

98. Utilizing renewable energy sources through the application of renewable-energy technologies is especially valuable in rural and remote areas: home to roughly 3 billion people, or 60 percent of the world's population. Residents of these areas do not have access to distribution networks to connect them to large-scale centralized energy-supply systems. Population increases exacerbate their poverty and push them to migrate to urban areas in search of sustenance. The resulting increases in demands placed on urban resources lead inevitably to increased energy use. That energy is supplied with the cheapest energy sources for which infrastructure is already in place: fossil fuels.

99. In order to break these trends, capital should be invested in energy-sector development in rural and remote areas and directed toward renewable energy sources. In many cases, renewables can provide energy services at least cost. Providing energy services to remote and rural areas will have three immediate impacts: 1) improved living conditions, 2) improved food and agricultural production, and 3) diminished rural migration. These three results, if achieved in an environmentally-benign way, are conducive to sustainable social development.

100. Utilizing renewable energy sources can provide training, employment and development opportunities that would not otherwise be available. The scale of facilities for manufacturing and assembling renewable-energy technologies (wind turbines, photovoltaic cells, biomass systems and solar thermal in particular) can be comparatively modest. Developing nations can establish endogenous manufacturing capabilities for such technologies. In these ways, a renewable-energy system can contribute to local economic development and may be able to reduce foreign debt by reducing both energy and technology import expenditures.

IV. Security

101. Access to secure energy supplies at acceptable prices is a key objective of all nations. In general, this can be achieved if energy resources and the infrastructure for utilizing them are within a country's own borders, or if a country has access to a functioning and reliable world energy market. Neither of these conditions currently exist for most countries.

102. Security aspects of energy issues can no longer be based only upon threat criteria generated by analyses of geopolitics, access to energy resources, transport, and price stability. Energy security must also be based upon safety, sustainability and environmental criteria.

103. In 1990, 40 percent of world commercial primary energy consumption was provided with oil. This strong and broad dependence on oil has created strategic economic interests that lead to political crises, military conflict and economic vulnerability. The Gulf crisis is a case in point. It clearly demonstrated the health and safety risks to mankind, the environmental risks, and the economic vulnerability caused by over dependence on resources that are not widely distributed across the globe. Globally, there has been an increase of $53 billion in the oil-import outlay in 1990 as compared to 1989: $41 billion from industrialized countries, $2 billion from Eastern Europe, and $10 billion from oil-importing developing countries.[27] A significant share of this increase can be attributed to the Gulf Crisis. These expenditures were particularly detrimental to the least developed countries and several countries in Eastern Europe. Exposure to such risks should be a key factor in national and international evaluations of the viability of existing and proposed energy systems.

104. The use of nuclear-power technologies must be curtailed because of the linkages between nuclear power and nuclear weapons, and the implications of nuclear-weapons proliferation on the hazards of international conflict. Uranium-based nuclear power generation results in the production of plutonium; a weapons material which is also very toxic. About 200 kilograms (kg) of plutonium is produced per gigawatt-year of power generated in a light-water reactor. On the order of ten kg are needed to produce a simple nuclear bomb.[28] In order to reduce the risks of nuclear-weapons proliferation, it is necessary to severely limit access to nuclear-power technology.[29]

V. Finding Solutions

105. The World Energy Conference (WEC), reflecting the thinking of the world energy industries, published a study at their latest meeting illustrating the present energy path.[30] Their scenario projects a 75 percent increase in energy demand by the year 2020, despite assumptions of lower energy intensities in the overall economy. A conventional supply mix is used to meet that demand in the WEC projection. In contrast to the current trend of rapidly decreasing investments in new nuclear power plants,[31] global nuclear capacity increases by 340 percent (an increase from 4 to 8% of total primary energy supply). In addition, renewable energy use increases from six to ten percent of total primary energy supply. The remainder of the demand is met with fossil fuels. The scenario results in a 69 percent *increase* in CO_2 emissions from 1985 levels by 2020. Such an energy future would be unsustainable.

106. While much of the rationale behind the Nairobi Program of Action is still valid, many of the reasons for utilizing renewable energy sources have been strengthened because of environmental concerns (especially the threat of climate change) and pressing development needs.

107. Technically-available and cost-effective efficiency measures are sufficient to reduce energy-related carbon-dioxide emissions by at least 20 percent by 2005 in many industrialized countries.[32] Efficiency measures can also play a large role in developing countries, where the level of services provided by future

---

[27] "World Economic Survey 1991," United Nations, page 91.

[28] Feiveson, H.A., von Hippel, F. and Williams, R.H., "Fission Power: An Evolutionary Strategy," *Science*, vol. 203, January 26, 1979, pp. 330-337.

[29] *Op. cit.* ref. 21.

[30] 14th Congress of the World Energy Congress, *Op. cit.* ref. 18.

[31] International Atomic Energy Agency, "Nuclear Power Reactors in the World," reference data series 2, Vienna, April 1990.

[32] Jäger, J. and Ferguson, H. (eds), "Climate Change: Science, Impacts and Policy. Proceedings of the Second World Climate Conference," Cambridge University Press, Cambridge, 1991, p. 498.

energy supplies can be significantly increased.[33] Nuclear power may provide an increment of electricity in specific cases, although the high costs of nuclear power facilities, their long lead times, and the risks associated with accidents, terrorism, waste disposal and nuclear-weapons proliferation all present formidable barriers to increasing global nuclear capacity. Such concerns about nuclear power have led to considerably decreased investments in nuclear energy since the mid 1980s. Providing required quantities of energy services while simultaneously protecting the environment requires, therefore, a combination of efforts to improve energy end-use and conversion efficiencies and increased use of renewable energy sources.

108. We recognize that changing to a sustainable energy path based on energy efficiency and the utilization of renewable energy sources is a substantial task. The fundamental changes required will only come about through our learning to think in new ways. Environmental, developmental and security issues are forcing a paradigm shift toward conserving resources, minimizing pollution, preventing degradation of the natural environment and promoting economic growth and social development duly endorsed and supported by governments, national and international institutions and enterprises, and the international community.

4. Resources, Technologies and Potentials[34]

I. Resources

109. The flow of renewable energy to the Earth's land surface is thousands of times greater than mankind's present rate of total energy use. The challenge is to find environmentally-benign and economic techniques for using it.[35]

II. Renewable-energy Technologies: An Overview

110. Renewable-energy technologies can be used for a variety of applications that can meet practically every type of final energy demand. The product or technology considered can yield electricity directly, or heat, or mechanical power, or chemicals to be used as fuels. Because of this flexibility in producing modern energy carriers, the use of renewable energy sources is well suited to the energy systems of both industrialized and developing countries. The present degree of maturity of a variety of renewable-energy technologies is indicated in Table 4.

111. The utilization of renewable energy sources will lead to environmental impacts. The character and level of these will depend on the technologies used, and, most importantly, on the procedures and practices employed. Generally, the environmental and health problems associated with using renewable-energy technologies are much smaller than those of conventional energy sources, if prudence is respected in their employment. In particular, their use does not result in greenhouse-gas emissions.

a) Hydropower

112. Large-scale hydropower plants have been built in all regions of the world. Hydropower provides about 18 percent of the world's electrical energy. It is the largest renewable energy source in most industrialized

---

[33] Goldemberg, J., Johansson, T.B., Reddy, A.K.N. and Williams, R.H., "Basic Needs and Much More With One Kilowatt Per Capita," *Ambio*, vol. 14, 1985, pp. 190-200.

[34] The list of new and renewable energy sources promoted by the Nairobi Conference included oil shale, tar sands and peat. These energy sources, however, present environmental problems similar to, or worse than, those of fossil fuels. In particular, their use results in CO_2 emissions. Consequently, they have not been considered here.

[35] Sørensen, Bent, "Renewable Energy," Academic Press, London, 1979.

countries. Pumped-hydropower plants play a role as a means of storing energy for peak-load demands.

Table 4[36]

Degree of Maturity of Various Renewable-Energy Technologies and Applications

Technology	Maturity Degree 1	2	3	4	5
Solar energy					
Solar Absorbers	X				
Solar Collectors (low temperature)	X		X		
Solar Collectors (process heat)	X	X	X		
Solar Thermal Electricity (troughs)	X	X			
Solar Thermal Electricity (other technologies)				X	
Passive-solar in buildings	X	X	X		
PV electricity (X-Si)	X	X	X		
PV electricity (a-Si)				X	X
PV electricity (other materials)				X	X
Solar production of energy vectors (e.g., hydrogen); Photochemistry					X
Wind energy					
Installations up to 400 kW	X	X	X		
Larger installations				X	
Hydro energy					
Large-scale hydro	X				
Small-scale hydro	X				
Tidal energy		X			
Wave energy				X	
Biomass					
Combustion	X	X		X	
Gasification	X	X		X	
Bio-alcohol	X	X			
Vegetable oil		X		X	X
Other energy crops				X	X
Geothermal					
Geoscientific foundation				X	
High-T reservoirs	X				
Low-T reservoirs	X	X		X	X
Hot dry rocks				X	X
Ambient heat					
Electric heat pumps	X				
Absorption heat pumps	X	X	X		
Applications and components					
PV application technologies (e.g., pumps, lights)	X	X		X	
Batteries, Fuel Cells	X	X	X	X	X
Control system	X			X	
Heat storage	X		X	X	
Hydrogen (electrolysis, storage, handling)	X		X		

Table 4 Notes: Maturity degrees: 1. technically mature for market (possibly with need of optimization); 2. application experience still missing (e.g., lifetime of equipment); 3. R&D needed for alternative solutions; 4. development needed; 5. research needed.

113. In developing countries, a substantial share of the aid funds made available for energy investments — in particular by the World Bank — has gone to large-scale hydropower projects.

114. Hydropower plants are primarily based on mature technologies. New developments are going on,

[36] Deutscher Bundestag, "Förderung und Nutzung 'Erneuerbarer Energiequellen' in der Bundesrepublik Deutschland," Drucksache 11/2684, July, 1988.

however. Significant examples include the introduction of roller-compacted concrete that reduces the cost of concrete dam construction and recent progress in underground work technology.

115. The cost of building and operating hydroelectric power plants depends very much on the site, financial conditions (e.g., cost of capital), construction times, and the extent to which the costs of externalities are incorporated in total costs. Hydropower plants are relatively simple and inexpensive to operate. Capital costs account for nearly all of the market-internalized cost of producing hydropower. The availability, therefore, of capital at low interest rates, and short construction times, can reduce hydropower generation costs. Typical investment-cost estimates for new projects range between 1500 and 3000 dollars (1986) per kilowatt ($(1986)/kW) of installed capacity,[37] excluding transmission costs and interest during construction. No simple scale factors are applicable, at least above 100 megawatts (million watts — MW) of power. Deducing the cost per kilowatt-hour (kWh) from these data is not straightforward, since it depends on the capacity factor, credits for multiple uses of the plant, the distance from end users, and the extent to which externalities are incorporated. In some cases, kWh costs can be very favorable. Hydro plants may have lifetimes of a century or more (with replacement of some equipment) and, after the initial investment is repaid, the cost of the electricity they produce is very low.

116. In industrialized countries, the remaining number of suitable, large-scale, environmentally-acceptable hydropower sites is limited. A large potential remains in developing countries and in the USSR. In these countries, however, applications are limited by the scarcity of capital, adverse environmental effects, and, often, by the cost of large-scale distribution grids. Although recent advances in electricity transmission, especially in high-voltage direct-current (HVDC) lines, have increased the economically-viable distance between electric power plants and end users to on the order of 1000 kilometers, technical, financial and environmental problems associated with the construction of HVDC lines have constrained the construction of large-scale plants. In addition, some favorable sites are still too far away from potential customers (particularly industries).

