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Reports of regional preparatory meetings

Addendum

Report submitted by the

Economic Commission for Western Asia *

* The report has been reproduced as received.

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I. INTRODUCTION

1. The United Nations General Assembly at its thirty-third session decided to convene an international conference on new and renewable sources of energy in 1981[1/] with the objective of elaborating measures for concerted action designed to promote the development and utilization of new and renewable sources of energy, with a view to meeting future over-all energy requirements, especially those of the developing countries.

2. The General Assembly confined the scope of the Conference to 14 specific new and renewable sources of energy, namely, solar and geothermal energy and wind power, tidal power, wave power and thermal gradient of the sea, biomass conversion, fuel-wood, charcoal, peat, energy from draught animals, oil shale, tar sands, and hydropower. Clearly, not all the sources are new, and, equally clearly, not all the sources are renewable.

3. More specifically, the Conference should, according to the General Assembly, concentrate on the following:

(a) The analysis of the state of technology related to new and renewable sources of energy;

(b) The identification of the potential, particularly in the developing countries, for the utilization of new and renewable sources of energy;

(c) The assessment of the economic viability of the use of new and renewable sources of energy in the light of the technologies now available and those being developed;

(d) The identification of measures for promoting, particularly in the developing countries, the development of the technology required for the exploration, development, exploitation and utilization of new and renewable sources of energy, taking into account the relevant results of the United Nations Conference on Science and Technology for Development;

1/ See General Assembly resolution 33/148 of 20 December 1978.

(e) The identification of the measures necessary for the transfer to developing countries of the relevant technologies available, taking into account the results of negotiations relating to the transfer of technology in the United Nations Conference on Trade and Development (UNCTAD), the United Nations Conference on Science and Technology for Development (UNCSTD) and elsewhere;

(f) The promotion of adequate information flows regarding all aspects of new and renewable sources of energy, especially to the developing countries, taking due account of their special conditions and requirements;

(g) The question of financing the activities necessary for promoting the identification, development, exploitation and utilization of new and renewable sources of energy.

4. The Conference is expected to provide an opportunity for member States to discuss and agree on a strategy for making the transition from an era marked by a heavy dependence on energy derived from oil and gas, coal and nuclear fission to an era marked by the increased use of alternative sources of energy. The Conference must therefore be seen as being concerned with identifying the constraints that impede the greater use of those other sources of energy and with proposing measures for promoting the wider use of such alternative sources.

5. In the developing countries, commercial energy consumption is relatively low, reflecting the low level of industrialization and economic development. The consumption of commercial energy in these countries is usually concentrated in the urban sectors. In the rural areas, where the vast majority of the population live, extensive use is made of non-commercial energy such as fuel wood, agricultural wastes and animal dung, as well as human and animal power.

6. Most of the developing countries are, by and large, amply endowed with renewable sources of energy, particularly solar and biomass resources. These resources are particularly well suited to meeting the energy needs of small communities, where defused sources of energy are more suitable for

rural applications. Owing to the lack and/or high cost of commercial energy in the rural and remote areas of the developing countries, the utilization of new and renewable sources proves to be more economical than its utilization in the industrialized countries. Progress can easily be hampered by the lack of a coherent national energy plan within which the role of renewable energy can be defined, priorities among the various technologies determined, and resources assigned, especially when programmes to develop renewable energy sources begin to require important policy and budgetary commitments 2/. Thus, the United Nations Conference on New and Renewable Sources of Energy may be considered as one more attempt by the United Nations system to discuss and find a programme of action for the serious problems of development and energy facing the third world.

7. The emphasis of the Conference and the developing countries is due to the fact that oil and oil-related product imports account for as much as 60 per cent of the total value of their exports combined. This fact reflects the importance and significance of the development and application of new and renewable sources of energy as a contribution towards the partial substitution of the oil in the energy balances of the developing countries 3/.

8. In the developing countries, non-commercial energy consumption is heavily concentrated in the rural areas; most of this consumption is of firewood, charcoal, crop residues and animal dung. The supply of non-commercial energy is mostly produced by users themselves at "zero" private monetary cost as they gather fuel wood and cow dung and expand their own labour for motive power. In some countries, this practice, particularly that of gathering fuel wood, has resulted in deforestation, soil erosion and desertification, involving, for the sake of private benefit, a high social cost 4/. Many developing countries are therefore facing a "second" energy crisis, which affects particularly the rural sectors of their economies.

2/ World Bank, Energy in the Developing Countries (Washington D.C., 1980), p. 4.

3/ E. Friedman, "Financing energy in developing countries", Energy Policy, March 1976. See also the report by the UNCTAD secretariat, "Investment by developing countries in the energy sector: A preliminary analysis of long-term financing requirements" (TD/B/C.3/146).

4/ A. Makhijani, "Energy policy for rural India", Economic and Political Weekly, August 1977.

9. In the ECWA region, about 60 per cent of the population lives in rural and remote areas in scattered small communities. Practically, neither commercial energy sources nor suitable transport facilities are available to these communities, except in the form of human and animal power. Women in these communities spend most of their time collecting twigs, animal dung and agricultural waste to be used as a source of energy for household uses. In the majority of cases, these women have to walk long distances in order to secure their drinking water.

10. The lack of commercial energy sources for these communities has impeded the development of modern agricultural methods and hampered their socio-economic development. One more negative impact of this situation is reflected in an increasing rate of migration from rural and remote areas to the already over-populated urban centres.

11. All the ECWA countries have constructed or are planning to construct large power plants as essential components of their economic development; the energy for the urban sectors of the ECWA region thus is and will be, at least in the foreseeable future, provided by fossil fuel, hydro and/or nuclear centralized power systems. These large power systems, though undoubtedly essential, have failed to provide the minimum basic energy needs of the rural and remote areas, since the extension of power lines from the electric utility grids to these areas would imply investment costs too high, compared with their possible energy consumption. Similarly, the use of diesel generator sets, with the difficulty and high cost of fuel transportation and the problems of finding technical skills for the repair and maintenance of these diesel sets, will result in high costs of energy for these communities. On the other hand, the dependence of some of these communities on human and/or animal power, animal dung and agricultural waste as primary sources of energy leads to negative economic, social and environmental impacts.

12. Given these facts, and recognizing that small-scale rather than large-scale renewable energy technologies are at present in a mature state of development and are commercially available, ECWA countries, both oil and non-oil-exporting, should seriously consider the promotion and increased use of renewable energy sources available in the region such as solar energy, wind power, hydro, biomass and geothermal energy.

II. PREPARATIONS BY ECWA FOR THE UNITED NATIONS CONFERENCE ON NEW AND RENEWABLE SOURCES OF ENERGY:

13. The ECWA staff assigned for the Conference started a crash programme of visits to almost all member States, to brief key officials on the preparations for the Conference, to identify the focal points, to collect information relating to new and renewable energy activities and to assist in preparing national papers when requested.

14. ECWA commissioned four highly qualified consultants in the areas of solar, wind, biomass and geothermal energy, to prepare studies on the state of the technology, on the economic, environmental and social aspects, on ongoing programmes and prospects for these four sources of new and renewable energy, on research and on their development and utilization in the Arab world as a whole and in ECWA countries in particular.

15. In the context of the preparation, ECWA convened a regional expert group meeting from 12 to 16 January 1981, at Beirut. The meeting was attended by representatives of nine member countries, intergovernmental and United Nations organizations[5/].

16. The participants discussed in depth the four consultancy reports and the draft regional report. They modified, contributed to and adopted the final version of the ECWA regional report as the main ECWA contribution to the Conference.

17. Representatives of eight ECWA member States (Democratic Yemen, Egypt, Iraq, Jordan, Kuwait, Lebanon, the Syrian Arab Republic and the United Arab Emirates) presented summaries of their national papers.

18. A key media panel on public information was organized by ECWA on 12 and 13 January 1981, with the active participation of professionals of the mass media in the ECWA region to seek methods and means of raising public awareness of the potentialities and the increased use of non-renewable energy sources in the ECWA region.

5/ The list of participants is attached as annex I.

19. The findings of the ECWA staff assigned to the Conference during their visits to the Arab countries and ECWA member States in particular; the synthesis of the four consultancy reports on solar, wind, biomass and geothermal energy in the Arab world; the inputs from the national experiences presented to the Preparatory Expert Group Meeting; the contribution of the participants during the meeting and the recommendations adopted by the meeting are presented in the following chapters.

III. THE AVAILABILITY OF RENEWABLE ENERGY RESOURCES IN THE ECWA REGION:

20. The available data on solar, wind, biomass and geothermal energy in the Arab world in general and the ECWA region in particular, although uncertain in many respects, owing to the lack of comprehensive studies and assessments of such resources in most of the Arab countries, could serve as a first guideline for evaluating the potential of these energy resources in the region. The evaluation is based mainly on the information gathered by the ECWA consultants during their visits to the Arab countries and from the published data.

