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Proceedings of the Seminar on Small-Scale Solar and Wind Technologies for Rural and Remote Areas in the ESCWA Region



UNITED NATIONS

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E/ESCWA/NR/86/WG.1/19

FOREWORD

The present publication contains the report and documents of the Seminar on Small-Scale Solar and Wind Technologies for Rural and Remote Areas in the ESCWA Region, organized by the Economic and Social Commission for Western Asia (ESCWA) secretariat with financial assistance from the United Nations Development Programme (UNDP). The report reflects the discussions and conclusions of the participants.

The documents of the Seminar are in two parts: working papers prepared by representatives of the ESCWA secretariat covering Asian as well as North African Arab countries, and a number of papers presented by experts representing the national, regional and international authorities that are involved, in one way or another, in the development of renewable energy sources.

The views expressed in signed articles are those of the authors and do not necessarily reflect the views of the United Nations Secretariat. On many issues the statements and conclusions of most of the experts who took part in the Seminar were, to a large extent, identical. Mention should be made of the keynote address of the Executive Secretary of ESCWA, which can be singled out as a major contribution that reflects the stand of the United Nations on the issues of energy requirements in rural and remote areas, and on the role of renewable energy sources in the overall development of these areas.

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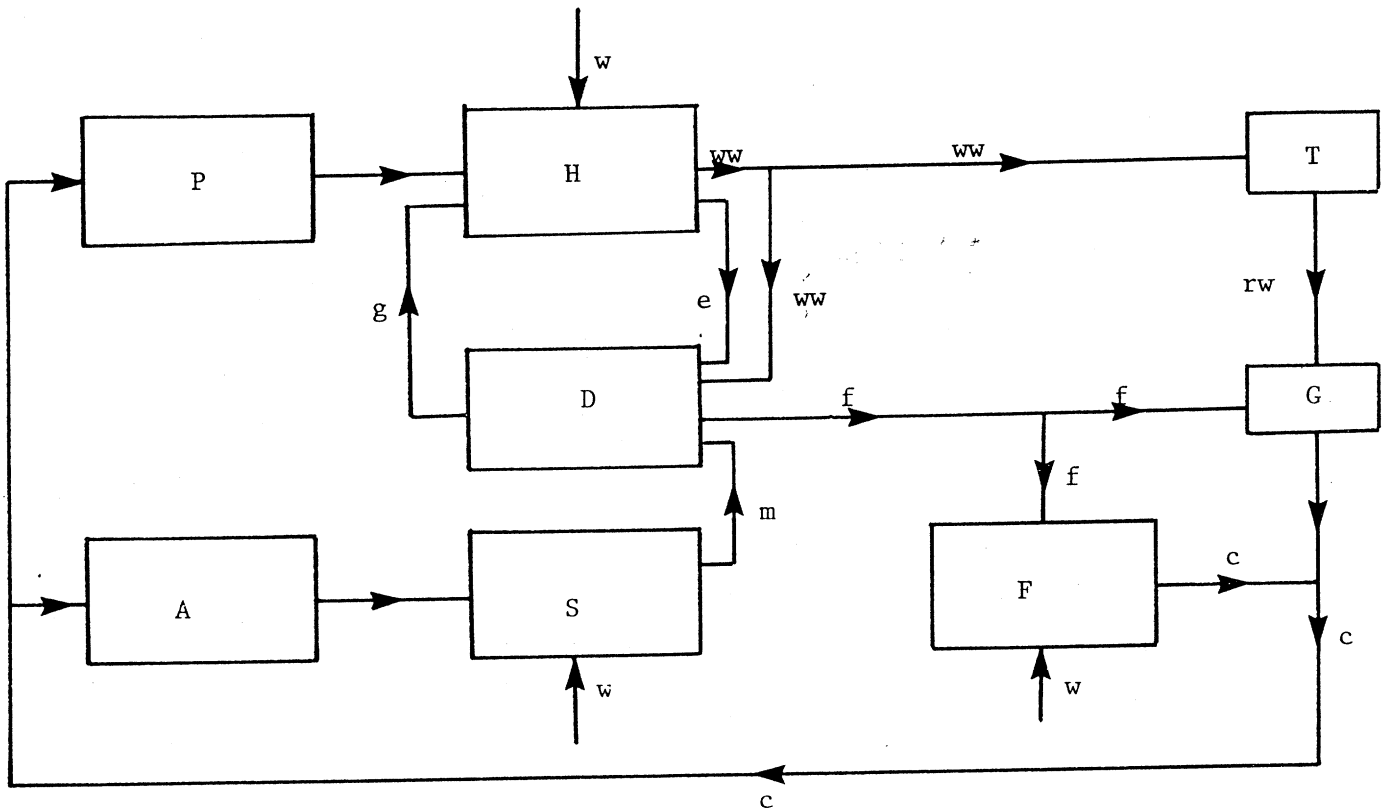
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BIOGAS SYSTEMS IN AL-HABEEL VILLAGE



P = People

H = House

A = Animals

S = Shed

D = Digester

F = Agricultural Fields

T = Water Treatment Plant

G = House Garden

m = manure

e = excreta

f = fertilizer

g = biogas

c = crops

w = water

ww = waste water

rw = recycled water

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ABBREVIATIONS

ASRT	Academy of Scientific Research and Technology
BMZ	German Federal Ministry for Economic Co-operation
C	Cost of unit energy (in mills/kWh); also Celsius when referring to temperature
D	Diameter of wind turbine (in metres)
E	Energy (in kWh)
F	Capacity factor
ft	Feet
GTZ	German Agency for Technical Co-operation (Deutsche Gesellschaft für Technische Zusammenarbeit)
h	Height (in metres)
ha	Hectare
H	Pumping height (in metres)
I	Capital investment per installed kilowatt (in US dollars)
km	Kilometre
kgm	Kilogram
kW	Kilowatt
kWh	Kilowatt hour
kWp	Kilowatt peak
(m)	Fraction of capital investment needed per year for operation and maintenance of WECS
m	Metre
m/s	Metre per second
MOE	Ministry of Electricity
n	Expected life-time of the WECS (in years)

ABBREVIATIONS (continued)

N/A	Not available
p	Power (in watts)
ppm	Particles per million
PCEP	Public Corporation for Electric Power
Q	Quantity of water (in cubic metres per day)
R	Recovery ratio
RO	Reverse osmosis
T	Number of hours for which the wind speed is larger than the rated speed, and smaller than or equal to the cut-out speed divided by the total number of hours for which wind measurements have been recorded
USAID	United States Agency for International Development
V	Mean wind speed (in metres/second (m/s))
V _o	Cut-in speed (in m/s)
V _r	Rated speed (in m/s)
V _k	Mid-point speed for the k th speed interval in the range between the cut-in speed and the rated speed (in m/s)
W	Working pressure (in bars)
W/m ²	Watts per square metre
WEPS	Wind energy pumping system
T _k	Number of hours corresponding to the k th speed interval, divided by the total number of hours for which the wind measurements have been recorded

INTRODUCTION

Scattered communities in rural and remote areas often utilize diesel sets to meet their electrical and/or mechanical energy needs for household applications, water pumping and various other purposes.

In many cases, small remote communities do not have the means to provide electrical or mechanical energy. These communities meet their basic energy needs by resorting to such traditional energy sources as fuelwood, agricultural residues and animal dung with all the adverse environmental effects their use usually generates.

Such communities are often located in areas far away from the main electric power grids. As electric power facilities are beyond the reach of the population and the extension of power lines undoubtedly involves high capital costs compared to energy needs, the use of diesel engines has long been considered as the best alternative for the provision of electric power for many rural and remote communities. The use of diesel engines entails, however, many difficulties in fuel transportation, the availability of technical capabilities for proper operation, maintenance and repair, in addition to the high cost of spare parts.

Small-scale solar and wind energy systems that are commensurate with the specific energy needs of rural and remote areas in the ESCWA region are proposed in view of the high solar energy potential in the region, the seasonal wind energy potential in several locations, and various other considerations.

However, experience gained in this field is still limited in the region and intensive efforts are needed to improve the region's capabilities in research, development and demonstration (RD and D) as well as in the construction, operation and maintenance of solar and wind energy systems. Moreover, these technologies are mostly in an early stage of development and many changes and modifications may be made to improve them.

In the light of the above, most ESCWA countries have initiated programmes and established facilities for testing and evaluating small-scale solar, wind and combined solar-wind energy systems.

On a regional level, some co-operation programmes for promoting the development of solar and wind energy systems through bilateral agreements have been worked out to exchange information and experiences pertaining to solar and wind technologies, and to implement joint projects in this field. However, no regional or subregional programmes or projects that can substantially contribute to a clearer perception of all the technical, economic, social and environmental aspects of the applications of the various solar and wind energy systems for rural and remote communities have been initiated. It is, therefore, of prime importance that ESCWA countries establish close regional and subregional co-operation for formulating projects aimed at testing and evaluating the techno-economic viability, social acceptability and environmental soundness of solar and wind technologies.

The Seminar was primarily aimed at providing a forum where experts in renewable energy and policy makers from ESCWA member countries and other Arab States could review experiences and the planned activities for various applications of small-scale solar and wind technologies, paying special attention to the basic energy requirements of the rural and remote areas of the Arab countries.

The long-term objective of the Seminar is to promote close co-operation among ESCWA member States and other Arab countries in the development and utilization of appropriate small-scale solar and wind energy technologies for rural and remote areas, and to contribute to a wider dissemination of information on technical, economic and environmental aspects of the various applications of these technologies.

However, the Seminar had another task which consisted of making a comprehensive assessment of the energy needs of rural and remote areas in the countries under consideration, with the immediate objective of identifying specific regional and subregional projects for the application of small-scale solar and wind energy technologies.

In order to fulfil these objectives, the Seminar focused on three major topics:

1. The prospects for using small-scale solar energy systems for rural and remote areas in the ESCWA region and some other Arab countries;
 2. Wind energy potential and prospects for the utilization of wind energy technologies in the ESCWA region, with special reference to rural and remote areas;
 3. A review of the national experiences of a number of ESCWA countries and some other Arab countries in the field of solar and wind energy development, together with an outlook of the utilization of small-scale solar and wind technologies for rural and remote communities.
-

Part One

ORGANIZATION OF THE SEMINAR AND WORKING PAPERS
OF THE ESCWA SECRETARIAT

I. REPORT OF THE SEMINAR

1. The Seminar was held in Amman, Jordan from 29 November to 3 December 1986. It was organized by ESCWA in co-operation with the Ministry of Energy and Mineral Resources of Jordan, with financial support from UNDP.

2. The main objective of the Seminar was to bring together experts and policy makers from ESCWA member countries, North African Arab countries and regional and international organizations in order to discuss the various issues of applications of small-scale solar and wind technologies to meet the basic energy needs of rural and remote areas in the ESCWA region. To this end, emphasis was placed on the identification of concrete proposals to promote the application of appropriate solar and wind energy technologies that will improve the social and economic well-being of rural communities and promote their contribution to overall economic development.

3. The Seminar was attended by representatives of the following countries: Bahrain, Egypt, Iraq, Jordan, Lebanon, Morocco, Oman, Qatar, Saudi Arabia, the Syrian Arab Republic, Tunisia, the United Arab Emirates and the Yemen Arab Republic. Representatives of the Organization of Arab Petroleum Exporting Countries (OAPEC), the Royal Scientific Society (RSS) of Jordan, the Arab Fund for Economic and Social Development (AFESD), the Federation of Arab Scientific Research Councils (FASRC), the European Economic Community (EEC), the Islamic Development Bank (IDB), the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), the United Nations Industrial Development Organization (UNIDO), UNDP, the United Nations Office of the Director-General for Development and International Economic Co-operation (DIEC) and a number of regional experts also participated in the seminar.

4. The Seminar was officially opened by the Executive Secretary of ESCWA.^{1/} In addressing the Seminar, the Executive Secretary stated that the seminar was of particular significance to the ESCWA region where the availability of oil resources in a number of countries and recent changes in oil prices had often overshadowed other factors that might be more relevant to promoting the use of renewable energy technologies. He stressed that the region should opt for a more diversified energy consumption mix that relied not only on finite petroleum resources, as was currently the case, but also on other alternative sources of energy. He further indicated that such a policy could substantially alleviate the heavy dependence on depletable energy resources, and would benefit those countries where energy costs still constituted a considerable burden on their national economies.

5. The Executive Secretary added that all ESCWA countries had witnessed, though in varying degrees, a considerable increase in the consumption of commercial energy, and owing to the lack of adequate energy conservation policies, energy intensity had also increased in most of the economic sectors in the region.

^{1/} The full text of the keynote address of the Executive Secretary of ESCWA is reproduced in annex I to this report.

6. He pointed out that several other factors such as distance from national electricity grids and distribution networks of conventional fuels, availability of repair and maintenance requirements and the impact of different technical options, influenced the use of renewable energy technologies.

7. The Executive Secretary drew the attention of the participants to the extensive use of fuelwood, charcoal, agricultural residues and other traditional energy sources to meet the energy requirements of most developing countries, and to the adverse environmental effects such as rapid desertification and soil depletion. These environmental effects had had particularly serious consequences for the ESCWA region, where arid and semi-arid zones cover large areas. In addition, in a number of countries in the region most of the population lived in areas where fuelwood was already scarce.

8. He added that as ESCWA countries were situated in areas subject to profuse insolation, and in view of the potential of wind energy in many locations, attention was turning to solar and wind technologies, especially since technology that used solar and wind energy was progressing rapidly. In the Seminar, the Executive Secretary went on, special attention would be paid to the utilization of these technologies so as to meet the energy needs of rural and remote communities. He then outlined the main difficulties facing ESCWA member countries in the development of solar and wind technologies, and the technical, economic, social and environmental implications of the application of these technologies. He emphasized the need for adequate renewable energy policies, the improvement of technological capabilities, an adequate data base and sufficient financial allocations.

9. The Executive Secretary concluded his speech by drawing attention to the importance of long-term energy planning and the provision of adequate industrial and institutional infrastructures. He also stressed the need to produce practical proposals for the utilization of solar and wind systems in specific rural and remote areas, and to draw up recommendations for the appropriate policies to be forwarded for consideration by the concerned authorities of the region.

10. He expressed his appreciation to the Ministry of Energy and Mineral Resources of Jordan for providing the required facilities for hosting the Seminar, and to the UNDP office at Headquarters in New York for their financial support.

11. In his speech, His Excellency Mr. Hisham Al-Khatib, the Minister of Energy and Mineral Resources of Jordan indicated that the share of solar energy in Jordan represented 2 per cent of total energy consumption. The annual rate of increase in the contribution of renewable energy was estimated at 1 per cent. He stated further that renewable energy was expected to complement commercial energy and to play a greater role in meeting energy requirements in Jordan, particularly in rural and remote areas.

12. Mr. Al-Khatib highlighted the various uses and applications of solar and wind energy technologies, such as solar water heating and wind energy for water pumping. He added that at least 20 per cent of the households in Jordan currently used a solar water heater.

13. With regard to wind energy, Mr. Al-Khatib pointed out that Jordan was experimenting with the use of wind energy to generate power, and that, pending the results of this undertaking, the manufacture of wind energy system components would be initiated.

14. Mr. Al-Khatib added that the widespread use of solar and wind energy technologies depended on the following factors:

(a) Adopting pricing systems that reflect the real cost of conventional energy in order to make solar and wind energy more competitive;

(b) Developing the local industrial infrastructure in order to improve the manufacturing capabilities of Jordan;

(c) Ensuring the maintenance and monitoring of solar and wind energy systems;

(d) Increasing public awareness of the benefits of using solar and wind energy technologies.

15. In particular, Mr. Al-Khatib stressed the importance of energy planning for the development and efficient use of energy resources. He concluded his speech by expressing the readiness of the Ministry of Energy and Mineral Resources to co-operate with the United Nations in the convening of more meetings and seminars of this nature in the future.

16. In his statement Mr. A. B. Harland, Deputy Assistant Administrator and Director of the Energy Office of UNDP said that, in view of the recent decline in the price of petroleum in the world market, there had been a corresponding decline in the interest of the donor community in providing funding through UNDP for programmes and projects in developing countries for new and renewable sources of energy. He considered this to be a most regrettable development as it could affect joint energy programmes that UNDP had initiated with the World Bank and other United Nations agencies, from which some countries of the region had received considerable benefit. Furthermore, in the view of UNDP, the price of petroleum was expected to increase and all resources needed to be mobilized in order to ease the dependency of the oil-importing developing countries in the future. Currently a number of the energy deficient oil-importing developing countries were required to spend up to 40 per cent of their foreign exchange earnings in order to meet their essential energy needs. He felt that this situation should not be allowed to continue, especially in rural areas where the problem was particularly acute and where there were few alternatives for energy substitution. Referring to the fuelwood crisis, Mr. Harland said that he believed that, even with massive investment in reforestation programmes, on the assumption that money could be found and that fast-growing tree species were utilized, it would be 10 to 15 years at the earliest before these plantations could be harvested.

17. Therefore, UNDP welcomed this Seminar, which brought together experts from developing countries to share their experiences, particularly in regard to small-scale solar and wind energy for remote and rural areas.

18. Mr. Harland reminded delegates that January 1987 was the start of the next UNDP programme cycle, and that this was an opportunity for countries to work with the UNDP Resident Representatives and to include energy programmes and projects in their new country programmes.

19. Reference was made to the successful symposia and workshops in Africa and Asia, organized by the UNDP Energy office with the participation of the private sector for the promotion of photovoltaic systems. Mr. Harland indicated that he was hoping to join with the Arab Fund for Economic and Social Development in organizing a similar workshop for the Arab region. Finally, he indicated that UNDP had recently initiated a global wind pumping evaluation programme with the World Bank in which a number of countries in the region would be participating. In the next few days there was going to be an opportunity to discuss both of these activities further.

20. In conclusion, Mr. Harland thanked the Executive Secretary of ESCWA and the Government of Jordan for organizing the Seminar, which he felt would be a very constructive meeting that would lead to the promotion of programmes and projects of new and renewable energy sources in the region.

21. In his message to the Seminar the RSS representative, Mr. Hani Al-Mulki indicated that renewable energy sources provided a new dimension to power generation, especially when its decentralized nature was taken into consideration. This in turn provided an appropriate solution for satisfying energy requirements in remote areas.

22. In briefing the Seminar on the activities of the RSS in the field of renewable sources of energy, Mr. Al-Mulki reported that the RSS had realized from the very beginning the importance of RD and D. Over the last 15 years, Mr. Al-Mulki added, the RSS had undertaken several RD and D projects and had been able to build up the required technical and technological infrastructure to fulfil its objectives for the development of renewable sources of energy.

23. He further indicated that special attention was being paid to the application aspects of research on renewable technologies in an effort to meet the specific needs of Jordan. He pointed out that a typical example of renewable energy application in Jordan was the utilization of domestic solar water heaters. The commercial application, he added, was the outcome of two major activities that complemented each other, namely the applied research which provided the system designs and manufacturing capabilities in Jordan.

24. He further highlighted the efforts deployed by the Ministry of Energy and Mineral Resources of Jordan in promoting the utilization of solar energy through studies of the problems that face consumers and the introduction of appropriate devices to overcome them. He concluded his message by inviting the participants to visit the RSS.

25. In his speech, Mr. Ahmedou Oued Abdulla, Special Co-ordinator for New and Renewable Sources of Energy (NRSE), in the Department of International Economic Co-operation (DIEC), said that he was very pleased to attend the Seminar, and congratulated the organizers and sponsors for convening such a seminar.

26. He went on to say that his intervention would be limited to a precise number of substantive questions that in his opinion were important for the promotion of new and renewable sources of energy. He first briefed the participants on the role of the special co-ordinator for NRSE in the office of the Director-General for Development and International Economic Co-operation, who managed a trust fund that had in the past prepared and convened four consultative meetings related to NRSE in ESCAP (1984), the Economic Commission for Latin America (ECLA) (1984), the Economic Commission for Africa (ECA) (1986) and a global meeting (1985). He said that as Chairman of the Inter-agency Group on NRSE, the special co-ordinator was inter alia interested and active in promoting the development and utilization of NRSE, and also in identifying areas for consultative meetings and providing services and support for such meetings.

27. He then drew attention to the following questions regarding the ways and means of implementing NRSE projects:

(a) To promote and help to implement NRSE projects, the sponsor needed to make his proposal part and parcel of a larger economic, social and cultural programme. Projects related to solar and wind energy needed to be part of an integrated scheme covering a geographical area and aimed at providing better conditions of life;

(b) In addition, a good project needed to be related to a mature and tested technology. If the project was a subregional one, the planning, training and testing of new technologies formed a prime area for co-operation.

In the area of funding the following approach would prove useful:

(i) The project needed to be on a priority list;

(ii) Parts of the project cost, especially some local expenditure, needed to be provided by the sponsor in order to show funding agencies that the originators of the project had an interest in it.

28. He concluded his statement by stressing the importance of maintaining close co-operation between ESCWA and other United Nations bodies, as well as with member countries and donor agencies.

Agenda item 2. Adoption of the programme of work

29. The Tentative Programme of Work for the Seminar on Small-Scale Solar and Wind Technologies for Rural and Remote Areas in the ESCWA Region (E/ESCWA/NR/86/WG.1/2/Rev.2) was adopted with a slight modification being made to the schedule of the last day of the session.

Agenda item 3. Consideration of ESCWA Working Paper on Wind Energy for Rural and Remote Areas in the ESCWA Region, parts I and II (E/ESCWA/NR/86/WG.1/3)

30. The Seminar had before it ESCWA documents (E/ESCWA/NR/86/WG.1/3) parts I and II which included the main issues of wind energy utilization and outlines of project proposals in the field of wind energy.

31. The ESCWA representative first briefed the Seminar on the traditional energy resources currently used by the widely dispersed rural and remote communities in the region to meet basic energy needs. He indicated that these communities are either deprived of or have very limited access to fuel supplies and electricity. As many rural and remote areas in the ESCWA region enjoy a reasonable wind potential, the ESCWA representative stressed that one of the most appropriate alternative solutions is to promote the utilization of the locally available wind resource. This can contribute to a substantial part of the energy requirements of these communities. An encouraging factor in the development of wind energy resources lies in the availability of a number of mature wind energy conversion technologies that are particularly suitable for decentralized application.

32. The ESCWA representative elaborated that the viability of the utilization of wind energy in a specific location mainly depends on wind characteristics, i.e. wind speeds and directions, and variations with time in the site under consideration. Owing to the fact that most ESCWA countries collect wind data for meteorological purposes only, the use of this data for assessing wind potential is extremely limited. However, he noted, some ESCWA countries have initiated specific programmes to assess wind energy potential. Countries like Egypt and Jordan have established measuring stations at specific sites.

33. Owing to the lack of adequate data specifically processed for the utilization of wind energy, the findings of the ESCWA paper were based on the assessment of wind potential in 23 sites, which was compiled from information collected from various sources.

34. The ESCWA representative added that the selected sites may not be the most appropriate ones for the installation of a wind energy conversion system (WECS), but they supplied appropriate wind data that could be recorded and made available.

35. Referring to the application of wind energy systems in rural and remote areas, he indicated that the most promising are water pumping for irrigation, domestic uses, power generation, brackish and sea water desalination and ice-making for fish preservation.

36. The ESCWA representative drew the attention of the participants to the fact that the identification of these applications was mainly based on the basic energy needs of rural and remote communities, and of the availability of relevant commercial small-scale wind energy conversion technologies at a reasonable cost. He emphasized the consideration of the economic viability of wind energy conversion technologies and the need to assess this through a cost-analysis of the system for use over its expected lifetime. He stated that, in spite of the potential of wind energy, the use of wind energy technologies was still very limited in the region.

37. He went on to explain that this could be the result of a number of factors such as:

- (a) The relatively high capital investment;
- (b) The lack of awareness of the authorities concerned;

- (c) The subsidization of prices for conventional energy;
- (d) The lack of technical experience in the field of energy technology;
- (e) The absence of social mechanisms that could enhance the community's acceptance of wind energy technology.

38. The ESCWA representative concluded the secretariat's paper by submitting a number of project proposals for the widespread use of wind energy technologies. These project proposals focused on:

- (a) The establishment of a wind measuring network in selected ESCWA countries;
- (b) Windmills to supply water in rural and remote areas in the ESCWA region;
- (c) Wind energy for brackish and sea water desalination in remote areas of the ESCWA region;
- (d) The production of ice for remote fishing communities in the ESCWA region using wind energy;
- (e) The organization of a training course-cum-study tour on small-scale wind technologies.

39. The ESCWA working paper on wind energy was discussed extensively by the participants. The comments of the participants focused on very specific points covering the various technical, economic and social aspects of wind energy applications for rural and remote areas. Some of the participants elaborated on the different wind measuring techniques by referring to their respective national experiences in this field. Many participants spoke of the difficulties encountered in the utilization of wind energy technologies, including such issues as social acceptance and environmental implications.

Agenda item 4. Consideration of ESCWA Working Paper on Solar and Combined Solar/Wind Energy for Rural and Remote Areas in the ESCWA Region
(E/ESCWA/NR/86/WG.1/6)

40. In his presentation of the ESCWA Working Paper on Solar and Combined Solar/Wind Energy for Rural and Remote Areas in the ESCWA Region, the ESCWA representative indicated that the main objective of this paper was to review the progress of research carried out to assess the potential utilization of solar and wind energy to meet various energy needs in rural and remote areas in the ESCWA region. He indicated that the paper presents information on the availability of climatic data, basic energy requirements for rural and remote areas and the economics of solar and wind energy, and that it highlights the present activities on solar and wind technologies in three selected ESCWA countries, namely Egypt, Jordan and the Yemen Arab Republic. He further indicated that the institutions and bodies involved in the preparation and implementation of projects on renewable energy were also elaborated on this paper.



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participants on a number of project energy needs in specific areas. These

settlement based on solar energy;

ination project;

on of a solar agro-industrial farm;

r "do-it-yourself" small-scale solar

ted on the ESCWA paper. Some of them identification of the energy needs of simple technologies. Other participants wable energy programming and projects. ial policies.

ESCWA Working Paper on the Experience
in the Field of New and Renewable Energy

/86/WG.1/5)

he participants on the main activities energy in North African Arab countries.

He indicated that activities concerning renewable energy in Morocco are concentrated on solar energy for water pumping, desalination, refrigeration, lighting and the production of ceramics.

44. He added that wind energy is used to pump water and to generate power. The ESCWA representative stated that the most common applications of solar energy in Algeria are solar space heating, water heating, distillation and power generation. Wind energy is mainly used to pump water.

45. In Tunisia, research, development and demonstration projects are carried out by several national establishments and laboratories. The ESCWA representative indicated that solar equipment such as solar water heaters are manufactured locally. He added that solar energy is also used for water desalination mainly in the central and southern regions of the country. Wind energy is mainly used for pumping water and lighting.

46. He then reviewed the main activities concerning renewable energy in the Libyan Arab Jamahiriya, which include photovoltaic applications, the use of solar energy for water heating, space heating and water desalination.

47. The ESCWA paper on the experiences of North African Arab countries in the field of renewable energy was discussed by the participants. The discussions centred on research, development and demonstration aspects, as well as applications and the manufacture of solar and wind energy systems.

Agenda Item 6. Presentation of papers prepared by United Nations organizations and other regional organizations

48. The OAPEC representative presented a paper on the role of the organization in the development of new and renewable energy resources in Arab countries. The paper included some detailed information on the activities undertaken by OAPEC to develop new and renewable sources of energy in the Arab world. He added that OAPEC activities included the organization of conferences to promote the development of energy resources in the Arab world. OAPEC also played a role in co-ordinating the energy policies of Arab States for the establishment of a regional institutional framework to deal with various energy issues. Among the main achievements of OAPEC in the field of renewable energy in the region, he added, was the establishment of the Arab Centre for Energy Studies. The Centre deals inter alia with the development of alternative sources of energy.