117. Even when suitable hydropower sites are located in satisfactory proximity to electricity demand, they may compete with other water and land uses. In order to improve prospects for new hydropower plants, it is necessary to devote increased attention to integrating the plant with other water uses. Water management and irrigation schemes can often benefit from the incorporation of a hydropower component. Where the main purpose of the scheme is hydropower production, designing in flexibility for incorporating other uses can often be beneficial.

118. Water impoundment may require local population displacements. Even when this is not the case, social disturbances in local communities are commonly caused.

119. A traditional procedure for building hydropower plants in developing countries has been to use components manufactured in industrialized countries and to rely on local enterprises for the labor. This procedure has a number of limitations. First, as mentioned previously, many components are presently built in developing countries. Second, not all developing countries have adequate know-how for the special construction needed in hydraulic plants. Organizational and training problems associated with large-scale plants have created difficulties in developing countries. Technology transfer and training should be provided. Geological complications in developing countries have sometimes created problems and led to caused cost overruns.

120. The potential negative environmental impacts of large dams include erosion, sedimentation, damage to flora and fauna, climatic effects, seismic aspects and spread of diseases, such as schistosomiasis. Dam safety is also a major concern.

121. Small-scale and mini hydro plants (up to a few MW) pose fewer problems than large-scale projects. Their diffusion in the last ten years has been important but less than predicted. Hydraulic and electric

---

[37] All monetary values are given in US dollars. Where constant dollars are used, the relevant year is given in parenthesis.

equipment producers have made a considerable effort to improve the quality and lower costs of components. Such improvements include design standardization, manufacturing, choice of materials, automation and remote operation. Production in this industry has been concentrated to a limited number of companies, with positive effects on costs and standardization. Some of the companies of international importance are located in developing countries (China, South America).

122. Innovations have improved many aspects of mini hydro plants, ranging from new dynamic seals to inflatable rubber transverses and simple control systems to devices that facilitate fish transit. In some cases, traditional concepts have been revived with new materials and improved design. Many schemes for integrating water uses have been implemented.

123. Less progress has been made in the development of micro-hydro plants (stand-alone plants, i.e. not grid-connected, and generally below 100kW), especially where components are concerned. Components designed for other uses, such as pumps and other types of generators, are often employed. Electronic load controllers that replace expensive and unreliable mechanical governors have been one positive development. A number of successful micro-hydro plants have been installed in several countries. The UN-sponsored Hangzhou regional Center for Small Hydropower in China has played a positive role in many such installations. Progress has been made in some countries (notably China and Nepal) in the local manufacture of plants. Such experience could be transferred to other developing countries.

b) Fuelwood and charcoal

124. Fuelwood continues to play a major role in many developing countries, where it represents the largest contribution to the energy supplied to rural populations. Conventional fuelwood supplies and use often result in, or contribute to, major environmental problems such as deforestation and land degradation. The health impacts of indoor biomass combustion afflict at least 500 million women and children.[38] The sustainable provision of fuelwood and its environmentally-sound use need to be high priorities. The low energy efficiency with which wood is used has prompted a number of programs to develop and diffuse wood stoves for cooking and heating that are much more energy efficient than traditional stoves. Some of these programs have been successful, especially those that addressed local social and cultural barriers. In China, 120 million fuel-saving stoves are reportedly in use.[39] In other countries, energy-efficient charcoal stoves are used in urban areas, where, unlike in rural areas, both fuel and stoves are costly commercial commodities.

125. Charcoal is also produced for industrial uses. The most important example is in Brazil, where over 7 million tonnes of charcoal are used annually in place of coal for pig-iron and steel production and produce iron with better magnetic qualities than with conventional furnaces.[40] Charcoal is generally produced with primitive earthen kilns that have an overall energy-conversion efficiency of less than 25 percent.[41] Important improvements have begun to be introduced in several countries. Improved earth kilns can achieve energy efficiencies of about 50 percent. Sophisticated and well-managed kilns can achieve energy efficiencies of 60 to 70 percent.[42]

126. Notwithstanding some improvements in fuelwood transformation and utilization, the situation on the whole is not much better today than it was ten years ago. The trend toward deforestation and desertification has continued, especially in semi-arid and mountainous regions, often for non-energy reasons. Further improvement in fuelwood use should be based on an assessment of past programs, learning from past failures. New programs should be designed in their broader context, including programs for sustainable

[38] World Health Organization, "Biomass Fuel Combustion and Health," Report EFP/84.64, Geneva, 1984.

[39] Derived from: Hu Chengchun, Chinese Academy of Science, China, 1991, personal communication.

[40] *Op. cit.* ref. 21.

[41] Kristoferson, L.A., and Bokalders, V., "Renewable Energy Technologies," Pergamon Press, Oxford, 1986.

[42] *Ibid.*

forest management, consideration of fuel collection and storage problems, use habits, the role of women, health issues and barriers to commercialization and market penetration. Many difficulties must be overcome in order to implement such integrated programs, including: problems of land tenure, trees and wood related to reforestation programs; wood use for other productive activities; and the need to formulate effective policies for managing resource substitution and energy transition.

127. In cases where fuelwood is increasingly scarce and cannot be used renewably, it is necessary to shift to different energy sources, such as fossil fuels like kerosene or LPG, or sustainably-managed bioenergy sources, such as agricultural residues and energy crops. Wood use should only be promoted when carried out in a sustainable manner.

c) Biomass: Energy crops and wastes

128. Sustainable biomass utilization as an energy source can be seen from two complementary points of view: the biomass resource and the technology used for its transformation and utilization. Biomass for energy use can derive from residues or by-products of food or other production processes, or be cultivated.

129. The accumulated experience with biomass technologies is much greater today than it was at the time of the Nairobi conference. A wide range of technologies exist for transforming and utilizing biomass. Some are well-established, such as direct combustion. The United States alone has nearly 9000MW of biomass-produced electricity generating capacity, mostly from agricultural and silvicultural residues. With an average capital cost of $1500 (1989)/kW and a fuelwood cost of 1.2 to 2.4¢/kWh, the resulting total generation cost in the U.S. is between 4.2 and 5.4¢/kWh.[43] Other technologies are still in the research stage, such as enzymatic hydrolysis of cellulosic materials to produce ethanol or biomass gasifiers coupled to combustion turbines to produce electricity. All of these technologies have been improved in the last decade. Most of the advanced conversion technologies with the greatest promise, however, still remain in the development stage.

130. Energy crops may compete with food crops for land utilization. In circumstances when agricultural land is not too limited, energy crops may be an option. The use of marginal lands for energy crops should also be considered. The very large-scale production of ethanol fuel from sugar cane in Brazil (11 million tons in 1990 under the ProAlcool program) has shown that such a process is indeed possible and economically competitive with higher oil prices and improved technologies.[44] The sugar- and ethanol-producing industries generate large quantities of bagasse, which up to now have been only partially utilized. Bagasse use in an efficient cogeneration plant could produce the heat requirements of the sugar industry and up to 40 times more electricity than the industry needs. Electricity sales to the grid could generate revenue comparable to those from the sugar and alcohol sales. This innovation alone could make bio-ethanol competitive with oil, even at present low oil prices.[45] The stillage from the same industries, when simply dumped into rivers, can be major sources of water pollution. It can, however, also generate significant quantities of biogas, producing residues that are more suitable for fertilization than the original liquid. Similar situations exists, for instance, in the fruit processing and vegetal-oil producing industries.

131. Energy crops are also interesting in countries where agricultural productivity increases result in food surpluses making fertile land available for other uses. Such land can be used to grow energy crops, several species of which are already available. Genetic improvements (including advanced biotechnologies) in wood

---

[43] United States Department of Energy, "The Potential of Renewable Energy: An Interlaboratory White Paper," Solar Energy Research Institute, Report SERI/TP-260-3674, Golden, Colorado, March 1990.

[44] Goldemberg, J., Monaco, L.C. and Macedo, I.C., "The Brazilian Fuel-Alcohol Program," in Johansson, T.B., Kelly, H., Reddy, A.K.N. and Williams, R.H. (eds), "Fuels and Electricity from Renewable Sources of Energy," Island Press, 1992 (in press).

[45] Williams, R.H. and Larson, E.D., "Biomass as a Major Option for Power," in Johansson, T.B., Kelly, H., Reddy, A.K.N. and Williams, R.H. (eds), "Fuels and Electricity from Renewable Sources of Energy," Island Press, 1992 (in press).

and herbaceous crops and development of appropriate processing methods for additional species are required. Aquatic biomass production may also provide a future source of energy crops. The use of oleaginous plants to produce oils for use in diesel engines is another possibility which is receiving increased attention.

132. Many of the potential environmental problems associated with using energy crops are common to other agricultural activities: reduction of biological diversity, pollution from pesticides and fertilizers, competition with alternative land uses, etc. On the other hand, the environmental advantages are important. They include avoiding the negative environmental impacts of the substituted energy sources (in particular CO_2 emissions from fossil fuels), alleviating the depletion of forests and woodlands, and avoiding land degradation in cases where agricultural land would otherwise be abandoned.

133. While at least a part of agricultural residues should be recycled on site to fertilize the soil, many agricultural, urban and industrial organic residues and wastes are available. Utilizing them for energy often solves environmental problems. Food industries, which are often the first industries in developing countries, produce organic wastes that can be transformed into methane (via anaerobic digestion) or used for heat and/or electricity generation, which in turn can be used at least in part by the same industry.

134. Large cities generate tremendous amounts of solid and liquid wastes, which constitute formidable environmental problems. These wastes, however, if properly collected and treated, could yield valuable energy for urban use. Gas production from municipal solid waste (MSW) landfills and burning MSW directly or through residue-derived fuel production for electricity generation are useful options. Much of the combustible waste, however, is often collected and used by the poor before it reaches the incinerator. Anaerobic fermentation of liquid wastes or sludge, with biogas production, can eliminate or at least reduce the need for external energy supply for waste-water treatment. In general, processes that avoid uncontrolled fermentation of wastes and releases of methane to the atmosphere are doubly important in terms of global climate: for their energy value (and therefore for the avoided effect of the fuel they replace) and for removing a methane-emission source. The use of wastes and residues is generally positive from an environmental point of view because it removes potential pollution problems.

135. Very simple technologies based on local materials and capabilities have not always lived up to expectations. One example is anaerobic digestors: the simple, backyard type, widely diffused in some countries (notably China, where several million household plants are still in operation[46]) have had operation and endurance problems. In many cases these have been replaced by systems which are still simple, but incorporate somewhat more sophisticated technologies. The blending of improved and even advanced technologies with traditional concepts has, in many cases, proven to be a successful approach.

136. There are many emerging biomass technologies with large potentials. We mention only a few. Gasification of crop residues, such as rice husks, is receiving some attention in South-east Asian and Latin American countries as a more effective use than direct combustion. Pilot plants of this type are operating in China and Indonesia. A concept that has raised some interest, but is not yet diffused in field use, is the coupling of gasifiers with gas turbines for electricity generation. Another example of a promising technology is the treatment of cellulosic materials by steam explosion, which may be followed by biological or chemical hydrolysis to produce ethanol or other fuels. Cost projections based on presently available technologies are on the order of 25 cents per liter (¢/l), but expected improvements could lower them to 15¢/l.[47] Small Stirling (hot air) engines, capable of using wood or agricultural residues as fuel, have recently received renewed interest. Pyrolysis of various biomass products to generate liquid bio-fuel or a bio-oil/bio-coal slurry that could replace fuel oil in existing power plants is being investigated, particularly in the European Community.

---

[46] *Op. cit.*, ref 39.