(a) Solar energy

21. An attempt has been made to evaluate the total incoming solar insolation at different sites in the Arab world, averaged over an entire year. This evaluation reveals that the Arab world lies in a region of very high insolation, which could be divided into four areas; namely: (i) areas of extremely high insolation (300-350 W/m^2)6/, including most of the interior of Mauritania, most of the southern tips of Algeria and the Libyan Arab Jamahiriya, the north-west corner of Sudan and the south-west area of Saudi Arabia; (ii) areas of very high insolation (250-300 W/m^2) including the coast of Mauritania, the south and south-east of Morocco, central Algeria, most of the interior of the Libyan Arab Jamahiriya, upper Egypt, the central and northern part of Sudan and most of the Arabian peninsula; (iii) areas of high insolation (200-250 W/m^2), including most of Morocco, northern Algeria, the coast of the Libyan Arab Jamahiriya, lower Egypt, Jordan and most of Iraq, as well as Somalia, south Sudan, Qatar and the United Arab Emirates; and (iv) areas of moderate insolation (150-200 W/m^2), including the coast of Algeria, northern Tunisia, Lebanon and the north of the Syrian Arab Republic.

22. The annual average insolation received by the Arab world is estimated to be about 250 W/m^2. Consequently, the average solar power

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6/ See annex II.

reaching the Arab world could be estimated as 3.4×10^9 MW. Thus, in one year the Arab world receives about 30×10^{15} kWh of solar energy. By comparison, the estimated value of the stored oil reserves, discovered and undiscovered, on the earth does not exceed 4.5×10^{15} kWh, of which only about 1×10^{15} kWh are proven resources, Therefore, the amount of solar energy reaching the Arab world annually is more than six times as great as the potential energy of the total estimated theoretical oil reserves of the Earth. It should be emphasized that only a minute portion of this amount of solar energy could be converted to other usable forms of energy, owing to the very low efficiency of solar energy converters, and to the large collection areas required to tap an appreciable amount of such energy. However, the potential of the utilization of such a non-depletable resource in the Arab world can never be over-emphasized.

(b) Wind energy

23. Most of the valuable wind data in the Arab countries are collected by the national meteorological services. Also, the oil companies have records of the surface wind data of some sites in OAPEC countries. Wind data recorded by both these sources have not been based on wind energy utilization requirements They are basically related to the general wind régime for the sites surrounding the observation stations. Nevertheless, some of these data are reliable long-term records, and are used to estimate the wind energy potential in some sites in the ECWA region. The analysis of the available wind data showed high annual average wind power densities in the coastal areas of the ECWA region, which is characterized by long coasts extending thousands of kilometres along the Mediterranean, the Red Sea, the Indian Ocean and the Gulfs. Data for the wind power densities averaged over an entire year for some selected sites in the ECWA region are given in table 1. It is clear from table 1 that very high average wind power densities (200-250 W/m^2) are found in Qatar, and high average wind power densities (100-200 W/m^2) are found in most of the coastal areas in the other ECWA countries.

24. Taking into account that the wind machines are relatively efficient, to the extent that they can convert up to 40 per cent of the available wind

power into useful mechanical power, it can be seen that the utilization of wind energy in the coastal areas of the ECWA countries should be seriously considered.

Table 1

WIND POWER DENSITIES IN SELECTED SITES IN THE ECWA REGION

Country	Site	Lat. N	Long. E	Effective wind speed, m/sec.	Average power density, W/m²	
					Available	Recoverable
BAHRAIN	Muharraq	26° 16′	50° 37′	6.12	141	59
EGYPT	El-Salloum	31° 32′	25° 11′	6.16	144	60
	Alexandria	31° 12′	29° 57′	5.49	102	42
	Hurghada	27° 17′	33° 46′	6.59	177	74
KUWAIT	Al-Ahmadi	29° 4′	48° 10′	6.5	170	70
LEBANON	Centre of Bekaa	33° 55′	36° 4′	4.93	75	31
QATAR	Doha	25° 17′	51° 34′	5.34	93	39
	Ras Rakan	26° 8′	51° 12′	7.26	236	98
	Halul Island	25° 40′	52° 24′	6.98	209	87
SAUDI ARABIA	Dhahran	26° 16′	50° 10′	6.49	170	70
	Ras Tanura	26° 24′	50° 5′	5.08	80	30
	Taif	21° 29′	40° 5′	5.19	87	36
	Yanbo	24° 07′	38° 03′	5.64	123	51
	Jeddah	21° 30′	39° 12′	4.86	70	29
UNITED ARAB EMIRATES	Das Island	25° 09′	52° 35′	5.6	108	45
	Jebel Dhanna	24° 11′	52° 37′	5.34	94	39
	Sharjah	25° 21′	55° 23′	5.31	92	38

(c) Biomass energy

25. Biomass energy (from fuel wood, charcoal, crop residues and animal dung) consumption is estimated to account for a little less than 10 per cent of all energy consumption in the ECWA region. This figure, like any other single indicator, conceals wide variations across the region and doubtless within the individual ECWA countries. The estimates of the biomass resource for some ECWA countries are summarized in table 2, which reveals the potential of the biomass components, namely, forest, crop residues and animal dung estimated in Giga Joules *per capita* per year. The potential of these components seems to be substantial in some ECWA countries, such as Democratic Yemen and Yemen, and very low in other countries, such as Kuwait and Saudi Arabia. The biomass use as a percentage of the *per capita* commercial energy consumption in some ECWA countries (e.g. Yemen), the biomass use is as high as 366 per cent of the commercial energy consumption. In some other ECWA countries such as Jordan, this figure comes down to 0.5 per cent. The striking feature of the information on biomass use in the ECWA region is that the lowest level of consumption is in the countries with the highest per capita GNP (Saudi Arabia, Kuwait, Iraq). Moreover, the major biomass-using countries are also the ones in which fossil fuel reserves are lowest within the region. Some ECWA countries (e.g. Egypt) having high dependence on biomass as a fuel, have at the same time very little forest, and the predominant source of biomass fuel is agricultural waste and animal dung. This in itself has a serious cost, since the use of agricultural residues and the burning of the animal dung divert them and their nutrients from the soil.

Table 2

BIOMASS RESOURCE IN SELECTED
ECWA COUNTRIES

Country	Current commercial energy GJ/cap/yr	Biomass potential		
		Forest GJ/cap/yr	Crop residues GJ/cap/yr	Animals GJ/cap/yr
Egypt	13.91	-	2.76	1.29
Iraq	21.38	1.96	1.38	4.66
Jordan	15.5	0.67	0.012	0.92
Kuwait	267.5	0.03	-	0.8
Lebanon	15.68	0.4	0.27	0.86
Oman	n.d.	-	0.06	3.0
Saudi Arabia	55.9	2.6	0.3	1.46
Syrian Arab Republic	21.88	2.72	3.27	2.43
United Arab Emirates	n.d.	0.07	-	2.68
Yemen	1.21	1.29	3.27	5.96
Democratic Yemen	9.13	21.58	0.6	2.22

Table 3

BIOMASS USE AS PERCENTAGE OF COMMERCIAL ENERGY USE IN SELECTED ECWA COUNTRIES

Country	Biomass use / Commercial energy use		GNP (rank)
	%	(Rank)	
Egypt	35	3	7
Iraq	1	5	2
Jordan	0.5	7	4
Lebanon	1.5	4	-
Saudi Arabia	0.1	8	1
Syrian Arab Republic	0.5	6	3
Yemen	420	1	5
Democratic Yemen	55	2	6

(d) Geothermal energy

26. The countries of the ECWA region are located in various geodynamic environments which potentially allow for the existence of different geothermal resources. The most common potential geothermal resources are certainly the low enthalpy (below 70°C) which may exist in the deep sedimentary basins such as the Arabian Peninsula basin; medium enthalpy geothermal resources (70°C - 150°C) exist in most of the ECWA countries (Egypt, Jordan, Lebanon, Saudi Arabia, Yemen and Democratic Yemen). High enthalpy geothermal fields (exceeding 150°C) may exist in smaller fields in Egypt, Jordan and Democratic Yemen. Other countries, such as Iraq, Lebanon, Oman and the Syrian Arab Republic are not totally excluded from high enthalpy geothermal potential, taking into consideration the recent occurrence of tertiary and quarterly volcanics and hot springs. The sizes of the geothermal fields differ, of course, from country to country.