49. The OAPEC paper also included a summary of the main renewable energy activities in the region.

50. The OAPEC paper was discussed by the participants and pertinent comments were made by them.

51. The representative of the RSS of Jordan presented a paper on the activities of the Society and other Jordanian authorities in the field of renewable energy in general. He gave a brief outline of the energy situation in Jordan and the potential for utilizing solar and wind energy sources.

52. He further elaborated on the specific projects conducted by the RSS on the demonstration and application of solar and wind energy, which included a sea water desalination project using the heat pipe principle, a solar house, the development of domestic solar water heating systems, the design and construction of windmills for pumping water and the use of photovoltaic systems for pumping water and generating power. The RSS representative also briefed the participants on the solar evaporation ponds near the Dead Sea that are used for potash recovery as well as the recently installed indoor/outdoor testing facility for solar collectors and photovoltaic panels designed to improve the quality of solar collectors. He concluded his presentation by outlining the future projects of the RSS in the field of solar and wind energy resources. The most important of these were projects for the design of mini-photovoltaic systems to supply basic electrical requirements for remote areas, a wind photovoltaic hybrid system and a wind farm which is to be connected to the national grid.

53. The RSS paper was discussed extensively and the participants stressed the lack of regional co-operation amongst the different national institutions.

54. The FASRC representative read a message from the Acting Secretary-General of FASRC in which he supported the holding of more meetings such as this and expressed the willingness to co-operate with ESCWA in preparing project proposals, searching for funds and helping in the implementation of projects.

55. The UNIDO representative presented a paper on the establishment of a Consultative Group on Solar Energy Research and Applications (CGSERA). He went on to brief the participants about the interest of UNIDO in solar and other new and renewable sources of energy, mainly for industrialization, the development of indigenous energy resources and the development of local technological and manufacturing capabilities.

56. He pointed out that, so far UNIDO had been mainly concerned with solar energy. However, as a result of the deliberation of this seminar he would advise UNIDO to include wind energy as part of its activities on renewable energy.

57. The participants discussed the UNIDO presentation and suggested that a joint ESCWA-UNIDO Consultative Committee on new and renewable sources of energy would be helpful.

58. The ESCAP representative presented a paper on the activities of the Commission in the field of energy. He gave a brief outline of the energy situation in the ESCAP region. He then elaborated on activities concerning new and renewable sources of energy and the regional network on biomass, solar and wind energy in the ESCAP region.

59. He pointed out that the contribution of commercial solar and wind energy is still very limited in regional terms, but that its application is growing and the manufacture of solar and wind energy system components has commenced in most countries. He also stressed the importance of interregional co-operation in the field of new and renewable sources of energy, the immediate objective being to enhance the utilization and development of NRSE for national socio-economic development and rural development in particular. ESCAP, he added, was given the task of developing interregional co-operation by the regional commissions, and has prepared a project document on this topic for which it is seeking funding. He went on to stress the need for further co-operation between ESCWA and ESCAP in the field of NRSE. He pointed out that ESCAP is implementing a large photovoltaic training programme on the evaluation and design of systems. Interest was expressed in the participation of ESCWA in this programme, and in the transfer to the Commission of the computer-based design and evaluation packages that have been developed.

Agenda item 7. Presentation of papers prepared by experts on their national experiences in the application of small-scale solar and wind systems for rural and remote areas

60. The national paper of Egypt, presented by the representative of Egypt, emphasized the fact that solar, wind, biomass and mini-hydro energy resources are the main sources of renewable energy in Egypt. He pointed out that the energy plans of Egypt aim at the use of NRSE to satisfy 5 per cent of the total primary energy needs by the year 2000, saving 3 million tons of oil equivalent (MTOE) annually. The activities include the assessment of NRSE resources and the demonstration of solar wind and biomass systems in selected remote areas of Egypt.

61. These systems included solar reverse osmosis desalination with a capacity of more than 150 cubic metres (m³)/day, ice-making, village electrification and navigation lights using photovoltaic systems. In addition, a number of solar pumps, telecommunications repeaters and chemical refrigerators were installed to serve remote areas.

62. The Egyptian representative also pointed out that a solar energy system components manufacturing industry has already been set up in Egypt. In the field of wind energy, he went on, a wind farm of 250 kilowatts (kW) is under construction and other projects for desalination, ice-making and village electrification are being considered.

63. He concluded his presentation by outlining the activities of the Egyptian Renewable Energy Development Organization in the fields of training, information and policy-making.

64. The paper was discussed and relevant comments were made on Egypt's activities in the field of solar and wind energy technologies.

65. Many of the participants elaborated on the various applications of solar energy technologies to meet the basic energy needs of rural and remote areas. The solar energy industrial infrastructure in Egypt was discussed extensively by several participants, along with the main socio-economic aspects of the utilization of solar and wind energy technologies.

66. The representative of the Yemen Arab Republic presented a paper on proposals for a solar energy programme in Yemen. He pointed out that solar energy is considered to be the most promising means of solving the energy crisis in the country. He went on to give a summary of energy consumption patterns in Yemen. The main sources of energy in Yemen, he pointed out, were imported oil, wood, agricultural residues and other traditional sources. It is estimated that petroleum products constitute about 32 per cent of the country's total imports and, therefore, the development of indigenous sources of energy, particularly solar energy, is not just important, but essential. The paper included a number of proposals for solar energy training programmes for Yemeni nationals.

67. Several participants commented on the paper on renewable energy in the Yemen Arab Republic. Discussions mainly focused on the availability of reliable data on solar and wind energy potential, and its application in rural and remote areas of the country.

68. The representative of the Sultanate of Oman presented a paper on the utilization of solar and wind energy in rural and remote areas in Oman. He pointed out the difficulties of meeting the energy needs of the numerous villages and communities scattered in rough mountainous areas through the national electricity grid. The development of solar and wind energy resources, he added, is of particular importance to Oman.

69. He indicated that the application of solar and wind technologies is limited to microwave telecommunications stations, solar water pumping and solar water heaters. He concluded his presentation by stressing the need to undertake extensive studies and investigation before embarking on large-scale projects in the field of solar and wind energy.

70. Many participants took part on the discussion on the Omani paper, which centred on the importance of solar and wind energy in a country like Oman. The need for close co-operation with other ESCWA member countries in order to exchange information and experiences was also stressed.

71. The representative of Qatar presented a paper on the solar pilot project in Qatar. The paper extensively described this project. The description included details of technical devices, chemical materials, performance and operation, registration and data acquisition, together with testing facilities.

72. Most of the participants took part in the discussion on the paper of the Qatar project. A detailed explanation regarding the functioning of the system and its reliability was given.

73. The representative of Tunisia presented a paper on small-scale photovoltaic applications in Tunisia. The paper reviewed the perspectives of photovoltaic utilization in rural areas. The representative briefed the participants on the measurement data for different photovoltaic applications. He indicated that comparative studies and cost-benefit analyses had been undertaken regarding the application of small-scale photovoltaic systems. The paper included a description of industrial applications based on different alternative systems. The representative went on to review current activities in the application of photovoltaic systems in Tunisia.

74. The experience of Tunisia was discussed by the participants, especially with regard to the application of photovoltaic systems.

75. A paper on renewable energy and photovoltaic applications in Morocco was presented. The paper included information on the potential of solar and wind energy, and detailed data on the various uses of solar and wind energy technologies in the country. Renewable energy issues are dealt with in Morocco by a National Centre for the Development of Renewable Energy, which operates under the auspices of the Ministry of Energy and Minerals. The national paper of Morocco emphasized photovoltaic applications in the field of telecommunications, pumping water, lighting and protection from corrosion. The paper also included a number of projects for generating power in selected rural areas: the establishment of a solar energy laboratory to test the facilities of flat-plate collectors and an experimental photovoltaic station.

76. The participants took note of the findings of the paper on the Moroccan experience in the field of renewable energy and photovoltaic applications. Several participants indicated that there are high prospects for the utilization of solar and wind technologies in Morocco.

Agenda item 8. Discussion of proposed projects

77. There was consensus among the participants that the inadequacy of data and information on solar, and especially wind potential is a major obstacle to the development of solar and wind energy resources in the region. It is therefore recommended that a proper approach to data acquisition from appropriately selected sites be developed. For this purpose, a consultative group should be formed to review the shortcomings of current practices in the collection and processing of relevant data, and to establish the criteria for the selection of sites, measuring techniques and the definition of parameters for the comprehensive assessment of solar and wind energy potential.

78. The participants agreed on the relevance of the standardization of data collection, processing and presentation at the regional level. The consultative group referred to above could also be assigned the task of reviewing and comparing the methodologies used in each country, with a view to establishing standardized formats applicable at the regional level.

79. The participants were of the opinion that special attention should be given to the development of the manufacture of solar and wind energy system components. To this end, activities concerning the development of solar and wind energy should focus on an assessment of the relevant industries in the region, an investigation of local resources and the availability of technological capabilities.

80. As the lack of relevant technical experience hampers the widespread use of solar and wind energy technologies, the participants recognized the need for training on the installation, operation, repair and maintenance of solar and wind energy systems. In order to achieve this objective, it is recommended that existing training facilities in each country be assessed comprehensively. The findings of such an assessment would then be used to develop training programmes at the regional level.

81. The participants agreed on the importance of developing regional manufacturing standards and specifications in order to facilitate the exchange of systems and/or components, and to ensure the high quality of products and their conformity with the specific needs of rural and remote communities.

82. It was agreed that social acceptance was one of the main factors to be taken into consideration in the promotion of the utilization of solar and wind energy technologies in rural and remote areas. It is therefore recommended that member States adopt promotional programmes in an effort to raise the awareness of rural and remote communities regarding the benefits to be gained from the use of solar and wind energy technologies. Such programmes should also include special provisions to involve users in the operation, maintenance and management of solar and wind energy systems.

83. Owing to the substantial investment required to develop solar and wind energy resources, the participants were fully aware of the need for closer regional co-operation in order to provide financial assistance to countries in the region where a shortage of capital hampered the implementation of national development plans.

84. At the national level, a policy to provide financial incentives should be adopted in an effort to alleviate the high capital cost of solar and wind energy systems. On the other hand, priority should be given to the provision of substantial financial incentives for rural and remote communities where per capita income is often very low.

85. The participants recognized that scant attention has been paid to the demand side of the utilization of solar and wind technologies in rural and remote areas in the region. In spite of the complexity of this issue, several options are offered for the consideration of concerned authorities in the region:

(a) The establishment of official bodies in rural and remote areas where solar and wind energy systems are most likely to be used, in an effort to render technical service, provide assistance and advise on various economic and social matters in connection with the utilization of these systems;

(b) To entrust the central governmental authority dealing with energy issues at the national level with the task of promoting the use of solar and wind energy technologies in rural and remote areas, which should form an integral part of its activities;

(c) To integrate the utilization of solar and wind energy technologies into global rural development programmes for the development of the agricultural sector and small-scale agro-industries in rural and remote areas.

86. As a follow-up to its work, the Seminar invites ESCWA, in co-operation with DIEC in New York, to prepare and convene as early as possible a regional consultative meeting to mobilize financial resources for the implementation of projects related to solar and wind energy in rural and remote areas.

Agenda item 10. Adoption of the final report of the Seminar

87. The report was adopted by the meeting on 3 December 1986.

II. WORKING PAPER ON
"WIND ENERGY FOR RURAL AND REMOTE AREAS IN THE ESCWA REGION"
(E/ESCWA/NR/WG.1/3)

Mahmoud Saleh*

A. Abstract

This paper briefly reviews the energy requirements of rural and remote communities in the ESCWA region and examines the role that wind energy can play to satisfy part of these needs. The basic indicators of wind potential for 23 selected sites in 10 different ESCWA countries are presented. These indicators are computed from the raw data collected for this purpose. It was shown that annual average wind power densities of up to 441 watt/m² could be found in the ESCWA region. Among the 23 selected sites, Socotra Island in Democratic Yemen, Ras Ghareb and Hurghada in Egypt, Ras Muneef in Jordan, Halul Island in Qatar and El Quneitra in the Syrian Arab Republic seem to be the sites with the highest wind potential.

The basic criteria for selecting and evaluating a site for wind energy utilization are discussed in this paper. Also, the potential applications for wind energy in rural and remote areas of the ESCWA region are identified, and the appropriate mature wind technologies relevant to these applications are reviewed. The basic formulae for the quick estimation of the size of WECS and the unit cost of energy generated by them are given in the paper. Tables for the capacity factor, which is considered to be the most important parameter affecting the cost of energy generated by WECS in each of the selected 23 sites, are computed and presented for different speeds of the wind turbines. This information aims at providing engineers in ESCWA member States with the basic tools to select the proper site, assess the wind potential at that site, choose the appropriate wind technology and quickly estimate the size of the system required to satisfy the energy needs of the community located near it, as well as to make a rough judgement of the economic viability of installing WECS at a specific site.

Wind energy activities, including resource assessment, research and development, demonstration projects, commercial applications and the manufacture of components in the ESCWA region are briefly reviewed.

The scope for regional co-operation is discussed and areas for regional and subregional activities are identified; these include the establishment of a wind measuring network, water pumping, sea and brackish water desalination, and ice-making for fish preservation.

B. Introduction

The oldest known use of wind energy was in the ESCWA region, and dates back to 3600 B.C. There is evidence that the ancient Egyptians used windmills for grinding grain and for pumping water from the Nile river to irrigate the surrounding arable lands. Wind energy was also utilized in Egypt in the nineteenth century for pumping water. In the late 1940s and early 1950s, windmills were used extensively for this purpose in many countries in the ESCWA

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region (Egypt, Lebanon, Saudi Arabia, the Syrian Arab Republic, Yemen, etc.). Some of these windmills and the associated pumps were of partial local manufacture.

However, the utilization of windmills declined abruptly with the discovery of oil and its availability at low prices in the ESCWA region, and with the developments in the technology of diesel engines. Failures which occurred in locally made windmills and the relatively high capital cost of imported ones further encouraged farmers to shift to diesel engines for pumping water. Nevertheless, a limited number of old windmills are still in operation in some countries of the ESCWA region (Egypt, the Syrian Arab Republic, etc.).

Nowadays, the situation differs from that of a quarter of a century ago. On the one hand, wind turbine technology has been the subject of intensive development over the last two decades, and on the other, prices have fallen to such an extent that the cost of a unit of energy generated from wind on some sites is comparable or even cheaper than that generated by conventional or non-conventional sources. In view of this, it is of prime importance to find ways and means to promote the utilization of locally available wind resources, using conversion technologies that have now reached a mature state.

In fact, commercially available wind energy conversion technologies are more suited to decentralized applications, which make them more relevant to the needs of small communities. These communities are usually located in rural and remote areas of the ESCWA region. It is worth mentioning that rural communities have mainly agriculture-based economies, while remote communities are characterized by their distant locations from urban sectors, low population density and low rate of socio-economic development. Both types of communities are widely dispersed all over the ESCWA region. Thousands of rural communities are found in ESCWA countries namely: in Democratic Yemen, Egypt, Jordan, the Syrian Arab Republic, the Yemen Arab Republic, etc., in the form of individual villages containing limited populations. Similarly, thousands of remote communities consisting of a small number of families or tribes are scattered in the deserts and mountains in Egypt, Iraq, Jordan, the Gulf countries, the Syrian Arab Republic and the two Yemens. These communities are usually located far from utility power grids, and the extension of power lines to them would imply high investment costs in view of their expected energy consumption. The installation of an autonomous diesel power plant does not seem to be the appropriate solution for their energy problems if there are difficulties in fuel transportation. Therefore, most of these communities are deprived of an adequate supply of energy, and they rely mainly on physical human and/or animal efforts, animal dung and agricultural waste as primary sources of energy. The installation of small-scale wind energy systems in locations that have good wind regimes may partially or totally cover the energy needs of these communities. Such systems are generally amenable to local manufacture, and their use is more likely to lead to the creation of a domestic technological capability and to stimulate small-scale manufacturing industries.

C. Energy requirements for rural and remote communities

The basic energy requirements for the people in rural and remote areas are mainly those covering food preparation, domestic water supply and lighting.

The thermal energy needed for cooking, estimated to be one kWh/capita/day (1) cannot be provided by wind energy, as the energy costs for cooking would be too high. Biogas or solar cookers could be used to supply thermal energy for cooking if the direct burning of agricultural and/or animal residues is to be avoided.

The water for domestic use in most desert and mountainous communities is pumped from scattered wells. In the majority of cases, domestic water from deep wells is hand-lifted by women using ropes and rubber pails who exert great physical effort in lifting the water. It is both a time and effort consuming operation for humans. Kerosene is used for lighting in most cases. The energy required for domestic water pumping, lighting and electrical appliances could be provided by a 3 to 5 kW wind turbine (2).

The major economic activity in rural areas and in some mountainous regions is agriculture. Therefore, irrigation from surface water or deep wells is the main energy consumer. In locations where reasonable wind is available, wind turbines of a rated capacity of from 5 to 10 kW (2) could provide sufficient energy to pump water to irrigate 10 hectares of arable land from depths up to about 20 m. For greater depth and larger areas of cultivated land, wind turbines with higher ratings could be used.

In coastal regions, small communities may have additional energy requirements for sea or brackish water desalination and also for ice-making to preserve fish. The amount of energy required for fresh water (≤ 500 ppm) production from saline water (5,000 to 40,000 ppm) using the reverse osmosis technique ranges between 2 to 12 kWh/m³. For 100 persons, a 3 to 18 kW wind turbine could provide sufficient energy to produce fresh water to cover basic needs. The amount of energy needed for ice-making ranges between 70 to 100 kWh/ton of ice (3).

It should be noted that all the above figures are rough estimates that require adjustment based on wind data, depth of water (surface or underground), kind of crops cultivated, type of arable land, salinity of water (sea or brackish), etc.

D. Wind resource data in the ESCWA region

The power that can be generated by WECS is directly proportional to the cube of the wind speed at the height of the wind turbine. Therefore, an accurate determination of wind speed at a particular site is essential in order to determine the wind turbine size and energy output.

The wind speed and direction vary continuously with time, and the annual average wind speed and wind power density are usually considered to be good indicators of wind potential. However, a detailed analysis requires knowledge of the pattern of wind speed variation. This pattern could be expressed simply by a daily, monthly or yearly frequency distribution curve.

Also, relatively large variations in average wind speed and wind power density may occur over relatively small geographical distances owing to the effects of terrain (mountains, valley tunnelling effects, ground contours, etc.), and of the uneven heating of the earth (coastlines, lakes, etc.). Consequently, wind potential is site specific, i.e., the wind data recorded in one site cannot be generalized either for an area or a country.

Wind data were collected and processed for 23 selected sites in 10 countries in the ESCWA region. These sites are not necessarily the best candidates for the installation of WECS, but they record appropriate wind measurements and made them available for this study. The data presented in table I include the basic indicators of wind potential for the respective sites; these include the annual mean wind speed and annual mean wind power density. The collected raw data were originally provided in different forms. However, one of the main criteria for selecting the sites included in table I is that their wind data are given in a form which allows computations of the different indicators. If the data are given in the form of tables of wind speed intervals versus the corresponding time duration on a daily, monthly or yearly basis, they are easily converted to mid-point speeds (V_k) in m/s versus, the annual percentage duration (T_k). Hence, the annual average of the wind speed V (m/s) and power density P (W/m²) are calculated as:

$$V = \sum_k (V_k \times T_k) \quad \text{m/s}$$

$$P = 0.61 \sum_k (V_k^3 \times T_k) \quad \text{W/m}^2$$

The multiplier 0.61 in the power equation is determined by taking the air density to be equal to 1.225 kg/m³ at 15° C and standard atmospheric pressure at sea level. For higher levels, correction factors should be introduced to both equations.

In the majority of ESCWA countries, data on wind are measured for meteorological purposes only. Therefore, the most valuable information on wind speeds and directions in ESCWA countries are to be found in the records of national meteorological services and oil companies. The utilization of these data has only a limited value as they are related mainly to the general wind regime and not to wind energy assessment requirements. Also, the sites of the measuring stations were selected without taking wind energy application into consideration. Nevertheless, some ESCWA countries (Egypt and Jordan), have initiated programmes to assess wind energy resources and via these programmes they have established wind measuring stations for this purpose.

It was expected that by the end of 1986, Egypt and Jordan would each have reliable data on wind speeds and directions over periods of one year or more for 12 sites selected as possible candidates for wind energy utilization. These data would make it possible for wind energy experts to undertake well-founded site evaluation studies on wind energy utilization.

However, it should be noted that if accurate wind resource data is not available, a number of techniques make it possible to predict the approximate wind regime on a site, if the annual or monthly average wind speed are the only known facts. These techniques stem from the similarity of the shape of the

Table II.1. Wind potential in selected sites of the ESCWA region

Country	Site	Latitude	N	Longitude	E	Source of data	Period	Height (m)	Annual mean		Energy pattern factor (EPF)
									Wind speed m/s	Wind power density W/m ²	
Bahrain	Muharraq	26°	16'	50°	27'	OCWCS	1959-1968	10	4.57	139	2.39
Democratic Yemen	Aden Airport	12°	05'	45	03'	MD	1968-1984	10	4.00	112	2.87
	Riyan Airport	14	38	49	12	MD	1973-1984	10	3.60	102	3.58
	Socotra Island	12	02	54	0	MD	1976-1978	10	6.60	441	2.50
Egypt	Ras Ghareb	28°	22'	33°	04'	EEA	1983	10	6.88	314	1.60
	Hurghada	27	17	33	46	EMA	1943-1975	12	6.30	283	1.13
	Abo Ghossoun	27	-	33	-	EEA/EMA	1983	10	4.93	148	1.23
	East Qainatt	22	54	28	24	GPC/EEA	1984	10	5.60	164	1.53
Jordan	Ras Muneef	32°	22'	35°	05'	RSS	1984	10	6.60	364	2.08
Kuwait	Al-Ahmadi	29°	24'	48°	10'	OCWCS	1960-1972	10	5.30	170	1.87
Oman	Masirah	20°	20'	58°	49'	DGM	1985	10	4.60	139	2.34
	Thumrait	17	40	54	2	DGM	1985	10	5.70	251	2.22
Qatar	Doha	25°	17'	51°	34'	OCWCS	1956-1972	10	3.82	95	2.78
	Ras Rakan	26	08	51	12	OCWCS	1957-1968	12	4.47	123	2.26
	Halul Island	25	40	52	24	OCWCS	1957-1971	10	6.09	261	1.89
Saudi Arabia	Ras Tanura	26°	42'	50°	05'	OCWCS	1967-1972	8	4.01	75	1.90
Syrian Arab Republic	El Quneitra	33°	08'	35°	49'	MOE	-	10	6.58	364	2.09
	Palmyra	34	36	38	15	MOE	-	10	4.95	192	2.60
	Abou Kamal	34	05	40	09	MOE	-	10	4.43	151	2.85
	Qarachuk	37	00	42	05	MOE	-	10	4.00	120	3.00
United Arab Emirates	Jebel Dhanna	24°	11'	52°	37'	OCWCS	1962-1971	12	3.95	79	2.11
	Das Island	25	09	52	35	OCWCS	1958-1972	12	4.13	109	2.57
	Sharjah	25	21	55	23	OCWCS	1960-1969	10	4.14	83	1.91

Keys: OCWCS : Oil Companies' Weather Co-ordination Scheme
 EEA : Egypt Electricity Authority
 EMA : Egypt Meteorological Authority
 GPC : General Petroleum Company

RSS : Royal Scientific Society
 DGM : Directorate General for Meteorology
 MOE : Ministry of Electricity
 MD : Meteorological Department

velocity duration curves measured at different sites, especially if normalized values of wind speed that take the annual mean speed as a reference are used. The Wiebull distribution (4) was found to give an acceptable approximation of velocity duration curves. In some cases, the Rayleigh distribution (4), a variation of the Wiebull distribution, is preferred owing to its apparent simplicity.

E. Site selection and evaluation

WECS are installed either to serve already existing communities in rural, desert or mountainous areas, or areas where new communities are going to be established. It is necessary to select the site of WECS very carefully so as to ensure that the windmill is installed in a location that has the highest wind speed in the area. Since wind characteristics vary significantly over short distances, and the cost of taking measurements on more than one site may be too high, it is more appropriate to utilize techniques that permit wind characteristics to be estimated for an area or site, without the necessity of initiating wind measurements everywhere. A number of techniques have been developed for this purpose. Among these is "existing and supplementary wind data analysis". It is a well-known fact that the atmosphere obeys a series of physical laws, and the knowledge of its state at one or more points allows its state to be predicted at other points. The data collected from a local weather station can be extrapolated so as to cover the area concerned by taking the topography, ecology, and geography of the different sites in the area under consideration into account. After locating the most likely high wind resource sites, measuring instruments could be installed to determine accurate wind characteristics at these sites. More details on site selection for WECS can be found in reference (5).

Once the site is selected, an evaluation should be initiated. It is presumed that wind resource data for the selected site is available either from direct measurements or by using any of the well-known techniques. The knowledge of wind data for the selected site allows the calculation of several indicators for wind potential such as the annual mean wind speed, annual average wind power density, the number of calm hours, the number of hours per year for which the wind speed is less than a certain specified value (e.g. cut-in speed), etc.

In addition, a number of other parameters should also be ascertained, including the maximum gust speed and the maximum number of successive hours for which the wind speed is zero or below a certain specified value.

A factor known as the "energy pattern factor" is commonly considered in site evaluation. This factor is the ratio of actual energy in the varying wind to the energy calculated from the cube of mean wind speed, i.e.,

$$EPF = \frac{\sum (v_k^3 T_k)}{v^3}$$

The energy pattern factor EPF for selected sites in the ESCWA region is included in table II.1. This factor is always greater than unity, indicating that estimates of energy based on mean (hourly) wind speeds are pessimistic.

Criteria other than wind characteristics should also be taken into consideration in site evaluation; these include the distance of the selected site from the water resource (well, river, etc.) in the area under consideration, the location of the site with respect to residential areas and arable land, etc.

F. Potential applications for small-scale WECS and relevant appropriate technologies for rural and remote areas

1. Water pumping

Small-scale wind energy technologies can play an important role in pumping water for household applications, animal husbandry and irrigation. The water requirements for each application are estimated as follows (1):

(a) People

The amount of water needed per capita of population is about:

5 litres per day for survival;
10 litres per day as a bare minimum to sustain life;
20-40 litres per day for a normal life-style in rural and remote areas.

(b) Animals

Horses and cattle : 40 litres per day per head;
Donkeys and camels: 20 litres per day per head;
Sheep and goats : 4 litres per day per head.

(c) Irrigation

The amount of water needed for irrigation depends on the crop, climatic conditions, the kind of land and efficiency of water use. This amount ranges from about 25 m³/ha/day for drip irrigation (corn, wheat, cotton, millet) to about 60 m³/ha/day for flood irrigation (100 m³/ha/day for rice, 70 for sugar-cane, 50 for cotton and 45 for other grains). The total daily water needs (Q m³/day) could be estimated by knowing the population, number of animals and area of land to be cultivated.

The total pumping head H(m) equals the sum of the pump depth (depth of aquifer, well, etc.), the storage tank height and head loss resulting from the water flow through pipes. The energy generated by the wind turbine to cover needs for water pumping may be approximately calculated as:

$$\frac{Q \times H}{\eta} \text{ kWh/year}$$

where η is the hydraulic efficiency ($\eta = 0.5 - 0.7$).