[47] Wyman, C.E., Bain, R.L. and Hinman, N.D., "Ethanol and Methanol form Cellulosic Materials," in Johansson, T.B., Kelly, H., Reddy, A.K.N. and Williams, R.H. (eds), "Fuels and Electricity from Renewable Sources of Energy," Island Press, 1992 (in press).

d) Solar thermal

137. A large number of different technologies and applications are available for direct-thermal and indirect (through thermodynamic cycles) uses of solar radiation. Some of them have been significantly improved in the last decade, some are still of uncertain success, and others are being abandoned.

138. Passive-solar heating and cooling of buildings is a practice that has traditional roots in many countries, and that has been revived in recent years by applying modern analysis and computing methods. Efforts have recently been made to blend new methods with local materials and building practices. Such schemes can have important effects on both comfort and building energy consumption both in rural and urban areas. When passive solar features have been introduced in the initial design stage, and appropriate solutions have been used, the extra costs involved have proved to be modest — typically 5 to 10% of the total cost of the building. They are partially recuperated by allowing for downsizing of heating and cooling equipment. The net costs are paid back with energy-bill savings in very few years. In addition, comfort levels are usually better than with active/conventional systems. Retrofitting passive-solar features into existing buildings is also possible in some cases, but the economics are very case specific.

139. Solar water heaters have been steadily improved: methods of producing collectors have gotten cheaper, control systems are better and simpler, and components are more rugged and reliable. But their diffusion has been slower than anticipated. They provide hot water, which is not widely available in many developing countries, at prices which are competitive with electricity, especially with respect to prevailing inefficient heaters. In industrialized countries, they are not yet competitive with natural gas where it is available. In several countries solar water heaters cannot compete with LPG because of high LPG subsidies. Efforts are needed in most countries to provide cheaper and better installation and maintenance services. Nevertheless, 1.8 million m^2 of solar collectors for water heating are in use in China.[48]

140. Solar driers for crops are a promising technology that still needs development. They can be built using simple schemes and inexpensive materials, but should include a minimum of temperature control in order to achieve optimum results on various types of crops. They can effectively replace oil-burning driers and help to avoid post-harvest losses common to traditional open-air natural drying practices. Year-round applications, such as timber drying or integrating different applications provide favorable investment returns. When waste products are available for fuel use this can represent a practical approach.

141. Solar cooker applications that replace inefficient wood stoves have met with difficulties, especially when their introduction has not adequately taken local traditions into account — such as cooking early in the morning or at night, or cooking indoors — and lack of availability in cloudy weather.

142. High-temperature solar heaters (reaching well above 100°C) can be built by concentrating solar radiation and/or using special materials. Fluids at such temperatures can be used in a number of applications, including refrigeration (by means of absorption coolers), desalination (e.g., by a multi-flash process), process heat or steam for industrial uses. Applications of all these types have been reported, and in many cases they have been a technical success. However, for the time being their diffusion is very limited, primarily for economic reasons.

143. Solar ponds both collect solar energy and store it as heat for relatively-long periods. They can be economically interesting under rather special circumstances: in particular, when salt is freely available and natural enclosures can be used for the pond. A number of solar ponds exist or are being built in several countries. The largest in operation is in Israel on the edge of the Dead Sea, and generates 5MW of electric power.[49] Others are being used for desalination and for heat storage.

---

[48] *Op. cit.*, ref 39.

[49] Rubin, H. and Bemporad, G.A., "The Advanced Solar Pond," *Solar Energy*, Vol. 43, no. 1, pp. 35-44, 1989.

144. Solar-thermal electricity can be obtained with several different technologies through thermodynamic cycles operating at relatively high temperatures. These temperatures can be obtained through different types of concentrators: mirrors aiming solar radiation at a central tower, parabolic dish collectors and parabolic troughs. Only the latter have met with success so far. An Israeli-US venture has built a number of power-generating solar installations. These now total over 350MW and are being expanded to 700MW in southern California. The cost of trough concentrators has decreased to about $\$200/m^2$ and electricity is sold to the grid at competitive prices.

145. Solar-thermal systems lead to very few environmental problems, other than those deriving from their surface-area requirements — a direct consequence of the distributed nature of solar radiation. This problem is minimized when solar collectors are integrated into existing structures or occupy areas not otherwise usable. Some solar-thermal systems (for power production and for refrigeration) use chlorofluorocarbon (CFC) fluids. Alternative fluids exist and will be used in the future.

e) Solar photovoltaic

146. Photovoltaic (PV) technologies directly convert solar insolation into electricity. Although they are much more expensive, in general, than other electricity-generating technologies, they are considered very promising.[50] There are three reasons for this: 1) they are highly innovative and based on components that are under rapid development, and therefore have a large potential for cost reduction as production volumes increase, 2) they are almost scale-independent, which makes even very small plants relatively interesting, and 3) they require very little, if any, intervention for operation and maintenance.

147. PV system costs have declined by at least one order of magnitude since 1970 to about $7000/kW, about $4500 of which is for the PV modules and $2500 for the rest of the system. With an electricity-generating level of 2200 kWh/kW per year, a plant life of 30 years and a six percent real discount rate, PV electricity currently costs about 30¢/kWh.[51]

148. Even though their costs are currently much higher than conventional energy sources for bulk electricity production, there are many market applications for which PV technologies are already competitive, such as telecommunication, cathodic protection of pipelines, signals at sea, and consumer electronics. In developing countries, applications also include the provision of drinking water, health care, lighting, etc. The size of these intermediate markets has increased rapidly as the prices of PV systems have decreased. PV sales have grown steadily, doubling every four to five years, to the present level of about 50MW/year.[52]

149. As PV prices decrease, PV technologies become increasingly cost competitive with diesel generators for power supply to locations not connected to grids. Such locations, however, are mostly found in rural areas of developing countries, where people often can hardly afford a diesel generator and little capital is available for the high initial-investment costs associated with PV systems. PV applications should be combined with high-efficiency end-use appliances, thereby optimizing the entire supply/utilization system in terms of cost of delivered energy services. Hybrid systems, combining PV and diesel generators, with PV providing between 35 and 70 percent of the energy, can greatly reduce the need for electric storage. Other hybrid systems, like PV and wind or PV and biomass, are also being explored.

150. Promising applications have recently been identified in special large grid situations. PV-system grid reinforcements may be cost-effective in the near future in parts of the distribution network that are far from

---

[50] Kelly, H., "Introduction to PV Technology," in Johansson, T.B., Kelly, H., Reddy, A.K.N. and Williams, R.H. (eds), "Fuels and Electricity from Renewable Sources of Energy," Island Press, 1992 (in press).

[51] Proceedings of the IEA/ENEL Executive Conference on Photovoltaic Systems for Utilities, Taormina, December 1990, Organization for Economic Cooperation and Development (OECD), forthcoming.

[52] Maycock, P.D., "International Photovoltaic Markets, Developments and Trends," in *Proceedings of the 10th European Photovoltaic Solar Energy Conference, Lisbon, 8-12 April 1991*, Kluwer Academic Publishers, Dordrecht, 1991, pp. 1396-1400.

generating stations and have large quantities of insolation, a good match between insolation and load, and where the costs of alternative generating solutions are high. If utilities adopt a more detailed, space-dependent system of cost analysis that takes into account demand-side management, the short- and medium-term potentials of PV are likely to be positively re-evaluated. In the longer term, increases in conventional fuel prices, more stringent environmental regulations, and availability of capital at low interest rates are factors that would facilitate the penetration of PV systems. Continued diffusion of grid-connected applications of PV systems in industrialized countries in parallel with the diffusion of stand-alone applications in developing countries would increase the PV market thereby driving down production costs.

151. PV-system prices are expected to decline further in the future, as a result of both economies of scale in manufacturing processes and a shift to cheaper new materials. The largest industrial plants now produce a few MW per year: a factor of ten scale-up would reduce cell-production costs by about a factor of two. In order to reduce material costs for crystal silicon (X-Si) technologies, it will eventually be necessary to rely on thin films, one candidate for which is amorphous silicon (a-Si).[53] Amorphous silicon has production costs that are already much lower than crystal silicon, but its present characteristics of low efficiency and initial degradation have slowed its penetration into the general energy market. So far, its applications have been limited to consumer electronics and gadgets, but wider applications may be approaching.

152. PV cells comprised of multiple layers of amorphous silicon have produced higher efficiencies and improved stability. Still higher efficiencies (above 13% in the laboratory) can be obtained by using layers of different materials, such as a-Si and amorphous germanium (a-Ge), or different silicon-germanium alloys (Si-Ge), in which each material optimizes the utilization of the various wavelengths of solar radiation.

153. Other materials are being investigated as candidates for PV cells. Among them, gallium arsenide (GaAs), which is also of interest for electronic applications, can be manufactured in thin films. Copper indium diselenide (so-called CIS) and cadmium telluride are other materials that appear promising and are receiving attention today.

154. As a result first of crystal silicon production improvements and economies of scale, and later of the introduction of thin film technologies and various reductions in other system costs, the total cost of PV systems is expected to decrease to $2500 to $3500 per kW by the year 2000 (with electricity costs between 10 and 15¢/kWh) and perhaps $1000 to $1500 per kW by the year 2020 (5 to 6¢/kWh).[54]

155. As with solar-thermal technologies, PV systems have large space requirements. Similar opportunities for reducing them are available. The promising approach of PV concentrators for electricity production offers the potential of high conversion efficiency at low cost because concentrators permit the use of small areas of high-efficiency cells coupled with low-cost lenses or mirrors.[55] PV module production presents potential environmental impacts similar to those of the electronics industry (use of CFCs as cleaning agents, possible toxicity of components for non-conventional materials such as GaAs and CIS, etc.). Such problems can and are being overcome.

f) <u>Geothermal energy</u>

156. In the last decade, global geothermal electricity-generation capacity has increased from 2000 to 5830MW_e (from 500 to 2000MW in developing countries). Technological developments for tapping geothermal sources have taken place, particularly in the Philippines, Mexico, Nicaragua and El Salvador.

---

[53] Carlson, D., "a-Si photovoltaics," in Johansson, T.B., Kelly, H., Reddy, A.K.N. and Williams, R.H. (eds), "Fuels and Electricity from Renewable Sources of Energy," Island Press, 1992 (in press).

[54] *Op cit.*, ref. 51.

[55] Boes, E. and Luque, A., "Photovoltaic concentrator power systems," in Johansson, T.B., Kelly, H., Reddy, A.K.N. and Williams, R.H. (eds), "Fuels and Electricity from Renewable Sources of Energy," Island Press, 1992 (in press).

The use of lower-enthalpy geothermal fluids for heating purposes (including urban buildings, greenhouses, aquaculture and animal breeding) has expanded, mostly in industrialized countries because of the lower demand for space heating in developing countries.

157. The technologies for harnessing geothermal energy are mature but constant technical improvements are still being made.[56] Within the last decade these have included: the ability to modulate the load in an economic and efficient way in both steam- and water-dominated situations, even for relatively small plants; the building of simple and reliable single- and double-flash systems at moderate cost installed in remote locations; the development of new techniques for drilling deep wells (4000m and beyond) through hard, hot rocks; the improvement of materials and sealing techniques; techniques for drilling multiple wells branching off of main wells at great depths; the drilling of quasi-horizontal wells; and the improvement of geo-physical and geo-chemical prospecting and evaluation methods.

158. The costs of direct heat applications are difficult to evaluate but, in general, cost-competitive direct geothermal heat applications are limited. Under favorable conditions, however, the cost of electricity generated with geothermal heat is competitive with that from conventional sources. A general evaluation, which takes into account all phases of electricity production starting from surface exploration and feasibility studies, yields a cost range of 3 to 8¢/kWh using a six percent real discount rate. The costs of direct heat applications vary much more because they depend not only on the characteristics of the reservoirs but also on the presence of potential users close to the drilling site.