(e) Hydro-energy

27. Hydro-energy resources can be identified in many of the ECWA countries (Egypt, Iraq, Jordan, Lebanon, Saudi Arabia and the Syrian Arab Republic). Some of these resources are utilized on large scale, (e.g. the High Dam in Egypt (2,100 MW installed capacity), the Samarra hydro-electric power plant in Iraq (84 MW installed capacity), the hydro-electric power installations on the Litani river (totalling 246 MW) in Lebanon, and the projects on the Euphrates river in the Syrian Arab Republic (Thawra plant of 800 MW installed capacity). The utilization of other hydro-energy resources is also planned in the ECWA region, for example the Qattarah depression project (expected installed capacity of 600 MW) in Egypt, the Dar Bandikhan and Haditha projects in Iraq, the Gulf of Dawhat-Salwa depression project in Saudi Arabia, and the Yousif Pacha plant (expected installed capacity of 300 MW) in the Syrian Arab Republic. However, it seems that there is no known micro-hydro power utilization in the ECWA region, although the possibilities for such micro-hydro power units (1-100 kW) do exist in many of the ECWA countries.

IV. POLICIES, ACTIVITIES AND PROGRAMMES ON RENEWABLE ENERGY IN THE ECWA REGION

28. The utilization of renewable energy resources in the ECWA region started long ago. There is evidence that the ancient Egyptians used wind energy as early as 3600 B.C. to pump water to irrigate their arid fields and to grind grain. Later on, in the twentieth century, wind energy was used in many ECWA countries for water pumping and salt work (Egypt, Kuwait, Lebanon, Saudi Arabia, the Syrian Arab Republic and Yemen). Some wind turbines are still operating in Egypt, Lebanon, Saudi Arabia and the Syrian Arab Republic. Solar energy has been used for crop drying, and biomass energy has been used as a fuel source in the rural areas of the ECWA countries for a long time. The first known solar power generation plant (of 37 kW capacity) was built near Cairo, Egypt, in 1913. Geothermal energy has been used in its very simple form in the ECWA countries, the traditional "Hammam", either with hot water or steam being found in many of them.

29. Policy planning organizations, and research and development activities on renewable energy resources were initiated in the ECWA countries in the 1950s, when the Solar Energy Unit was established in the National Research Centre of Egypt. Later on, in the late 1960s, the University of Petroleum and Minerals in Saudi Arabia started research activities in solar energy.

30. At present, most of the ECWA member countries have already established governmental comittees or councils to draw up policies in the field of energy, including new and renewable sources, and other countries are planning to establish such bodies. In fact, most of the ECWA countries either have at present ongoing programme on renewable energy, or have taken considerable steps towards the promotion of research, development, assessment and utilization activities on renewable energy resources.

31. The policies, activities and programmes of each of the ECWA countries are briefly reviewed in the following paragraphs:

A. Bahrain

32. In 1977, the Ministry of Development and Industry commissioned the Bahrain National Oil Company (BANOCO) to initiate a solar energy programme

in Bahrain. This programme is being developed now in conjunction with the Kuwait Institute for Scientific Research (KISR). The activities undertaken within this programme included the organization of two solar exhibitions in 1977 and 1978; monitoring solar global and diffuse radiation; and collecting data on the performance of a flat plate collector which was partially assembled at KISR. The budget for the Bahrain Solar Energy Programme in the fiscal year 1980 was $ 75,000.

B. Egypt

33. The Supreme Council for Energy, under the chairmanship of the Deputy Prime Minister, was established in 1980 to supervise the planning, development and utilization of energy resources, including new and renewable sources. This Council established three working groups, on "energy resources"; "energy production"; and "energy conservation and consumption".

34. The New Energy Supreme Council was established in 1977 with the function of drawing up policies and plans for the utilization of new sources of energy, namely solar, wind, geothermal and other new sources. This Council is headed by the Minister of Electricity.

35. The "Qattara Hydro and Renewable Energy Authority" was empowered to implement the hydro and renewable energy projects, under the over-all auspices of the Ministry of Electricity.

36. The Ministry of Electricity and Energy has completed some studies and projects and is undertaking a number of new ones on renewable energy resources, which are briefly described below:

(i) The United States Agency for International Development (USAID) financed in 1978 an energy assessment project for Egypt up to the year 2000. The project was carried out by the Egyptian Ministry of Electricity and the United States Department of Energy (DOE). A considerable part of the fourth volume of the five-volume assessment report, which was published in 1979, is concerned with new and renewable energy (solar, wind, biomass and geothermal).

(ii) A joint programme of study on wind energy resources in Egypt has been conducted jointly by the Egyptian Ministry of Electricity and Oklahoma State University since 1972. The project was financed by the United States National Science Foundation. Phase I and phase II of the project have been completed and the final reports were submitted in July 1975 and November 1979 respectively. Phase I was a resource availability study and Phase II was a detailed measurement and hardware programme on wind characterisitcs. Plans for phase III are being prepared in the meantime, to obtain more accurate measurements for the wind profile in the vertical direction and to establish some experimental wind system.

(iii) USAID sponsored a study on the potential of renewable energy resources and their applications in Egypt. The Mitre Corporation of the United States jointly with the Egyptian participants carried out the study and published a report on its findings in July 1980.

(iv) Egypt, in an agreement with the European Economic Community (EEC), is planning to establish a specialized organization named the Egyptian Renewable Energy Development Organization (EREDO), which will develop strategies and policies for the utilization of renewable energy resources covering the collection of information, analysis, testing and development programmes, the implementation and industrial promotion of renewable energy systems, educational programmes, and technology transfer in the fields applicable to Egyptian needs. EEC has already allocated eight million European units of account to the initial budget for EREDO.

37. The Ministry of Electricity signed agreements with the French Commissariat l'energie atomique (CEA), and the Société française d'etudes thermiques et d'energie solaire (SOFRETES). These agreements provide for the supply of:

(a) A complete heliometric laboratory, with six mobile acquisition units to map the solar energy potential all over the country;

(b) A heliothermic laboratory for the testing and evaluation of the thermal performance of solar collectors according to international standards;

(c) Equipment for night cooling experiments to gather data on the amount of heat radiated to the sky during the night;

(d) A solar energy documentation centre, including library, bibliographies, photocopying and micro film and microfiche equipment;

(e) A solar water heater of a capacity of 5000 litres of hot water per day, installed at the El-Ma'ady Military Hospital in Cairo; other heaters of capacities ranging between 120-1500 litres of hot water per day were installed at the "Wafa and Amal" city;

(f) A reverse osmosis solar desalination unit of 60 m^3 of potable water daily capacity, installed at Al-Hamrawin on the Red Sea coast;

(g) A solar refrigeration unit of five tons' storage capacity and producing about 800 kg. of ice daily will be installed at Nasser Lake, adjacent to the High Dam; this unit is equipped with a solar pump capable of delivering 100 m^3 water daily to irrigate the surrounding areas.

38. An Egyptian public company (ELMACO) of the Ministry of Electricity signed an agreement with SOFRETES for the production of solar thermal systems in Egypt. According to this agreement, the Egyptian participant will manufacture the flat plate collectors, while SOFRETES will supply the thermal loops. Another agreement signed with the French Ciodrano Company, provided for the manufacture in Egypt of domestic solar water heaters.

39. The Ministry of Electricity signed an agreement with the Ministry of Scientific Co-operation of the Federal Republic of Germany, under which the Germans will supply nine photovoltaic units of a total power of 10 kWe to operate various devices. The Germans have already supplied a number of solar water heaters of family size, which were installed in the village of Mit Abu El-Koum.

40. The National Research Centre (NRC) of Egypt included in its energy programme a number of renewable energy research projects:

(i) A solar power generation project was jointly conducted by the Solar Energy Laboratory of the NRC and the Mechanical Engineering Department of the University of Merryland (United States of America) in the period 1975-1978. The project budget totalled $ 150,000 supplied from the United States and $ 200,000 from Egypt.

(ii) A 10 kWe solar power plant started operation in 1978 in the NRC. The Government of the Federal Republic of Germany, under an agreement with the NRC, contributed DM 5 million for the equipment of the power plant and the NRC has contributed DM 6 million for facilities, salaries and preparation of the site, which extends over an area of 8000 m^2. The installation and testing of the plant is being carried out jointly by the parties to the agreement. Some modifications are being carried out on the concentrators, expanders etc., after two years of testing.

(iii) A solar cooling project is being carried out in the NRC. The Government of the Federal Republic of Germany has contributed DM 2 million for equipment design and for implementation and the NRC has contributed DM 1 million for facilities. A 1.5-ton solar cold-store is now operating and being tested in the NRC Solar Energy Laboratory.

(iv) A solar water desalination project is also being undertaken mutual co-operation between the Feberal Republic of Germany and the NRC. The contributions are DM 0.5 million from the Federal Republic and DM 0.6 million from Egypt. The design and economic evaluation is shared by both parties, but the implementation and testing is totally carried out by the Egyptians. Four greenhouse types and one dehumidifier (water from the air) were built and being tested.

(v) The International Development and Research Centre (IDRC) of Canada financed jointly with the NRC (Canadian $ 110,000 from IDRC and $ 90,000 from the NRC) the design and implementation of solar vegetable dehydration units. The design, implementation and testing is carried out completely by the Egyptian party.