The proper size of the wind energy system may be selected on the basis of knowledge of wind characteristics at the site where the wind turbine will be installed, the amount of energy required for water pumping per year and the type of WECS chosen.

Two categories of WECS can be used for water pumping, namely the direct mechanical pumping system and the wind-electrical pumping system. The first category, i.e., the direct-mechanical pumping system, includes the following three basic types of windmills:

(i) Traditional multi-bladed windmills

The traditional multi-bladed windmill was widely used to pump water and traces of these windmills can be found in some ESCWA countries. A number of workshops still manufacture them in the Syrian Arab Republic. In these systems the windmill rotor is either coupled to the pump directly or through a mechanism that converts the rotary motion of the windmill rotor into a reciprocating one before it is transmitted to the pump. The wind turbine consists of a number (from 6 to 24) of galvanized steel blades. These machines are material-intensive but reliable, robust and require only simple maintenance.

(ii) Modern multi-bladed windmills

During the last decade, new multi-bladed windmill designs have been developed to suit the requirements of modern manufacturing techniques. The larger windmills are similar in size to traditional multi-bladed windmills, but they are much lighter and perform better. Smaller modern multi-bladed windmills are also light and simple to manufacture, but they are not robust and cannot withstand as much heavy use as the traditional small ones. These windmills can be manufactured locally in simply equipped workshops of ESCWA States at a comparatively low cost, provided that the designs are adapted to locally available materials.

(iii) Self-built windmills:

The sails made of cloth or wood to capture wind with wooden or basic steel structure can be manufactured locally at a very low cost, but only in small sizes. The operating performance of such windmills is usually very poor.

The only widely-used mechanical application for windmills is water pumping. Quite a large number of manufacturers both in the developed and developing countries produce direct-mechanical wind pumping systems on a commercial scale. Basic data and prices at 1983 for selected systems are given in table II.2. More details on specifications of these and other systems are found in reference (6).

The terms cut-in, rated, cut-out and survival speeds are defined as follows:

The cut-in speed is the lowest wind speed at which the rotor spins.

The rated speed is the lowest wind speed at which the windmill is designed to generate its rated power.

The cut-out speed is the highest wind speed after which the windmill is shut down to eliminate the possibility of damage.

Table II.2. Basic data on wind mechanical pumping systems

Rotor diameter (m)	Number of blades	Speed (m/s)				Total price (US dollars)
		Cut-in	Rated	Cut-out	Survival	
1.8-7.6	10-20	1.5	-	-	-	4,600-13,500
1.8-4.9	18	4	9	11	-	1,850-11,800
4.8	24	1.7-2.2	-	-	-	1,250
3.0	4	3	-	-	-	4,000-7,000
2.4	4-8	2.7-4.5	6-7	10-14	-	1,200-1,800
5.0	4.5	4	7	15	-	3,000-3,500
3.0	4	3	-	-	-	3,500
5-8	16-20	2.5	-	10-12	-	4,400-12,000
2.7-7.0	18	-	6-7	-	-	2,100-9,500
1.5	2-6	3.5	7.5	20	-	350-900
3.0	6	3	7	12	40	900
3.6	24	2.2	13.5	-	67	

Source: D. Both and L.E.R. van der Stelt, Catalogue of Wind Machines, Working Group on Development Techniques/Consultancy Services Wind Energy Developing Countries, CWD 84-2 (February 1984).

The survival speed is the highest wind speed that the tower and turbine can withstand before being broken.

Usually the power output of the windmill remains constant at its rated value at speeds equal to and higher than the rated speed. The amount of water that can be pumped daily by the wind pumping system may be calculated approximately as:

$$Q = 0.7 \times V^3 \times D^2/H \quad \text{m}^3/\text{day}$$

where V = average daily wind speed (m/sec);
D = rotor diameter (m);
H = total pumping head (m).

In the above formula, the power output of the windmill is taken to be equal to $P = 0.1 V^3$ watts per square metre of the area swept, assuming both the power coefficient and hydraulic efficiency to be equal to 0.4.

The second category of WECS used for water pumping is the wind electric pumping system. In principle, all the wind turbines for electric power generation can also be used to power electric motor-driven pump sets. Therefore, as far as wind turbines are concerned, they are discussed in the

following section. Nevertheless, the wind turbine generator set should be correctly matched to the motor pump set, otherwise system performance will be very poor. This matching should be done by someone with good technical experience in this field. For this reason, some suppliers offer the wind turbine generator set and motor pump set as one package in an effort to ensure the high performance of the system.

The wind-electric pumping system surpasses mechanical systems in that wind turbines can be located on the site with the best wind characteristics, irrespective of the location of water resources. Also, wind-electric systems are more efficient and part of their electric energy output could be used for other purposes, e.g., charging storage batteries that could provide electric energy for some household appliances. However, the technology of wind-electric systems is sophisticated and more time is needed to judge their reliability and lifetime; the technology of wind mechanical systems, on the other hand, is simple and has been known for centuries.

Both types need to be associated with a water storage facility in order to make maximum benefit of the intermittent nature of the wind, and also to have water always available on demand.

2. Small-scale electric power generation

Small-scale wind electric energy conversion systems consist of stand-alone (autonomous) systems of rated output ranging from a few watts up to 25 kW. Most of the commercially available wind turbines in this range are of the propeller-type (horizontal axis), which have either two or three blades. These are low torque, high rotational speed wind turbines that mainly use gears for power transmission. These systems can generate direct current (DC), variable frequency alternating current (AC), or constant frequency AC power, depending on the type of electric generator coupled to the wind turbine, and on the power conditioning unit, if any, associated with the system.

The main components of the commercially available wind electric power generating systems are as follows:

(a) Wind Turbine

This is usually a two or three blade propeller-type (i.e., horizontal axis). The blade material may be either solid or laminated wood, with or without a fibreglass coating. Sheet aluminium blades and fibreglass blades can also be used. The turbine is usually equipped with a control mechanism in order to avoid excessive mechanical stress on the blades at high wind speeds. This control mechanism either changes (feathers) the blade angle or tilts the wind rotor out of high winds.

The parameters that characterise the wind turbine are solidity, which is defined as the ratio of the blade surface area to the rotor swept area; the tip-speed ratio, which is defined as the ratio of the blade tip peripheral speed to wind speed; and the power coefficient, which is defined as the ratio of the output power of the turbine to the power available in the wind stream.

(b) Generators and associated electrical equipment

The most appropriate types of wind-driven electric generators to operate with free-standing systems in rural and remote areas are the synchronous generators (alternators) and asynchronous (induction) generators, which both produce alternating current. The direct current generators are not recommended owing to their regular need for maintenance over short periods of time, and to the expected frequent failures in their commutators. Induction generators are preferred in small WECS since they are self-regulating in that they adjust to varying torques and load conditions. Their output voltage and frequency can be kept constant within a certain range of variation in wind turbine rotational speed, while synchronous generators must be followed by a rectifier-inverter set to obtain a constant magnitude, constant frequency output voltage. Generators coupled to WECS should be designed to withstand severe operating conditions in deserts and on mountains (high ambient temperatures, high humidity, sand-blasts, dust accumulation, etc.).

Equipment to control and regulate the output of AC generators is normally contained in the assembly kit of the wind turbine and generator.

The aperiodic nature of wind necessitates the use of storage systems. Battery storage seems to be the most economic at present. Lead-acid batteries are the most appropriate to store energy in WECS owing to their lower cost as compared with nickel-cadmium ones.

(c) Towers

The tower elevates the wind turbine and generator (for horizontal axis machines) and weighs from several hundred kilograms to a few tons, supporting them at a height that enables the blades to capture the higher winds above the ground, free from any surrounding obstacles. The towers are subject to two types of mechanical stress: compression stress vertically downwards owing to the large weight of the wind turbine, generators and dead weight of the tower itself, and down-wind bending movement resulting from the drag forces of the turbine and tower. The towers can be made of galvanized steel posts or angles, with or without a lattice structure, steel tubular masts, telephone poles, etc. The towers may be free-standing (unsupported) or supported by guys.

Quite a large number of different types of small WECS are produced in developed and developing countries on a commercial scale. Some basic data and system costs for a selected number of commercially available small WECS (up to 25 kW) are given in table II.3. One criterion for selection is the relatively low value of the rated speed (less than 11 m/s) of the system, since the ESCWA region in general is not characterized by high wind regimes. The selected turbines are all of the propeller type and have two or three blades. The generators coupled to the wind turbine are mostly AC generators.

Table II.3. Basic data on wind electric power generation systems

Rated output (kW)	Price (1983) \$US	Speed m/sec				Tower height (m)	Rotor diameter (m)
		Cut-in	Rated	Cut-out	Survival		
11-22	33,000	3.5	8.5	24	50	10	11.0
0.06-1	3,000-7,800	3-3.5	7-9	60-90	60-90	-	1.34-3.2
1.2-5	6,600-7,500	3.5-4	7-9	60-80	-	-	5-7
0.5	1,000-1,150	-	-	-	-	12	2.8
0.5-10	-	3.1-3.6	9.4-10.7	23-25	49-53	11.3	2.3-8.2
0.2-1	1,685-2,500	3.0	8.5	-	20	4.6	1.8-3.3
1-3	8,000	3.5	9	34	-	18	6.0
0.03-15	-	3.0	8	25	40	6-9	0.8-15
0.24-0.3	350	4.5	9	17.9	-	-	2.44
0.5	2,350	3.2	8.5	25	-	7.5-10	2.5
1.8-15	6,000-16,000	3.6-4.5	8.9-10.7	17.8-20	-	-	4-6.1
6.0	-	2.0	8.5	30	0	-	7.6
3-10	15,000-30,000	3.0	9	40	60	-	-
2.2	13,000	3.6	9	30	74	12	5.0
0.5-1	2,300-3,600	3.1-3.8	9.8	-	35-58	15-30	2.03-3.65
6.0	-	4.5	9	-	-	9-12	7.0
10.0	25,000	3.5	9	-	-	-	10.0

Source: D. Both and L.E.R. van der Stelt, Catalogue of Wind Machines, Working Group on Development Techniques/Consultancy Services Wind Energy Developing Countries, CWD 84-2 (February 1984).

3. Water desalination

Small remote communities in deserts, mountains and bordering the sea suffer from a lack of fresh water and have an urgent need for a safe water supply. Some of these areas experience quite abundant and regular wind regimes. The energy of these winds can be harnessed to power desalination plants in order to produce the fresh water necessary to cover the basic requirements of small populations in these communities. It is to be noted that technical capabilities in remote communities are very limited, thus the desalination plants need to be reliable, simple to operate and easy to maintain and use locally available manpower, materials and supplies. RO is a simple, modular desalination process for which energy consumption can be very low,

making it particularly suitable for use with wind energy systems. RO, besides being a proven technology, requires lower capital investment, lower operating and maintenance costs, less construction time and less space than other desalination technologies. RO desalts both brackish water (with a salinity of 1,000 to 10,000 ppm) and sea water (with a salinity up to 40,000 ppm). In both cases, total dissolved solids (TDS) can be reduced to less than 500 ppm, the drinking water standard recommended by the World Health Organization (WHO). Naturally, sea water desalination systems consume five to six times more energy than that consumed by brackish water desalination plants, since they have to desalt water that has a salinity several times higher.

The RO wind-powered desalination plant usually consists of a WECS and desalination equipment. The energy required to produce one cubic metre of fresh water is approximately (7):

$$E = \frac{W}{25 R} \text{ kWh/m}^3$$

where W is the working pressure in bars and R is the recovery ratio, i.e., the ratio between the volume of fresh water and the volume of treated water.

The above formula is derived assuming a 70 per cent efficiency for the pump.

For brackish water, RO membranes can operate at recovery ratios as high as 0.75 to 0.9, and at a pressure of about 30 to 40 atmospheres (one atmosphere = 0.9869 bars). For sea water, the recovery ratio is 0.2 to 0.3 and pressure ranges from 60 to 70 atmospheres. If the RO plant is provided with an energy recovery device, energy consumption can be reduced by 25 to 30 per cent. Therefore, the energy required to produce one cubic metre of fresh water from very low salinity brackish water is estimated to be 1.3 kWh/m³, and from very high salinity sea water it is 13.8 kWh/m³. With an energy recovery system, these values may be reduced to about 1 kWh/m³, and 10 kWh/m³, respectively. If the potable water requirements of the community are known (Q m³/day), and the mean capacity factor for the site where the plant is to be installed is F, then the rated power P of the WECS may be calculated as follows:

$$P = \frac{W \times Q \times F}{600 R} \text{ kW}$$

A typical sea water RO desalination plant producing six m³/day of drinking water is powered by a four kW wind generator with a rated speed of seven m/s.

4. Ice-making

Several fishing villages can be found scattered on the long coasts of the ESCWA region. One of the most serious problems facing fishermen in these remote villages is the preservation of fish until it reaches the consumption centres. Wind energy, which is abundant in most of these coastal areas, can be utilized to drive an ice-making plant producing ice from sea water. A

significant advantage of an application such as ice-making is that the product (ice) can be easily stored. The ice can be produced during periods when enough wind power is available, and it can be stored at a relatively low cost until required.

The energy consumption for fresh water ice-makers varies from 65 kWh/ton for small plants (three tons/day) to 40 to 50 kWh/ton for larger plants (six tons/day), (3). Energy consumption for sea water ice-makers is from 33 per cent to 67 per cent greater than that for fresh water ice-makers. The component that consumes the major part of energy in an ice-making plant is the compressor (about 70 per cent of the energy), followed by the sea-water pump (about 10 per cent of the energy), then the other components and auxiliaries.

The price of an ice-maker with a capacity of 3 tons/day ranges between \$US 20,000 to 24,000, excluding the cost of WECS, interfacing equipment and storage facilities. The economics of such plants should be thoroughly examined for each case, taking into account the social benefits of installing these plants.

G. Economic considerations

The economic viability of harnessing wind energy in a specific site is one of the basic criteria that should be considered when comparing the utilization of different energy resources such as fossil fuels, solar energy, wind energy, etc. Economic viability is mainly judged by making a cost-analysis for the system over its expected lifetime. There are different approaches for the analysis of the system cost, some of which are highly sophisticated while others are quite simple. The "present value" and "unit energy cost" methods are considered to be suitable approaches for judging the economics of WECS. The "unit energy cost" approach has been adopted in this paper so as to enable the user to judge the economics of different WECS at a site with certain wind characteristics quickly and also to compare different sites with reasonable accuracy as far as the economic use of wind energy is concerned.

Many factors should be taken into account when calculating the unit cost of energy generated by the wind energy conversion system on a specific site. However, the most important of these factors is the capital investment in the system and the capacity factor of the system on that site. The term "capacity factor" (F) is defined as the ratio of the total energy generated by the WECS per year under the wind conditions prevailing at that site to the energy generated per year if the WECS were to operate at its rated capacity all the time. This term can be expressed simply as follows:

$$F = \frac{\text{kWh generated/year}}{8,760 \times \text{rated capacity in kW}}$$

The value of F varies for each wind regime and for the different WECS operating under the same wind conditions, i.e., F is a function both of the wind characteristics and the turbine power curve that is governed by its cut-in, rated and cut-out speeds, as well as efficiency.

If efficiency is assumed to be constant in the range of wind speeds from cut-in up to the rated value, then the power output of the turbine in this range will be proportional to the cube of the wind speed.

Hence, the capacity factor at a site with a known wind frequency distribution curve, or with records from a wind spectrum analyser (wind classifier) can be expressed as:

$$F = \sum_k \left[\left(\frac{V_k}{V_r} \right)^3 \times T_k \right] + T$$

In another approach, the turbine power curve is approximated by a quadratic equation in the range between the cut-in and rated speed. In this case, the capacity factor is computed as:

$$F = \sum_k \left[\left(\frac{V_k - V_o}{V_r - V_o} \right)^2 \times T_k \right] + T$$

where V_k = the mid-point speed for the k^{th} speed interval of the classifier, which is larger than the cut-in speed and smaller than or equal to the rated speed;

V_o = cut-in speed;

T_k = the number of hours corresponding to the k^{th} speed interval, divided by the total number of hours for which the measurements have been recorded (preferably one year or a multiple number of years);

V_r = rated speed of the wind turbine;

T = the number of hours for which the wind speed is larger than the rated speed and smaller than or equal to the cut-out speed, divided by the total number of hours for which measurements have been recorded.

The expression F is derived from the assumption that the WECS generates no power either below the cut-in speed or over the cut-out speed. Also, the WECS output is considered to be constant at its rated value in the range of wind speeds between the rated speed and cut-out speed. The value of F can be easily obtained from the wind power duration curve or frequency distribution curve under the above-mentioned assumptions. Usually the annual energy output is calculated from the turbine power curve of the WECS, provided by the manufacturer and the available wind data. Nonetheless, the proposed approach gives more quick and reasonably accurate values for the capacity factor at a certain site as a function of the rated speed of the turbine. The cut-out speed in this analysis is assumed to be 25 m/s. The deviation of the cut-out speed from the assumed value within practical limits will not have any marked effect on the value of the capacity factor in the specific wind conditions of the ESCWA region.

Based on the available wind data and the above assumptions, the capacity factors are computed for the different values of both the cut-in speed (2, 2.5, 3 and 3.5 m/s) and the rated speed (7, 8, 9, 10, and 11 m/s) of the wind turbine for selected sites in the ESCWA region. Table II.4 gives the capacity factors for these sites at a cut-in speed of three m/s, and different values for the rated speed of the wind turbines using the constant efficiency assumption and quadratic approximation for the wind turbine power curve. The values of F between brackets in table II.4 are those that have been computed using the quadratic approximation of the power curve. It can be seen from table II.4 that both approaches give very close results. Hence, the capacity factors for other values of the cut-in speed (2, 2.5 and 3.5 m/s) are computed using the quadratic approximation for the power curve which is presented in table II.5.

The higher the capacity factor, the lower the cost of the energy unit generated by WECS at that site. Therefore, the data given in table II.5 indicate that the most promising sites among those selected from the point of view of energy generation cost are Socotra Island in Democratic Yemen, Ras Ghareb and Hurghada in Egypt, Ras Muneef in Jordan, Thumrait in Oman, Ras Rakan and Halul Island in Qatar, and El Quneitra in the Syrian Arab Republic.

The cost C of one kWh in mills generated by WECS is given by the following (1):

$$C = \frac{r(1+r)^n}{(1+r)^n - 1} \cdot \frac{I}{8.76F} + \frac{mI}{8.76F} \text{ mills/kWh}$$

where I = total capital investment in the WECS in US dollars per installed kilowatt;

n = expected lifetime of the WECS in years;
r = annual interest rate in US dollars per unit;
m = fraction of the capital investment needed per year for the operation and maintenance of the WECS.

The above formula is derived while assuming that the time taken for the planning and construction phases is short when compared to the lifetime of the WECS, hence the effect of inflation on the capital investment is not taken into account. Otherwise, the value of the capital investment should be adjusted from the base year cost (the start of the planning phase) to the year of commercial operation of the WECS.

The above formula can be approximated to a more simple form if an expected lifetime is assumed (say 15 years) and a range of the variation of the interest rate is considered (say 0.04 to 0.16). The exact lifetime of the wind turbine cannot be predicated since a number of wind turbines installed at the South Pole have been performing for more than 20 years, while those installed in mountainous regions were damaged after only a few months of operation (8). Both locations are windy and subject to severe weather conditions.

The cost C can be simply expressed, with a reasonable degree of accuracy, as follows:

$$C = \frac{I}{F} (0.084 r + 0.114 m + 0.0066) \text{ mills/kWh}$$

The above expression is valid for $n = 15$ and $0.04 \leq r \leq 0.16$. The value of m , i.e., the fraction of capital investment needed per year for the operation and maintenance of the WECS, usually varies between 0.02 and 0.07, depending on the labour cost in the country under consideration. It is assumed to be 0.04 for Egypt and the Syrian Arab Republic, 0.05 for Democratic Yemen and Jordan, and 0.07 for all of the Gulf countries in this analysis.

It is obvious from the above expression that the cost of an energy unit generated by WECS is directly proportional to the capital investment per installed kilowatt of the WECS, and inversely proportional to the capacity factor at the site where the WECS is to be installed and for the relevant rated speed. It is necessary, therefore, to emphasize that the capital investment per installed kilowatt is not by itself an indicator of the energy cost. To illustrate this fact, two WECS selected from those mentioned in keyed reference 6 (pp. 37 and 42), have the following manufacturer's data:

	<u>Model-A</u>	<u>Model-B</u>
Cut-in speed	3.5 m/s	3.6 m/s
Rated speed	7 m/s	11 m/s
Cut-out (survival) speed	80 m/s	26 m/s
Rated power output	2.5 kW	2 kW
Price of wind turbine and generator	\$US 6,600	\$US 5,100

The capital cost of the wind turbine and generator per installed kilowatt is 2,640 \$/kW and 2,550 \$/kW for Models A and B respectively. It would seem at first glance that it is more economical to install model-B on a site, rather than to install Model-A on the same site. However, computations reveal that the unit of energy generated by Model-A costs much less than that generated by Model-B. This is clearly shown in table II.6 where the unit energy cost at an interest rate of 6 per cent is given for selected sites in the ESCWA region for both model A and model B.

In general, if the cost is the criterion applied for selecting the WECS to be installed on a specific site, a careful judgement should be made since wind characteristics at that site must be taken into account.

The capital investment per installed kilowatt that was taken into consideration when computing the unit energy cost presented in table II.6 does not include the cost of storage facilities, the tower and peripheral equipment. The addition of this could increase the value of C by 50 to 100 per cent, depending on the type of load and the number of windless days at the WECS location.

For the sake of comparison, the average cost of a unit of electrical energy at the end user terminal generated by electric utilities is given in table II.7 for selected ESCWA countries (9) at 1982 oil prices.

Table II.4. Capacity factors for selected sites in the ESCWA region at different rated speeds for wind turbines
($V_0 = 3 \text{ m/s}$)

Country	Site	Capacity factor for rated speed (m/s)							
		8		9		10		11	
Bahrain	Muharraq	0.28	(0.27)	0.23	(0.22)	0.18	(0.18)	0.15	(0.15)
Democratic Yemen	Aden Airport	0.29	(0.29)	0.23	(0.22)	0.17	(0.16)	0.13	(0.13)
	Riyan Airport	0.24	(0.24)	0.19	(0.19)	0.14	(0.14)	0.11	(0.11)
	Socotra Island	0.59	(0.59)	0.49	(0.49)	0.40	(0.40)	0.34	(0.34)
Egypt	Ras Ghareb	0.63	(0.60)	0.53	(0.51)	0.44	(0.43)	0.34	(0.36)
	Hurghada	0.55	(0.52)	0.49	(0.46)	0.40	(0.39)	0.35	(0.34)
	Abo Ghossoun	0.37	(0.33)	0.28	(0.25)	0.23	(0.21)	0.18	(0.17)
	East Qainatt	0.44	(0.40)	0.33	(0.30)	0.26	(0.24)	0.20	(0.19)
Jordan	Ras Muneef	0.58	(0.58)	0.50	(0.49)	0.43	(0.41)	0.34	(0.34)
Kuwait	Al-Ahmadi	0.34	(0.34)	0.30	(0.30)	0.21	(0.20)	0.17	(0.17)
Oman	Masirah	0.31	(0.27)	0.26	(0.23)	0.20	(0.18)	0.16	(0.15)
	Thumrait	0.40	(0.36)	0.39	(0.32)	0.30	(0.26)	0.25	(0.24)
Qatar	Doha	0.20	(0.19)	0.16	(0.16)	0.13	(0.12)	0.10	(0.10)
	Ras Rakan	0.44	(0.43)	0.41	(0.40)	0.27	(0.27)	0.22	(0.22)
	Halul Island	0.44	(0.43)	0.40	(0.39)	0.33	(0.33)	0.27	(0.27)
Saudi Arabia	Ras Tanura	0.19	(0.19)	0.15	(0.15)	0.11	(0.11)	0.09	(0.085)
Syrian Arab Republic	El Quneitra	0.58	(0.56)	0.57	(0.56)	0.49	(0.48)	0.38	(0.38)
	Palmyra	0.38	(0.35)	0.37	(0.35)	0.31	(0.30)	0.24	(0.23)
	Abou Kamal	0.30	(0.27)	0.29	(0.27)	0.23	(0.23)	0.19	(0.18)
	Qarachuk	0.24	(0.21)	0.23	(0.21)	0.20	(0.18)	0.15	(0.14)
United Arab Emirates	Jabal Dhanna	0.21	(0.21)	0.17	(0.17)	0.13	(0.13)	0.10	(0.10)
	Das Island	0.22	(0.22)	0.18	(0.18)	0.15	(0.14)	0.12	(0.11)
	Sharjah	0.22	(0.22)	0.17	(0.17)	0.13	(0.14)	0.11	(0.10)

Table II.5. Capacity factors for selected sites in the ESCWA region at different cut-in and rated speeds for wind turbines

S i t e	$V_o = 2 \text{ m/s}$					$V_o = 2.5 \text{ m/s}$					$V_o = 3.5 \text{ m/s}$				
	$V_r=7$	8	9	10	11	7	8	9	10	11	7	8	9	10	11
Muharraq	0.38	0.30	0.25	0.21	0.17	0.36	0.28	0.24	0.19	0.16	0.35	0.26	0.21	0.17	0.13
Aden	0.31	0.30	0.24	0.19	0.15	0.30	0.30	0.23	0.17	0.14	0.29	0.29	0.22	0.16	0.12
Riyan	0.26	0.25	0.20	0.16	0.13	0.25	0.25	0.19	0.15	0.12	0.24	0.24	0.18	0.13	0.10
Socotra Island	0.60	0.60	0.51	0.42	0.37	0.59	0.59	0.50	0.41	0.36	0.59	0.59	0.48	0.39	0.33
Ras Chareb	0.73	0.64	0.55	0.47	0.39	0.71	0.62	0.53	0.45	0.37	0.67	0.58	0.49	0.41	0.33
Hurghada	0.65	0.55	0.50	0.42	0.37	0.63	0.54	0.48	0.41	0.36	0.61	0.50	0.45	0.37	0.32
Abo Ghossoun	0.43	0.37	0.29	0.24	0.20	0.41	0.35	0.27	0.22	0.18	0.37	0.31	0.23	0.19	0.15
East Oainatt	0.51	0.44	0.34	0.28	0.23	0.49	0.42	0.32	0.26	0.21	0.43	0.37	0.27	0.21	0.17
Ras Muneef	0.62	0.53	0.45	0.38	0.32	0.60	0.51	0.43	0.36	0.30	0.56	0.47	0.39	0.32	0.26
Al-Ahmadi	0.46	0.37	0.32	0.23	0.19	0.43	0.35	0.30	0.21	0.17	0.42	0.32	0.28	0.18	0.15
Masirah	0.40	0.31	0.27	0.22	0.18	0.38	0.30	0.25	0.20	0.16	0.34	0.25	0.21	0.17	0.13
Thumrait	0.47	0.40	0.36	0.31	0.27	0.45	0.38	0.34	0.29	0.25	0.41	0.34	0.31	0.26	0.22
Doha	0.29	0.22	0.18	0.15	0.12	0.27	0.20	0.17	0.13	0.11	0.26	0.18	0.15	0.11	0.09
Ras Rakan	0.51	0.46	0.40	0.27	0.22	0.49	0.43	0.39	0.26	0.22	0.48	0.40	0.37	0.24	0.19
Halul Island	0.53	0.46	0.42	0.39	0.29	0.52	0.45	0.40	0.34	0.28	0.51	0.42	0.38	0.32	0.25
Ras Tanura	0.28	0.21	0.17	0.13	0.10	0.26	0.20	0.16	0.12	0.09	0.25	0.17	0.14	0.10	0.08
El Quneitra	0.57	0.57	0.57	0.50	0.40	0.56	0.56	0.56	0.49	0.39	0.56	0.56	0.56	0.48	0.36
Palmyra	0.37	0.36	0.36	0.32	0.25	0.36	0.35	0.35	0.31	0.24	0.35	0.35	0.35	0.30	0.22
Abou Kamal	0.30	0.29	0.28	0.25	0.20	0.28	0.28	0.27	0.24	0.19	0.27	0.27	0.27	0.23	0.17
Qarachuk	0.24	0.23	0.22	0.19	0.15	0.22	0.21	0.21	0.18	0.14	0.21	0.21	0.21	0.18	0.13
Jabal Dhanna	0.31	0.24	0.20	0.15	0.13	0.29	0.22	0.18	0.13	0.11	0.28	0.20	0.16	0.11	0.09
Das Island	0.31	0.24	0.20	0.16	0.13	0.29	0.22	0.19	0.15	0.12	0.28	0.21	0.17	0.13	0.10
Sharjah	0.33	0.25	0.20	0.15	0.12	0.32	0.23	0.18	0.14	0.11	0.30	0.21	0.16	0.11	0.09

Table II.6. Cost of unit of energy generated by two WECS with different rated speeds if installed on selected sites in the ESCWA region

Country	Site	O & M (m)	Capacity factor (F)		Unit of energy cost (C) mills/kWh	
			Model-A	Model-B	Model-A	Model-B
Bahrain	Muharraq	0.07	0.35	0.13	72	188
Democratic Yemen	Aden Airport	0.05	0.29	0.12	67	155
	Riyan Airport	0.05	0.24	0.10	80	186
	Socotra Island	0.05	0.59	0.33	33	56
Egypt	Ras Ghareb	0.04	0.67	0.33	24	48
	Hurghada	0.04	0.61	0.32	27	49
	Abo Ghossoun	0.04	0.37	0.15	44	105
	East Qainatt	0.04	0.43	0.17	38	93
Jordan	Ras Muneef	0.05	0.56	0.26	34	72
Kuwait	Al-Ahmadi	0.07	0.42	0.15	60	163
Oman	Masirah	0.07	0.34	0.13	74	188
	Thumrait	0.07	0.41	0.22	62	111
Qatar	Doha	0.07	0.26	0.09	98	272
	Ras Rakan	0.07	0.48	0.19	53	129
	Halul Island	0.07	0.51	0.25	50	98
Saudi Arabia	Ras Tanura	0.07	0.25	0.08	101	306
Syrian Arab Republic	El Quneitra	0.04	0.56	0.36	29	44
	Palmyra	0.04	0.35	0.22	47	72
	Abou Kamal	0.04	0.27	0.17	61	93
	Qarachuk	0.04	0.21	0.13	78	122
United Arab Emirates	Jabal Dhanna	0.07	0.28	0.09	91	272
	Das Island	0.07	0.28	0.10	91	245
	Sharjah	0.07	0.30	0.09	85	272

Table II.7. Cost of electrical energy generated by electric utilities in selected ESCWA countries

Country	Cost of unit energy mills/kWh
Democratic Yemen	146
Egypt	42
Jordan	77
Kuwait	110
Oman	130
Qatar	62
Saudi Arabia	49
Syrian Arab Republic	84
United Arab Emirates	135

The values given in table II.7 should be doubled or more than doubled for remote and rural areas that rely on small diesel generator units which have a much higher capital investment per installed kW or that require the extension of special power lines from the national grid, which implies high additional costs.