159. New techniques for utilizing geothermal reservoirs are being developed and diffused. They include, for example, using geothermal heat for chemical processing and producing pure water from the plant. Promising improvements have been made in the development of hot dry rock (HDR) technologies. The availability of HDR technology would extend the geothermal resource base to many more countries.

160. Measures for reducing the negative environmental impacts of geothermal plants are implemented much more widely today than they have been in the past. Re-injection of water and dissolve wastes is now a universal practice. Gaseous-pollutant emissions (such as H_2S) are also being avoided with increasing efficiency. The costs of such measures are already being included in economic evaluations of geothermal projects.

g) Wind energy

161. In areas with adequate wind patterns, wind turbines are presently the cheapest renewable energy source for producing electrical and mechanical power, with the exception of some hydropower.[57] Wind patterns are very variable. Ground configurations around the wind turbine and the presence of vegetation have important effects. It is necessary, therefore, to have accurate measurements and evaluations of actual conditions on each site considered for wind-turbine installations.[58]

162. Wind-power technologies have evolved remarkably in the last decade. Most of this evolution, and of the new applications of wind turbines, however, is concentrated in industrialized countries and designed to suit their conditions. Wind turbines provide electricity to the grid in California (over 1500MW), Denmark (350MW), India (40MW), and the Netherlands (40MW). Electricity-production costs decreased by more than 60 percent in the 1980s, and are currently roughly equal to the cost of electricity generated by coal-fired

---

[56] Palmerini, C., "Geothermal power," in Johansson, T.B., Kelly, H., Reddy, A.K.N. and Williams, R.H. (eds), "Fuels and Electricity from Renewable Sources of Energy," Island Press, 1992 (in press).

[57] Smith, D. and Hock, S., "Wind energy: technological and economic aspects," in Johansson, T.B., Kelly, H., Reddy, A.K.N. and Williams, R.H., "Fuels and Electricity from Renewable Sources of Energy," Island Press, 1992 (in press).

[58] Grubb, M. and Meyer, N.I., "Wind energy: regional strategies and potentials," in Johansson, T.B., Kelly, H., Reddy, A.K.N. and Williams, R.H., "Fuels and Electricity from Renewable Sources of Energy," Island Press, 1992 (in press).

plants. The average size of the turbines employed has risen steadily in the last ten years from a few tens of kW to a few hundred. Large-scale turbines, one or several MW of power, are still at an experimental stage, and it is not clear whether or not they will eventually become more cost effective than medium-sized ones, except where space is limited and in off-shore applications.

163. Recent wind-technology developments include advanced airfoils, variable-speed turbines that employ solid-state advanced electronic power-conditioning systems, and continued development of new materials that yield lighter, stronger components. Energy capture has been increased ten percent or more, while capacity factors that were in the range of 15 percent ten years ago are now as high as 35 percent. All of these improvements are directly reflected in lower electricity generating costs.

164. In developing countries, stand-alone systems may be required rather than grid connected systems; environmental conditions may be more severe (as where sand-carrying winds are common); average wind velocities may be smaller; and reliability is particularly important. However, it is important to draw from the experience already gained by industrialized countries, where turbines have been tested for several years and have penetrated the market most successfully.

165. Smaller turbines, up to a few kW, have long been used in many countries to pump water for human and cattle use, for irrigation and to charge batteries. In industrialized countries, this practice declined with the expansion of rural electrification. The demand for these applications is large in developing countries. Wind pumps are economically attractive, at least for drinking water, even when average wind velocities are low. About 110 thousand wind generators and 1600 wind pumps are operating in China.[59]

166. Modern wind technologies are more reliable, lighter and cheaper than traditional ones. Positive results have also been obtained by using locally-available materials and by varying traditional schemes in modern applications.

167. Environmental problems associated with wind generators have been extensively investigated in connection with major installations.[60] The effects considered include: damage to birds; electromagnetic disturbances to television transmissions; noise; and aesthetic alterations of landscapes. Apart from the last of these, which is a matter of personal evaluation, environmental impacts have proved to be minor or negligible.

h) Other energy sources

168. Several different energy sources are present in oceans: tides, currents, waves, and thermal gradients.[61] All of these energy forms are only available at near-shore locations and are therefore particularly interesting on islands. Their potentials also vary considerably with location. Only the case of tides has been demonstrated: a 240MW plant exists in France, and smaller ones exist in the USSR and China. Several other tidal projects are being considered. Only a minute fraction of the 3TW tidal resource, however, can even theoretically be captured. The other ocean technologies are at the experimental or conceptual design stages, and there are no prospects for large-scale utilization, at least in the next 10 to 30 years.

---

[59] Chengchun, H. and Wei De, L., "The Development of New and Renewable Sources of Energy in China," in Meyer, N.I. and Nielsen, P.S. (eds), *Conference Proceedings: Global Collaboration on a Sustainable Energy Development,* Technical University of Denmark, April 1991.

[60] See, for example: "Wind Energy and Environment," Institution of Electrical Engineers, Swift-Hook, London, 1989; Bellmo, B., Fattore, A., Maffei, C. and Montesano, G., "Studies for the Insertion in the Environment of Wind Power Plants," in *Proceedings of the European Wind Energy Conference (EWEC '91),* Amsterdam, 14-18 October, 1991.

[61] Price, R., Clarke, J.H. and Cavanagh, J., "Ocean energy systems — wave energy, tidal energy and OTEC," in Johansson, T.B., Kelly, H., Reddy, A.K.N. and Williams, R.H., "Fuels and Electricity from Renewable Sources of Energy," Island Press, 1992 (in press).

169. The use of animal power in agriculture is important. Its use can be improved with appropriate technologies, such as more efficient harnessing devices, more appropriate tools and implements (e.g., pumps), better breeding, health care and feeding programs. Using animal power can also be advantageous in swamps and where soil could be damaged by machinery.

III. The Annual Economic Supply Potential

a) Factors affecting the annual economic potential

170. An assessment of the economic potential to supply energy with renewable resources begins with an appraisal of existing technologies and unsubsidized production costs, even if such an appraisal is difficult to make given the numerous factors influencing the estimates. The economic potential changes over time as a function of technological and other cost-reducing progress, changes in the cost of renewable-energy technologies, and changes in the prices of competing energy sources. In addition, subsidies for conventional energy sources, in place in many countries, may largely reduce the accessibility of the economic potential.

171. The proximity of populations to renewable energy sources and the range of energy carrier transmission capabilities are also important factors.

172. Various non-economic constraints affect the economic potential for renewable energy production and use. These include the variable nature of many renewable energy sources over time (diurnally as well as seasonally); the diffuse nature of some renewable sources; and the availability of sufficient infrastructure and skills to construct, operate, and maintain renewable energy systems.

b) The annual economic supply potential: 1991-2000

173. The annual economic potential for supplying energy with renewable resources by the year 2000 has been estimated in a study prepared for the UNSEGED by Dessus *et. al.*[62] Their estimates are based on proven commercially available technologies and existing equipment-production costs, current market prices for fossil fuels, and a five percent real discount rate for all technologies considered and compared. They find that globally, 1985 levels of renewable energy production (see Table 5) could more than double, from a limited economic point of view, during the 1990s.

174. The economic potential for renewable energy supply by the year 2000 is disaggregated into four northern and six southern regions in Table 6. The economic potential for electricity production based on primary renewable energy sources by the year 2000 equals approximately half of the 1985 total global electricity production (see Table 7). Countries in the southern hemisphere generally have larger potentials, in relation to their current production, than do countries in the northern hemisphere.

175. Technological development is not required to increase the use of renewable energy sources to the levels indicated in Tables 6 and 7. Barriers to utilizing the available potential include: limited equipment-manufacturing capacity, capital constraints, direct market barriers, inadequate institutional structures, and the organization of the energy industry. New technologies face the additional challenge of requiring very high market penetration rates in order to take over significant shares of the energy market. For example, although PV sales have doubled every four to five years, the total amount of installed PV capacity is very low. It would take 30 to 40 years at the current growth rate (about 20% per year) before PV technologies could provide a significant share of world energy supply. Great efforts should be made on the part of governments, industries and utilities to accelerate such growth rates.

---

[62] Dessus, B., Pharabod, F., and Devin, B., "Renewable Energies: Actually Accessible Regional Potentials and Environmental Impacts Analysis for the Nineties," La Houille Blanche, no. 1, January 1992.

Table 5[63]
World Energy Conference Estimates of the 1985 Contribution
of Renewable Sources of Energy (RSE) to Global Energy Supply
(Mtoe)

	Hydro	Geo-thermal	Solar	Wind	Biomass				Total RSE	Total Energy	RSE Share %
					WO c.	WO n.c.	BI Crops	Waste			
North	312	8.5	8	0.8	98	22	2	10	461	5352	8.5
South	133	3.5	5	0.2	77	583	8	80	890	2317	38.3
Total	445	12	13	1	175	605	10	90	1351	7669	17.5
% of Total Energy	5.8	0.2	0.2	0.01	2.3	8	0.1	1.2	17.5		
% of Total RSE	33	1	1	0.07	13	45	0.7	7	100		

Table 5 Notes: Biomass energy is disaggregated into four categories. Commercial wood products derived from multi-use forests are designated as "WO c." and non-commercial wood products so derived are referred to as "WO n.c." Biomass cultivated strictly as energy crops is referred to as "BI Crops." Urban and rural wastes (including cattle and crop residues) are referred to as "WASTE." Primary electricity is counted in thermal equivalents using the heat rate adopted by the World Energy Conference (0.222 Mtoe per TWh_e).

c) <u>The potential for the year 2020</u>

176. Beyond 2020, the economic potential for renewables may become enormous. The potential will increase for two reasons. First, progress along the learning curve for existing technologies and systems will lead to reduced delivered energy costs. In addition, governmental support for renewable-energy technologies today will help build up markets, thereby helping industry onto the learning curve. Second, research, development and demonstration (RD&D) is likely to lead to cost reductions and new technologies and systems (e.g., solar-hydrogen).[64] New opportunities will arise from technological improvements and the turnover of existing capital stock, that take place between the years 2000 and 2020.

177. An example of the importance of RD&D is presented in *The Potential for Renewable Energy: An Interlaboratory White Paper*, prepared by five of the U.S. Department of Energy's national research laboratories.[65] The study concludes that if federal RD&D expenditures were expanded by two to three times (~$3 billion during the next 20 years) renewable energy sources could provide 28 percent of projected U.S. energy demand (roughly half of current U.S. energy consumption or 1.9 Gtoe) by the year 2030.

[63] Based on Dessus *et. al.*, *Op. cit.* ref. 62. See also ref. 14.

[64] Ogden, J. and Williams, R.H., "Solar Hydrogen: Moving Beyond Fossil Fuels," World Resources Institute, Washington, D.C., 1989.

[65] *Op. cit.* ref. 43.

Table 6[66] Annual Accessible Renewable Energy Supply Potential By Region and Technology Year 2000 (Mtoe)									
	Hydro	Geo-thermal	Solar	Wind	Biomass				Total RSE
					WO c.	WO n.c.	BI Crops	Waste	
N. America	169	3.5	17.5	16.4	204	7.5	13.6	67	498
W. Europe	174	3	6.5	14	43	5	5.3	52	303
Jap., Aus., NZ	34	3.6	6.5	9.8	17	0	3.9	16	91
USSR, C. Europe	180	3.1	7.5	1.8	218	15.5	15.4	56	497
TOTAL NORTH	557	13.2	38	42	482	28	38	191	1389
Latin America	144	1.5	17	1.8	324	158	15.7	55	717
N. Africa, M. East	7.5	0.1	11	0.1	10	11	0.9	6	47
Africa	24.5	0.3	19.5	1.2	70	200	3.9	24	343
India	17.5	0	43	5.3	9	66	5.2	69	215
China	71.5	2.1	32	6.3	17	48	3.2	84	264
Asia, Oceania	56	2.7	39.5	3.3	68	162	2.8	65	399
TOTAL SOUTH	321	6.8	162	18	498	645	32	313	1996
TOTAL WORLD	878	20	200	60	980	673	70	504	3385
% of Total RSE	26	0.6	6	1.8	29	20	2	15	100

Table 6 Notes: Passive-solar heating and cooling of buildings, solar crop or lumber drying, solar ponds, offshore wind systems, mechanical energy (e.g., for water pumping) provided by windmills, and tidal and ocean-thermal energy conversion systems are not included in the table. Offshore wind plants are currently on the brink of commercialization in Denmark. Energy costs assumed by Dessus *et. al.*: Solar water heating 4 to 7¢/kWh; PV decentralized 50¢ to $2/kWh; grid solar electricity (PV or thermal) 30 to 70¢/kWh; grid wind 7 to 25¢/kWh; decentralized wind 15 to 50¢/kWh; Hydropower 1.2 to $3/W$_p$.