(vi) The Solar Energy Laboratory of the NRC organized an International Solar Energy Symposium, held at Cairo in 1978 and sponsored by Rockefeller Foundation.

(vii) There is a group in the Solid State Physics Laboratory of the NRC working, jointly with the Laboratory of Bellevue (France), on solar cells. A photovoltaic - solar water-pumping project is being carried jointly between the Solid State Physics Laboratory and the Federal Republic of Germany.

(viii) A joint project between the NRC and the Intermediate Technology Development Group (ITDG) of the United Kingdom was started in 1977 to develop a design for a wind turbine-driven water pump. The ITDG supplied the original designs, while the NRC took the responsibility for the modification and adaptation of the original design, the supervision of the local manufacture of the first prototypes, preliminary testing and financing.

(ix) An ambitious biogas research programme at both the laboratory and pilot-scale levels is being carried out in the NRC. Different models of digesters were built and are currently being tested, using cattle manure, and it is planned to use residues and water hyacinth. The project is financed by USAID, but all the work is carried out by the Egyptians. The Egyptians have constructed different Chinese and Indian digester models, and modified the Chinese version to suit the local rural Egyptian conditions.

41. The Agricultural Research Centre of the Ministry of Agriculture in Egypt started an experimental biogas project, in which the major field experiments are carried out in the village of Moushtuhor in the Nile Delta. Different types of digesters were constructed by the farmers themselves and are now operating, and the biogas produced is utilized for heating and lighting on cow and chicken farms. At present, the experiment is being applied to household uses on the farms.

42. Various activities in new and renewable energy research and development are being carried out in universities in Egypt, e.g.:

(a) A joint project has been conducted between Cairo University and the University of Stuttgar, Federal Republic of Germany, since 1979 to develop the design of a solar power plant to be used in rural areas.

(b) Cairo University is currently undertaking a number of solar energy projects, such as the assessment of solar energy availability in Egypt, studies on multipass collectors, studies on solar energy storage, the direct conversion of solar energy into electricity, the testing of various factors affecting solar collector performance and parabolic troughs. Studies are also under way on the conversion of residues to electricity.

(c) Other Egyptian universities have already initiated research activities on solar water heating, desalination and solar dehydration.

(d) The Institute of Higher Studies of Alexandria University has recently signed an agreement with the Netherlands for the manufacture of solar silicon cells and module assembly as a first step towards the complete manufacture of solar photovoltaic plants.

(e) The American University of Cairo (AUC) initiated the first work on social aspects of solar energy utilization and has chosen Al-Basaysah as a typical small village in the Nile Delta for a preliminary investigation. Solar cells to supply television, a solar communal oven and a solar water system were introduced, to study their social impact. The AUC also started a pilot project to establish an integrated renewable energy centre, combining work on solar, wind and biomass energy, in a desert area between Cairo and Alexandria. This project is financed by USAID.

43. Four firms (Egyptian companies and joint ventrues with foreign firms) started the production of solar water heaters on a commercial scale two years ago. The production capacity of each firm is about 3000-4000 units annually. The water heaters produced are of 150-500 litres per day capacity.

C. Iraq

44. The National Committee for Energy was established in 1980 under the chairmanship of the Minister of Oil. Among the objectives of this Committee is the promotion of research and development relating to new and renewable energy sources.

45. The Solar Energy Centre (SEC) of the Scientific Research Council is the co-ordinator of applied research in the field of solar energy at the national level. The SEC is conducting and promoting research on solar energy and its applications, in collaboration with the universities and the Ministries of Agriculture, Industry, Reconstruction and Housing.

46. The SEC is working on solar thermal power conversion and solar photovoltaic cells jointly with the Universities of Baghdad, Sulaymania, and Al-Mustansiriyah. The Technological University is organizing a solar energy conference this year. There are also solar energy courses given at the M.So. level in some of the universities.

47. Plans are being prepared for the introduction of some solar energy applications, such as solar water and space heating, solar drying, solar water desalination, solar passive architecture, and the preparation of a solar energy map for the country.

D. Jordan

48. The Royal Scientific Society (RSS) of Jordan initiated the Solar Energy in 1971. Then the RSS established a Department of Solar Energy in 1975. The most important project undertaken by RSS is the Aqabah solar desalination plant, which was designed and built by the Federal Repulbic of Germany and has been in operation since October 1977. The programme of foreign economic aid of the Federal Republic contributed DM 2.3 million and the RSS contributed DM 1 million for this project. The plant is working as a multi-effect solar still. Other projects, such as those concerning single-effect solar water stills, the testing of solar collectors, space heating and cooling, are undertaken by the RSS, and the last project is jointly undertaken with the Kuwait Institute for Scientific Research (KISR).

49. One of the largest industrial applications of solar energy in Jordan is the project for the production of potassium and minerals from sea water. The evaporating area of 110 km^2 produces 1.2 million tons of potassium fertilizer, 8 million tons of salt, 30,000 tons of bromine and 50,000 tons of magnesium annually. The utilization of solar energy in this project saves the country the equivalent of 4.5 million tons of oil annually.

50. The application of solar energy in agriculture started in 1970. Solar greenhouses are increasingly used and at present cover more than 100,000 hectares. The use of solar greenhouses increased agricultural production about fivefold, saved 75 per cent of the water used for irrigation, protected the plants from insects and the negative effects of climate changes, and made possible the cultivation of different crops at different times of the year.

51. The Jordanian Telecommunication Company has developed a photovoltaic telephone system to serve remote areas and has installed 100 such systems along the highways and 30 in scattered and remote communities.

52. A joint five year co-operation programme with the KISR started by the end of 1980 for designing and constructing a solar house, suitable for the local climatic conditions in Jordan and Kuwait.

53. The RSS five-year plan includes research and studies on the assessment of the needs of Jordan in the utilization of new and renewable sources of energy, the techno-economic feasibility of solar water heater utilization in Jordan, the preparation of a design manual for solar water heaters, the development of the desalination project, the application of solar energy in space heating and cooling and power generation by photovoltaic cells, solar ponds and thermal cycles utilizing concentrators. Also, projects for water pumping using wind energy and solar energy are included in the plan.

54. There are some other Jordanian institutions interested in solar energy, such as the Faculty of Agriculture at the University of Jordan, which is involved in ground sterilization using solar energy within a study on "plastic agriculture".

55. Solar water heaters are produced in Jordan on a commercial scale by two companies, each of them producing about 30 heaters per day. The selling prices are JD 143,180 and 240 for the 120, 160 and 180-litre heaters, respectively. There are about 20 companies in the West Bank of Jordan producing water heaters.

56. A survey of the volcanic and geothermal areas of Jordan was performed by a French-Italian team in 1973. A techno-economic feasibility study for the exploration and mining of oil shale and its utilization for power generation in a plant of 300-400 MW capacity is being carried out in Jordan.

E. Kuwait

57. An Energy Committee at the national level was set up in Kuwait early in 1980. Representatives of the Ministry of Oil, the Ministry of Electricity and the Kuwait Institute for Scientific Research (KISR) are members of this Committee. Planning for a research and development programme on renewable energy is one of the objectives of this Committee.

58. In 1976, the responsibility for carrying out research and development on renewable energy was delegated to the KISR. Some of the projects undertaken by the KISR are briefly reviewed below.

> In the area of solar thermal power generation, the KISR is installing a 100 kWe system, which is manufactured mainly by MBB, of the Federal Republic of Germany. The collector field consists of 56 parabolic dish concentrators, with 6 m diameters. A thermal fluid collects heat at a nominal temperature of 350°C and is transferred to a storage tank. The tank feeds energy to an Organic Rankine engine rated at 100 kWe. The dish concentrator and the engine are of novel design. The system, which cost $ 2.8 million, will start operation in 1981.

In the area of solar cooling, an absorption air-conditioning system using an Arkla 501-WF3-ton unit with flat-plate collectors was installed in 1976 and operated for about two years.

A solar house containing many energy conservation features was built in 1980. It also has a 3-ton solar cooling unit with both hot and cold water storage. The system utilized flat-plate collectors. The solar house also has an air-heating system with solar air collectors, and a 1 kW photovoltaic system. The installation of a 40-ton solar cooling system for a kinder**garten** school was also completed in 1980. It uses a 4-10 ton unit, 350 m^2 Yazaki collectors and hot water storage only.

The present plans in solar cooling call for a comprehensive programme in this area, with strong emphasis on alternative cooling methods like the Rankine Cycle. It also calls for the development of a heat engine test facility for the evaluation and potential development of new solar cooling systems.