H. Wind energy activities in the ESCWA region

1. Resource assessment

(a) Egypt (10)

In 1972, the Ministry of Electricity (MOE) of Egypt, jointly with the Oklahoma State University of the United States, launched a wind resource assessment programme. This programme was financed by the United States National Science Foundation.

Phase I and phase II of the programme were completed and their final reports were published in 1975 and 1979 respectively. Phase I of the programme included a resource availability study in which the already existing wind data from meteorological records were collected and analysed to define the most promising locations for wind energy utilization. Phase II of the programme started in 1978, and mainly consisted of a detailed measurement hardware programme. Several continuous wind recording instruments were installed in different sites on the Mediterranean coast (Mersa-Matruh, Ras El-Hekma, Sidi Abdel-Rahman, El-Alamain and Borg El-Arab) and on the Red Sea Coast (Safaga, Hurghada, and Ras Ghareb). The data collected from these stations were analysed and the main conclusion was that, throughout the year,

the average wind speeds on the Mediterranean coast are not as high as were expected. Nevertheless, the data revealed that the Red Sea coast seems to be the region with the highest wind potential. Phase III of the programme was intended to improve the time accuracy of the anemometers in order to handle data processing automatically using microcomputers, and to determine the wind profile in the vertical direction up to heights of 75 metres. For reasons that are not known, this phase was not implemented.

In 1984, the Egyptian MOE/United States Agency for International Development (USAID) awarded a contract to Battelle Pacific North-west Laboratories (PNL) to conduct a wind resource assessment for Egypt within the MOE/USAID renewable energy resource field demonstration project. In March 1985, six measurement stations were installed at three sites on the Red Sea coast, namely: Ras Ghareb, Hurghada and Ras Golan and at three sites on the Mediterranean coast, namely: El-Kasr, Obied and Ras El-Hekma. While this present paper was being prepared, it was reported by officials of MOE that data for these six sites had been collected over a one year period and are being processed in the meantime. Also, it was reported that MOE is installing measuring stations at another six sites.

The Academy of Scientific Research and Technology (ASRT) is financing an R and D project on the utilization of solar and wind energy in Sinai. A research team from the National Research Centre (NRC) has been implementing this project since July 1984. The first phase of the project covered the analysis of wind data for three sites in Sinai, namely: El-Arish in the northern part of Sinai (longitude 31°16' E and latitude 33°45' N), and El-Torr in the southern part of Sinai (longitude 28°14' E and latitude 33°37' N), and Abo-Rdais in the southern part of Sinai (longitude 28°53' E and latitude 33°11' N). The raw data was collected from the records of the Egyptian Meteorological Authority for several years before 1967. Some additional data was measured by mobile measuring instruments.

MOE jointly with the General Petroleum Corporation (GPC), installed a wind classifier in East-Oainatt (longitude 29° E and latitude 23° N) in the south-western part of Egypt to evaluate the wind potential in that region.

(b) Jordan (11)

In 1983 RSS undertook a study assigned by the German Agency for Technical Co-operation (GTZ) and financed by the German Federal Ministry for Economic Co-operation (BMZ). Parts of this study consisted of drawing up an inventory and processing the available wind data collected from about 30 stations run by the Jordanian Meteorological Department (JMD), the Natural Resources Authority (NRA), the Jordan Valley Authority (JVA) and RSS. This analysis was the first attempt to assess wind energy potential in Jordan.

In 1983 RSS also set up its own wind measuring network. Four stations were installed in Jesr Al-Ruwaished (longitude 32°35' E and latitude 38°30' N), Kharana (longitude 31°45' E and latitude 36°40' N), Jarf Al-Darawish (longitude 35°55' E and latitude 36°45' N), and Al-Tayeba (longitude 35°40' E and latitude 35°50' N). A number of additional data acquisition systems to monitor wind data on the sites of wind energy pilot projects were being installed during the preparation of this paper.

(c) Oman (12)

In 1986, a private sector organization OMZEST Group Companies commissioned an expert to assess solar and wind potential in Oman. This expert collected data recorded by 21 stations run by the Directorate-General of Meteorology, and three stations run by Petroleum Development of Oman. The collected data were being processed during the preparation of this paper. This is the first attempt to undertake an assessment of wind resources in Oman.

(d) Syrian Arab Republic

In 1984, the Directorate of Research in the Syrian MOE published an overall assessment of wind potential in the Syrian Arab Republic, based on the data recorded by the meteorological services. However, a more detailed analysis has to be carried out, and more measuring stations to assess wind resources need to be installed before a solid wind data base becomes available.

2. Research and development

A number of universities and research institutes in the ESCWA region are carrying out R and D projects on different aspects of wind energy. Research papers on wind energy assessment, application, component design, etc., are being presented at technical meetings and conferences and published in scientific journals by researchers working in a number of academic and applied research institutions in the ESCWA region.

3. Demonstration projects

(a) Democratic Yemen (13)

In December 1979, the Public Corporation for Electric Power (PCEP), initiated a pilot experiment consisting of an 18 kW wind energy conversion system. This was the first WECS designed to generate electric power to be installed in the ESCWA region. The WECS was supplied and erected in the form of aid from the Danish organization Development Aid from People to People. The rated power of the WECS was generated at a wind speed of 20 knots (10.28 m/s). The wind turbine diameter was 9 m and the height of the tower was 12 m. The cost of the system was estimated to be about 4,925 Democratic Yemen dinars (YD) (\$US 12,312), including installation. The plant faced a number of mechanical difficulties. As the speed of the rotor increased to a certain value, the system resonated with the natural frequency of the structure at the hub. Trials have since been made to eliminate this phenomenon, but only the rotor speed at which resonance occurred was shifted from 80 rev/min to 82 rev/min, which is still within the working range of the rotor. Also, the system was installed on the site of PCEP, which seems to be a site of low wind potential. Eventually the system was dismantled. It is hoped that PCEP will take the decision to reinstall the system at another promising site, provided that the problem of vibration can be solved.

(b) Egypt (10)

Two WECS, each with a rated power of 20 kW, are being installed on the first experimental farm at East-Oainatt. This is located about 1,500 kilometres (km) to the south-west of Cairo at the interception of longitude 29°E and

latitude 23°N. The WECS will be provided by a German company according to a technical assistance agreement between the Government of Egypt and the Government of the Federal Republic of Germany. One WECS will have a horizontal axis wind turbine and the other will have a Darrieus-type vertical axis turbine. Both will be tested in the wind regime of East-Oainatt.

A solar village is currently being built in the area of East-Oainatt. The Government of Italy will provide the financial resources, as well as the technical expertise, to implement this project. All the energy requirements for the solar village will be provided by an integrated solar/wind/biogas energy system of 240 kWp solar photovoltaic panels and 240 kW wind energy conversion systems. The wind system consists of six WECS each with a rated power of 40 kW. The procurement of the hardware has already been completed. It is hoped that the systems will be installed by the end of 1986.

A 55 kW WECS to provide energy for an ice-maker, has been procured by the MOE within a UNDP financed project executed by the United Nations Department for Technical Co-operation for Development (UNDTCD). This system will be installed in Abo Ghossoun (400 km to the south of Hurghada) on the Red Sea coast. The detailed specifications of this system were not available.

A project document on the development of East-Oainatt has been finalized by MOE/UNDTCD and submitted to UNDP for possible financing. Among other energy resources wind energy is proposed for use in this area. Units of 250 kW rated power are proposed for use, in addition to solar photovoltaic power systems of 25 or 50 kWp water pumping systems and 250 kW diesel generators as a back-up for essential services.

A wind farm connected to the grid is proposed for establishment in Ras-Ghareb on the Red Sea coast within a MOE/USAID project. This project aims at the design and installation of a multi-unit wind farm suitable for inter-connection with the existing diesel-powered grid distribution system. The project also includes an on-the-job training programme on operation, repair and maintenance of the wind systems for local technical manpower.

(c) Jordan (11, 14)

A wind-electric pumping system (WEPS), based on a 24-blade 10 kW wind generator, battery storage and three submersible pumps at depths of 90, 100 and 110 m, was installed in Jarf Al-Darawish. The overall efficiency of the WEPS is 7 per cent and the pumping rate is 30 m³/day from a depth of 87 metres. The system has faced many problems. The capacity of the associated generator was much larger than the rotor capacity. New blades were manufactured to replace the old ones in order to increase the rotor diameter to match the rotor capacity with the capacity of the generator. The front bearing house of the gear box was broken and replaced by another. At times the hydraulic safety system did not function properly. This WEPS was reinstalled in 1985 on a new site at Al-Kharana about 70 km to the south-east of Amman. The site is being prepared as a fully equipped wind station with wind measuring instruments (wind classifiers, natural power data loggers, etc.), a microcomputer for data storage and processing, test facilities, etc.

A 17.5 kW WEPS driven by an Aeroman wind generator has been installed in Jarf-Al-Darawish. The average expected output of this system is 100 m³/day from a depth of 50 m.

A WEPS that will pump 150 m³/day from a depth of 180 m is being installed in Jesr Al-Ruwaished.

There are plans to install WEPS with a pumping rate of 100 m³/day from a well 55 m deep at Al-Twana.

A mechanical wind pump with a rotor diameter of 4 m, designed and manufactured by RSS, including the pump and gear box, has been installed in El-Mudawara. It has a daily output of 50 m³ from a depth of 13 m.

All the above-mentioned demonstration projects in Jordan were installed by RSS.

(d) Oman (2, 12)

Petroleum Development of Oman financed the manufacturing and installation of a 12-blade fan wheel type windmill for pumping water. The designs were made by the Intermediate Technology Development Group (ITDG) of the United Kingdom. The windmill was installed in 1980 at the Khabourah Agricultural Development Project near Muscat. However, this windmill faced several operational problems in operating it and the system was dismantled.

(e) Syrian Arab Republic (15, 16)

In 1979, the MOE of the Syrian Arab Republic installed a hybrid solar-wind power system in Edra about 25 km to the north-east of Damascus. The system consists of two kWp solar photovoltaic panels at 24 volts, a 1 kW wind turbine driving a 220/380 three-phase generator connected to a step-down transformer and rectifier with an output voltage of 24 volts DC which supplies 2,700 ampere-hours (Ah) 24 volt storage batteries that are also connected to the photovoltaic panels. The batteries supply a communications station. The wind turbine has a horizontal axis two-blade rotor. This system is probably the first combined solar wind system to be built in the ESCWA region. Unfortunately, the system is not equipped with measuring instruments for monitoring and its output power is not currently utilized; therefore, the system is not in operation. One of the problems is a shortage of manpower, and the other is the fresh water supply. The water pumped from the site is brackish, not potable, though it can be used for purposes other than drinking. Drinking water is brought in daily from Damascus.

(f) Yemen Arab Republic (17)

A few windmills for pumping water, provided by the Ministry of Agriculture, were installed in the early 1970s around Taiz and other isolated areas; they all broke down. The trials revealed that there was considerable co-operation on the part of the rural people and local authorities. However, they also demonstrated that without proper organization, the availability of trained fitters to look after the wind system, spare parts and funds, the provision of mechanical equipment is only a partial requirement that does not lead to the successful promotion of this technology.

4. Commercial applications

(a) Syrian Arab Republic (15, 16)

About 4,500 direct mechanical wind pumping systems are in operation in the Syrian Arab Republic. Most of these WEPS are installed in and around Nabek, about 100 km to the north-east of Damascus. Most were locally manufactured. However, a few imported machines can also be found (Aeromotor). The WEPS are used to pump water to small farms in and around Nabek.

5. Manufacturing of components

(a) Syrian Arab Republic (15, 16)

Wind pumping systems have been manufactured in the Syrian Arab Republic for more than forty years at a workshop in Nabek. The design of manufactured wind pumps follows the traditional one. Local machines are manufactured in three sizes:

- (i) The large size has a rotor with a 16 ft diameter and a pumping rate of two litres/s from a depth of 25 m at a wind speed of eight m/s. The system cost, including the pump, tower and installation, is about 17,000 Syrian pounds (£S) (\$US 2,100);
- (ii) The medium size has a rotor with a 12 ft diameter and a pumping rate of one litre/s, from a depth of 25 m at a wind speed of eight m/s. The total system cost, including installation, is about £S 14,000 (\$US 1,750);
- (iii) The small size has a 10 ft diameter rotor with a pumping rate of 0.4 litres/s from a depth of 25 m at a wind speed of eight m/s. The total system cost is £S10,000 (\$US 1,250).

However, the WEPS industry in the Syrian Arab Republic is facing a serious problem in that the depth of the underground water has increased rapidly in the area of Nabek since some owners started to utilize diesel-driven pumps with comparatively high pumping rates, which has led to the depletion of the underground water supply.

I. Scope for regional co-operation

The wind data compiled for selected sites in ESCWA countries reveal that a number of locations in this region enjoy a reasonably high wind potential (annual average wind power densities of up to 441 watt/m² and capacity factors up to 0.73). In many cases, the communities located near these sites either suffer from a shortage or are deprived of adequate energy supplies. In other cases, they are provided with energy at a very high cost from small thermal power plants, or from individual diesel generator units. In addition, several manufacturers in different developed and developing countries produce various types and sizes of small-scale wind energy conversion systems on a commercial scale.

In the light of the above-mentioned facts, it is obvious that in selected sites in the region an energy source (wind potential), the need for energy that can be provided by this source and the means (WECS) to enable this source to satisfy these needs at a reasonable cost, exist. These are the three basic requirements needed to promote the utilization of any energy source. However, the ESCWA region is still a long way from taking meaningful action to promote the utilization of its available wind potential. Except for Egypt, Jordan and to some extent the Syrian Arab Republic, the ESCWA region has no serious activities or programmes in any wind related area such as resource assessment, research and development, demonstration projects, etc. Among other reasons, this could be owing to the lack of awareness at the policy-making level, a lack of experience in that field, the unsuccessful trials to utilize wind energy in some ESCWA countries (Democratic Yemen, Oman and the Yemen Arab Republic). However, it is of prime importance at this stage to persuade concerned decision makers and experts in ESCWA member States to take the necessary measures to promote the utilization of wind energy, and to place special emphasis on rural and remote areas. It is envisaged that regional co-operation would strongly support any action taken at the national level to achieve this target. Regional co-operation is activated and strengthened inter alia through the exchange of information, exchange of experiences, organization of joint research and development activities, and the implementation of demonstration projects in the area of wind energy at the subregional and regional levels.

In this connection, the ESCWA secretariat has contributed to the activation of regional co-operation in promoting the utilization of renewable energy resources, including wind, and placing special emphasis on rural and remote areas. The ESCWA secretariat has established a Renewable Energy Information Network for Western Asia (REINWA), organized a number of regional meetings in this area (including this seminar), prepared several studies on the topic and launched a demonstration project on biogas technology.

The ESCWA secretariat recognizes the need to launch demonstration projects that are aimed at examining the feasibility of utilizing small-scale wind technologies as a way to provide part of the energy needs of rural and remote communities that are located in areas with good wind regimes. In this context, ESCWA organized this seminar to exchange ideas and to recommend concrete project proposals that can be presented for adoption to the Intergovernmental Technical Meeting that follows this seminar.

The project documents for the adopted projects will be prepared by ESCWA and submitted for possible financing to donor agencies within and outside the United Nations system. In line with this, some areas for regional or subregional co-operation in the field of wind energy are identified, and the outlines of the relevant project proposals are given in part two.

J. Conclusion

Wind energy activities in the ESCWA region are very limited, despite the fact that there are several rural and remote areas in the region that enjoy a sufficiently high wind potential. At the same time most are without, or have

only expensive access to a fuel supply and electricity. In addition, small-scale wind technologies have reached a state of maturity that enables them to contribute to energy supplies in specific applications in these areas, at a reasonable cost. It is believed that the high initial capital investment needed, the lack of technical experience, subsidized energy prices and the lack of social mechanisms that assist social acceptance are the main reasons why the dissemination of small-scale wind technologies for rural and remote areas has been prevented.

A wide range of regional co-operation activities could be streamlined to promote the application of small-scale wind technologies in remote and rural areas of the ESCWA region. The focus of regional co-operation should be on proving the reliability and economic viability of these technologies by means of field experiments under realistic local application conditions, and on creating the necessary social mechanisms that assist in making these technologies acceptable to local people.

Therefore, regional co-operation should cover not only project proposals and formulation, but also implementation and dissemination so that the necessary prerequisites for the diffusion of technology, as well as acceptance by future users, can be created. It is extremely important in this phase that future users be more thoroughly trained and informed.

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III. OUTLINES OF PROJECT PROPOSALS IN THE FIELD OF WIND ENERGY

Mahmoud Saleh*

A. Establishment of a wind measuring network in selected ESCWA countries

1. Objectives

(a) Development objectives

- (i) To assess wind potential in selected sites of the ESCWA region;
- (ii) To develop a reliable data base for the different parameters related to wind energy utilization in rural and remote areas of the ESCWA region;
- (iii) To extend, support and/or upgrade the existing wind data collection and measuring facilities so as to serve the purpose of wind energy assessment.

(b) Immediate objectives

- (i) To install a number of wind measuring stations in selected sites of the ESCWA region;
- (ii) To train local manpower in the operation, repair and maintenance of wind measuring equipment;
- (iii) To organize training programmes on wind data collection, processing and analysis.

2. Background and justification

The assessment of wind resources at a specific location is fundamental to the evaluation of the suitability of wind to meet energy needs. Wind data have been measured by several stations spread over the ESCWA region for a number of years (in some cases for more than 40) for the purposes of weather forecasting and agriculture. However, these stations are neither located in appropriate sites nor equipped with suitable instruments for the assessment of wind potential as an energy source. Also, large areas in the ESCWA region have good wind regimes but do not have any wind data measuring facilities. Parts of these areas are inhabited by small, scattered communities suffering from a shortage of energy. The installation of wind measuring stations in these areas would assist the evaluation of wind potential as a step towards utilizing wind energy to provide the communities settling there with a part of their energy needs. In addition, some of the existing wind measuring stations could be up-graded or supported to suit the purposes of wind energy assessment, provided that their sites are properly chosen.

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3. Proposed participating ESCWA countries

Democratic Yemen, Oman, Saudi Arabia, the Syrian Arab Republic and the Yemen Arab Republic.

4. Activities

(a) Preparing the specifications of measuring equipment for two levels of measurements, namely a simple measuring programme and a more detailed one;

(b) Identifying rural and remote areas for the possible utilization of wind as an energy source based inter alia on the availability of water (fresh, brackish or saline) and the existence of settlements;

(c) Classifying these areas in accordance with priorities, taking into account the sensed availability of wind resource;

(d) Selecting three to four areas with the highest priority in each of the participating countries;

(e) Screening the potential candidate site in each of the areas identified;

(f) Providing the site given first priority with fully equipped stations and the other two or three of lesser importance with wind classifiers;

(g) Collecting, processing and analysing data over one year and thereafter defining the secondary candidate site;

(h) Transferring the fully equipped station to the second most important site, and the wind classifiers to sites with lower priority and collecting, processing and analysing data over one year;

(i) Repeating the above-mentioned steps every year so as to cover all of the areas identified.

5. Estimated inputs of donor agencies

B. Windmills for water supply in rural and remote areas in the ESCWA region

1. Objectives

(a) Development objectives

- (i) To contribute to a clearer perception of the technical, economic and social implications of the application of WEPS to the securing of a water supply for selected rural and remote areas in the ESCWA region;
- (ii) To produce reliable country-specific data on the technical and economic viability of WEPS by conducting field tests and performance evaluations of complete systems under realistic conditions;

(b) Immediate objectives

- (i) To assess the experience gained in the ESCWA region in utilizing WEPS and to define the shortcomings encountered in the previous trials in order to promote the application of WEPS in the region;
- (ii) To select the most appropriate WEPS technologies and the best potential sites on which to test them;
- (iii) To install a number of WEPS and to monitor their performance over a whole year;
- (iv) To identify the social work necessary to promote this technology and to establish model social mechanisms in communities where pilot WEPS are installed.

2. Background and justification

A substantial part of the population in the ESCWA region lives in rural, desert and mountainous areas. In these areas, water for domestic application and/or irrigation is pumped from surface or underground water sources using either diesel engines, electric motor-driven pumps or human effort. In many cases, these areas are located at some distance from the main power networks, which means that electric motor-driven pumping systems cannot be used. The use of diesel engines to drive water pumps, in many locations involves, problems of fuel transportation, lack of technical capabilities for repair and maintenance and the high cost of spare parts. In some desert and mountainous areas of the ESCWA region, women exert great physical effort in lifting water from deep wells using ropes and rubber pails. This is both a time and human consuming operation. Some of these communities enjoy good wind potential, so the promotion of WEPS in these communities offers an appropriate solution to secure a water supply for them.

Direct mechanical pumping systems were tested and utilized in many ESCWA countries more than half a century ago, but the results of this experience were mostly negative. There were many reasons for this, including the inappropriateness of the selected technology and sites where the WEPS were installed, the poor mechanical design of the WEPS, insufficient social work to raise the awareness of people to accept this technology, the low cost of diesel engine fuel at that time, etc. In one ESCWA country for example: ^{1/}

"The trials of installing two windmills showed considerable co-operation on the part of the village people and local authorities, who all appreciated the importance of wind water pumping for the farming community, but they also demonstrated that without proper organization, trained fitters to look after the pumps and windmills, spare parts and funds, provision of equipment only is a half-cock effort which, with the

^{1/} W. A. M. Jansen, Feasibility study of windmills for water supply in the Yemen Arab Republic, Report of the Steering Committee, Consultancy Services Wind Energy Developing Countries (Netherlands, March 1980).

best intentions, may do more harm than good, and in any case can create a lot of problems for all concerned. In one village -- in this country -- it was said that pregnant women were saying prayers for the extension staff--of the WEPS project who had relieved them from the heavy task of drawing water from a very deep well. While in another village, where the windmill was constantly tampered with, the women were cursing the same extension workers for putting the pump, which was constantly breaking down, in the way of their drawing the water."

In the light of the above, an assessment of the experience of ESCWA countries in utilizing or testing WEPS, including the social dimension of the communities, should be undertaken in advance of any further demonstration activity. The problem areas have to be defined and proposals for solutions have to be recommended. Further, appropriate systems and proper sites have to be selected, and the necessary social work has to be done in order to ensure the success of this activity.

3. Proposed participating countries

Democratic Yemen, Egypt, Oman, Qatar, Saudi Arabia, the Syrian Arab Republic, the United Arab Emirates and the Yemen Arab Republic.

4. Activities

(a) Visits to participating countries by a group of experts, including energy engineers, an economist and a social scientist to collect information on previous experiences, if any, of wind energy pumping systems, as well as to identify possible sites for installing the proposed new systems that take into account the availability of wind and water and the possibility of establishing social mechanisms that enhance community acceptance of this technology;

(b) Preparation of a detailed report that assesses past experiences, identifies deficiencies and problems encountered in previous experiments and that recommends measures to avoid similar or other mistakes;

(c) Identification of the most appropriate sizes and types of WEPS, including the direct-mechanical and wind-electrical pumping systems to be installed in each country (two WEPS are proposed for demonstration purposes in each country);

(d) Preparation of the specifications of identified types of WEPS and monitoring instruments and the bid documentation for procurement;

(e) Selection of suppliers and procurement of equipment;

(f) Preparation and implementation of a monitoring programme for system installation and on-the-job training of community people in the operation and maintenance of WEPS;

(g) Assessment of the techno-economic feasibility and social acceptability of WEPS technology one year after the system has been in operation.

5. Estimated inputs of donors

\$US 50,000 for hardware per each participating country;
\$US 60,000 for consultants;
\$US 20,000 for travel.

C. Wind energy for brackish and sea water desalination in remote areas of the ESCWA region

1. Objectives

(a) Development objectives

To assess the techno-economic feasibility of wind energy utilization for seawater and underground brackish water desalination using the reverse osmosis technique to secure a potable water supply for mountainous and desert areas in the ESCWA region.