[66] Based on Dessus *et. al.*, *Op. cit.* ref. 62.

Table 7[67]

Annual Economic Potential for Primary Electricity for the Year 2000 (TWh)

	Hydro	Wind		Solar		Total	1985 Production
		Grid	Remote	Grid	Remote		
North America	767	75	0.1	60	0.7	903	2980
Europe	793	63.4	0.5	13	1.6	872	1875
Japan, Australia and New Zealand	155	44.8	0.3	19	0.3	219	795
USSR and Eastern Europe	816	8	0.7	24	0.8	850	1710
Latin America	656	5	2.9	37	10.8	712	525
N. Africa and the Mid. East	34	0	1.2	21	9.5	66	200
Africa	111	1.5	3.6	15	25.8	155	185
India	80	5.2	18	13	63	179	260
China	325	9	18	13	33.6	398	450
Asia and Oceania	252	0	15.4	12	55	334	320
Total World	3990	212	61	227	200	4690	9300

178. Table 8 shows a highly conservative estimate of the economic potential for renewable energy supply in 2020.[68] This estimate is based upon already proven technologies (without accounting for future technological breakthroughs) and today's energy prices. The increased potential shown in this table is a function of population growth and learning-curve effects, not of technological change. Technological development would increase the potential further. The economic potential corresponds, nevertheless, to more than half of present total global energy use.

[67] *ibid.*

[68] *Op. cit.* ref. 62.

Table 8[69]
Minimum Annual Accessible Renewable Energy Supply Potential
By Region and Technology
Year 2020
(Mtoe)

	Hydro	Geo-thermal	Solar	Wind	Biomass				Total RSE
					WO c.	WO n.c.	BI Crops	Waste	
N. America	195	6.8	40	35	227	0	80	70	654
W. Europe	180	5.2	20	30	60	0	65	57	417
Jap., Aus., NZ	40	5.7	30	20	23	0	11	16	146
USSR, E. Europe	240	5.6	30	15	250	0	34	62	636
TOTAL NORTH	655	23	120	100	560	0	190	205	1853
Latin America	245	4.1	60	12	500	120	70	86	1097
N. Africa, M. East	8	0.2	80	2	20	5	10	17	142
Africa	63	0.7	60	3	240	140	60	52	619
India	26	0	40	8	40	55	5	90	264
China	128	3.8	50	10	40	50	5	90	377
Asia, Oceania	90	7.2	60	10	150	130	10	80	537
TOTAL SOUTH	560	16	350	45	990	500	160	415	3036
TOTAL WORLD	1215	39	470	145	1550	500	350	620	4889
% of Total RSE	25	0.8	9.6	3	32	10	7	13	100

d) Integrating supply and demand

179. In order to estimate the *share* of future energy supply that can be provided by renewable energy sources it is necessary to integrate estimates of the annual economic potential for adopting renewable-energy technologies with scenarios of future energy demand. Demand scenarios vary considerably, depending on underlying assumptions. Assumptions regarding end-use efficiencies are often the most important sources of differences in demand-scenario results.

180. In the World Energy Conference scenario (WEC:M), global average energy demand grows at a rate of 1.7 percent per year for the period 1985-2020, while annual economic growth is assumed to be three percent.

[69] *Op. cit.* ref. 62.

The energy-demand growth rate is slightly lower than the 1.9 percent per year rate experienced between 1973 and 1985. In this scenario, global annual energy demand grows from 7.7 billion tonnes of oil equivalent (Gtoe) in 1985 to 13.5 Gtoe in 2020.[70]

181. The scenario presented by Goldemberg *et. al.* in *Energy for a Sustainable World* (ESW) indicates that energy demand can be restrained to 8.4 Gtoe in 2020 if energy efficiency is increased across all major end uses and sectors to a level corresponding to that of the presently most energy-efficient technologies that are commercially-available or close to commercialization. Such technologies are assumed to be introduced at the rate of capital turnover and expansion.[71] A gross domestic product (GDP) indicator is not explicitly used in the ESW scenario. Social and economic growth assumptions in the scenario are consistent with a global per capita GDP growth rate of up to about three percent per year.[72] Developing countries are assumed to be successful in leapfrogging over the average energy end-use efficiencies presently prevailing in industrialized countries by acquiring highly-efficient end-use technologies that are already commercially available or close to commercialization as development and capital expansion occur.

182. By the year 2020, if the economic potential for utilizing renewable energy sources shown in Table 8 is applied in the WEC:M scenario, approximately one-third of global energy would be provided by renewables. The same renewable supply potential could supply half of global energy consumption under the ESW demand scenario.

IV. Potential Benefits with Respect to Global Problems

183. By reducing the demand for fossil fuels, the utilization of renewable energy sources can achieve important benefits in the areas of environment, development, security, and employment.

a) Avoiding greenhouse-gas emissions

184. Meeting a larger share of energy demand with renewable energy sources would have beneficial effects on a key contemporary environmental problem: global climate change. Greenhouse-gas emissions-reduction targets could be met if renewable energy was employed extensively.

185. In the following analysis, published estimates of carbon-equivalents (C_{eq}), which allow for the inclusion of greenhouse gases other than the carbon that result from the combustion of fossil fuels, have been utilized. Fuel-cycle emissions associated with the mining, processing, transporting and burning of fossil fuels are included. The known effects of methane (CH_4) and tropospheric ozone (O_3) from methane oxidation are also included.[73]

186. Figure 1 shows percentage changes in carbon-equivalent emissions between the years 1985 and 2020 resulting from two levels of energy demand (WEC:M and ESW) and three levels of renewable energy supply. Both the WEC:M and ESW scenarios assume that renewable energy supply increases between 1985 and 2020. Neither of the scenarios, however, assume increases as large as the 2000 and 2020 accessible potentials identified in Tables 6 and 8. The original WEC:M scenario for 2020 would result in an emissions increase of 68 percent compared to 1985 emissions. The original ESW scenario for 2020 would reduce emissions by ten percent. If the renewable energy supply potential presented in Table 6 for the year 2000 were utilized, emissions would increase by 35 percent in the WEC:M scenario and be reduced by 41 percent in the ESW

---

[70] *Op. cit.* ref. 18.

[71] *Op. cit.* ref. 21.

[72] Goldemberg, J., Johansson, T.B., Reddy, A.K.N., and Williams, R.H., "An End-use Oriented Global Energy Strategy," *Annual Review of Energy*, 10:613-688, 1985.

[73] Wilson, D., "Quantifying and Comparing Fuel-Cycle Greenhouse Gas Emissions from Coal, Oil and Natural Gas Consumption," *Energy Policy*, vol. 18, no. 6, July/August 1990, pp. 550-562.

Figure 1

Global Change in Greenhouse-gas Emissions

Year 2020

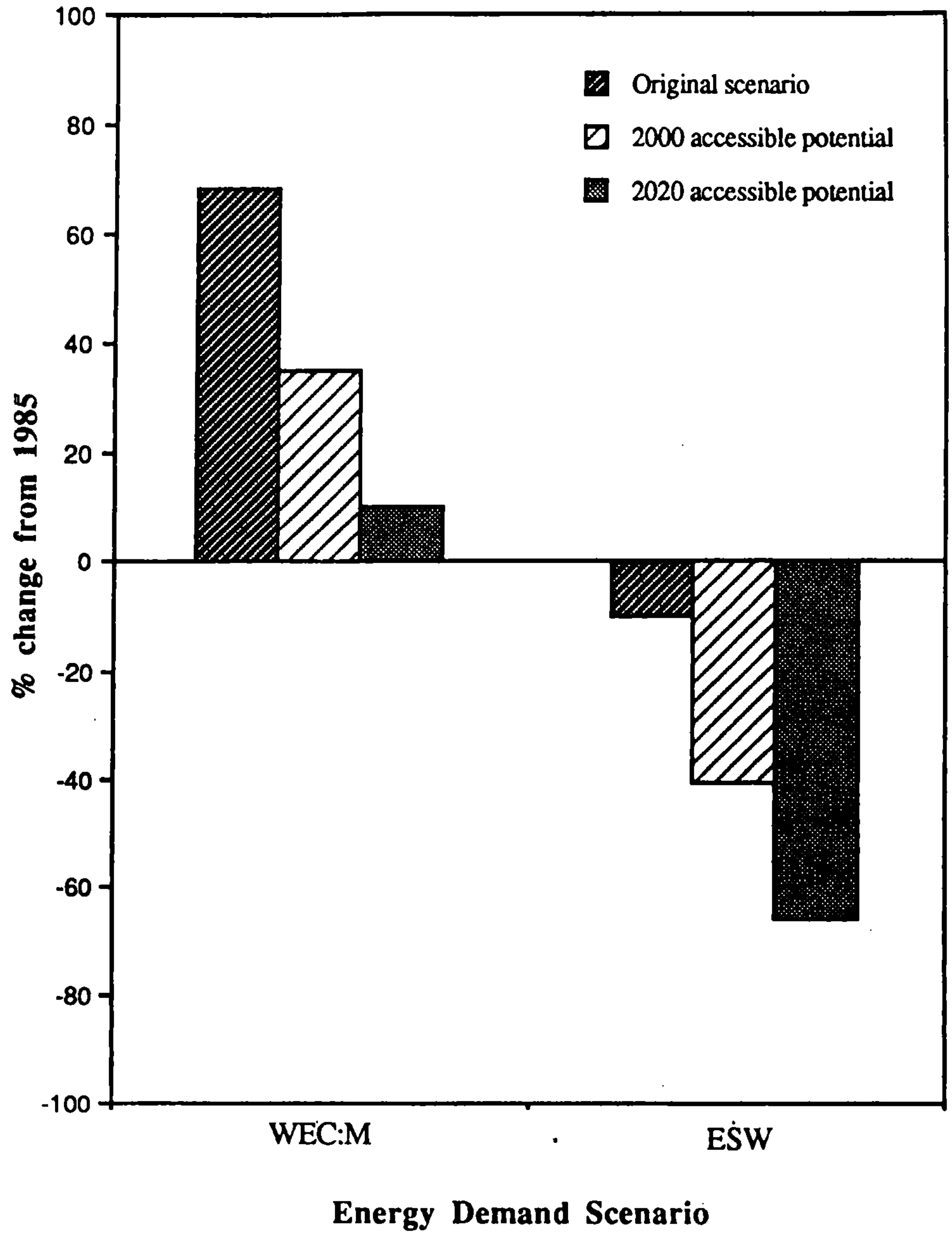

Figure 1 Notes: Original scenario refers emissions calculated using primary fuel consumption data as reported in the original WEC and ESW scenarios for 2020. The 2000 and 2020 accessible potentials refer to the total renewable energy supply potentials presented in Tables 6 and 8, respectively, applied to the original WEC and ESW scenarios for 2020. The accessible supply potentials are applied toward reducing coal, oil, and natural gas consumption in each scenario using the weighted average of each of the fossil fuel's contribution to 1985 world energy consumption as reported by WEC. Emissions factors: coal 30.6g C_{eq}/MJ; oil 24.6g C_{eq}/MJ; natural gas 17.2g C_{eq}/MJ. A 20 year time horizon is assumed in calculating the radiative forcing of the given gases.

scenario. Applying the economic potential in Table 8 for the year 2020 would lead the carbon-equivalent emissions in the ESW scenario to be 66 percent less than those in 1985, approximating the 60 percent emissions reduction identified by the Intergovernmental Panel on Climate Change (IPCC) as necessary for stabilizing atmospheric concentrations of CO_2. This higher level of renewable energy supply would not, however, enable attainment of atmospheric CO_2-concentration stabilization if energy demand were to grow as depicted in the WEC:M scenario: 2020 carbon-equivalent emissions would be 10 percent greater than they were in 1985.