In the area of solar water desalination, emphasis was placed on the study of multi-stage flash (MSF) desalination system using a solar heat source. Two designs are considered; the first is an MSF unit fed from a well with brackish water, and solar heat is obtained from line focusing collectors. The MSF unit is expected to produce 10 m^3 of fresh water daily, which is roughly of an order of magnitude higher than that of the standard solar still for the same collection area. The second project utilizes the 500 kW waste heat from the 100 kWe solar power generation project to drive an MSF unit to produce 30-40 m^3 of fresh water daily. Moreover, some of the electrical output of the plant will be used to operate a small reverse osmosis unit for brackish water desalination

Work in the area of photovoltaics involves applications of solar cell technology in areas like water pumping, telecommunications and air conditioning. It also involves the testing of dust and weather effects on cell performance. There is a starting activity on amorphous silicon solar cells and in the use of dyes to shift the spectrum in a concentrated manner for improved cell efficiency.

Activity in agricultural applications has been concentrated on studying various types of greenhouses for Kuwait agriculture. Both passive and active measures are incorporated in several designs which were studied both experimentally and theoretically by developing adequate greenhouse simulation models. The most successful designs will be constructed in commercial sizes in conjunction with the 100 kWe power plant project.

A weather station which monitors temperature, wind speed and direction, relative humidity, insolation etc. has been installed in the KISR.

All solar and wind data acquisition and collection will be fully automated and computerized, starting from 1981.

An assessment of wind energy utilization in Kuwait is being conducted at present by the KISR. Plans for a combined solar photovoltaic and wind power project are being discussed.

F. Lebanon

59. The National Council for Scientific Research (CNRS) is the executive arm of the Government in research, including research in renewable energy. The energy programme of the CNRS is supporting some projects, such as the establishment of a radiometric network for the measurement of solar energy availability in Lebanon, water heating and water distillation. Photovoltaic conversion, wind energy utilization in the coastal areas and

biogas generation are under consideration by the CNRS and some universities in Beirut.

60. The Reconstruction and Development Council is the governmental organization responsible for planning, financing and following up the implementation of development projects in energy, including new and renewable energy applications and utilization.

61. The establishment of the Higher Council for Solar Energy in Lebanon is under-way. Recently, the private sector has been showing interest in the introduction of small-scale energy applications, particularly the solar heating and cooling of buildings.

G. Oman

62. In 1972, solar water heaters were installed at the Royal Air Force base at Salalah on an experimental basis. In 1977 the Princeton Energy Group (United States of America) visited Oman to study the feasibility of solar energy application in two remote villages (Dalquot and Raqyout). The Group, in its report to the Omani Government, identified water pumping, water desalination, water heating and solar power conversion as the areas in which solar energy activities were to be initiated in Oman.

63. The Petroleum Development Company of Oman financed the manufacture of a wind turbine for water pumping. The designs for the system were offered by the Intermediate Technology Development Group (ITDG) of the United Kingdom. The first prototype was completed and installed in 1980 near Muscat. Some technical troubles led to the dismantling of the wind turbine, to enable some modifications to the design to be reconsidered.

H. Qatar

64. In 1972, Lucas Service Overseas (United Kingdom) supplied a small demonstration photovoltaic generator. At present, the Qatar General Petroleum Company is considering the application of solar energy in cooling, heating, thermal energy conversion, desalination and greenhouses. A study on the assessment of solar energy use in Qatar has been undertaken by the Middle East Economic Consultant, of Beirut. The report on this study was published in 1979.

65. At present, Qatar is planning to establish a solar energy project with an estimated budget of $ 3 million. The project includes solar water desalination, space cooling and power generation.

I. Saudi Arabia

66. The pace of solar energy in Saudi Arabia is now set by the Saudi Arabia Centre for Science and Technology (SANCST) in Riyadh, which is managing, along with the United States Deparment of Energy (USDOE), the Saudi Arabian United States Programme for Co-operation in Solar Energy (SOLERAS). Each participating Government has contributed $ 50 million over a five-year period starting in 1978. The Solar Energy Research Institute (SERI) of Golden, Colorado, is the operating agent for SOLERAS. One of the aims of the SANCST is to enhance the research capabilities of Saudi Arabian universities through SOLERAS, to establish an order of priorities in solar research in Saudi Arabia and to create co-ordinated efforts between the different Saudi institutions. The projects that have been approved by the Board of SOLERAS are those concerned with solar energy availability in Saudi Arabia, the establishment of a 350 kW solar photovoltaic station (which might be expanded to 1000 kW), solar cooling, involving the establishment of solar cooling laboratories in four Saudi universities, solar desalination, solar energy applications in agriculture, and educational and training activities. The other solar energy project which falls under the sponsorship of the SANCST is that undertaken by Electricité de France (EDF) jointly with the Electrical Branch of the Ministry of Industry and Electricity, Riyadh, Saudi Arabia. EDF will supply a 45 kW SOFRETES solar pump at a cost of FF 5.4 million and one 30 kW SERI-RENAULT photopile unit at a cost of FF 6 million.

67. The University of Petroleum and Minerals (UPM) organized the first International Conference on Solar Energy in 1975. The UPM is undertaking a number of solar energy projects, such as the assessment of solar energy availability in Saudi Arabia, studies on solar energy storage, the direct conversion of solar energy into electricity, including photovoltaic, thermoelectric and thermionic converters, solar housing studies, the testing of solar collectors and the separation of magnesium chloride from saline

water using solar energy. Also, the UPM carried out an economic evaluation for heliohydroelectric power generation by building a dam between Saudi Arabia and Bahrain, and between Bahrain and Qatar, creating the artificial depression of Dawhat Salwah, due to solar evaporation. The estimated power output of this project is 50 MWe. The UPM is now building a new research institute which will include in its activities a solar programme.

68. The activities in renewable energy research at the University of Riyadh are mainly concentrated in the Department of Mechanical Engineering, where a solar energy laboratory for undergraduate students was established and experiments on water distillation, water heating, space heating and cooling, solar drying and solar concentration could be carried out. A 3-ton air conditioning unit was acquired from the Georgia Institute of Technology, Atlanta (United States of America), at a cost of $ 75,000. A proposal for a research project on the assessment of wind energy potential all over the Kingdom has been submitted by the University to the Solar Energy Committee of the SANCST for approval and funding. Another two minor wind energy projects are being studied, one for the utilization of locally manufactured wind turbines to clean solar collectors installed in desert areas, and the other for combined solar and wind power generation by heating air in an enclosed space, using solar energy, the air then being used to drive a wind turbine.

69. The King Abdul-Aziz University (Jeddah) acted as host to a National Solar Energy Conference in 1978. The University agreed on a programme of co-operation on solar energy with the Federal Republic of Germany, with a budget of SR 5 million. The University ordered a 1-kW SOFRETES solar pump for demonstration at a cost of SR 400,000. The Institute of Meteorology and Arid Land Studies at the same University is collecting data on insolation and wind speeds from a number of meteorological stations. The decision has been taken to establish a space and energy research centre within the framework of the King Abdul-Aziz University. Research and development in new and renewable energy will be one of the activities of this centre.

70. The Dir'iyah Institute has among its activities a one million dollar grant to Terraset Elementary School (Virginia, United States of America) to instal a solar heating and cooling system and a grant to the Georgia Institute of Technology to survey solar energy applications for a study of the state of the technology in solar energy water pumping.

71. There are some solar and wind energy applications in Saudi Arabia. The largest solar energy application is the solar powered heating complex for the Airborne School (TABUK), where 50 hectares are heated by solar energy. the cost of this project, which started in 1978, is $ 1.5 million. In 1980, the General Directorate of Telephones installed more than 300 photovoltaic powered emergency telephones on the Saudi highways. Also, the photovoltaic beacon established by the French at the Airport of Madinah in the early 1960s is considered as one of the first applications of solar energy in Saudi Arabia. Some windmills were installed near Dhahran by the Aramco Oil Company for water pumping.

72. Surveys for geothermal resources have been carried out in Saudi Arabia and a new and extensive programme is in progress to assess medium enthalpy fields which are expected to be found in Al-Lith, Jizzan and Hofuf for electric power generation for agriculture and small industry development. Surveys for high enthalpy geothermal resources, which are expected to be found in Harrats, are being carried out at present.

J. Syrian Arab Republic

73. The Supreme Committee for Energy was established under the chairmanship of the Deputy Minister in 1980. This Committee is in charge of policy planning and implementation for the gradual transition from the use of conventional energy sources to the use of new and renewable sources of energy, in line with socio-economic developments in the Syrian Arab Republic.

74. Subcommittees on energy were also established in the Ministries of Electricity, Oil, Housing and Municipalities, and in the Ministry of Industry. Also, a subcommittee on energy was established in the Atomic Energy Authority.

75. The Ministry of Electricity has programmes on renewable energy, including the combined use of wind generators and solar photovoltaic panels to charge storage batteries capable of producing continuous electric power of 400 W for a period of 10 days, and a solar heating system for an apartment building. Flat plate collectors are being developed in the Solar Energy Unit of the Faculty of Mechanical and Electric Engineering of the University of Damascus.