(b) Immediate objectives

- (i) To install a reverse osmosis desalination unit driven by wind energy in a selected mountainous area for brackish water desalination, and another unit in a coastal area for sea water desalination so as to secure a drinking water supply for small communities settled in these areas;
- (ii) To monitor the performance of the units over a year;
- (iii) To assess the economic viability of these units, taking into consideration the social benefits of securing freshwater in these locations.

2. Background and justification

Small populated communities in the mountainous, desert and coastal regions of ESCWA countries in many cases have an urgent need for safe water supplies. These regions are usually located at some distance from power distribution lines. The incentive to use a self-supporting water desalination plant is consequently quite considerable. Many of these regions, especially those in the mountains or along the coasts of the Gulf, Red Sea, Mediterranean or Indian Ocean, have reasonable wind regimes. Therefore, wind can be utilized in these regions to drive desalination plants. Also, technical capabilities in these regions are limited, requiring plants to be reliable, simple to operate and easy to maintain through the use of locally available manpower, materials and supplies. RO technology offers an appropriate solution for this situation. The RO plant is simple, it requires a lower capital investment, incurs lower operating cost and demands less construction time and space than plants that utilize other desalination techniques. Also, RO is a proven technology. The promotion of wind-energy-driven RO plants could be of a great benefit to remote areas in the ESCWA region.

3. Proposed participating countries

Democratic Yemen, Oman, Saudi Arabia and the United Arab Emirates.

4. Activities

(a) Selection of an appropriate site in a desert or mountainous area. The criteria for selection should include inter alia the availability of underground water with low salinity (brackish) at reasonable depths; the presence of sufficient data indicating a high wind potential on the site; the existence or possibility of establishing human settlements around or near the site; access of the site to an urban sector for the easy transport of engineers, technicians and equipment for monitoring purposes;

(b) Selection of an appropriate site in a coastal area that satisfies the requirements mentioned in the previous activity, except for that of the availability of underground water;

(c) Preparation of the specifications and bid documentation for two wind-energy-driven RO water desalination units (capacity 10 to 15 m³ of freshwater per day), one for low salinity water (1,000 to 10,000 ppm) with all the monitoring instruments and a training programme on operation for 2 to 3 technicians, with the repair and maintenance of these systems being implemented by the supplier;

(d) Selection of suppliers and procurement of equipment;

(e) Selection of the trainees and preparation of the training programme in consultation with the chosen supplier;

(f) Installation of the two units and testing for a complete year;

(g) Preparation of a report evaluating the performance of each of the two units and assessing the technical feasibility and economic viability of wind-driven RO desalination technology.

5. Estimated inputs of donors

\$US 100,000 for equipment;
\$US 20,000 for consultants;
\$US 10,000 for travel.

D. Producing ice using wind energy for remote fishing communities in the ESCWA region

1. Objectives

(a) Development objectives

- (i) To assess the technical feasibility of the introduction of ice-making technology that uses wind as a power source to remote fishing communities in the ESCWA region;
- (ii) To evaluate the social and economic impact of using wind energy to provide the means to preserve fish, the main product in these communities, until it is transported to consumption centres.

(b) Immediate objectives

- (i) To install a pilot wind-driven ice-making facility in a selected fishing community in the ESCWA region;
- (ii) To monitor the performance of the system under local conditions;
- (iii) To identify the problems encountered in the use of this technology, and the methods of storing ice and fish;
- (iv) To evaluate the social and economic benefits associated with the possibility of increasing fish production.

2. Background and justification

The ESCWA region is characterized by long coasts that extend for thousands of kilometres along the Mediterranean, Red Sea, Gulf and Indian Ocean. Several small communities whose main economic activity is fish production are scattered along these coasts. However, since most of these communities are located far from fish consumption centres, and because of the difficulty of reaching these locations by conventional means of transport, fishing activities in these communities must therefore be limited in quantity in order to avoid the spoilage of fresh fish. Also, these locations are usually far from electric power lines that could provide cold stores with their energy requirements. Alternatively, diesel power units could be used for this purpose, but the problems of repair, maintenance and inefficient fuel transportation for diesel units may hinder their use. These locations usually enjoy a reasonable if not a high wind potential.

In view of this, wind energy could offer an appropriate solution to power ice-making facilities or cold stores. This technology is being tested in a site on the Red Sea coast (Abo Ghossoun in Egypt), which is not a fishing community. However, the results of the experiment undertaken in Abo Ghossoun could be used as an input for this project. It is believed that the testing of this technology in a fishing community is of prime importance for the promotion of its future utilization.

3. Proposed participating countries

Democratic Yemen, Oman and Saudi Arabia.

4. Activities

- (a) Selection of a site in a fishing community with a high wind potential;
- (b) Preparation of the specifications and bid documentation of a wind-driven ice-making system (capacity 1 to 2 tons of ice per day from sea water), including a training component for 2 to 3 technicians on the installation, operation and maintenance of the system to be undertaken by the supplier;
- (c) Selection of the supplier and procurement of the equipment;

(d) Selection of the trainees and preparing the training programmes in consultation with the supplier;

(e) Visiting the site by a social scientist to assess the social and economic impacts of installing this system;

(f) Preparing a comprehensive report on the technical performance of the system, the financial implications of installing it and the social and economic benefits of the application of the system. Also, it is expected that the report will include recommendations related to the promotion of this technology.

5. Estimated inputs of donors

\$US 100,000 for equipment;
\$US 20,000 for consultants;
\$US 10,000 for travel.

E. Training course-cum-study tour on small-scale wind technologies

1. Objectives

(a) Development objectives

- (i) To promote the application of small-scale wind technologies in rural and remote areas of the ESCWA region;
- (ii) To upgrade local capabilities on installation, operation, maintenance and repair of wind energy conversion systems (WECS);
- (iii) To create a nucleus for the design and manufacture of wind system components.

(b) Immediate objective

To organize a training course on the installation, operation, repair and maintenance of the different components of small-scale wind energy conversion systems, which will include a study tour in ESCWA countries that have wind energy programmes.

2. Background and justification

One of the main factors hindering the promotion of wind energy utilization in the ESCWA region is the lack of local technical expertise capable of installing, operating, maintaining and repairing the different components of wind energy conversion systems. Past experience of wind energy utilization in ESCWA countries has shown that the lack of qualified technicians to repair a mechanical failure or replace spare parts in the simple wind pumping systems utilized in the region at that time led to the farmers' preference of diesel pumping systems. It is therefore believed that the training of a number of qualified technicians on different aspects of wind energy conversion systems will assist in promoting this technology in the trainees' respective countries.

These trained technicians may also form a nucleus for wind energy training centres in these countries. Some experience has been gained in ESCWA countries which have active wind energy programmes in the field of training, and this should be taken into consideration during the preparation of the training programmes.

3. Proposed participating countries

Democratic Yemen, Oman, Qatar, Saudi Arabia and the Yemen Arab Republic.

4. Activities

(a) Visits to ESCWA countries that have activities in wind energy in order to become acquainted with their experiences in training local manpower;

(b) Preparation of details of the training programmes and the qualification requirements of the experts who will conduct the training, and the trainees;

(c) Identification of and contact with the institutions where the training course will take place, and preparation of the contract to be signed with these institutions;

(d) Contact with the participating countries to nominate the candidate trainees;

(e) Identification of and contact with the experts who will conduct the training course;

(f) Identification of the institutions and pilot projects to be visited by the trainees during the study tour;

(g) Finalization of the training programmes and arrangements for the study tour, in consultation with the selected institution where the training will take place;

(h) Undertaking of the pre-training evaluation for the candidate trainees;

(i) Preparation of a final report to assess this activity;

(j) Follow-up on the role of trained manpower in promoting wind energy utilization in their countries.

5. Estimated input of donors

\$US 30,000 consultants;

\$US 4,000 travel and daily subsistence allowance (DSA) per participant;

\$US 10,000 cost of convening the training course.

IV. WORKING PAPER ON SOLAR AND COMBINED SOLAR/WIND ENERGY FOR RURAL AND REMOTE AREAS IN THE ESCWA REGION

(E/ESCWA/NR/86/WG.1/6)

Mohammad Amr*

A. General issues

This part of the study focuses on small-scale solar and combined solar/wind technologies, which could be expected to contribute to the improvement of the quality of life of rural areas and remote agglomerations in situations where conventional fuels and power systems have not yet penetrated, or are too expensive to become practical alternatives in the near future. The report discusses alternative available technologies that would satisfy rural and individual family needs.

The most promising renewable energy resources for utilization in the ESCWA region are: solar, wind and biomass resources, which have the following advantages:

- (a) Availability in many parts of the region;
- (b) Simplicity of the technology, which makes them suitable for remote and rural areas;
- (c) Reliability of renewable energy conversion systems;
- (d) The modular capacity of these systems, which is appropriate for rural applications;
- (e) The cleanliness and non-polluting nature of the conversion process;
- (f) Low running costs;
- (g) Possibility of quick system installations;
- (h) Suitability for hybrid applications.

However, several obstacles that preclude the widespread utilization of renewable sources should be taken into account. These can be summarized as follows:

- (i) Resources are not continuously available, and their intensity varies with time;

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- (ii) High initial cost of the conversion systems used;
- (iii) Low intensity of the resource makes it necessary to collect energy from extensive areas;
- (iv) Low efficiency of the conversion systems;
- (v) The technology is not yet fully developed.

Table 1 shows the world-wide status of renewable energy systems.

B. Background information on the ESCWA region and the use of solar and wind energy

The ESCWA region is located between 25° E and 60° E longitude and between 12° N to 37° N latitude. The territory of this region amounts to 4,500,000 km², of which more than 90 per cent is desert and arid areas. The total population exceeds 110 million. In some countries of the region, a substantial part of the population is spread out in many small isolated villages where non-commercial sources of energy such as fuelwood, charcoal and animal and agricultural wastes have the largest share in energy consumption.

A great deal of research is being carried out in the ESCWA region on the use of solar and wind energy. However, each country has its own plans and programmes. These programmes differ from one country to another, according to the availability of funds and the needs and priorities of each country.

ESCWA countries may be divided into the following categories:

1. The oil rich countries: Saudi Arabia, Kuwait, Iraq, the United Arab Emirates and Qatar, which are distinguished from other ESCWA members by the abundance of oil resources and the fact that the average energy consumption per capita is very high. It is also to be noted that energy prices are substantially subsidized by the Government.

However, the application of solar and wind technologies has several advantages. Indeed, the use of solar energy can contribute to the development of rural areas and can provide remote areas with energy for certain purposes such as telecommunications, measuring instruments, cathodic protection, etc.

2. Countries such as Jordan and South Yemen that are deprived of significant oil resources, and which are hence heavily dependent on imported oil.

The average energy consumption per capita in these countries is relatively low. They depend on imported oil for their consumption. However, the need for energy in these countries is continuously increasing. The use of solar and wind energy in these countries must therefore be given serious consideration as an alternative solution to the energy problem. A large percentage of the energy consumed for space heating, cooling and water heating, can be saved through the use of solar energy.

The development of practical and economical solar systems is essential if attempts are to be made to save energy on a national scale, in addition to the benefits that can be obtained from using these energy resources in rural areas to meet basic needs such as lighting, cooking and water pumping for drinking and irrigation.

3. The above considerations also apply to countries with substantial oil resources and with more diversified economies, where a great deal of effort is deployed in providing rural and remote areas with basic energy requirements.

C. Climatic data available in some ESCWA countries

In any system design, the solution of problems depends on the proper selection and sizing of the components of the proposed system. If he is to achieve this, the engineer needs to be provided with sufficient relevant data and information.

In the field of solar and wind energy, the availability of data is a major concern for designers and decision makers. Hence, it is necessary to co-ordinate with various departments, particularly those that are involved in meteorology, in order to obtain data already available in their organizations and to consider the possibility of developing the measuring process so as to make the data obtained available for an estimation of the potential of solar and wind energy.

Most Arab countries do not have sufficient or adequate data for solar radiation and wind. As a result, they cannot make a realistic assessment of the present and future role of solar and wind energy in their economic studies and in planning.

It should be mentioned here that the selection of solar and wind energy conversion equipment should suit a specified site. Therefore, it is extremely important to obtain detailed information about the particular site of the application.

Given the abundance of renewable energy resources, mainly solar energy, in the region, solar and wind technologies can have a wide application provided that more accurate data is made available.

Therefore, it is important to stress that additional efforts should be directed to the continued collection of data on solar radiation and wind. It is also important to establish programmes to evaluate the potential of solar and wind energy in the region.

In Jordan, the Department of Meteorology collects weather data in 24 stations, including wind characteristics and solar radiation in some of the stations, although this was considered to be insufficient by the RSS. However, correlation factors were calculated in order to make use of the available data. The RSS has also installed some 15 stations to take wind measurements.

Table IV.1. Renewable energy system status

RENEWABLE ENERGY SYSTEM	LEVEL OF TECHNOLOGY	SYSTEM AVAILABILITY	SYSTEM RELIABILITY
WIND	PROVEN	GOOD	GOOD
PHOTOVOLTAICS	PROVEN	GOOD	GOOD
ACTIVE SOLAR	PROVEN	EXCELLENT	EXCELLENT
PASSIVE SOLAR	PROVEN	N/A	N/A
SOLAR THERMAL	PROVEN	GOOD	FAIR
SOLAR PONDS	EMERGING	LOW	FAIR
TIDAL POWER	PROVEN	LOW	FAIR
GEO THERMAL	PROVEN	GOOD	EXCELLENT
HYDROPOWER	PROVEN	EXCELLENT	EXCELLENT
BIOMASS	PROVEN	GOOD	EXCELLENT
OCEAN THERMAL	R&D	NO SYSTEMS	NO SYSTEMS

Owing to the need for more information needed to predict wind energy potential in Jordan, the Ministry of Energy and Mineral Resources, together with the RSS, will install another 30 stations to measure wind over the whole country.

In Egypt, the data available may be regarded as sufficient for the purpose of evaluating the potential of wind and solar energy applications in various fields.

According to officials from the Yemeni Department of Meteorology, there are many weather stations located all over the Yemen Arab Republic. However, these stations are only operated for a few hours per day, owing to the lack of trained personnel. As a result, little data is available, and even less is stored and processed.

In spite of the presence of a number of water stations in many of the countries in the region and the efforts that are deployed to collect and process relevant information, the available data is not adequate for energy assessment purposes.

D. Solar and wind technologies for rural and remote areas in the ESCWA region

1. Energy supply for rural and remote areas

In rural and remote areas, non-commercial sources of energy such as fuelwood, charcoal, animal and agricultural wastes, are widely used to meet the basic energy needs of a community in cooking, baking and space and water heating.

Such resources are used only through direct burning. This method has many disadvantages: (i) it has a very low efficiency rate (2 to 10 per cent); (ii) obtaining the fuel and preparing it is a difficult, inconvenient and time-consuming process; and (iii) the use of the fuel may result in respiratory diseases.

Moreover, the use of these materials as fuel, leads to desertification and deprives the industry of valuable raw materials. Agriculture is also affected since the animal waste could be used as high quality fertilizers.

2. Basic energy needs of rural and remote areas

Needless to say, the development of rural and remote areas and improvements in the standard of living of scattered communities, can only be achieved through the implementation of comprehensive programmes that give the highest priority to basic energy needs. The first task of the planner looking into the possibility of using renewable energy resources for rural and remote areas is therefore to identify those basic energy needs.

The basic energy needs of rural and remote areas can be classified into three groups: domestic needs, community needs and national needs.

(a) Domestic energy needs consist of electricity for lighting and small appliances, energy for cooking, water heating and cooling and heating;

(b) Community needs are: street lighting, water pumping, water desalination and electricity. Energy is also needed for schools, clinics, telecommunications, police stations and public utilities;

(c) National needs include energy for services on a national level such as microwave telephones, repeater stations, railway stations, cathodic protection for pipelines, measuring instruments, alarm systems, etc.

3. Agricultural needs

One of the major problems facing many countries of the region is how to increase the food production by using high-yield crop production methods.

The application of renewable energy sources for food production and preservation is very important for rural areas and is gaining momentum in most of the countries of the region. Several national, regional and international organizations have been involved in investigating various aspects of this issue. The main methods used can be summarized as follows:

(a) Protected agriculture. This can be achieved by the creation of a micro-climate that is more favourable to plant growth through the use of greenhouse technology. The major advantages of greenhouses are: lower water requirements; increased crop yields (4 to 5 times more for vegetables); and extension of the cultivation period by a number of months;

(b) Food drying for preservation;

(c) Soil sterilization. Chemical sterilization methods can be replaced by methods that use solar energy (covering the soil with plastic foil during the hottest month of the year);

(d) Seed sterilization (solar treatment), which has the following advantages: less seed is needed owing to higher fertility; high crop production (up to 20 per cent higher); and earlier crop production.

It is worth mentioning that all of these technologies can be used successfully all over the ESCWA region.

4. Electrical energy for remote areas

The supply of reliable electric power for remote locations has raised interest in most countries of the world. The greatest need is in developing countries such as ESCWA countries, where many remote areas are not yet covered by the national electric grids. Extending national grids to supply-scattered remote areas, is very expensive and not practical. These areas are commonly supplied by diesel and gasoline generators which, for the past 40 years, have been considered to be the most appropriate technology for the provision of electric energy in remote areas.

However, the use of diesel and gasoline generators depends on the availability of fuel and maintenance, which represents the major part of the cost of generating electricity. The decision to use generators is not usually based on the availability of technology, but primarily on considerations relating to the reliable supply and cost of fuel and maintenance.

Until recently, there were few alternative technologies to diesel or gasoline generators that were developed to meet the demands of remote areas for electricity. At present, however, renewable energy systems that utilize local wind and solar resources have become an important substitute for the supply of electric power to remote locations.

Wind and photovoltaic systems have been tested successfully in various countries throughout the world. The only drawback to the use of solar and wind energy in remote areas is the intermittent nature of these resources.

In densely populated villages, supplying houses with electricity from a renewable energy power station can be provided more efficiently through the use of the following systems:

(a) Photovoltaic (PV) stand-alone system (PV generator, storage batteries, power conditioning equipment and control system);

(b) Wind energy conversion system (wind generator, storage batteries, power conditioning equipment and control system);

(c) Hybrid power system (PV generator, wind generator, storage batteries, power conditioning equipment and control system).

It is worth mentioning that diesel generators can be used as a back-up system to enhance the reliability of energy supply.

In some villages, however, houses are scattered and the establishment of an electric network therefore becomes too expensive. In cases such as this, it is advisable to use decentralized power systems that are similar in nature to the above-mentioned systems, but smaller in size.

This arrangement can also be used for isolated houses and buildings.

An alternative system can be used for these applications for the supply of decentralized street lighting, schools, clinics, emergency telephones consisting of a PV or wind generator and storage batteries to supply DC power.

5. Water pumping and desalination

One of the essential needs of remote areas is a water supply for the inhabitants, their livestock and various agricultural purposes. To supply these areas with water by trucking is very costly and inconvenient.

Approximately 90 per cent of the territory of the Arab world consists of arid land. Water pumping and desalination are important applications for the development of the region in general, and for rural areas in particular. In many areas of the region, groundwater is brackish and the salinity of water reaches values up to 10,000 ppm. Specific devices, therefore, have to be applied for water pumping and water desalination.

In the ESCWA region, solar and wind energy are among the most appropriate technologies for water pumping in rural areas.

It is important to define the physical and climatic conditions under which solar pumping is most efficient. The cost of pumping water using solar energy is affected by solar radiation and the static level of the water.

In order to decide the size of the solar pumps it is necessary to measure solar radiation in the critical month, which is defined as the month in which the available solar energy is at a minimum.

Wind powered pumping systems can provide more cost-effective energy than solar powered pumping systems. The baseline case for wind powered systems is a minimum average wind speed of three m/s. Large areas in the region have such average wind speeds.

Some rural and remote areas in the ESCWA region desperately need potable water, which can be obtained by using reverse osmosis, solar distillation and solar evaporation.

Hybrid systems could also be used for applications in remote areas. These systems combine the main features of different renewable sources, and can consist of the following:

- (i) Wind-PV diesel batteries;
- (ii) Wind-diesel batteries;
- (iii) PV-diesel batteries;
- (iv) Wind-PV batteries.

E. The economics of solar and wind energy in rural and remote areas

The socio-economic benefits of supplying energy to remote communities should be the overriding element when deciding on the application of solar and wind technologies. It should be borne in mind that the availability of energy in remote communities can improve the quality of life, create jobs, and thus curb immigration into already crowded cities.

Among the other social benefits, educational programmes such as teaching proper agricultural technologies through television could contribute to the improvement of skills in rural communities.

In order to assess the economic feasibility of the use of renewable energy resources (solar and wind) to provide rural areas with electricity, the following alternatives should be considered:

- (i) Supplying rural and remote areas from the national electric grid;
 - (ii) The use of free-standing diesel generators;
 - (iii) The use of wind and solar energy systems.
-

Given the current level of international prices, the cost of a PV generating system is about \$US 10 per peak watt. The cost of a wind generating system is about \$US 1,500 per installed kW.

The economic analysis is proceeded by:

(a) A definition of the characteristics of the load (peak power demand, annual electrical energy requirements);

(b) A calculation of the size of the wind system, PV or diesel options that would satisfy the requirements of (a);

(d) The use of wind and solar data to calculate the annual energy produced by wind or PV options (kWh per year);

(e) Finding the cost of energy produced by each option. This can be calculated by using the following formula:

$$CE = \frac{(FCR \times IC) + O\&M}{AE}$$

where: CE - cost of energy delivered by the generation system;
AE - annual energy production (kWh/year);
IC - installed cost;
FCR - annual fixed charge rate which is equal to the capital recover factor.

$$FCR = \frac{K}{1 - (1+K)^{-N}}$$

where: K is the discount rate;
N is the life duration of the equipment in years;
O and N is the operation and maintenance cost (\$US/year).

The cost effectiveness of using small-scale wind and solar energy conversion systems, as compared with diesel generators depends largely on the average wind speed and its distribution on the site, and the daily average of solar radiation per one m² at that site. It also depends on how far the site is from the nearest diesel supply, and on the ease of maintenance for the system.

F. Present activities on solar and wind technologies in selected countries of the ESCWA region

1. Jordan

Electrification in Jordan is being extended at a very high rate. According to some estimates, all rural villages with more than 100 inhabitants, which represent 90 per cent of the rural population in the country, have been already connected to the national grid. However, the use of solar and wind energy has great importance because it can alleviate the load on the national grid and can meet most of the energy requirements of remote and scattered communities. Indeed, renewable energy resources are being used successfully

for water pumping using PV and wind energy systems in remote desert areas. In view of the need of water for livestock in such areas and because of the availability of water wells (ground water) in these areas, it is expected that the use of wind-assisted and PV-assisted water pumping systems will increase.

An ongoing project to provide electricity to a remote village, Jurf Al-Daraweesh, 170 km south of Amman, uses a hybrid wind-PV system. The system consists of a PV generator of 20 kWp capacity, a wind generator of 40 kW capacity, and a storage system of 300 batteries (100 ampere-hours (Ah) at 12 volts each), which are connected together to build 220 volt DC blocks.

A new pilot project using wind energy conversion systems to generate electricity that will be connected to the national grid, is under construction at Ras Muneef in the northern part of Jordan. It is interesting to note that the maximum wind speed in this area coincides with the peak demand for electricity, which therefore makes the use of such a system highly economical. Nearly 15 per cent of the peak load is expected to be supplied by wind energy conversion systems. The feasibility study of the above-mentioned pilot plant shows that the cost of a unit of wind energy (kWh) is 50 per cent less than that of a unit of electricity (kWh) provided by the national grid.

Other projects that use renewable energy resources in Jordan are as follows:

(a) PV systems used to supply five repeater stations belonging to the civil defence and police. Each system consists of a 160 watt peak (Wp) PV generator, a charge regulator and a storage battery of 240 Ah at 12 volts. The total energy needed for each of the stations is 460 watt hours (Wh);

(b) Individual applications of PV systems. The objective of this project is to develop PV systems for remote and isolated areas that will meet basic electricity needs such as: clinic refrigerators, electric lighting, educational televisions and emergency telephones;

Two PV systems were selected for use in two remote villages:

(i) A centralized PV system (power capacity 4.5 kWp, storage capacity of 1,500 Ah at 12 volts) and an inverter to provide AC loads;

(ii) A decentralized PV system (power capacity one kWp, storage capacity of 1,500 Ah at 12 volts). This system consists of several PV mini-systems, each of which provides a DC load with electric power.

(c) A PV system to power the transmitter/receiver equipment at the train station Fatab (power capacity of 1,760 Wp, a shunt regulator, storage capacity of 800 Ah at 24 volts). The energy consumption at this station is 6.25 kWh/day.

2. Yemen Arab Republic

The Yemen Arab Republic may be regarded as the ideal country in the region with regard to the use of renewable energy resources to supply remote areas with their basic energy needs. This is owing to the following:

(a) The national electricity networks are limited to the main cities and only 56 per cent of houses are electrically lighted;

(b) Per capita electrical energy consumption is very low (45 kWh/year);

(c) Road networks are not well developed (3,000 kms of roads, of which 1,000 kms are not paved). A large number of villages and populated areas are not connected to these networks;

(d) Many villages are located on the top of mountains and rough areas that are inaccessible except by foot or by animal. It is therefore very difficult to supply these areas with fuel;

(e) Unlike other ESCWA countries, the population of the Yemen Arab Republic is scattered throughout the country in rather small communities;

(f) At present, more than 70 per cent of houses are deprived of a running water supply;

(g) About 60 per cent of the energy consumed in the country is obtained from fuelwood, agricultural and animal wastes.

Although there are significant solar potential and renewable wind energy resources, the use of solar and wind energy in the Yemen Arab Republic is very limited. There is very little published information concerning plans for implementing solar energy.

- (i) Sana'a University has sought assistance from the Georgia Institute of Technology to develop some programmes, and studies and research have been undertaken on the use of solar energy in the Yemen Arab Republic;
- (ii) The Confederation of Yemeni Development Associations (CYDA) has carried out a number of experiments using PV systems for lighting and house appliances. In co-operation with UNDP, the Confederation has carried out a study aimed at establishing two power generation stations using a PV system: the first will light a school and teachers' residence, and the second will establish four pumping stations to pump water for irrigation in Taiz and Hodeida;
- (iii) The Tihama Development Committee and Federal Republic of Germany have carried out a study to construct 84 pumping stations in the Moor valley;
- (iv) The Ministry of Transport has used PV systems to provide electricity to operate some of the telephone networks that connect the districts of the Yemen Arab Republic;
- (v) Several companies are working on solar water heaters, either by manufacturing or importing the equipment needed;

The American Peace Corps have considered several projects that use PV systems:

- a. A PV lighting system for a school, a clinic and a community assembly hall at Jurran and Nahiya Bura;
 - b. Twenty-one PV pumping stations at Tahama;
 - c. The American Peace Corps, together with Sana'a University are trying to establish a solar energy research centre within the University.
- (vi) A Danish company (DHV) has carried out a study on the cost effectiveness of a project that uses wind energy to pump water, which would be funded by the Danish Government.

3. Egypt

Egypt is the most populated country in the ESCWA region (with approximately 50 million inhabitants). Although the country exports oil, the annual average fuel consumption is low (0.5 tons of oil equivalent (TOE) per capita). More emphasis has been placed in the national development strategy on the promotion of the use of resources. It should be noted that in an effort to ensure food security, Egypt is paying special attention to the increase in arable land and land reclamation. The use of renewable energy resources could constitute an important factor in providing basic requirements for the development of the agricultural sector in this country.