187. The comparative costs of these scenarios have not been analyzed in depth. However, given that the cost of avoiding energy demand with efficiency investments in the ESW scenario is lower than the competing costs of supplying that demand, the total economic cost with the given level of renewable energy utilization would be lower for the ESW scenario which would achieve a 66 percent reduction of carbon-equivalent emissions than the cost of the WEC:M scenario that would result in a 10 percent increase in emissions.

188. Various case studies of emissions and economic impacts for industrialized and developing countries show the no-regrets aspect of using renewable energy sources in combination with high end-use efficiencies. The *Second World Climate Conference* concluded that even for the very near term, "technically feasible and cost-effective opportunities exist to reduce CO_2 emissions in all countries. Such opportunities...are sufficient to allow many industrialized countries to stabilize CO_2 emissions from the energy sector and to reduce these emissions by at least 20 percent by 2005... As additional measures to achieve further cost-effective reductions are identified and implemented, even greater decreases in emissions would be achieved in the following decades."[74]

b) Development and employment generation

189. Expanding the use of renewable energy sources in rural areas of developing countries can enhance the development process more rapidly and at a lower cost than non-renewable sources. The following are three illustrative examples:

- Implementation of small-scale (e.g., village-scale) power systems can make domestic, agro-industrial and other energy services available far sooner than would be the case if electricity from large central-station plants were to be transmitted over long distances.

- Other amenities (e.g., hot water) can be made more widely available faster with renewable approaches (solar domestic hot water systems) than with fossil-fuel-based systems (e.g., natural-gas pipelines and associated end-use heating systems).

- Solar driers for crops can help avoid post-harvest losses common to traditional open-air natural drying practices.

190. The construction, operation and maintenance of renewable energy systems can provide sizeable employment opportunities, especially in the rural context. Moreover, renewable-energy supply technologies are inherently more effective at generating employment than fossil-fuel-based supply technologies because operations and maintenance represent a larger fraction of their total costs. Opportunities for domestic manufacturing of the components of renewable energy systems bring double benefits of (a) increased employment and (b) reduced foreign debt.

191. The case of the Brazilian ethanol fuels program provides an example of the employment-generation benefits of renewable energy systems. In Brazil, ethanol production today provides approximately 700,000 jobs.[75] Most other economic activities in Brazil require larger investments per job created, the average being at least twice the cost per job created in the ethanol agro-industry. Costs per job created in the

---

[74] *Op. cit.* ref. 32.

[75] *Op. cit.* ref. 44.

petrochemical industry have been up to 20 times higher. The average wage earned by sugar-cane laborers in São Paulo is higher than that of 80 percent of those working in other agricultural sectors, cattle raising, forestry, and fishing. In addition, the ethanol-production industry has a relatively low index of seasonal work.

c) Supply security and foreign debt reduction

192. Reducing fossil-fuel consumption lessens energy supply vulnerability for oil-importing countries. Shifting toward domestic renewable energy investments can improve the balance of payments for both energy-importing and energy-exporting (by increasing fuel stocks available for export) countries. Shifting toward domestic fuels offers the opportunity to diminish foreign debts owed by many developing countries.

V. Conclusions

193. If the world energy system were to develop in a direction where an increasing fraction of energy supply came from renewable energy sources, the energy-related problems associated with environment, development, and security would be considerably reduced. To make this possible within the next several decades, the energy system must also become increasingly more energy efficient. However, the potential of economically-efficient measures is not large enough for this strategy to be sufficient. A combination of energy efficiency and renewable energy sources is required. Energy services will be significantly less costly in an energy system based on comparable investments in end-use efficiency and renewable supply than if only renewable energy is considered.

194. The contribution of renewable energy sources to global energy supply will primarily be a function of the degree of political commitment to renewable energy systems, both in creating fair market conditions and in supporting technology research, development, demonstration and deployment.

5. An Agenda for Renewable Energy Sources in the 1990s and Beyond

I. Introduction

195. The environment, development, and security problems associated with the current energy-supply system are global in nature. Strong action is needed within industrialized and developing countries, and internationally, to bring about a transition to an energy system compatible with a sustainable future. Such an energy system must be based on the efficient utilization of energy, especially at the point of end-use, and the utilization of renewable energy sources.[76] Actions conducive to a transition to an energy system based on renewable energy supply should include policy changes that address six key areas: policy and planning; financing and funding; technology research and development; technology transfer, adaptation, and deployment; capacity building; and institutional arrangements at both the national and international levels. These key areas are discussed in the following sections, with emphasis on recommendations for action.

II. Policy and Planning

196. In order to bring about a transition to an energy system based on renewable energy sources, activities should be promoted through large, coordinated, national programs, within the framework of energy strategies compatible with sustainable development, and not as scattered projects. For this purpose, it will be necessary to establish, enlarge, or strengthen national institutions responsible for developing, implementing, and coordinating these programs, set in the context of overall national energy policy. The national programs

[76] The World Commission on Environment and Development, "Our Common Future," Oxford University Press, Oxford, 1987; Goldemberg *et. al.*, *Op. cit.* ref. 17.

should be the major vehicle for developing cooperation in the field of renewable energy sources providing a much more efficient way of channelling the flow of, *inter alia*, new and additional financial resources, in particular to developing countries, and for bringing about cooperation regarding technology development and transfer.

197. A minimum level of market infrastructure and renewable-energy activities — in the form of sales, service and maintenance support — is necessary in order to establish and maintain renewable-energy systems. Similarly, it is important to be able to take advantage of organizational learning and economies of scale in production to reduce the costs of renewable-energy technologies.

198. In the near term, therefore, transitional policies will be needed to break the momentum behind conventional energy systems that has been gained through decades of preferential treatment in the energy market. Temporary investment subsidies linked to, for example, reducing environmental impacts may be called for in order to bring new technologies, that promise exceptional performance from environmental, developmental, and/or security points of view, onto the learning curve.

199. Permanent policies for ensuring a global energy system that is compatible with sustainable development must establish a level playing field on which all potential supply and demand options compete and are judged on their economic merits alone, free from all kinds of direct and indirect subsidies. In doing this, it is important to incorporate the full costs, including environmental, developmental, and security aspects, as well as traditional economic criteria in evaluations of investment opportunities.

200. A number of policy tools are available to, and being used by, governments for affecting energy supply. In one example, legislation is used to keep kerosene prices low so that low-income households can afford to use kerosene for lighting purposes. Additional legislation keeps diesel prices low in order to prevent the use of cheap kerosene in trucks. This has resulted in a remarkable switch from rail to road freight transport.[77] Other more direct subsidies for conventional fuels provide favorable conditions for oil and gas exploration and insurance of drilling sites, advance surcharges on electricity to secure interest-free funds for utility investments, etc. Legislation can also promote the use of renewable energy sources. In some jurisdictions, utilities are required to pay small power producers for electricity supplied to the grid on an avoided-cost basis. Such policies supported an expansion of wind and biomass power production during the 1980s.

201. Much of the current use of policy tools in the energy sector steers markets along the conventional supply path and forms market barriers to renewable energy sources. The same tools can be used to discourage energy practices that degrade the environment while promoting those that are environmentally benign and facilitate development.

202. In order to use these tools effectively, governments will have to assess the effects of existing legislation on the energy sector and make changes where necessary. New, innovative legislative measures may also be needed.

a) Legislative measures

203. Legislative measures, aimed at providing equal opportunity for competition within societally-acceptable bounds, will promote the use of environmentally-benign and secure energy systems that capitalize on development opportunities (as do many renewable energy systems).

204. For competition in the market arena to be unbiased, direct and indirect subsidies for conventional energy systems must be removed. Taxes and fees can be used to internalize the environmental impacts

[77] Reddy, A.K.N., "Energy Strategies for a Sustainable Development in India," in Meyer, N.I. and Nielsen, P.S. (eds), *Conference Proceedings: Global Collaboration on a Sustainable Energy Development*, Technical University of Denmark, April 1991.

associated with the use of specific energy sources and technologies in their market prices. Performance standards for both energy conversion and end-use technologies can be used to avoid negative impacts that are not easily monetized. Legislation such as utility regulatory policy acts can be used to ensure open access to the energy supply market, and non-discriminatory pricing systems can ensure equal access for private suppliers to transmission and distribution infrastructure (such as electricity grids).

205. Regulatory measures that oblige the use of renewable-energy technologies such as solar water heaters or photovoltaics in certain applications/situations should be considered.

206. National legislation will increasingly be influenced by the regional and/or global environmental concerns addressed in international agreements and conventions. A global climate convention could, for example, have a large influence on energy-related national legislation in many of the countries ratifying it.

b) Full costing of environmental impacts

207. In most countries, energy policy and planning are almost entirely based on narrow definitions of costs. Only direct monetary costs and benefits are considered, while resource depletion and social and environmental impacts are generally excluded. This type of approach inherently favors energy sources and systems such as fossil fuels, nuclear power and unsustainable use of biomass which have large external environmental, social and resource depletion costs.

208. The first necessary step toward promoting renewable energy sources is to establish policies that ensure that social and environmental costs and benefits are internalized by the market, thus reflecting the true total costs in economic comparisons of different energy options. Doing this is in line with the polluter-pays principle.

209. Progress has been made in the development of methodologies for incorporating environmental costs and benefits in energy prices, and reflecting them in policy and planning. There is an urgent need to continue this work and to harmonize methods at the international level, taking individual countries' resources and traditions into account.

c) Support of policy planning

210. The actions taken within nations must be seen in their international context in order to meet the global goals of protecting the environment, achieving continued economic development, and maintaining world peace. It is important, therefore, that individual nations collaborate in international forums designed to achieve those goals. Part of that collaboration should include participating in an ongoing dialogue regarding renewable-energy policy and experiences. To support such a dialogue, individual nations should report on their domestic policies and national programs of action for promoting the development and utilization of renewable energy sources to the international community.

211. International cooperation is essential to a uniform approach to energy pricing, in order to ensure that national industrial competitiveness is not used as an excuse for delaying action and that energy-intensive industries do not relocate to countries with less-restrictive legislation.

d) Utility planning

212. The role of utilities should expand from being traditional energy suppliers to also being purchasers of energy based on renewable resources from small producers. Achieving this may require regulatory action and a reorganization of the utility industry. Planning methods should be developed with the objective of optimizing electricity production, distribution, and end use, as is already done by some utilities. The role of demand-side management, in particular, is increasingly important. Diffusion of these methods would favor dispersed electricity generation, while decreasing the total cost of energy services.

213. Certain technologies for utilizing renewable energy sources, especially photovoltaic power production, are sufficiently mature that they pose little risk to utilities and other investors. They should, therefore, be

evaluated at a lower discount rate than is accorded conventional thermal power plants for which future operating (fuel) costs are uncertain. Because the levelized energy cost is very sensitive to discount rates, current practices penalize capital-intensive technologies, such as photovoltaics, unnecessarily.