K. United Arab Emirates

76. A National Committee on Energy was established in late 1980 to co-ordinate and follow up issues related to alternatives to conventional energy.

77. A Centre for Applied Research on Solar Energy Applications is being established, in co-operation with Japan. This Centre will concentrate basically on sea and brackish water desalination, solar power generation, solar space heating and solar water pumping for remote areas. It should be mentioned that a 1 kW SOFRETES solar pump has been installed and tested in Al-Ayn.

L. Yemen

78. The only renewable energy application identified in Yemen is the utilization of solar and wind energy to operate a number of pilot transmitters installed in some remote and mountainuous locations by the Ministry of Communications. In addition, FAO, under its tenchnical co-operation programme, signed a project document in 1979 on the introduction of solar pumping units in order to provide irrigation and drinking water to the Anssifera Farm project. Nevertheless, there seem to be possibilities of developing other renewable energy projects in the fields of geothermal and biomass energy. A survey of the geothermal potential was undertaken in 1980, which enabled an area in the south-west of Damor to be selected as the most favourable for geothermal applications. An assessment programme is under way. A proposal was also made by an Italian company (Electric Consult) for the same area.

M. <u>Democratic Yemen</u>

79. The National Committee for Energy, under the chairmanship of the Minister of Industry, the President of the Oil and Minerals Board, was established in 1980. The planning and promotion of renewable energy R & D and applications are among the responsibilities of this Committee.

80. The Public Corporation for Electric Power installed at the end of 1979 an 18 kW experimental wind system for electric power generation. This project was financed ($ 17,000) by the Organization of Development Aid from People to People, of Denmark. The wind system was designed, manufactured and erected by Danish concerns.

81. The Ministry of Industry invited an Italian team to assess the potential of geothermal resources in Democratic Yemen. The Department of Tourism requested the help of the Bulgarians for the utilization of a geothermal reservoir for touristic and recreational purposes in the province of Hadramout. The French organization BRGM undertook a preliminary geothermal survey for the country in 1976-1977. The Italians recently approached officials of the Geology and Mineral Exploration Department to survey the solare energy potential in Democratic Yemen

V. ECONOMIC ASPECTS OF NEW AND RENEWABLE SOURCES OF ENERGY IN THE ECWA REGION

82. An economic evaluation of the utilization of new and renewable sources of energy, particularly solar, wind, geothermal and biomass energy, is not very meaningful at the present stage. Much more information is needed than the mere cost of production of solar collectors, wind turbine or biogas digestors before a definitive assessment of the economics of the utilization of any new or renewable source of energy in the ECWA region is carried out. In addition, the problem is also compounded by the lack of information and the rapid rate of development and commercialization in many of the renewable energy technologies.

83. Most of the cost data for the new and renewable energy technologies either come from the design studies or are based on international market prices. These data do not always reflect the actual cost of the application of the technology in the ECWA countries. The countries of the ECWA region are generally charged much higher prices than the international selling prices for the new technologies. In addition, many of the technologies in question are still in the phase of research and development at the international level. Therefore, any cost estimate under present circumstances may be a poor guide to longer-term economic assessments. Owing to the differences in the economic structures of the ECWA member States, and in the degree of renewable resource availability (solar intensity, the wind régime, the amount and kind of the biomass resource), which may vary even from site to site in the same country, a prediction or a general economic assessment of the utilization of renewable energy resources all over the ECWA region will be far from realistic. A small community located on the Gulf coast, with abundant solar and wind energy, is radically different from a village located in the centre of the Delta in Egypt, where the biomass resource is found in abundant quantity, while the wind speeds are relatively low. Any attempt to find a regional model for all these situations will be full of generalities and will be of no use to the specific micro-economies for which economic assessments should be forecast in each individual case.

84. In this chapter, an attempt is made to give a rough evaluation of the cost per unit of energy produced by some specific renewable energy technologies when utilized in the ECWA countries, and specifically in rural and remote areas. However, the use of renewable energy resources has environmental and social benefits, which could be evaluated quantitatively and included in the cost effectiveness of these technologies as environmental and social cost benefits. These factors are not included in the following cost analysis of renewable energy in the ECWA region.

A) Solar energy technology

85. The rural applications of some solar energy technologies could be considered as already economically competitive in most of the remote areas of the ECWA region. For instance, the cost of a single-effect solar water still is the sum of the cost of land and the cost of the structure. In desert and remote areas, land cost may be a negligible part of the over-all cost, while in the urban sectors and agricultural areas it cannot be neglected. The cost of the structure may vary from one country to another in the ECWA region, owning to the differences in material and labour cost. Generally, the total cost of the solar still in the ECWA region ranges between \$ 11 and \$ 35 per square metre of the net evaporating area. If the lifetime of the solar still is assumed to be 10 years, then the corresponding cost of distilled water ranges between \$ 0.75 and \$ 3 for cubic metre (m^3). While, the cost of fresh water in Cairo is \$ 0.02 per m^3, this cost can be as high as \$ 4 per m^3 in remote areas of Saudi Arabia and other ECWA countries. At present, solar stills are cheaper than any other desalination devices for applications requiring less than 200 m^3 per day of fresh water in remote areas.

86. The cost of solar dryers for food products is estimated to be about \$ 15 per m^2 in the ECWA region.

87. Solar pumps are expensive at present. Their costs vary from \$ 20,000 to \$ 60,000 per installed kilowatt. This estimate is based upon prices of pumps sold to different ECWA countries. Solar pumps will not be competitive unless their cost is reduced to \$ 2,000 per installed kW.

88. The cost of solar greenhouses is about \$ 45 per m^2 at present, but is expected to decrease to \$ 13 per m^2 in the near future. The yield of the greenhouses per unit of area could be further increased by growing more than one crop per year. The annual square metre of greenhouse may reach, in this case, about \$ 100.

89. Solar refrigeration, although in the early phases of development, has good prospects for implementation in many countries of the ECWA region. The production cost of ice using solar refrigerators is estimated to be about \$ 20 per m^3, which is less than the cost of ice produced by using fossil fuels in locations far from large cities.

90. Solar water heaters are considered economical for applications in both rural and urban sectors in the ECWA countries. The cost of a locally manufactured family-size solar water heater is around \$ 900 in Jordan and \$ 500 for the same unit in Egypt. These costs may be further reduced by improving production techniques.

91. The cost of electrical energy generated from solar power plants (thermal or photovoltaic) is still much higher than that produced by fossil-fueled systems, even in the remote areas. For instance, a solar thermal conversion power plant installed in Kuwait costs \$ 28,000 per kWe i.e., about \$ 140,000 per average kWe, giving a cost of electrical energy of about \$ 2 per kWh, while that generated from fossil fuels costs from \$ 0.07-- \$ 0.106 per kWh in Kuwait.

The estimated cost of the photovoltaic project which will be installed in Al-Uyaynah in Saudi Arabia is more than \$ 50,000 per peak kWe installed (\$ 350,000 per average kWe and \$ 3.5 per kWh), although it is planned to use concentrators, which are supposed to decrease the cost. The cost of fossil-fueled electrical energy in Saudi Arabia is about \$ 0.6 per kWh. On the other hand, a study carried out in Egypt showed that the cost of a unit of energy produced by photovoltaics in a remote area is \$ 0.66 per kWh, whereas it would cost \$ 0.27 per kWh if diesel engines were used in the same area. These high costs are expected to be appreciably reduced if solar electric power generation is undertaken on a large scale in the ECWA region.

Table 4 gives the expected time at which each solar application will be economically viable in the ECWA region.

B) Wind power technology

92. The cost of the energy generated by a wind energy conversion system (WECS) depends mainly on the capital cost (P) of the system (whether totally or partially imported), the wind régime at the site of installation, which is quantitatively characterized by the load factor (K), the estimated lifetime of the system, which is considered to be 15 years in the local conditions of the Arab world, the interest rate on the capital investment, which is taken as 10 per cent in the present economic situation, and the annual operation and maintenance cost (m) which is assumed to range from 2 per cent to 7 per cent of the capital investment. Taking into account all the above mentioned factors, the cost ranges per kWh of energy generated by a WECS in some selected sites in the ECWA region are listed in table 5.

93. The cost range per kWh is based on a capital investment of $ 1,000 - $ 2,500 per installed kW, which corresponds to the prices offered by many manufacturers. The highest estimated cost is in Jeddah in Saudi Arabia (K = 0.195, m = 7 per cent and P = 2,500 $/kW), where the estimated energy cost is $ 0.3 per kWh. The cost of fossil-fueled energy in the remote areas of Saudi Arabia is around $ 0.6 per kWh, which is much higher than the energy generated from wind. At a site like Hurghada in Egypt (K = 0.474, m = 2 per cent and P = $ 1000/kW), the cost is about $ 0.04 per kWh which is distinctly lower than the cost of energy generated by a diesel generator unit (0.27 $ per kWh).