Average energy consumption in Egypt has increased at the rate of 13 per cent every year. This increase in energy consumption on the one hand, and the need to provide rural and remote areas with basic energy requirements on the other, have stimulated interest in the use of renewable energy resources for various purposes.

Egypt has significant renewable energy resources (hydropower, biomass, solar and wind energy). A substantial part of the hydropower potential has already been utilized, and its full utilization is planned for the near future.

In a recent joint Egyptian/USAID assessment of renewable energy resources, some of the prospects and priorities of applications in Egypt were identified as follows:

- (a) Solar domestic water heating: an agreement for an amount of some 1.5 million US dollars has been signed with the French Atomic Authority and SOFRETES Company to study the feasibility of manufacturing solar energy equipment mainly, solar water heaters, a deep freezing plant, a 5 kW solar pump and a complete solar energy centre locally.
- (b) Solar collectors for industrial process heat;
- (c) Solar desalination;
- (d) Rural biogas digesters;
- (e) Photovoltaics for applications in remote areas;
- (f) Passive solar architecture for new settlements;

(g) Wind systems for pumping water and generating electricity.

The National Research Centre, established in 1956, is the main institution for solar research in Egypt. The Centre has implemented the following projects:

- (i) A power generation plant that uses paraboloidal concentrators (costing \$US 250,000). The total area of the collectors is about 108 m². Steam is produced at 280° C under eight atmospheres of pressure. The system is capable of producing up to five Kilowatt electricity (kWe). This project was implemented in co-operation with the United States National Science Foundation;
- (ii) A power generation plant in co-operation with the Federal Republic of Germany, costing 11 million deutsche marks (DM). The collectors are 600 m² heat pipe-type and 200 m² cylindro-parabolic-type collectors. The aim of the project is to produce hot water at 110° C under five atmospheres of pressure. This will be used to evaporate Freon F113, so as to produce 10 kWe peak during five to seven hours per day;
- (iii) A solar cooling project has been implemented in co-operation with the Federal Republic of Germany. This project is expected to power a cold store for vegetables using an ammonia/water absorption refrigeration system. The design temperature of the cold store is +5° C to +8° C, and its volume is 27 m³. The cooling load is one ton and the area of the collectors is 25 m²;
- (iv) A solar water desalination project (costing DM 1.1 million) has been implemented in co-operation with the Federal Republic of Germany.
- (v) A solar drying project, including a solar vegetable dehydration unit (with 12 cell modules, each with an area of 2 m²), which produces hot air (60° C to 80° C) for the vegetable drying process. This project has been implemented in co-operation with IDRC (the International Development and Research Centre) of Canada;
- (vi) Solar water heaters in a newly reconstructed village (Mit-Abo-Elcom). A photovoltaic generator to power a refrigerator has been installed in Mid-Abo-Elcom clinic.

USAID recently supported the study and implementation of several projects, including the following:

- a. PV-powered desalination plant at El-Kasr;
 - b. Wind-powered desalination system at Hurghada;
 - c. Wind farm at Ras Ghareb.
- (vii) A solar village in the East-Owainat area in co-operation with the Italian Government.

Given the limited financial resources, the allocation of 20 million Egyptian pounds in the Five-year Plan (1982-1987) to the solar energy budget, reflects the keen interest of the Egyptian authorities in implementing renewable energy projects. In addition, some progress has been achieved in manufacturing solar and wind energy equipment.

The energy hybrid systems that use different renewable energy resources (solar, wind and biogas) will find a potential market in the new villages established by the Government in Sinai.

G. Institutions and bodies involved in the preparation and implementation of projects on renewable energy

Member States now seem to be paying increasing attention to the importance of using solar and wind energy for development purposes, especially in rural and remote areas. This is mainly reflected by the establishment of specialized institutions to undertake research and prepare and implement projects that promote the use of solar and wind energy.

Solar energy organizations in the ESCWA region

1. Egypt : Renewable Energy Authority/Ministry of Electricity (1985), to co-ordinate research and initiate projects;
2. Iraq : Solar Energy Research Centre (1980), under the auspices of the Scientific Research Council;
3. Jordan : Solar Energy Research Centre, Royal Scientific Society, (1984);
4. Kuwait : Solar Energy Department, Kuwait Institute for Scientific Research (KISR), (1976);
5. Lebanon : National Council for Solar Energy (1980), to set standards and represent business, rather than research interests;
6. Qatar : Solar Research Centre (1980), agreement signed with France to establish the centre at Umm Said;
7. Saudi Arabia : Solar Energy Commission (1977), to collect pertinent information and to support solar energy projects;
8. Syrian Arab Republic : Solar Energy Committee (1977), to collect pertinent information and to support solar energy projects.

In addition to these specialized institutions, several governmental and academic bodies such as the Ministry of Energy, Ministry of Communications, Ministry of Agriculture, universities and other research institutions, rural development organizations and water authorities, conduct research and benefit directly from the implementation of solar energy projects.

In Jordan, the following institutions are particularly active in the field of new and renewable sources of energy:

- (a) Royal Scientific Society (RSS);
- (b) Ministry of Energy and Mineral Resources;
- (c) Water Authority (pumping and desalination);
- (d) Electricity Authority (power generation to supply remote villages and to supply the national grid);
- (e) The Jordan Telecommunications Corporation, (emergency telephones, repeater stations, etc.);
- (f) Jordanian universities (Jordan, Yarmouk).

In Egypt, more than 30 institutions and bodies deal with the development of new and renewable sources of energy:

- (i) The Supreme Council of NRSE;
- (ii) Ministry of Electricity/Renewable Energy Authority;
- (iii) Ministry of Electricity/Egyptian Renewable Energy Development Organization (EREDO);
- (iv) National Research Centre;
- (v) The Ministries of Petroleum, Industry, Defence and Agriculture;
- (vi) The universities (14 universities and the American University of Cairo);
- (vii) The private sector (eight companies that manufacture solar water heaters).

In the Yemen Arab Republic, the only public institution involved in the development of renewable energy resources is the University of Sana'a. The American Peace Corps is engaged in a number of activities that provide solar PV systems for pumping water and for lighting that will be used in rural areas.

In co-operation with the American Peace Corps, Sana'a University is working on the establishment of a solar energy research centre.

It should be stated here that the situation in Yemen is critical owing to the fact that 60 per cent of the country's total energy consumption is met by using fuelwood. Hence, there is an urgent need for an institution responsible for national renewable energy planning, the collection of adequate data to assess the potential of renewable energy resources and the implementation of programmes.

H. Conclusions and recommendations

The report reveals that solar and solar/wind hybrid systems could play a prominent role in meeting energy demands in rural and remote areas. This would help to stabilize the population of these areas, and is also cost-effective.

Judging from the cases studied in this report, renewable sources of energy could provide an effective substitute for conventional sources for a number of purposes, especially to meet the basic energy needs of scattered rural and remote communities.

It is important to indicate that more data and information on renewable energy resources, mainly solar and wind data, are needed. Indeed, the lack of adequate data is one of the major obstacles to assessing the feasibility of solar and combined solar/wind systems in many areas of the region. But, in spite of these shortcomings, the use of renewable energy resources is highly promising. The report also reveals that centralized solar, wind or hybrid energy systems are most suitable for densely populated villages, whereas decentralized mini-systems mainly suit dispersed houses and scattered settlements.

In reviewing the existing technologies for the use of renewable sources of energy, the study aims at identifying the most appropriate devices to meet the needs of specific areas in the region. Cost-effectiveness, based purely on dollar values, might occasionally be negative. However, this is offset by the socio-economic merits of the use of energy in remote areas, with all the social benefits associated with it.

In taking into consideration the above-mentioned remarks and summing up the other main findings of this report, the use of renewable sources of energy is economically, socially and technically advisable, provided that due attention is paid to the selection of appropriate technologies and the sound application of energy systems.

It is to be noted, however, that closer regional co-operation is needed in order to avoid a duplication of activities and to find ways and means to exchange experience and information that will promote the use of renewable sources of energy in the region.

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V. PROJECT PROPOSALS FOR THE APPLICATION OF SMALL-SCALE
SOLAR TECHNOLOGIES FOR RURAL AND REMOTE AREAS
IN SELECTED ESCWA COUNTRIES

Anhar Hegazi*

A. Development of a solar energy based herders' settlement

1. Background

Most ESCWA countries suffer from a shortage of arable land and the extension of desert areas with limited water resources. This fact has forced herder tribes to move across deserts in search of water and pasture.

The development of a herders' settlement requires water, fodder and an energy supply. The minimum water requirements in desert climates is estimated to be up to 8 l/day/head for sheep and goats, where sheep herding is assumed to be the most profitable enterprise in the desert. The capacity of natural pastures is about one sheep per hectare. ^{1/} This can be doubled if pastures are partially irrigated and planted with a high nutrient fodder crop; livestock development will help to cultivate the pasture effectively.

The use of solar energy for the development of a herders' settlement seems to be an appropriate approach for the following reasons:

(a) Livestock water requirements increase in summer as does solar energy, which therefore reduces energy storage needs;

(b) Water needs are limited and require limited power capacities, which means that a diesel motor could be under-utilized;

(c) Settlements would normally be located in remote areas where diesel refuelling operations and maintenance pose serious problems;

(d) The cost of solar photovoltaic systems is declining, particularly free-standing decentralized systems, which can be economically viable in remote areas.

The development of a solar energy based herders' settlement would serve to satisfy the Nairobi Programme of Action (NPA) by ensuring food and water

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^{1/} Henry Steingass, "Market assessment of photovoltaic power systems for agricultural applications in Morocco", report prepared for the United States Department of Energy (September 1981).

security for herder tribes. In addition, both thermal and free-standing photovoltaic systems are particularly suitable for application in remote areas in ESCWA countries. ^{1/}

2. Objectives

The overall goal of this proposal is to suggest an approach for the improvement of the quality of life and productivity of herder tribes in the desert areas of the ESCWA region. The establishment of permanent settlements for herders in the Arabian desert, close to natural pastures, will help to secure food supplies and enhance the interrelation between herder tribes and the urbanized part of the country.

The specific objectives are as follows:

(a) Demonstration and evaluation of solar thermal and photovoltaic systems that will satisfy the energy needs of a settlement, including:

- (i) Water pumping for livestock watering, irrigation and drinking needs;
- (ii) Solar passive housing;
- (iii) Domestic water heating;
- (iv) Fodder preparation and sheep wool spinning.

(b) To evaluate the socio-economic impact of the use of solar energy for the development of a desert settlement;

(c) To assess the potential for the replication of a similar type of community in the ESCWA region, and its possible impact on the productivity of the agricultural sector.

3. Project description

The project will include the following main activities, in addition to the project plan preparation.

(a) Identification of project sites and requirements

- (i) Assessment of possible natural pasture in the ESCWA region, the existing population patterns of herder tribes and their production capacities;

This activity should be complemented by the identification of two to three sites for project implementation;

^{1/} Economic and Social Commission for Western Asia, Report on the Infrastructure Required to Disseminate Mature Solar and Wind Technologies in Selected ESCWA Countries, Part II: Solar and Wind Technologies for ESCWA Region (E/ESCWA/NR/86/5/Add.1) (Baghdad, April 1986).

- (ii) Identification and assessment of energy needs for the proposed settlement at each site. Table V-1 shows the preliminary size and energy needs development for each site;
- (iii) Site layout, provision of a water point and access roads.

(b) Energy system design and installation

- (i) Design and building of a simple desert passive housing complex with the participation of the herder families in the identification of housing needs;
- (ii) Design and preparation of tender document for the appropriate modular photovoltaic and thermal solar systems to be replicated as the settlement expands;
- (iii) Procurement, installation and operation of the proposed system;
- (iv) Training of the herder families in the operation and maintenance of solar systems.

(c) Testing and evaluation

The project will be subject to testing and evaluation for two years, with an appropriate assessment and comparative studies for:

- (i) The technical performance of the system;
- (ii) Socio-economic impact.

(d) Reporting

The following reports will be produced:

- (i) Progress reports every three months;
- (ii) An assessment of herder settlement energy needs report;
- (iii) A system design and performance report;
- (iv) A project evaluation report.

4. Project plan

The project will be implemented on two or three sites in an ESCWA country. The site identification activity will be devoted to choosing the sites, and other activities will then be implemented simultaneously at each site. The total project duration is four years, and the implementation plan is as shown in table V-2.

5. Institutional framework and inputs

The institutional framework of the project will be a major factor contributing towards its success. The project organization should involve ESCWA, concerned government authorities and a consultancy and advisory group.

ESCWA will take responsibility for the following:

- (i) The follow-up with a donor country or agency and the United Nations system on project approval and financing for technical assistance and the supply of equipment;
- (ii) The provision of the required project manager and short-term consultancy services;
- (iii) The initiation of the necessary training programmes in collaboration with the official authorities;
- (iv) Participation in site identification and requirements;
- (v) The follow-up on project progress and evaluation.

Table V.1. Proposed development size of a herder settlement

Year	1	2	3	4
Population (families)	2	2	4	6
Number of sheep and goats	120	250	500	1,000
Total area of pasture (hectares) ^{a/}	60	120	240	500
Irrigated area	10	20	40	80
Approximate system capacity	10 kWp	20 kWp	40 kWp	80

^{a/} A sheep should optimally not walk more than 2.5 km/day (1). Within a 2.5 km diameter, there are about 490 hectares. The size of the area of pasture of the settlement - 500 hectares - is based on these considerations.

The concerned government authorities will take over some of the project costs, either in kind or in cash. These will include:

























- (a) Project site area and infrastructure;
- (b) Project office;

(c) Counterpart technical staff;

(d) Local transportation;

(e) Miscellaneous services.

Table V.2. Project plan and activities

Activity	Duration (Months)	First year	Second year	Third year	Fourth year
<u>Identification of site and requirements</u>	6				
Site identification	4				
Energy needs	3				
Site layout	2				
<u>Total energy system design and installation</u>					
Passive housing	6				
Design and tender document					
Procurement and installation	4.5 each				
Training	8				
<u>Testing and evaluation</u>	27				
Technical performance	24				
Socio-economic impact	27				
<u>Reporting</u>					
Progress reports					
Assessment of energy needs					
System design and installation					
Project evaluation					

The project organization should give consideration to the active participation of the herder families in implementation.

6. Project budget

Table V-3 shows the estimated budget of the project for one site, distributed between project duration and the different parties. The total budget is about \$US 3.15 million for each site, of which \$2.8 million is to be provided by the donor country or agency and the rest by the government concerned.

B. Subregional solar water desalination project for the ESCWA region

1. Background

A shortage of potable water has been a major constraint to the development of large areas of the ESCWA region. The development of desert areas and the creation of decentralized urbanized centres has always been impeded by the limited supply of potable water, which affects both social and economic activities.

The governments concerned have undertaken the construction of pipelines or have built large desalination plants operated by conventional energy sources. However, these efforts have failed to maintain the stability of the water supply in remote areas, particularly in small, decentralized communities.

Different types of desalination plants have been used in ESCWA countries, particularly in Egypt, Saudi Arabia and other Gulf States. Multi-stage flash (MSF) types were mainly used for large desalination plants, while electrodialysis (ED) and reverse osmosis (RO) were used for several studies to show that decentralized small-scale desalination is more economical than water transport owing to the high transportation costs of water.

Since remote areas in the ESCWA region enjoy very high solar radiation rates, solar water desalination is an attractive and logical solution to the problem of water supply.

2. Objectives

The overall objective of the project is to demonstrate and evaluate the appropriateness of the use of solar energy for water desalination in ESCWA countries.

The specific objectives are as follows:

(a) To conduct a detailed survey of the potable water supply and demand in remote areas of the ESCWA region, including an evaluation of existing desalination plants;

(b) To survey the commercially available small-scale desalination technologies and to investigate their suitability for the region;

Table V.3.. Project budget

Cost item	Budget (US dollars)							
	First year		Second year		Third year		Fourth year	
	Ga/ Donor country or agency	Donor country or agency	G	Donor country or agency	G	Donor country or agency	G	Donor country or agency
Personnel and technical staff	20 000	50 000	15 000	40 000	15 000	40 000	15 000	40 000
Consultants	-	100 000	-	80 000	-	80 000	-	50 000
Site preparation	50 000	-	30 000	-	30 000	-	-	-
Housing	30 000	10 000	-	-	40 000	15 000	40 000	20 000
Equipment	-	250 000	-	250 000	-	500 000	-	1 000 000
Travel	5 000	10 000	5 000	12 000	5 000	15 000	5 000	15 000
Training	5 000	10 000	15 000	20 000	10 000	20 000	-	-
Miscellaneous and contingencies (10 per cent)	10 000	45 000	5 000	40 000	7 000	7 000	5 000	100 000
Total	120 000	475 000	60 000	442 000	107 000	677 000	65 000	1 215 000

a/ G = Government concerned.

(c) To demonstrate and test solar desalination plants of different types, mainly solar stills, photovoltaic powered RO and/or photovoltaic powered ED at each site. Three typical remote areas will be considered in three countries. Each plant will have a typical capacity of 10 m³/day;

(d) Based upon the project results, to recommend appropriate types of solar desalination for each of the typical areas of the ESCWA region.

(e) To establish a data base for small-scale solar desalination in the ESCWA region, with comprehensive programmes for managerial and technical training.

3. Project description

As this project stresses the need to identify the supply/demand pattern of potable water for remote areas, and because system design is dependent on the analysis of the quality of brackish water at each site, the following activities will be undertaken:

(a) Project plan preparation

The first step towards the implementation of the project is to prepare a programme of work to identify the action required and to estimate the cost and duration of each phase.

(b) Survey of potable water supply/demand pattern and desalination technologies

To conduct a detailed study, along with site surveys, that covers:

- (i) An assessment of the present condition of the water supply;
- (ii) A forecast for the supply/demand of potable water and a programme for desalinated water production;
- (iii) Identification of the possible alternative sites for project implementation;
- (iv) Selection of desalination processes for the project, together with recommended capacities.

(c) System design, procurement and installation

For each site, the following will be performed:

- (i) The design of three desalinating plants, each with a capacity of about 10 m³/day, but using different technologies;
- (ii) Preparation of tender document;
- (iii) Procurement, installation and check out;
- (iv) The training of users and technicians.

(d) Testing and evaluation

Technical performance will be evaluated for a full year, including productivity, efficiency, maintenance and repair of equipment, etc.

(e) Reporting

The following reports will be produced:

- (i) Progress reports every three months;
- (ii) project plan report;
- (iii) Potable water supply/demand patterns in the ESCWA region;
- (iv) Suitability of desalination techniques for small-scale applications in ESCWA countries;
- (v) System design and performance report;
- (vi) Project evaluation report.

4. Project plan

The total duration of the project will be three years. One year will be devoted to surveys and the pre-system configuration, and two will be dedicated to procurement, installation, testing and evaluation. Table V-4 shows the proposed project plan at each site.

5. Institutional framework and inputs

The institutional framework of the project will be a major factor in achieving the objectives. The organization of the project should involve the concerned authorities of ESCWA member States, together with a consultancy or advisory group.

ESCWA will be assigned the following tasks:

- (a) The follow-up on the approval of the project and its funding within the United Nations system, for the purposes of technical assistance and the supply of equipment;
- (b) Designation of a project manager and providing short-term consultancy services;
- (c) Initiation of a training programme in co-operation with the concerned official authorities in the region;
- (d) Participation in the identification of the site and its requirements;
- (e) The follow-up on the progress of the project and its evaluation.

The concerned official authorities in the region will bear some of the costs of the project, either in kind or in cash. These will include:

- (i) Project site area and infrastructure;
- (ii) Project office;
- (iii) Counterpart technical staff;
- (iv) Local transportation;
- (v) Miscellaneous.

6. Project budget

Table V-5 shows the estimated budget of the project for one site distributed between project duration and among the different activities. The total budget is about \$US 622,000 for each site, of which \$US 494,000 is to be provided by a donor country or agency and the rest by the government concerned.

C. Development and demonstration of a solar agro-industrial farm

1. Background

Most of the plans for the development of rural and remote areas in ESCWA countries focus on land reclamation, the enhancement of water resources and the supply of power. However, their objectives could be better achieved if agro-industries were introduced as an integral part of the rural community. This approach would enhance productivity, as well as the social interaction between remote and urbanized areas. The most common agro-processes are milk processing and drying, which are usually carried out by traditional techniques that considerably limit the rate of production.

In view of the fact that these areas enjoy high solar radiation rates, solar thermal and PV systems could be appropriate devices for the development of agro-industrial activities in remote rural communities. Solar drying systems are currently being tested in Fayoum, Egypt, and the use of solar energy for milk processing plants has been demonstrated in Jordan.

2. Objectives

The development objective of this project is to improve the productivity of remote areas by introducing agro-industrial activities that are based on solar energy as the main energy source.

The immediate objectives include:

- (a) Designing, procuring and installing small-scale pilot solar agro-industrial plants for milk processing and food drying;
- (b) Testing the plant under local conditions, and identifying its suitability for use in the region;
- (c) Investigating and developing local capabilities for the manufacture of the equipment;

Table V.4. Project plan and activities

Activity	Duration (Months)	First year	Second year	Third year
<u>Project plan preparation</u>	2			
<u>Survey of supply/demand patterns and desalination</u>	8			
Present conditions	5			
Forecast of supply/demand	3			
Site identification	1			
Recommendation of technology	8			
<u>System design, procurement and installation</u>	7			
Design and tender document	2			
Procurement and installation	4			
Training				
<u>Testing and evaluation</u>	15			
Technical performance				
Socio-economic impact				
<u>Reporting</u>				
Progress reports				
Project plan				
Supply/demand				
Desalination technologies				
System design and installation				
Project evaluation				

Table V.5. Project budget/site

Budget (US dollars)						
		First year		Second year		Third year
	Ga/	Donor country or agency	G	Donor country or agency	G	Donor country or agency
Personnel and technical staff	20 000	70 000	15 000	20 000	15 000	20 000
Consultants	-	50 000	-	20 000	-	20 000
Site preparation	20 000	-	-	-	-	-
Housing	-	-	-	-	-	-
Equipment	-	20 000	-	15 000	-	-
Travel	5 000	15 000	5 000	12 000	5 000	15 000
Training	5 000	10 000	15 000	20 000	10 000	20 000
Miscellaneous and contingencies (10 per cent)	5 000	15 000	5 000	20 000	3 000	7 000
Total	55 000	180 000	40 000	242 000	33 000	72 000

a/ G = The government concerned.

(d) Training potential users and technicians to improve their capability of installing, operating and maintaining similar systems;

(e) Evaluating the socio-economic impact and benefits of the establishment of agro-industrial based remote communities.

3. Project description

(a) Preparation of the project implementation plan;

(b) Selection of a site in an ESCWA country: Egypt, Iraq, Jordan or the United Arab Emirates. The selected site should be based on animal husbandry and/or crop production;

(c) Preparation of the tender document for the proposed system, including the identification of energy needs and appropriate technologies;

(d) Supply, installation and function proof tests;

(e) The conducting of on-the-job training;







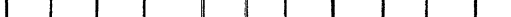
(f) Operation and testing for one full year;

(g) Reporting, including progress reports, technical performance and socio-economic evaluation reports.

4. Project plan

The proposed project duration is three years in accordance with the schedule shown in table V-6.

Table V.6. Project plan and activities

Activity	Duration (Months)	First year	Second year	Third year
Project plan	2			
Site selection	2			
Tender document	4			
Procurement and installation	6			
Testing and evaluation	18			
Training				
Reporting				

5. Institutional framework and inputs

The institutional framework of the project will be a major factor contributing to its success. Project organization should involve ESCWA, the concerned government authorities and a consultancy and advisory group.

ESCWA will take responsibility for the following:

(a) The follow-up on project approval and financing for technical assistance and the supply of equipment with the donor country or agency and the United Nations system;

(b) Provision of the required project manager and short-term consultancy services;

(c) Initiation, in collaboration with the concerned official authorities, of the necessary training programmes;

(d) Participation in site identification and requirements;

(e) The follow-up on the progress of the project and evaluation.

The concerned government authorities will take over some of the project costs, either in kind or in cash. These will include:

(i) Project site area and infrastructure;

(ii) Project office;

(iii) Counterpart technical staff;

(iv) Local transportation;

(v) Miscellaneous services.

6. Project budget

The total estimated budget for the project is as follows:

(a) \$US 120,000 for consultancy;

(b) \$US 500,000 for equipment;

(c) \$US 20,000 for training;

(d) \$US 15,000 for travel.

The cost of the project will be about \$US 655,000.

D. Dissemination programme for "do-it-yourself" small-scale solar equipment in remote areas

1. Background

Many parts of the small-scale solar equipment for distillation, cooking, water heating and drying could be manufactured in remote areas by using local material. The development of remote areas, especially those with dispersed small communities will depend, to a large extent, on how self-sufficient they are. As a result, intensive training and dissemination programmes are required for the population in an effort to help them improve their standard of living.

2. Objectives

The main objective of the project is to promote the manufacture of simple, low-cost solar equipment that will meet the basic energy needs of small communities in remote areas of certain ESCWA countries. More specifically, the project aims at:

(a) Developing modular designs for small-scale low-cost solar equipment such as stills, cookers, water heaters and crop dryers using local materials in remote areas;

(b) Training the technicians and young engineers on the manufacture, installation and operation of solar systems;

(c) Training the population in remote areas on the use of the equipment on a "do-it-yourself" basis.

3. Project description

The project includes the following activities:

(a) The visit of a group of experts to selected remote sites in the ESCWA region in order to investigate the type and size of the equipment that is needed;

(b) The development of simple, low-cost designs for the required solar equipment. This will include design drawing and description, installation instruction and conditions for use, all with illustrative materials;

(c) The conducting of a training workshop for the technicians responsible for the dissemination processes;

(d) The arrangement for units to be taken periodically by technicians on a two week mission to different sites in order to train the population and to furnish them with all the necessary information and skills through "do-it-yourself" publications;

(e) Evaluation of the project.

4. Project plan

The project duration will be 18 months. The tasks will be spread out as follows:

(a) Activities to be carried out as indicated in items (a) to (c) above: six months;

(b) Activities to be undertaken as indicated in items (d) to (e) above: 12 months.

5. Project budget

The total project budget will be about \$US 80,000. The breakdown of the budget is as follows:

- (i) \$US 40,000 for consultancy;
- (ii) \$US 20,000 for prototypes;
- (iii) \$US 10,000 for training;
- (iv) \$US 10,000 for travel.

VI. WORKING PAPER ON THE EXPERIENCE OF NORTH AFRICAN ARAB
COUNTRIES IN THE FIELD OF RENEWABLE ENERGY UTILIZATION

(E/ESCWA/NR/86/WG.1/5)

Ali Sayigh*

A. Introduction

The Arab countries were some of the earliest users of alternative energy. Egyptians and Babylonians utilized wind energy in 3000 B.C. to sail their boats on the Nile and in the Mesopotamian region, and the early civilizations in those parts of the Arab world worshipped the sun.

In 1913, a German engineer, living near Cairo, developed a solar steam engine to operate a 37.5 kW pump. Another scientist in the early 1950s, made a full study of the Qatara depression in Egypt and proposed a helio-hydroelectric scheme (HHE). ^{1/} Later this was also proposed for Dawhat Salwah in the eastern province of Saudi Arabia. ^{2/} Both authors proposed a method to use the potential difference between the sea and the depression where sea water evaporates, and to maintain this difference to generate electricity through the use of a low head turbine.