214. The use of renewable energy sources, such as biomass in the agricultural sectors, can be improved by using organizational mechanisms such as cooperatives and third party investors.

III. Financing and Funding

a) Transitional subsidies

215. In all countries, government funds can be allocated in the form of special credit facilities for industrial development or transitional subsidies to specific types of renewable-energy systems. The level of subsidy depends on the relative costs of energy alternatives and the level of political will devoted to promoting renewable energy sources. These subsidies could gradually be reduced as production costs decrease. One successful example of such a scheme is the Danish Government's support of the windmill industry through subsidies to windmill buyers. Initially, the Government subsidized 30 percent of the investment. The subsidy was gradually reduced and eventually removed as new windmill investments became cost effective.[78]

b) Capital availability

216. It is critical that the share of energy-sector investments devoted to utilizing renewable energy sources increases in all countries. Without such a shift in investment shares, the contribution of renewable energy sources to total energy supply cannot be expected to increase.

217. When addressing the question of financing energy systems, it is necessary to differentiate between the situations in developing and industrialized countries. In addition, it is important in the developing-country context to consider the different requirements for large-scale centralized supply and decentralized rural development needs.

218. In industrialized countries, appropriate use of the measures discussed above would, ideally, lead to a situation where decision makers would increasingly invest in technologies that utilize renewable energy sources based on straight-forward assessments.

219. The share of World Bank energy-related loans that go toward renewable energy sources in developing countries is only ten to 15 percent, excluding large-scale hydro, of a total annual energy expenditure of 2.5 to 4 billion dollars, and 40 to 50 percent if large-scale hydro is included.[79] This level of support can be compared with the World Bank estimate that the investment needs in developing countries in the electricity sector alone amounts to some 100 billion dollars per year during the 1990s.[80] This situation restricts renewable-energy-system development, and implementation. The high initial-investment costs associated with many renewable-energy technologies compared to fossil-fuel based systems (even in cases where total costs are low) particularly restricts broad deployment of renewable-energy systems.

220. In all countries, but in particular in the developing ones, the availability, cost and distribution of capital

---

[78] Danish Ministry of Energy, "Energy 2000: A Plan of Action for Sustainable Development," Danish Energy Agency, Copenhagen, Denmark, April 1990.

[79] The Nordic UN Project, "Towards sustainable energy development: The energy activities of the UN system and the development banks," report no. 1:1989.

[80] Moore, Edwin A. and Smith, George, "Capital Expenditures of Electric Power in the Developing Countries," The World Bank Industry and Energy Department, February 1990.

are important factors determining investments in renewable energy sources. In addition to existing allocations, new and additional financial resources should be made available to finance investments in renewable-energy technologies and programs. The share of World Bank energy-related loans that are allocated to the utilization of renewable energy sources (other than large-scale hydropower) should increase, initially to at least 20 percent.

221. For rural applications the situation is different, because decentralized uses of renewable energy sources coupled with end-use efficiency may require smaller investments than extending the central supply infrastructure. Local small-scale credit facilities, available to households and local organizations, can be crucial in such cases. A study from the Dominican Republic, for example, concluded that almost 20 percent of the rural households without access to electricity could afford a domestic photovoltaic system if small-scale loans at reasonable interest rates were made available.[81]

c) International funding agencies

222. Agencies participating in multinational and bilateral development cooperation should coordinate their activities under the guidance of the governments of countries where cooperation is taking place.

223. In order to strengthen the role of renewable energy sources in multilateral and bilateral development cooperation, there should be a shift from projects to coordinated national programs that are an integral part of social and economic development.

224. Experience from the implementation of the Nairobi Plan of Action has demonstrated that the existing international financing systems, in their present form and level of activity, are inadequate for promoting the increased utilization of renewable energy sources. Existing funds and mechanisms should be improved and strengthened. The Energy Sector Management Assistance Program (ESMAP), established by UNDP and the World Bank, should support the development of national energy strategies defining an increased role for renewable energy sources and the preparation of national programs of action on renewable energy sources. A revised Global Environment Facility (GEF), established jointly by UNDP, UNEP and the World Bank, should, *inter alia*, make special allocations for financing national programs on renewable energy, in particular in the development countries. The future role of the UN Trust Fund for New and Renewable Sources of Energy should be reviewed with a view to integrating it with other financing mechanisms.

225. New mechanisms should be considered in order to make renewable energy a major feature of the new energy agenda. The funding mechanism of a global convention on climate change could play a major role in financing the implementation of national programs of action on renewable energy, in particular in the developing countries. The strong international institutional arrangement needed for promoting renewable energy sources (see paragraph 268) should be the framework for providing policy guidance to relevant funding mechanisms regarding renewable energy.

226. One option for providing the necessary funds for renewable-energy activities, on either the national or international level, is to impose environmental impact taxes (such as carbon/energy taxes) on energy sources, such as those being discussed within the European Community and in several european countries. Such taxes will be especially interesting if the revenues that they generate can be earmarked for investments in the renewable-energy sector.

IV. Research and Development

227. Many cost-effective renewable-energy technologies exist today and only need appropriate market conditions and removal of barriers in order to penetrate energy markets. But large untapped potentials exist

---

[81] Lovejoy, D., "Electrification of Rural Areas by Solar PV," United Nations Department of Technical Cooperation for Development, September 1991.

for harnessing all renewable energy forms, and much could be gained in terms of economics, availability, reliability and applicability of renewable-energy technologies by increasing scientific and technological research and development efforts. This is clearly illustrated in the White paper on renewable energy sources from five national laboratories in the United States[82] and in the state-of-the-art review, "Fuels and Electricity from Renewable Sources of Energy," prepared for the UNSEGED.[83] In the US White paper it is estimated that a two to three-fold increase in funding would enable the US to cost-effectively raise the contribution of renewable energy sources from the present four percent to about 50 percent of present total energy demand.

228. The areas with greatest potential for improvements are those which are innovative, such as photovoltaics and the sustainable utilization of biomass. Efforts in these areas should include basic and applied scientific research and the adaptation of existing renewable-energy technologies for applications in new and varied contexts.

229. The International Energy Agency (IEA) countries' energy research and development budgets described in Chapter 2 (Table 3) illustrate the low level of effort devoted to renewable-energy R&D in industrialized countries. They also indicate that renewable-energy R&D could be adequately funded by shifting priorities for existing energy RD&D financial resources. A shift in funding priorities should be extensive enough to increase public funding of renewable energy sources by at least a factor of three, on average, within five years.

230. It is important to advance the research and development efforts on renewable energy sources in developing countries, to facilitate self-reliant development, and to orient the work to take national and regional considerations regarding natural resources and cultural conditions into account.

V. Technology Transfer, Adaptation and Deployment

231. Transfer of both knowledge and technology, in the form of capabilities for producing and deploying components and whole systems, is essential for successfully utilizing renewable-energy resources on the global level.

232. Making technologies available is an essential component of the development process. The resources needed for acquiring and applying new technologies, both in terms of funds and skills, are inadequate. There is a great need for transferring knowledge and technology from industrialized to developing countries on favorable and concessional terms. This process poses much greater challenges than exchange among industrialized countries.

233. Adaptation to local conditions is necessary, although not always sufficient, for successful technology transfer to developing countries. Experience, gained primarily from aid-based transfer activities in the last two to three decades, clearly indicates that technology transfer usually fails when a process of adapting technologies to specific conditions in the recipient country is not undertaken. The many deserted or non-operational industrial and energy plants are evidence of ambitious attempts to introduce new technologies into societies without taking into account local conditions, such as lack of resources or skills to secure maintenance, inadequate supply of raw materials, fuel and spare parts etc. In many cases, lack of genuine cooperation objectives and inadequate institutional arrangements in both donor and recipient countries has led to failure of so-called demonstration projects. It is also important to distinguish between the completely different problems faced when dealing with centralized and with rural applications.

234. Ability to assess the specific requirements of a given technology and the ability to meet them is of primary importance in developing countries. Therefore, international institutions in general, and the United

[82] *Op. cit.* ref. 52.

[83] *Op. cit.* ref. 2.

Nations system in particular, should provide support for establishing endogenous expertise in evaluating new technology applications in specific local and regional contexts to countries receiving technologies, and, in general, carry out technology assessment in the energy area.

235. The transfer of technologies that utilize renewable energy sources is not qualitatively different from that of other energy technologies. The main practical difference is that most renewable-energy technologies are new and rapidly developing in comparison to well-established conventional technologies. A special effort is needed, therefore, to ensure that renewable-energy technologies are made available in developing countries together with the knowledge necessary for developing endogenous production, operation and maintenance.

236. Present international funding structures favor the transfer of knowledge and technologies from the North to the South. Several of the developing countries, such as India, China and Brazil, have developed expertise and technologies which may be more easily applicable in other developing countries than systems from industrialized countries. It would be very valuable, therefore, to promote direct South -- South transfer of renewable-energy systems.

VI. Capacity Building

237. Capacity building includes training, education and awareness building. These are crucial components in creating sustainable societies.

238. As a basis for broader action toward promoting the utilization of renewable energy sources it is necessary to generate both public and political awareness of energy-environment issues, and scientific and technical knowledge as a basis for development, planning and implementation of renewable-energy systems.

239. Governments should build on existing educational systems and training institutions, focusing especially on including renewable-energy and other energy-environment issues at all education levels, and generating awareness among energy consumers through:

- extension programs involving local non-governmental organizations in local planning through information training and support for instance in the form of local energy offices,
- demonstration projects based on local interest and carried out in collaboration between local organizations and academic and government institutions.

240. A global network of internationally-supported Centers of Excellence on New and Renewable Energy Sources should be established, along the lines described in the Castel Gandolfo Colloquium.[84] These Centers should be responsible for research and development as well as technical training programs for technicians, planners and representatives of non-governmental organizations (NGO). These Centers should work in close collaboration with national or regional development centers, and national authorities. They could also provide a forum for information exchange and function as a focal point for inter-regional cooperation in their fields of competence. Most of the Centers should be located in developing countries. Their activities should include:

- assessment of locally-available accessible renewable-energy supply potential,
- project planning and economic analysis methods,
- applied research into applications and adaptation of specific renewable-energy technologies,
- environmental impact assessment and costing, and
- collaborative research for development of renewable-energy systems.

---

[84] "Note by the Secretary-General: Colloquium of High-level Experts on New and Renewable Sources of Energy," United Nations, General Assembly, Committee on the Development and Utilization of New and Renewable Sources of Energy, fourth session, 1988 (doc. A/AC.218/14).

241. Training and education activities cannot be seen in isolation from the actions we recommend, in particular with respect to those related to technology transfer, adaptation and deployment. Utility engineers and technicians may lack the knowledge required to install and operate renewable-energy systems. Increased efforts in the area of training and education are, therefore, crucial both for creating awareness and for ensuring successful implementation of renewable-energy technologies. Many of the actions recommended above aim at strengthening the capacity for decentralized applications. It is equally important to ensure that planners and policy makers are aware of the physical and technical potentials of the different renewable-energy technologies for large-scale centralized applications, and of the environmental costs associated with conventional energy systems.

242. Government collaboration with non-governmental organizations is of increasing importance in the energy field and has shown great promise, both in the areas of training and of transfer and adaptation of renewable-energy technologies. Collaboration at this level should be increased.

VII. Institutional Arrangements

243. The action areas discussed in the previous sections and chapters of this report indicate that promoting renewable energy sources effects not only energy policy and environmental policy but also agricultural, transport, industry, and research policy, and policies regarding housing and regional development. Strong institutional mechanisms are therefore needed, both on the national and international levels, to assure the necessary integration of renewable-energy concerns in relevant policy fields and to coordinate the work that is already ongoing in several institutions. Such mechanisms should play a visible and powerful role in the overall policy-formulating process.