94. The costs given in table 5 show that the immediate utilization of wind energy in the remote areas of some ECWA countries (Egypt and Saudi Arabia) is economically viable. In other ECWA countries, the use of a WECS in remote areas will be economically feasible if the capital investment is reduced towards the lower limit of the range (1000 $ per kW). This may be achieved if some of the components of the WECS are manufactured in one of the ECWA countries, preferably one with low labour costs and with an industrial infrastructure capable of manufacturing the components assigned.

Table 4

TIME-TABLE FOR SOLAR APPLICATIONS

Application	Product	Area of implementation	Proposed year
Soalr dryers	Preserved dried food	Sea shores and rural areas	1981
Solar stills	fresh water	individual houses and sea shores	1981
Solar pumps	pumped water	remote rural areas	1990
Solar greenhouses	vegetables	all rural areas	1981
Soalr refrigeration	preserved food, ice	fishing villages and pastoral settlements	1985
Solar air-conditioning	conditioned space	cities	1990
Solar heating	comfort heat	cities	1981
Water heaters	hot water	cities	1981
Solar electricity	electricity	communication systems	1981
Solar electricity	electricity	remote areas	1985
Solar electricity	electricity	general applications	2000
Solar furnaces	heat 1000°C	mining	1985
Solar heat	heat 200°C	industry	1981

Table 5

COST PER KWH OF ENERGY GENERATED BY WIND ENERGY CONVERSION SYSTEMS AT SELECTED SITES IN THE ECWA REGION

Country	Site	Operation and maintenance	Range of wind energy cost $/kWh
Bahrain	Muharraq	7%	0.07 - 0.18
Egypt	El-Salloum	2%	0.06 - 0.15
	Alexandria	2%	0.07 - 0.18
	Hurghada	2%	0.04 - 0.09
Kuwait	Al-Ahmadi	7%	0.07 - 0.16
Lebanon		5%	0.08 - 0.21
Qatar	Doha	7%	0.10 - 0.24
	Ras Rakan	7%	0.06 - 0.15
	Halul Island	7%	0.06 - 0.16
Saudi Arabia	Dhahran	7%	0.10 - 0.24
	Ras Tanura	7%	0.11 - 0.26
	Taif	7%	0.10 - 0.24
	Yanbo	7%	0.09 - 0.22
	Jeddah	7%	0.12 - 0.30
United Arab Emirates	Das Island	7%	0.09 - 0.22
	Jebel Dhanna	7%	0.09 - 0.23
	Sharjah	7%	0.09 - 0.22

C) Biomass technology

95. One aspect only of the economics of biomass processes is discussed here; it is the economic viability of biogas production, including the evaluation of the other inputs and outputs (slurry) to the system.

96. The economics of biogas production is discussed on the basis of the Indian and Chinese experiences, since there is no experience in the ECWA countries of biogas production, except the projects undertaken in Egypt. These projects are not yet at a stage such that their economic aspects could be considered as a basis for analysis.

97. Different sizes of biogas plants are considered; the first is a 2-cow unit producing 0.4 m^3 of gas per day, the second is a 5-cow unit producing 1 m^3 gas per day, and the third is a 20-cow unit producing 4 m^3 gas per day. The capital costs of both designs, namely the Indian design and the Chinese design, are given in table 6. Although the units are treated in terms of the number of heads of cattle, this does not preclude the use of other (perhaps more attractive) inputs (e.g. crop residues). The calculations in table 6 are based on disregarding the labour and maintenance costs. The plant owner is assumed to repay the fixed capital cost of the plant in fixed instalments over five years with a 10 per cent interest charge. The results of calculations for a typical year in the first five years of the project are given in table 6.

98. The results show that the metal design (Indian), 5-cow unit is not financially attractive, if the slurry value is zero. The 20-cow unit is viable but not particularly attractive under these conditions. However, if the high slurry valuation is included, both units are financially viable and quite attractive. The results for the stone design (Chinese) show the undoubted advantages to be obtained by cost reduction. The very small unit is not viable if the slurry value is zero, but is attractive for higher slurry values. The stone design is always a better proposition than the metal design and an argument could be made in favour of the 5-cow unit, even on the basis of zero slurry. At higher capacities, the unit looks extremely attractive. The very simple technology of the construction of the stone design and its economic viability make it appropriate for rural areas in the ECWA countries. However, the biogas experts in Egypt found

that the biogas produced by the Chinese digestor lost its pressure much more rapidly than the biogas produced by the Indian digestor.

Table 6

ECONOMICS OF BIOGAS PRODUCTION

Design	Size (cows)	Capital cost ($)	Annual repayment ($)	Gas		Slurry value ($ pa)			Net cash flow ($ pa)		
				m^3/day	$ pa	Low	Med.	High	Low	Med.	High
Indian	5	240	80	1	58	0	45	90	-21	23	68
	20	550	183	4	233	0	180	360	50	230	410
Chinese	2	70	23	0.4	23	0	18	36	0.4	18	36
	5	110	37	1	58	0	45	90	21	66	111
	20	215	72	4	233	0	180	360	161	341	521

D) Geothermal technology

99. The economics of utilization of a geothermal resource depends on many factors such as well temprature, flow rate, composition of the water, well depth, etc. Therefore, the economics of geothermal technology cannot be discussed without reference to a specific case. Since there is no single geothermal plant that has yet been built or operated in the ECWA region, it seems very difficult to fix any precise estimate for the cost of energy from geothermal resources in this region. Only rough estimates of the cost of geothermal energy, based on the experience gained in the other regions of the world, are presented. Two cases are considered; the first is a high enthalpy project and the second is a low enthalpy project. The tentative cost analysis of a 20 MW high-enthalpy project is based on adverse conditions (new geothermal area, high geological risk, etc.). The total capital investment ranges between $ 94-144 millions, including investment in exploration, the process, power plant and well renewal. The operating costs for the power plant and well maintenance amount to $ 43 million over 10 years, which is the assumed life-time of the plant. The total estimated cost of a unit of energy ranges between $ 0.056 and $ 0.072/kWh for a 0.9 load factor.

100. The investment in a low enthalpy geothermal project is estimated to be $ 2.425 million when deep wells producing hot water are available, $ 4.25 million when there are no available deep wells and single-well exploitation is selected, and $ 6.425 million when there are no available deep wells and double-well exploitation is selected. In addition, the annual operating expenses are $ 275,000. The output of such a project is around 0.8 TOE/h, i.e., equivalent to 9.25 MW.

VI. ENVIRONMENTAL AND SOCIAL ASPECTS OF NEW AND RENEWABLE SOURCES OF ENERGY IN THE ECWA REGION

101. It is generally accepted that most of the renewable energy systems (solar, wind and geothermal) are pollution-free, since they produce no exhaust gases, particulate emissions, or residuals, which is not the case with fossil-fueled energy systems. These systems operate without using any combustible materials, i.e. there is no possibility of accidents during the transportation of fuel or during the operation of the system, and there is no possibility of serious water or air pollution, and also no liability for loss of property or death of living organisms.

102. In fact, most renewable energy resources are dilute forms of energy that are used mainly in decentralized energy systems, which suit the rural and desert communities in most ECWA countries.

103. The wide utilization of renewable energy resources in such applications as heating, cooling, water pumping, crop drying, water desalination, electric power generation, etc. in the ECWA region will reduce the consumption of fossil fuels and consequently the amount of pollution resulting from burning them.

104. The use of the available solar, wind and geothermal energy in rural areas of the ECWA countries where fossil fuels are hardly available and biomass is used instead, may help in stopping the continuous desertification in many areas of the region.

105. Renewable energy systems, particularly solar energy systems requiring large collecting areas, are also affected by environmental constraints with regard to land use. This may be of importance in agricultural rural areas where land is cultivated and is therefore of high value, but in desert areas the productivity of the land is low and it is not highly valued by the inhabitants.

106. If renewable energy systems are manufactured totally or partially in the ECWA region, then the assessment of their environmental impact should take into consideration the total energy cycle, and not only their

final and most visible aspect. Most renewable energy sources are of a diffuse nature and are intermittent and therefore require large collection and storage devices. The large quantities of materials required to manufacture these devices imply huge industrial efforts in mining, fabrication, construction and installation. Each form of these industrial activities has its own level of risk to human health. There has been no evaluation in the ECWA region of the total risk to human health per unit of energy output of the system.

107. When solar energy utilization for space heating and cooling of buildings is considered, the choice of the orientation of these buildings with respect to solar radiation is important. This will in turn, influence the location of water and sewage pipes, electric cables, road directions, etc. This may not create any problems when new building are constructed, but in already established communities, it will represent a serious problem.