The countries under consideration in this paper are the Libyan Arab Jamahiriya, Tunisia, Algeria and Morocco. The average number of hours of sunshine in these countries is 8 to 9 per day, while solar radiation varies from 4.3 to 7.0 kWh/m²/day (see figure 1). Table VI-1 shows oil production, electricity capacity in the country and other relevant information about the four countries. Sixty to 75 per cent of the population lives in rural areas. Farming is restricted to the area around oases or a few mountain streams. The water supply sources are underground water tapped through wells and pumps, or occasional rain that falls during winter time. Apart from Tunisia, 90 per cent of the land of the other countries is desert. In the following paragraphs, each country will be discussed separately.

B. Experience of North African Arab countries

1. Morocco

The availability of solar radiation in the country is one of the best in the North African States. Morocco enjoys 2,800 to 3,400 hours of sunshine per year and solar insolation of between 4.7 to 5.6 kWh/m²/day (see figure 2). Among the many solar types of application are heating, cooling, desalination, power generation, pumping and greenhouse applications. The following give a few examples of solar applications in Morocco.

* Solar energy expert.

^{1/} Solar Energy Engineering, A. A. M. Sayigh, ed. (Academic Press, 1977).

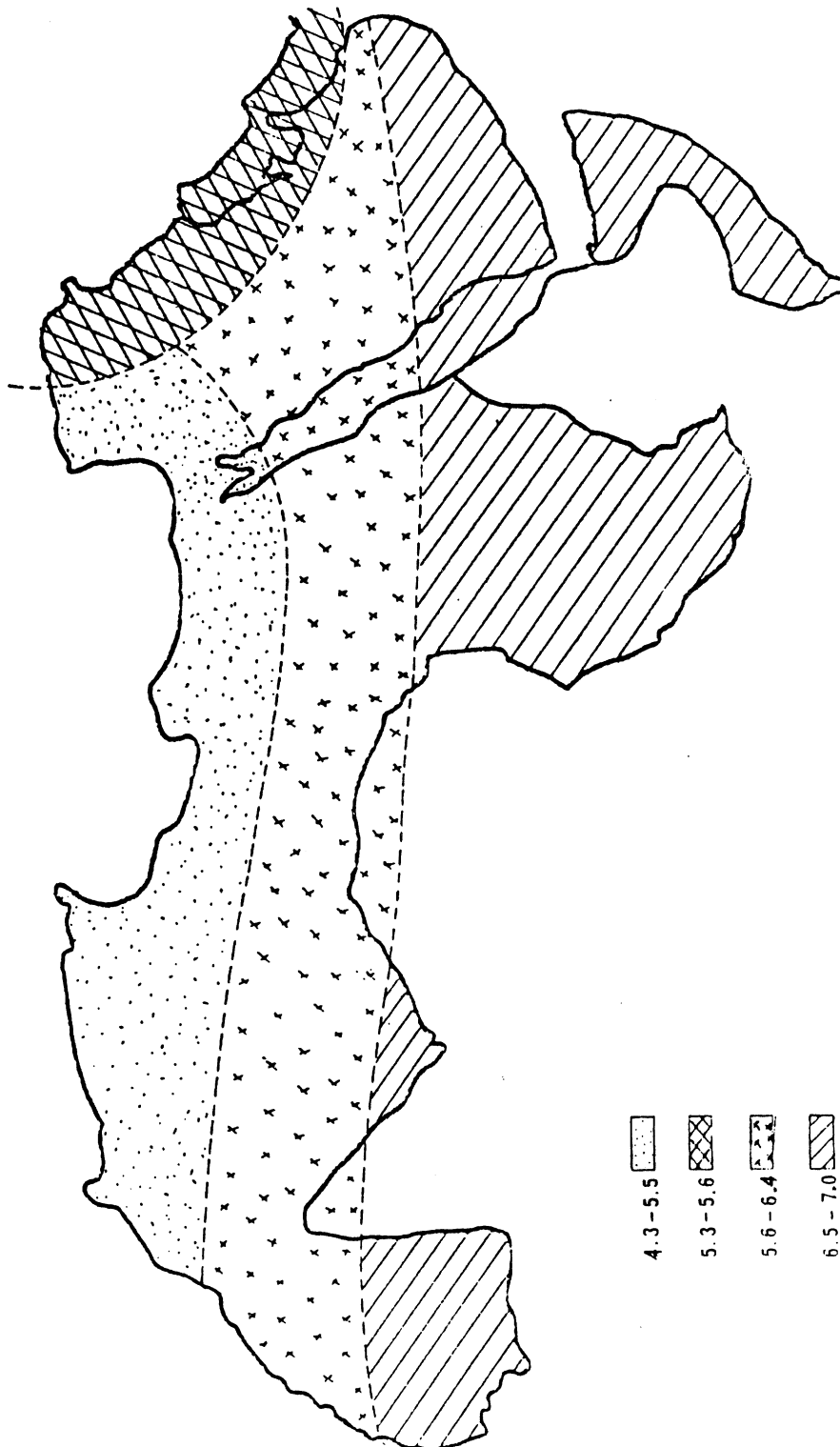
^{2/} M. A. Kettani, "Storage of solar energy in the form of potential hydraulic energy", Proceedings of Heliotechnique and Development.

Table VI.1. Relevant information about north African Arab countries

Country	Area (km ²)	Population (Millions)	Gross National Product			Oil production (Thousands of barrels)	Gas production (10 ⁶ m3)	Electricity production (MW)	Cost of Electricity (\$/kwh)
			Product						
Morocco	458 730	22.3	670	1.21	83.1	5 950	0.07		
Algeria	2 381 745	21.0	2 000	632.00	93 821.0	8 807	0.05		
Tunisia	164 150	7.0	1 100	120.00	510.0	3 373	0.07		
Libyan Arab Jamahiriya	1 759 540	3.5	8 700	1 036.00	12 350.0	8 400	0.07		

Source: A. A. Sayigh, "Solar energy-economy and prospective", Proceedings of the Second Arab International Energy Conference (Bahrain, 15-21 February 1986) and A. A. Sayigh, "The recent development and future of photovoltaic technology and the solar village in Saudi Arabia", Oil and Arab Co-operation, vol. 10, No. 4 (1984).

Figure I. Annual average solar radiation in Arab countries
(kWh/m²/day)



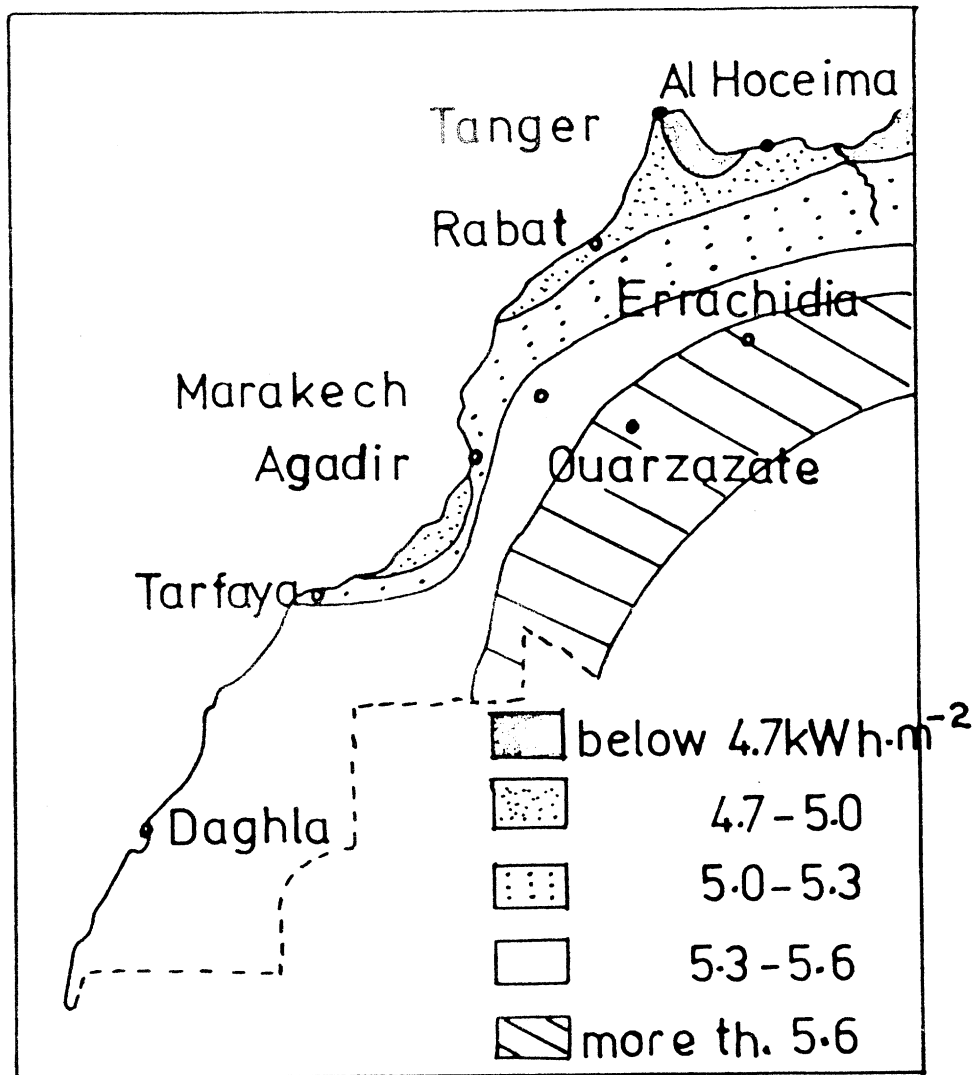


Figure II. Solar radiation in Morocco

(a) Pumping

There are several photovoltaic pumping stations in the country. In the province of Oujda, the Beni Oukil pumping station consists of 2,600 W photovoltaic cells. The station's pumping capacity is 116 m³/day. Another station is the Al-Jahwi Centre for farming help and innovation in Tarodant. Figure 3 shows this station.

(b) Refrigeration

Several photovoltaic refrigerators are used in Morocco for medical purposes. Some of them have a power capacity of 216 W and a cooling volume of 200 litres, as that shown in figure 4, which is used in the Sidi Moussa Medical Centre in the province of Marrakech. Another is used in the Bouabout Medical Centre in Imin Tanout province, which has a power capacity of 165 W and cold store volume of 112 litres. It maintains medicine at 4° C, while vaccine is kept at 25° C. Another example of refrigeration used for medical purposes, shown in figure 5, is the Bu-About Medical Centre in Marrakech province.

(c) Power stations and lighting

Several schools in remote areas are powered by solar energy from photovoltaic stations. Figure VI shows solar lighting in one of the classes in the coastal Souq Al-Arbia School, Tazneet province. A typical solar electricity generating station is shown in figure 1. This station was installed in the school of metallurgy in Marrakech, and has a capacity of 4,320 W. The station is used for pumping water, cooling and lighting. Electricity is stored in lead-acid batteries and used during the night.

(d) Desalination

Many solar stills have been installed in villages around the country. Figure 8 shows a station located in Abbou Abbes Essebti, in Marrakech province, which produces 800 litres of water per day for human consumption, 350 litres per day for cooking and 200 litres per day for animal use.

(e) Solar concentrator

A few projects were built in order to gain experience with solar thermal power generation. For example, a solar furnace with a capacity of 11 kW, is shown in figure IX. It is made of a parabolic concentrator with a fully tracking heliostat, which was installed by the College of Agriculture in Tamara in the province of Skhirat. The temperature range of the furnace is 500 to 1,100° C, and is used for making ceramics.

(f) Wind energy

Wind energy potential in Morocco is just as great as solar availability. Figure X shows the wind isopaths of the country that enjoy an average wind speed of 5.3 m/s. Ninety per cent of the country has wind speed variations of 5.5 to 8.3 m/s. Several wind machines have been installed in rural areas for

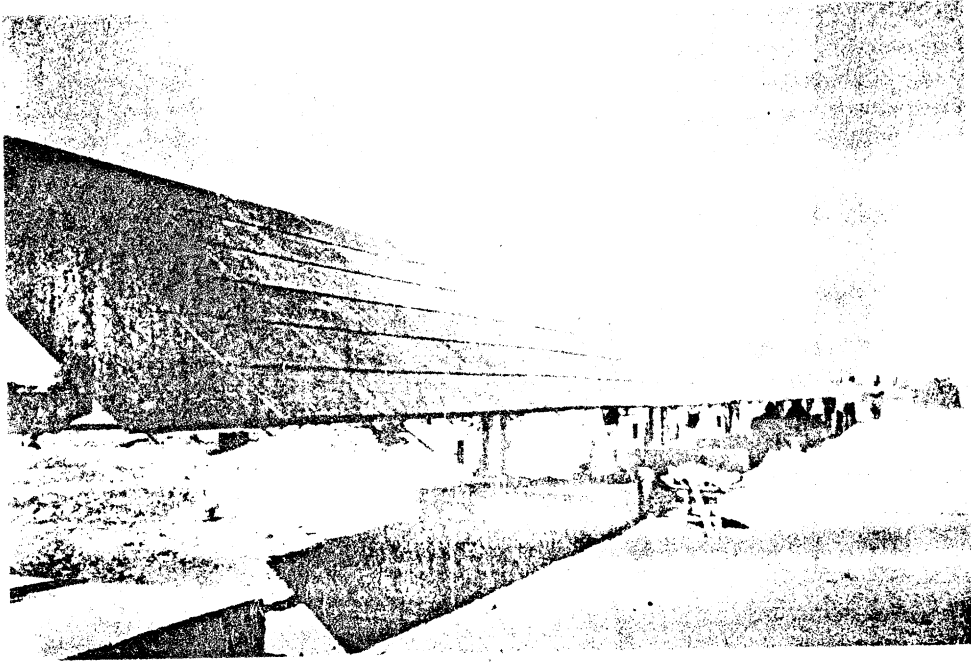


Figure III. Solar Pumping in Btarodant

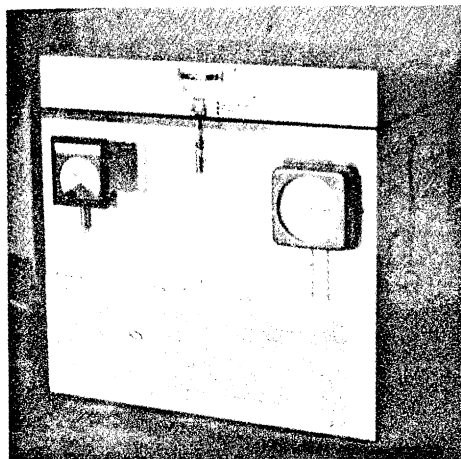


Figure IV. 216W Solar refrigerator

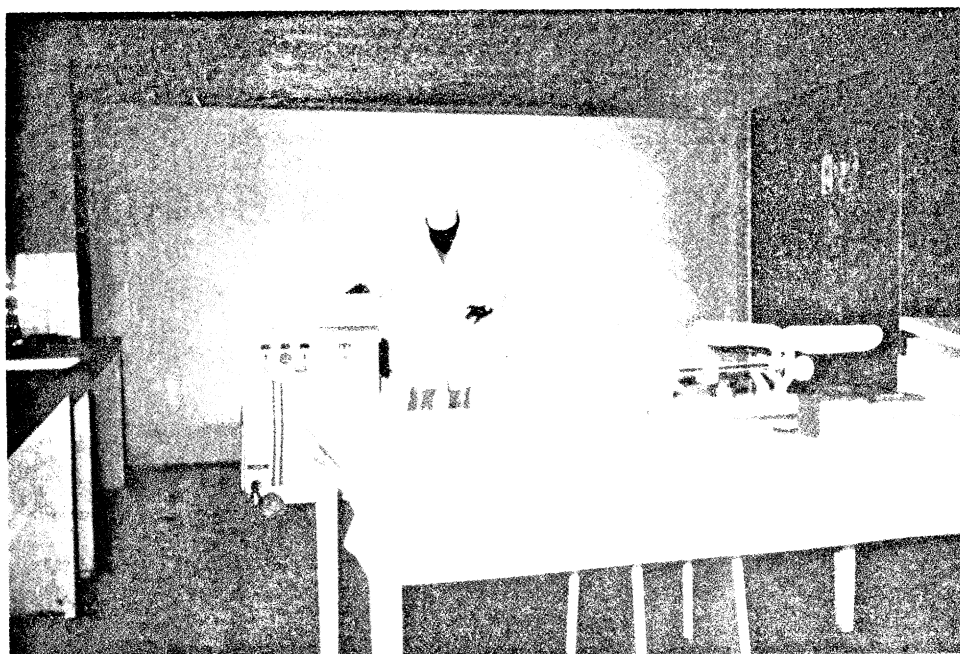


Figure V. Bu-About Medical Centre refrigerator

pumping water or for telecommunication purposes. Most machines are of the multi-blade type with a power rating of 1 to 5 kW. Figure XII shows one of these machines being installed for pumping water.

(g) Biogas

Perhaps one of the most effective ways of utilizing animal waste in rural villages is to produce methane gas by a biomass digester. Morocco has gained some excellent experience in this field. Several biogas digesters have been installed in the provinces of Ouarzazate, Beni Mellal, Taroudant, Marrakech, Errachidia and Kenitra. The gas is used for cooking and lighting. Both the Indo-Nepalese and Chinese digester types are used in Morocco. Figure XII shows two of them. Each one produces 1.5 m³/day of biogas.

2. Algeria

Owing to its position between the nineteenth and the thirty-ninth parallels, Algeria is a particularly sunny area, especially in the Sahara region, which is one of the best exposed regions in the world.

Thus, at any one point, Algerian territory can benefit from between 2,500 to 4,000 hours of sunshine per year, depending on its location.

Under these conditions, on a yearly average, one square metre of horizontal area receives more than 4 kWh per day in Algiers and over 6 kWh per day in Tamanrasset (2,000 km south of Algiers).

From a quick calculation, it can be seen that in 25 minutes, Algeria receives the equivalent of its present energy consumption of 18 million tons of oil equivalent. Solar energy has been in use in Algeria since the early 1950s when the French occupied the country. The 22 kW solar furnace in Algeria was built in 1956 and achieves a temperature of 4,000° C at its focus. The dish was used for melting metal.

In the early 1980s, the Government established a Renewable Directorate, and the solar energy programme is now one of the most important achievements of the country. Table VI-2 shows the solar radiation intensity in kWh/m²/day in three towns in the country, while table VI-3 provides some wind data for Algeria.

In Algeria there is an urgent need to use solar energy owing to the existence of many remote areas that have no access roads and to the government policy of decentralization. Also, there is a need to save oil for the future.

Solar heating and water heaters were the first applications in Algeria to be introduced by the Directorate. In 1983, four different types were produced. Eventually, one design was selected and 50 heaters with a collector area of 4 m² per heater were produced. Now a joint venture with the National Plastics Establishment and the Mechanical Division of the Directorate has been established to produce 2,000 heaters per year. Since 1984, after perfecting the technique of solar desalination using simple stills, 100 units were made and installed in hospitals and remote areas in the south of the country. Solar still units that produce 50 litres/day are being manufactured to provide enough water for 300 inhabitants in the village of Bishar.

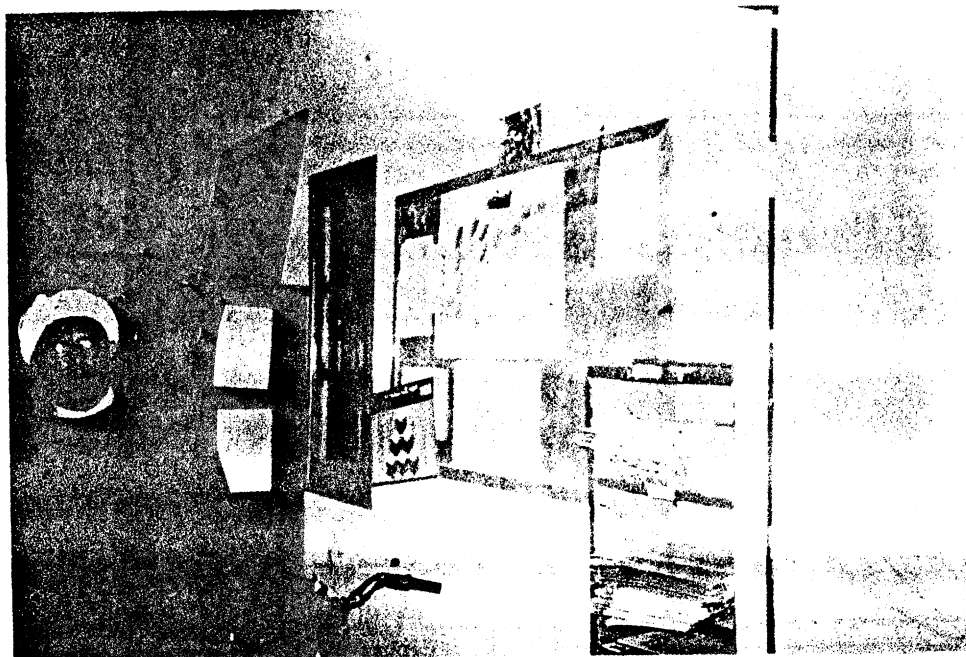


Figure VI. Lighting in Souq Arbia school

Table VI.2. Solar radiation in three towns in Algeria
(kWh/m²/day)

Months	Djelfa	Tamanrasset	Algeria
1	3.0	5.2	2.5
2	3.8	6.2	3.6
3	5.0	7.1	4.9
4	6.2	7.5	6.2
5	7.3	7.6	7.3
6	7.7	7.3	7.5
7	7.5	7.2	6.8
8	6.8	6.6	5.5
9	5.5	..	..
10	4.2	5.8	4.2
11	3.0	5.2	2.9
12	2.5	5.2	2.5
Average	5.2	5.9	5.1

Table VI.3. Wind speeds in two towns in Algeria
(m/s)

Months	Annaba	Algiers
1	3.8	3.5
2	4.1	4.1
3	3.7	3.8
4	3.5	3.4
5	3.0	3.1
6	3.6	3.4
7	3.7	3.3
8	3.5	3.3
9	3.5	3.0
10	3.5	3.0
11	3.4	2.8
12	3.3	2.9
Average	3.5	3.3