244. <u>At the national level</u>, institutions must be arranged with the aim of strengthening the role of renewable energy sources, and given the mandate to promote the utilization of renewable energy sources through: formulating integrated energy policies and programs; carrying out education, training and information programs; coordinating relevant policies and programs; and directing research, development and demonstration programs. The following are examples of areas to consider in this context, in addition to areas discussed in earlier sections of the report.

245. One lesson to be learned from the implementation of the NPA is that it is important to formulate targets. To establish targets for contributions of the different renewable energy sources to energy supply, commensurate with the time frames of technical and economical feasibility discussed, is essential. Such targets should be derived from environmental (e.g., CO_2 and other emissions reductions) as well as social and developmental objectives. Such targets should be introduced as soon as possible.

246. One example of formulating targets is given in the São Paulo Declaration,[85] with respect to rural electrification. The aim of this Declaration is to help meet the basic needs of two billion rural poor by installing one million basic photovoltaic systems by 1995, thereby reaching one percent of the world's rural poor, and expanding the program to reach ten percent of the rural poor by the end of the century.

247. To enhance the dialogue within the international community on the utilization of renewable energy sources, each country should report annually on its policies and national program of action for promoting renewable energy sources, and progress on their implementation, to the international community.

248. There is a need to establish and implement procedures for recording statistical data on applications of renewable energy sources in each country in a harmonized form, to facilitate the use of such data at the international level.

---

[85] International Workshop on Mass Production of Photovoltaics: Commercialization and Policy Options, "São Paulo Declaration 1991," United Nations Centre for Science and Technology for Development, September 1991.

249. At the international level, arrangements must be made, in close collaboration with existing international and national institutions and non-governmental organizations, to strengthen international cooperation for promoting the utilization of renewable energy sources. Such arrangements should, *inter alia*, stimulate renewable-energy-technology RD&D, intensify broad dissemination and application of available renewable-energy technologies, and provide for information exchange and manpower training for the production and use of such technologies.

250. Policy planning needs to be promoted and supported, *inter alia*, by organizing annual dialogues with individual nations, based on national renewable-energy policy and program of action reports (see paragraph 206). Such annual dialogues have proven valuable in the economic sector.

251. An international body should gather statistics from individual countries on, and perform ongoing evaluations of, renewable-energy applications.

252. Studies on new technological developments, techniques and strategies for identifying, and evaluating the future role of renewable energy sources in global energy supply need to be prepared and disseminated.

253. Energy issues are integral to most other societal activities. This implies a need to coordinate international activities aimed at utilizing renewable energy sources.

254. There is a need to coordinate the exchange of information and experience on research, development and applications of renewable-energy technologies.

255. A body should provide policy guidance to relevant funding mechanisms, in the form of criteria for selecting projects and guidelines for formulating and implementing projects, and regularly review their activities aimed at utilizing renewable energy sources.

256. The international community has responded to energy-sector challenges in several ways. Presently existing institutional arrangements are focussed on energy supply. Within the United Nations system, efforts are directed at nuclear, oil, natural gas, coal, and large-scale hydropower. Secretariat functions for addressing energy issues are assigned to various units within the United Nations system.[86]

(a) The Directorate-General for Development and International Economic Cooperation (DIEC) is responsible for all matters related to the Economic and Social Council of the United Nations. It is the highest United Nations secretariat body for energy matters, although there is no special section for energy. DIEC has a total staff of only a dozen people. After the Nairobi Conference, a position as Special Coordinator, New and Renewable Sources of Energy was created within the DIEC. The Special Coordinator, however, has been given no support staff within the DIEC. He chairs the interagency group on NRSE and manages the United Nations Trust Fund for New and Renewable Sources of Energy.

(b) The Department of International Economic and Social Affairs (DIESA) provides information and analysis. The Energy Branch follows the energy markets, conducts special studies, and services, with DTCD (see below) and DIEC, the UN Committee on Natural Resources and the UN Committee on Development and Utilization of New and Renewable Sources of Energy.

(c) Other energy-related work is carried out by several UN units. The Department of Technical Cooperation for Development (DTCD) has an energy section in the "Natural Resources and Energy Division." It services the Committee on Natural Resources. The International Atomic Energy Agency (IAEA) is in charge of a single energy source: nuclear energy. The Centre for Science and Technology for Development (CSTD) was established to follow up the Vienna Program of Action for Science and Technology for Development. The UN Regional Commissions have energy activities of varying intensity. The UN Agencies (FAO, UNDP (which, *inter alia*, has operated the Energy Sector Management and

[86] *Op. cit.* ref. 67.

Assistance Programme (ESMAP) together with the World Bank), ILO, UNEP, UNIDO, UNITAR, and others) have energy programs in line with their mandates and constituencies.

257. Outside the UN system, important energy activities are carried out by regional organizations such as OLADE, the regional energy organization for Latin America, and the International Energy Agency (IEA), a cooperative body for most of the industrialized countries. The World Energy Council (WEC) is an important forum for the energy industries. Renewable energy sources, except for large-scale hydropower, receive limited attention in these organizations.

258. Renewable energy sources have not been given priority within the international institutional structure, although most of the functions needed have been assigned to some institution. The weak and scattered position of renewable energy sources in the present structure of international institutions is one of the reasons why more was not achieved in this area during the 1980s. This is not in line with what would be required in order to make use of the opportunities in this area to support environmental, development and security goals.

259. **We conclude that** a strengthened international institutional structure is required.

260. There are several options to consider with the aim of strengthening the international institutional structure for promoting the utilization of renewable energy sources.

261. One option is to strengthen the existing intergovernmental mechanism of the Committee on the Development and Utilization of New and Renewable Sources of Energy through, *inter alia*: a review of its mandate; regular support by a group of intergovernmental experts for better preparation of the committee meetings (including, *inter alia*, evaluation and analysis of renewable-energy technologies, areas for detailed discussion and other relevant subjects); and strong political support from governments by ensuring high-level participation in the committee meetings.

262. In this regard, the present staff and facilities of the secretariat supporting the committee should be strengthened accordingly. The creation of a special department for renewable energy sources, located inside an existing organization, could also be considered.

263. Another option is to establish a new intergovernmental arrangement, with secretariat support being provided by a new institutional body. This arrangement may take the form of an open-ended intergovernmental committee with a new and enlarged mandate with regard to renewable energy sources, within the purview of the United Nations or established as an independent body with a United Nations mandate.

264. Accordingly, the new institutional body may be either a new United Nations agency or an independent international agency.

265. The experience in the decade after the NPA indicates that more restricted changes, such as those discussed in paragraphs 262 and 264, are not likely to be sufficient to create the dynamics that are needed for the present, new situation. A department in an existing organization would be possible, if there were a suitable host. This is not the case, because already-existing institutions have clear mandates that are not easily adapted to the new tasks to be performed. In addition, the existing structures within present organizations are not conducive to carrying out new tasks with the vigor that is now called for.

266. A new institutional structure for renewable energy sources may be considered as part of a larger institutional framework for the broader task of supporting, in an integrated manner, the transition to environmentally-safe and sound energy systems compatible with sustainable development. Such energy systems must increasingly be based on the use of renewable energy sources and on improved energy efficiency in energy end-use and supply. Such broader solutions must be considered, *inter alia*, in connection with a convention on climate change.

267. **We recommend that** a new agency be established. Its role will be to promote renewable energy sources,

not only with respect to energy and environmental policies, but also agricultural, transport, industry, and research policy, and policies regarding housing and regional development. The specific needs described in paragraphs 251 through 256 should be met by this agency. The creation of an International Renewable Energy Agency, with sufficient political and financial support from governments to carry out its tasks, would be a strong signal that an increased role of renewable energy sources is required to deal with problems of environment, development, and security.

268. The establishment of an International Renewable Energy Agency does not imply that all activities by existing bodies should be integrated in the new Agency. In most instances, it would be efficient to continue the renewable energy work performed by existing bodies, but with a more pronounced focus and coordination. Also, more limited institutional changes in existing bodies may be appropriate, in order to strengthen their efforts to develop and utilize renewable energy sources.

Appendix A

United Nations Solar Energy Group
on Environment and Development (UNSEGED)

Members

Professor **Thomas B. Johansson**, Chairman Lund University	Sweden
Dr. **Hu Chengchun**, Vice Chairman New Energy Resources Committee The State Science and Technology Commission	China
Mr. **James J. Chitauro**, Permanent Secretary Ministry of Energy, Water Resources and Development	Zimbabwe
Mr. **J. Michael Davis**, Assistant Secretary Conservation and Renewable Energy United States Department of Energy	USA
Mr. **Edmundo De Alba A.**, Executive Coordinator National Commission of Ecology	Mexico
Mr. **Bernard Devin**, Co-rapporteur Chapter 4 Advisor to the Chairman French Agency for Energy Management (AFME)	France
Mr. **John B.S. Diphaha**, Managing Director Botswana Technology Center (BTC)	Botswana
Mr. **Ahmed Djoghlaf**, Rapporteur of the 1992 UN Conference on Environment and Development Deputy Director, Ministére des Affaires Atrangères	Algeria
Mrs. **Martha Dueñas**, Counsellor Vice Chairman, UN Committee on Development and Utilization of New and Renewable Sources of Energy Permanent Mission of Ecuador to the United Nations	Ecuador
Professor **Ugo Farinelli**, Co-rapporteur Chapter 4 Scientific Advisor to the Chairman, ENEA	Italy
Dr. **J. Gururaja**, Adviser Non-conventional Energy Sources, Ministry of Energy	India
Mr. **Ghazi Jomaa**, First Secretary Permanent Mission of Tunisia to the United Nations	Tunisia
Professor **Niels I. Meyer**, Co-rapporteur Chapter 5 Physics Laboratory III, The Technical University of Denmark	Denmark
Professor **José Roberto Moreira** Secretaria de Ciencia e Tecnologia	Brazil

Dr. **Edda Müller** — Germany
Bundesministerium fur Umwelt, Naturschutz und
Reaktorsichterheit

Mr. **Evgeny V. Nadezhdin,** Senior Specialist — USSR
USSR State Commission for Science and Techr.ology

Mr. **Eduardo Praselj,** Rapporteur Chapter 2 — Venezuela
Manager, PEQUIVEN

Professor **Jean Pierre Reveret,** Rapporteur Chapter 3 — Canada
representing the Institut International de l'Energie
des pays francophones (IEPF)

Mr. **Ulf Svensson** — Sweden
Assistant Under Secretary, Swedish Ministry
of Foreign Affairs

Mr. **Otto Zellhofer** — Austria
Austrian Federal Ministry for Science

Scientific Editor:
Ms. **Deborah Wilson**
Lund University
Sweden

Consultant on Chapter 4:
Dr. **Evan Mills**
Lund University
Sweden

UN Participants

Mr. **Ahmedou Ould Abdallah,** Special Coordinator NRSE
United Nations DIEC/ODG

Mr. **Gustavo Best**
Research and Technology Development Division, FAO

Mr. **John Christensen,** Co-rapporteur Chapter 5
UNEP Collaborating Center on Energy and Environment

Mr. **Derek Lovejoy,** Interregional Advisor
United Nations DTCD

Mr. **Shem Arungu Olende,** Chief, NRSE Section
United Nations DIESA

Mr. **Janos Pasztor**
Secretariat of UNCED

Mr. **Gérard Saunier**
Economic and Social Commission for Asia and the Pacific
United Nations

Observers

Dr. F.V.G. Bevort,
Directorate-General for Development Cooperation
Dutch Ministry of Foreign Affairs

Mr. Andrew Kerr
Greenpeace International

Dr. W. Rasch
Future Energies Forum

Dr. Hermann Scheer
Member of Parliament, Bonn, Germany