108. Wind energy systems have a positive ecological impact when they replace diesel engines for water pumping in coastal areas of the ECWA countries, since their use reduces the danger of inducing underground water salinity due to overpumping. This is due to the fact that the pumping rate in wind systems is, of course, much lower than that of a diesel-driven pump. The negative environmental impacts of wind energy systems, such as catastrophic failure, the chopping of electromagnetic waves, the killing of birds struck by rotating blades, the adverse aesthetic impact, noise, etc. are of minor importance when small-scale wind systems are used in rural and desert areas in the ECWA countries.

109. Some environmental factors, such as climatic (high temperature, humidity, dust, etc.) and ecological conditions may seriously affect the operational performance of renewable energy systmes. Such factors should therefore be taken into account in the design or selection of renewable energy devices to work in the ECWA countries.

110. Supplying energy from renewable resources to rural and desert communities where there is little commercial energy results in a number of social benefits, such as the provision of clean drinking water and an increase in agricultural production and other gains, since a substantial

part of the available human and animal labour will be released for other tasks. The provision of light for reading in the evenings improves the progress and quality of education. Other social benefits include the broadening of community and personal activities such as adult eduction, and attendance of evening classes and health clinics, and also the stimulation of small industries or handicrafts and the associated infrastructure.

111. If renewable energy resources are to be widely used in the ECWA countries, most of the necessary equipment should be manufactured in the region, thus creating more employment opportunities.

112. Should biogas technology be considered, then the social benefits of improved waste disposal methods and health control are of special interest to rural and desert communities in the ECWA region.

113. All the above-mentioned social benefits would help in relocating Bedouin tribes and would also attract people from over-populated urban centres to new farming communities in remote under-populated areas.

114. The increasing need for these new sources of energy could lead to conflicting needs among groups and individuals, a situation which usaully accompanies the introduction of any new technology. This, in turn, would necessitate some legal decisions regarding standards, quality control, pollution control, tax incentives for industry and users, the encouragement and protection of local manufacture and import and export policies relating to new and renewable sources of energy.

VII. CONSTRAINTS HINDERING THE INCREASED USE OF NEW AND RENEWABLE SOURCES OF ENERGY IN THE ECWA REGION

115. The absence of over-all policies and strategies on new and renewable energy sources at the national level in all ECWA member countries is in fact one of the major obstacles impeding the development and increased use of renewable sources of energy. Therefore, the efforts and acitivities devoted to the promotion of research and development and the utilization of new and renewable sources of energy, seem to be diffused and fragmented, and, in some cases, are even misdirected.

116. A major constraint impeding research and development activities on new and renewable sources of energy is the lack of an indigenous scientific, technical and industrial infrastructure in most of the ECWA member countries. In fact, these technologies encompass an extremely wide range of scientific specialities and the range of knowledge required for their development covers many classical scientific disciplines. Research activities must therefore be broadly interdisciplinary, a situation which does not exist yet in most of the ECWA countries. Ongoing research and development, even where it exists, is often directed towards long-term fundamental objectives, to the disadvantage of application-oriented practical development and field testing. Also, the allocation of financial resources, manpower, and equipment to research and development is insufficient. Mechanisms for the promotion of these activities are complex and slow.

117. Some Governments in the ECWA region subsidize energy prices for their consumers, e.g. the selling price of one kWh of electrical energy in Kuwait is around four per cent of its actual production cost. On the other hand, there does not exist a national policy in any of the ECWA countries for subsidizing the capital cost of renewable energy equipment (solar collectors, wind turbines, etc.). This situation does not encourage either the private or the public sector to allocate investment in the field of new and renewable source of energy.

118. The absence of a common market at the regional level to facilitate the free movement of scientists, technical personnel and products relating to new and renewable energy results, on the one hand, in the indigenous regional development of new and renewable energy technology being hampered, and on the other hand in complete dependence on the import of such systems as finished products.

119. Technical co-operation at the regional level among the ECWA member countries is at its minimum level at the present time. This inadequate regional co-operation leads to duplication and reduces the efficiency of R & D as a whole. However, there are many bilateral agreements between individual ECWA countries and some industrialized countries in the field of new and renewable sources of energy. In such agreements, most of the responsibility for the inception, design, development and manufacture of renewable energy equipment is borne by the industrialized countries, while the role of indigenous scientists and technical manpower is confined, at best, to installation and experimentation and becoming acquainted with the operation and maintenance of the equipment. This fact by itself is an obstacle to the development of an indigenous infrastructure for renewable energy technologies, and the region becomes only a market for imported renewable energy technologies.

120. In most of ECWA member countries, there is a severe lack of co-ordination between the policy-makers and the technical and scientific institutions working in the field of new and renewable sources of energy. In addition, the public is not sufficiently aware of the advantages of their applications. These facts reveal the obstacles associated with the lack of a co-ordinated policy and programmes for the development and application of new and renewable energy technologies in most of the countries of the region.

RECOMMENDATIONS

A. At the national level

(1) ECWA member countries are requested to build and strengthen the machinery for energy planning and to formulate a comprehensive national policy for the utilization of new and renewable sources of energy for the present time and for the near future. Governments of the ECWA countries should also give priority to the initiation of a programme of action in the field of renewable energy, after an assessment of the new and renewable resources available in their countries. This plan should be co-ordinated with and integrated within rural development and should take into account the real needs and the social, environmental and cultural acceptability of the proposed energy alternatives.

(2) The ECWA member countries should set up and strengthen the appropriate institutional infrastructures needed to promote and undertake research and development and the testing of new and renewable energy technologies, taking into account the experiences gained by other countries in the region.

(3) A system of incentives, subsidies and assistance should be formulated by each ECWA member State to encourage the use of economically viable and technically proven renewable energy technologies and the commercialization of their processes and prototypes.

(4) The ECWA member countries are requested to introduce into their educational systems, at all levels, special topics on science and technology relating to new and renewable energy sources.

(5) The research and development institutions in the ECWA member countries should participate actively in a consultative and/or executive capacity in the various phases involved in the process of formulating and adopting policies related to new and renewable sources of energy.

(6) The ECWA member countries are requested to allocate sufficient funds for activities on research and development and demonstration of new and renewable energy technologies.

B. At the regional level

(7) The ECWA member countries are requested to establish, in consultation with the Economic Commission for Africa (ECA) and the League of Arab States an inter-Arab renewable energy technology transfer advisory body, to assist interested ECWA countries, at their request, in negotiating with foreign manufacturing firms for the local manufacture of well-established commercial renewable energy system components. This body should place emphasis on the assessment of the technology, its suitability for local application and the terms of relevant commercial, technical and economic agreements.

(8) ECWA member countries should periodically organize regional meetings to exchange information regarding the optimum utilization of new and renewable sources of energy and to facilitate the exchange of scientists and experts on new and renewable energy between the individual countries of the region.

(9) It is recommended that the ECWA member States initiate the implementation of co-operative and joint projects for the exploration and utilization of renewable energy technologies.

(10) It is recommended that the ECWA member States should establish educational institutions and training centres at the regional level to train scientists, engineers and technicians in various areas of new and renewable sources of energy relevant to the region.

(11) Co-operation at the regional level should start to enable the ECWA member States to manufacture components, equipments and other materials related to the development and utilization of new and renewable sources of energy, and to build an indigenous technical and industrial infrastructure capable of testing and manufacturing all components needed for systems for the utilization of such sources of energy.

C. At the global level

(12) The United Nations should make the appropriate institutional and other arrangements needed to enhance its role in the area of new and renewable sources of energy, more particularly in the interest of the developing countries.

(13) The existing bilateral and multilateral agreements of the ECWA member countries on technical co-operation, at both the regional and the interregional level, should be strengthened to include explicitly the area of new and renewable sources of energy.

(14) The ECWA countries should participate actively in interregional and international seminars, symposia and conferences on new and renewable sources of energy.

(15) The interregional and global organizations and institutions concerned should co-operate to establish an information network on new and renewable sources of energy.

(16) The developing countries should co-operate to exchange informations and to produce collectively components and equipment related to the development and utilization of new and renewable sources of energy, in order to enhance their collective self-reliance in this area.

(17) The existing international channels should be used to exchange and disseminate information on the development of new and renewable energy technologies, and on field testing, demonstration projects and prograss in the implementation and evaluation of previous experience, including any negative results.

ANNEX I

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ANNEX II

List of units

Area

1 hectare (ha) = 10^4 square metre (m^2)

Volume

1 litre = 10^{-3} m^3

Mass

kilogramme (kg)

Power

Watt (W) - Joule per second (J/s)

Energy

kilowatthour (kWh)

Joule (J)

1 ton of oil equivalent (TOE) = 11.6 MWh

1 kWh = 3.6×10^6 J

Multiples of units

Giga (G) = 10^9

Mega (M) = 10^6

Kilo (k) = 10^3