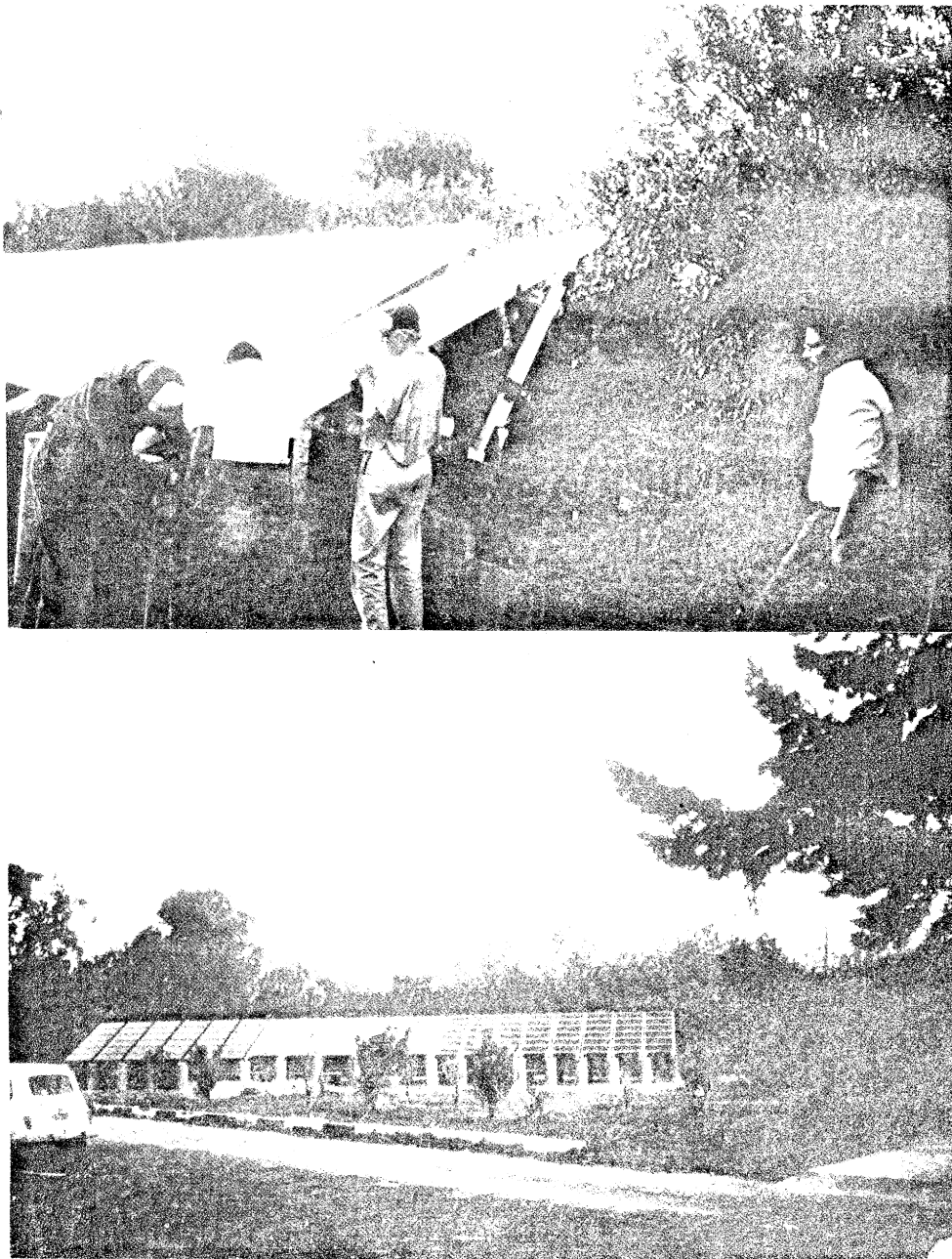


Figure VII. Photovoltaic station

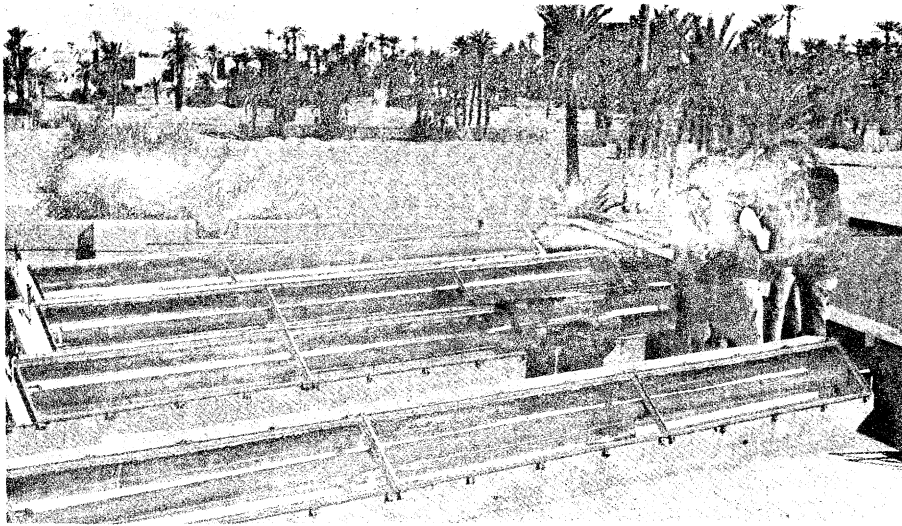


Figure VIII. Abbou Abbas Essebti desalination plant

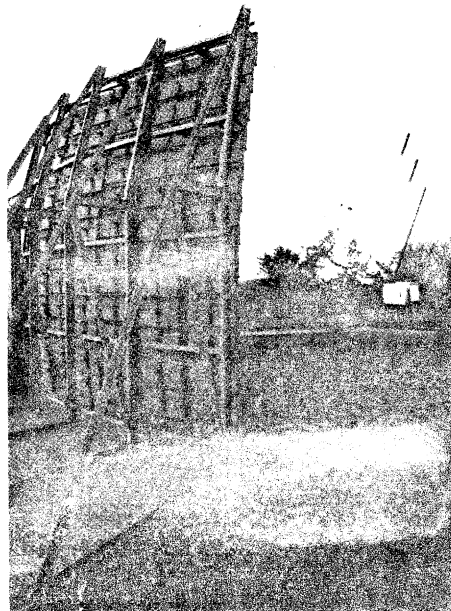


Figure VIX. Eleven-kW solar furnace

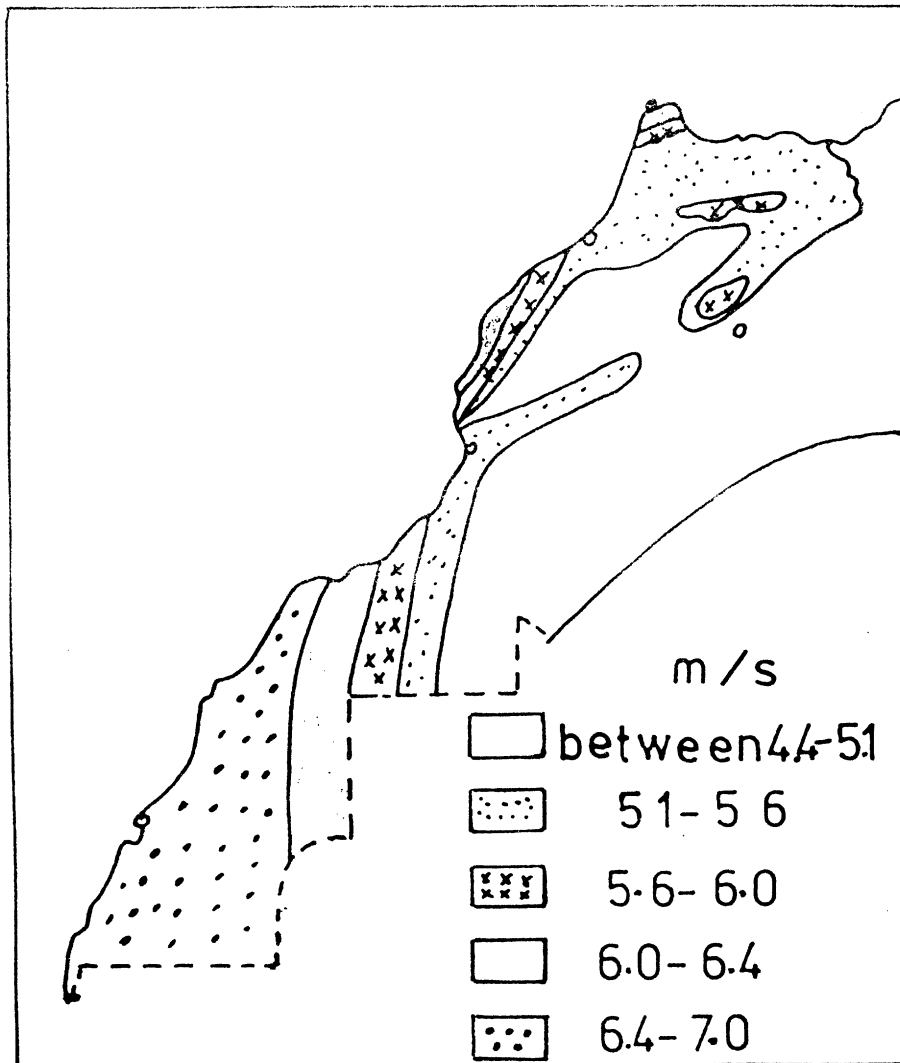


Figure X. Wind isopaths of Morocco

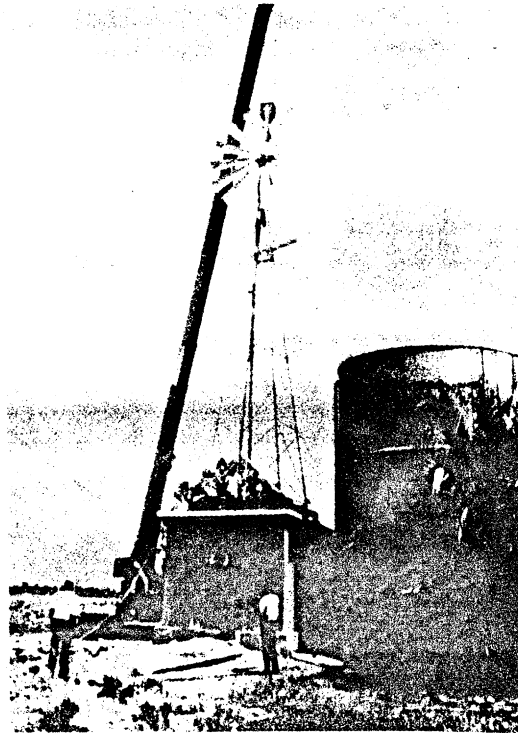
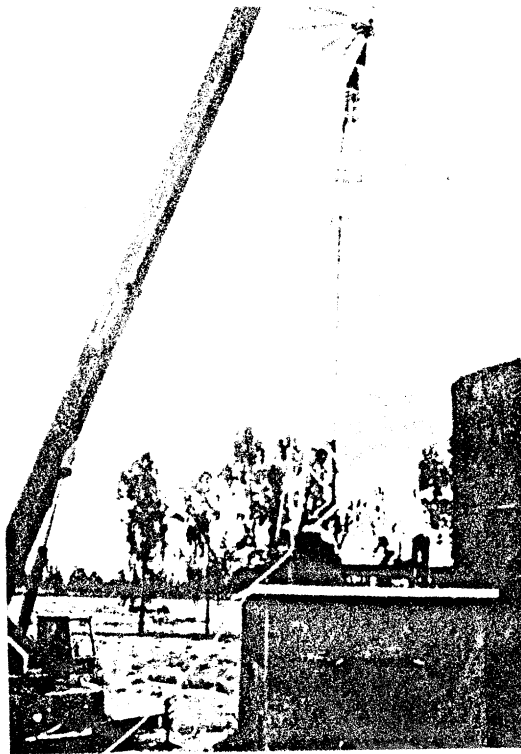


Figure XI. Wind machine for water pumping

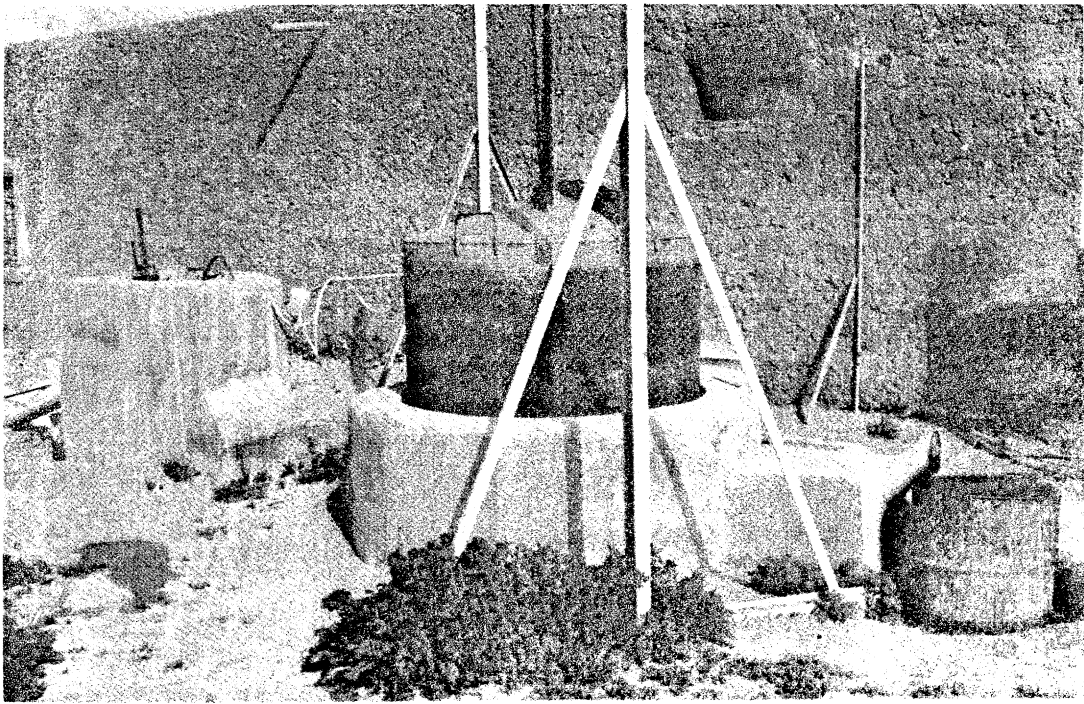


Figure XII. Biogas digesters

More than 30 photovoltaic pumps are located around the country. The experiment at Batra village, which consists of 11 houses, each with a television, radio, refrigerator and three electric lamps that are totally run by a solar photovoltaic station, is in use in three more villages. Also, several hundred solar refrigerators were made in collaboration with the inhabitants of the remote southern region for use in preserving medicine.

Telecommunications are also totally powered by solar energy in the centres of Aris and Adrar, as well as in the provinces of Tamanrasset, Beshar and Tendouf.

Perhaps the most effective and vital solar energy project in Algeria is that of lighting the 670 km road that connects Regan and Burg Baji Mukhtar. The road is not paved and lighting consists of free-standing lamps placed at intervals of half a kilometre along the road. It is worth mentioning that the dangerous Tenzarofet desert cuts across this road.

With regard to wind energy, 10 different machines have been installed in various parts of the country for water pumping. It has been found that wind machines are well suited for deep well pumping in Algeria.

Biogas applications are also utilized in agricultural areas to produce methane from animal refuse or decayed dates. In 1982, the Office Nationale de la Recherche Scientifique (ONRS) used funds from the United Nations Development Programme to build a solar village for 2,000 people near Bou Saad in Msila province.

3. Tunisia

The country has an excellent number of hours of sunshine, 2,700 to 3,600 hours per year, as is shown in figure XIII. Table VI-4 shows solar radiation data in some of the major towns of Tunisia.

The solar energy programme is divided into several parts, as follows:

(a) Research and development

This deals with research in thermal, chemical and photovoltaic conversion. In Sidria tower, three laboratories have been established. One deals with photovoltaic technology, and has a small production unit. Another laboratory deals with thermal applications, and in particular with the production and testing of solar water heaters. The third laboratory deals with water desalination, and several models using simple stills, multi-stage flash, reverse osmosis and electrodialysis, have been built and tested. Other establishments also have active solar programmes. These are the Meteorological Organization, the Tunis School of Engineers, the College of Science in Tunis, the College of Science and Technology in Spax, the Teacher Training College for Technical Education and the College of Buildings and Architecture, also in Tunis.

Several companies are interested in conducting feasibility studies for solar energy. They are the Tunisian Petroleum Establishment, the Tunisian Gas and Electricity Company, the Energy Control Company and SEREPT for renewable energy.

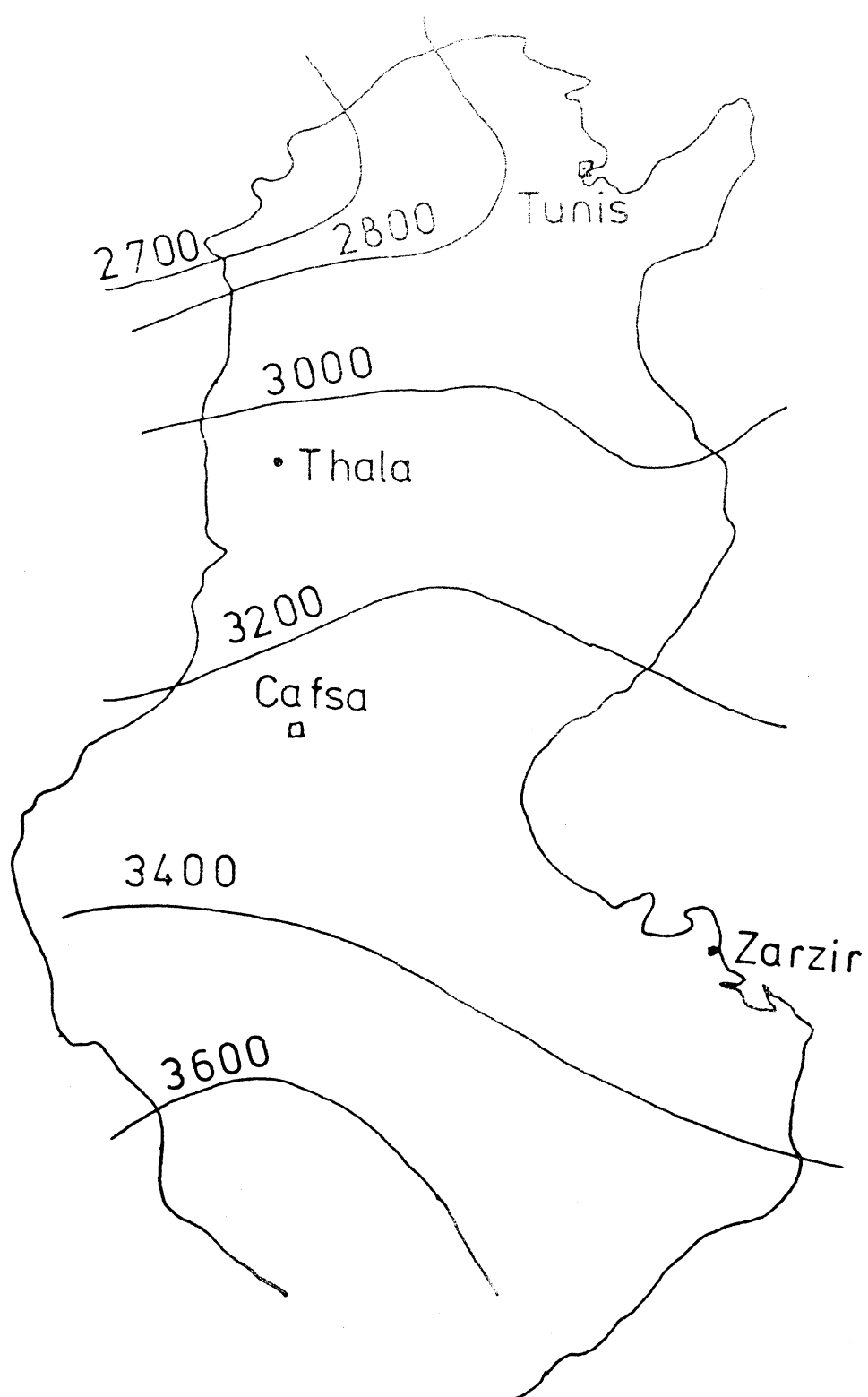


Figure XIII. Sunshine hours in Tunisia

Table VI.4. Solar radiation in the major towns of Tunisia
(kWh/m²/day)

Months	Dow Said	Jendouba	Kairouwan	Spax	Qapsa	Gabes
1	2.4	2.1	2.9	3.0	2.9	2.9
2	3.2	2.8	3.6	3.8	3.8	3.6
3	4.4	4.0	5.0	5.0	5.1	4.9
4	5.4	5.0	5.8	5.8	6.1	5.9
5	6.5	6.0	6.9	6.9	7.1	6.8
6	7.3	6.7	7.4	7.4	7.3	7.2
7	7.4	6.8	7.3	7.6	7.3	7.3
8	6.6	5.9	6.5	6.9	6.5	6.5
9	5.3	4.9	5.4	5.3	5.3	5.4
10	4.0	3.5	4.2	4.4	4.3	4.2
11	2.9	2.6	3.3	3.4	3.3	3.2
12	2.3	2.0	2.8	3.0	3.0	2.4
Average	4.8	4.4	5.2	5.9	5.2	5.0

(b) Demonstration projects

The solar village of Hamam Beyatha, which belongs to the Gas and Electricity Company, lies about 150 km south-west of the capital and has 22 families, mostly farmers. It has a school for 400 students, a mosque, a health centre and several shops. The village has a 29 kWp photovoltaic station. The health centre has a solar water heater with a capacity of 300 litres. The village uses wind energy for water pumping, and all of the houses were built with a passive design in order to reduce energy consumption and to increase energy conservation.

The Hindi Al-Zaiton Experimental Farm is under the supervision of the Agricultural Engineering Centre, and consists of two pumping stations where the photovoltaic conversion units are of 600 W and 1,600 W capacity respectively. There are numerous photovoltaic pumping stations throughout the country, in Al-Nuzha near Zaghwan, Al-Napheath near Burj Al-Amiry and Bu Hudba near Jabal Al-Wassat.

Another project in this area will supply electricity (2,400 W) to an army camp in the extreme south of the country.

(c) Manufacture of solar equipment

Several companies produce solar energy equipment. The Gas and Electricity Company has established two sub-companies, SIAME and SEREPT, which mainly deal with alternative energy. SIAME manufactures solar water heaters with a capacity of 150 litres and supervises their installation. The heaters only use the thermosyphon system. SEREPT introduced different-sized water heaters with capacities of 120 to 150 litres and 250 litres. They use either forced circulation or a thermosyphon system. Solar water heater production in Tunis amounts to about 8,000 units per year. It is becoming more popular owing to its cost effectiveness and reliability. Figure XIV shows one of these heaters. Water desalination in Tunisia is vital to the southern region. The Burg Al-Sidria experiments show the effectiveness of all of the desalination methods. A few large-scale units are in use in the central and south regions.

(d) Wind energy

Tunisia has utilized wind energy for the last 200 years. During the early part of this century more than 10,000 units were in use all over the country for pumping water and lighting. This was the situation until 1960, when diesel and electric generators replaced most of the wind machines. The authorities have recently taken the initiative to develop several wind machines for pumping and electricity generation. One of these projects is the Al-Hawaria lighting project which has a power capacity of 21 kW. SEREPT has produced several wind machines for pumping and has utilized them in the central part of the country. Other areas such as Sajnan in the north-west and Al-Khumasia near Zaghwan have been provided with experimental wind machines. Figure XV shows a SEREPT wind generator with a 5 m diameter wheel consisting of eight blades and a pumping capacity of 100 m³/day, to a depth of 20m at a wind speed of 5 m/s.

(e) Biomass

Owing to the nature of the country which consists mainly of farmland, and in view of the forestry situation, biomass conversion has excellent prospects in Tunisia. Several experimental units that utilize cow dung have been produced in Sajnan. The units were produced under a Tunisian-German co-operation programme. A similar programme, in conjunction with the Belgians, was built in Kap Sirat for the production of fertilizer. Biogas is now in use on several farms for heating, cooking and lighting. Figure 16 shows one of these digesters.

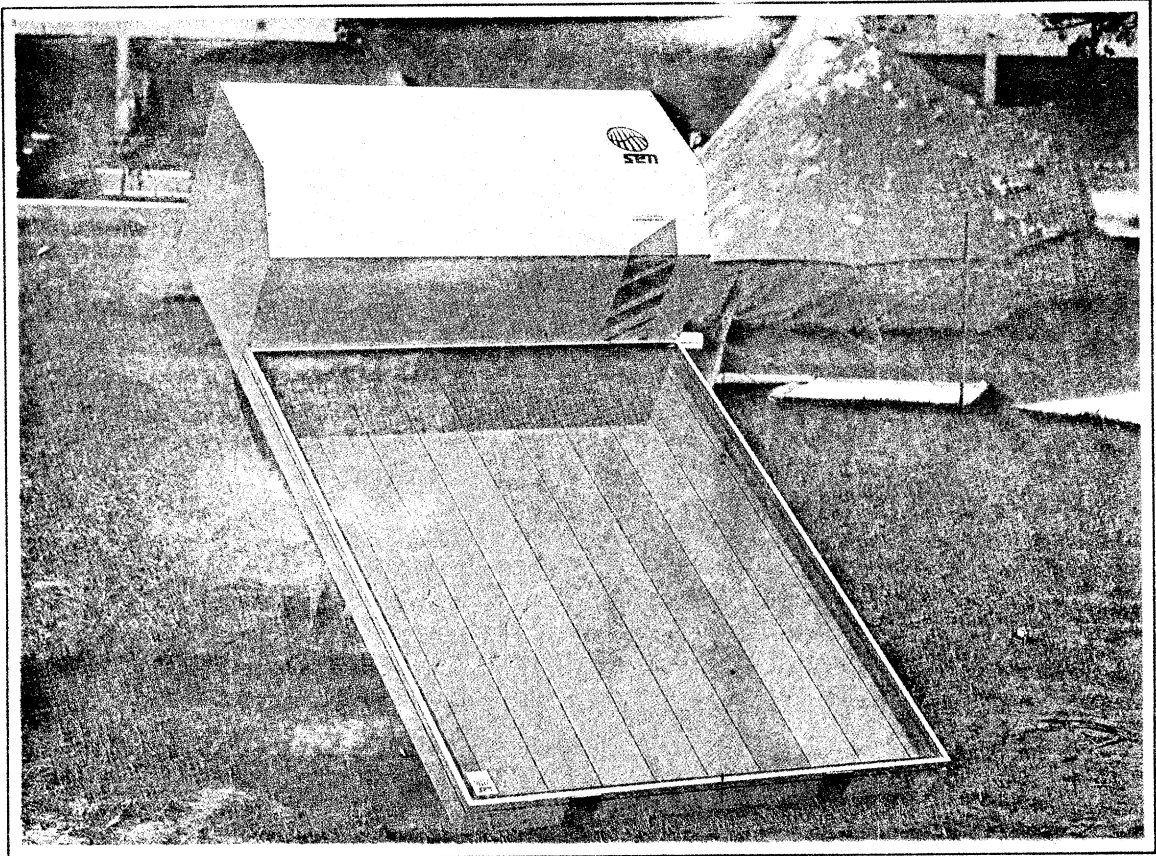


Figure XIV. SEN solar water heater

4. Libyan Arab Jamahiriya

Owing to the vast size of the Libyan Arab Jamahiriya, which has solar radiation reaching as high as $7 \text{ kWh/m}^2/\text{day}$, solar applications such as water pumping and electricity generation in remote areas are not only cost effective, but also the most promising method of getting electricity to these remote areas. Solar activities started in the Libyan Arab Jamahiriya in about the mid-1970s and a well equipped solar energy centre has been established. Figure XVII shows the isoradiation lines in the Libyan Arab Jamahiriya.

The photovoltaic applications are as follows: several solar cell applications which were used by telecommunications and oil companies in relay stations for generating electricity and cathodic protection, water pumping and television transmission in remote areas. The Solar Energy Centre in the Libyan Arab Jamahiriya has carried out several studies in the following areas: a feasibility study on the establishment of photovoltaic production facilities, solar water heating, passive heating and cooling, solar gain in buildings and methods to reduce it, solar energy storage, the use of solar ponds in cooling and desalination, as well as various studies about the nature of solar radiation and its components in the Libyan Arab Jamahiriya. All educational establishments such as the Qar Unis University in Benghazi, the Al-Fatih University in Tripoli and Al-Najm Al-Satia in Braiqa, are involved in fundamental research in solar energy.

(a) Wind energy

Potential of wind energy in the Libyan Arab Jamahiriya is equal to that of solar energy. Figure XVIII shows a map of wind isopaths in the country. The use of wind machines in the Libyan Arab Jamahiriya reached a maximum in about 1950, when 249 machines were used to pump water, but owing to lack of maintenance and a fall in the water level of wells, and the availability of cheap diesel fuel, electric generators have replaced them. Several scientists are now being trained abroad on the utilization of the wind energy. Up till now the country has no facilities to manufacture wind turbines.

C. Conclusion

North African Arab States have an excellent solar and wind potential. An average of 3,000 hours of sunshine and solar radiation of $5 \text{ kWh/m}^2/\text{day}$ are shared by the four countries. Wind speeds in excess of 5 m/s are common in most areas in the four countries. All four countries have effective programmes for the utilization of solar energy, wind energy and biomass energy in most of their rural areas. Solar water heaters are produced in Tunisia, while biogas digesters are built in Morocco, Algeria and Tunisia. Solar wind and biomass resources can meet energy demands in all four countries if there is adequate co-ordination and utilization of these sources.

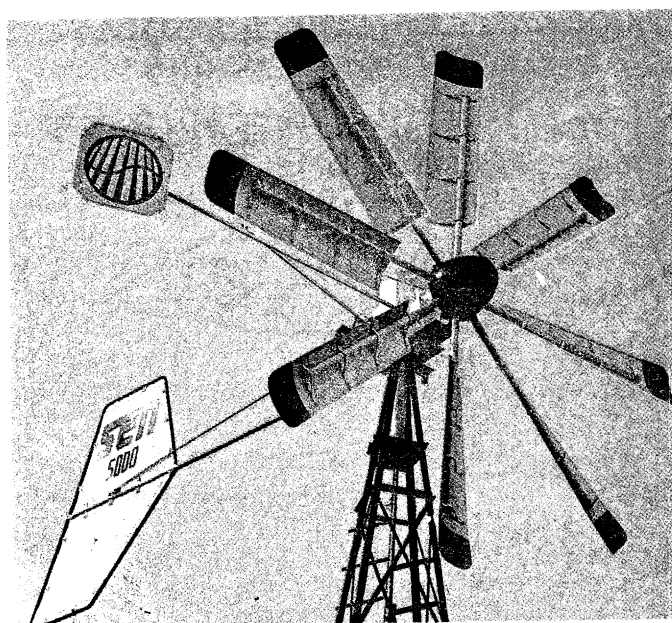


Figure XV. SEREPT wind generator

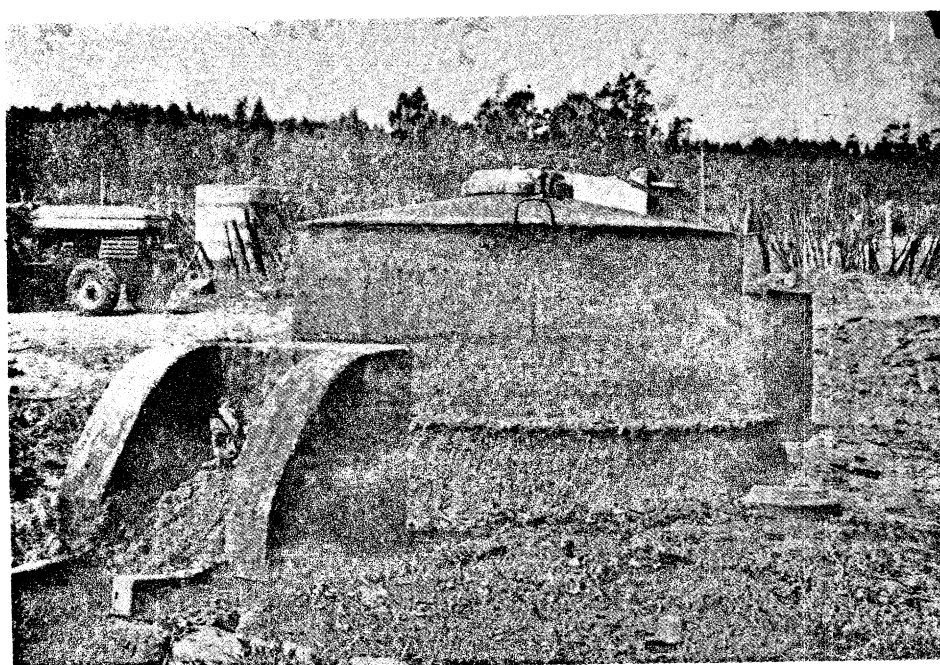


Figure XVI. Biogas generator

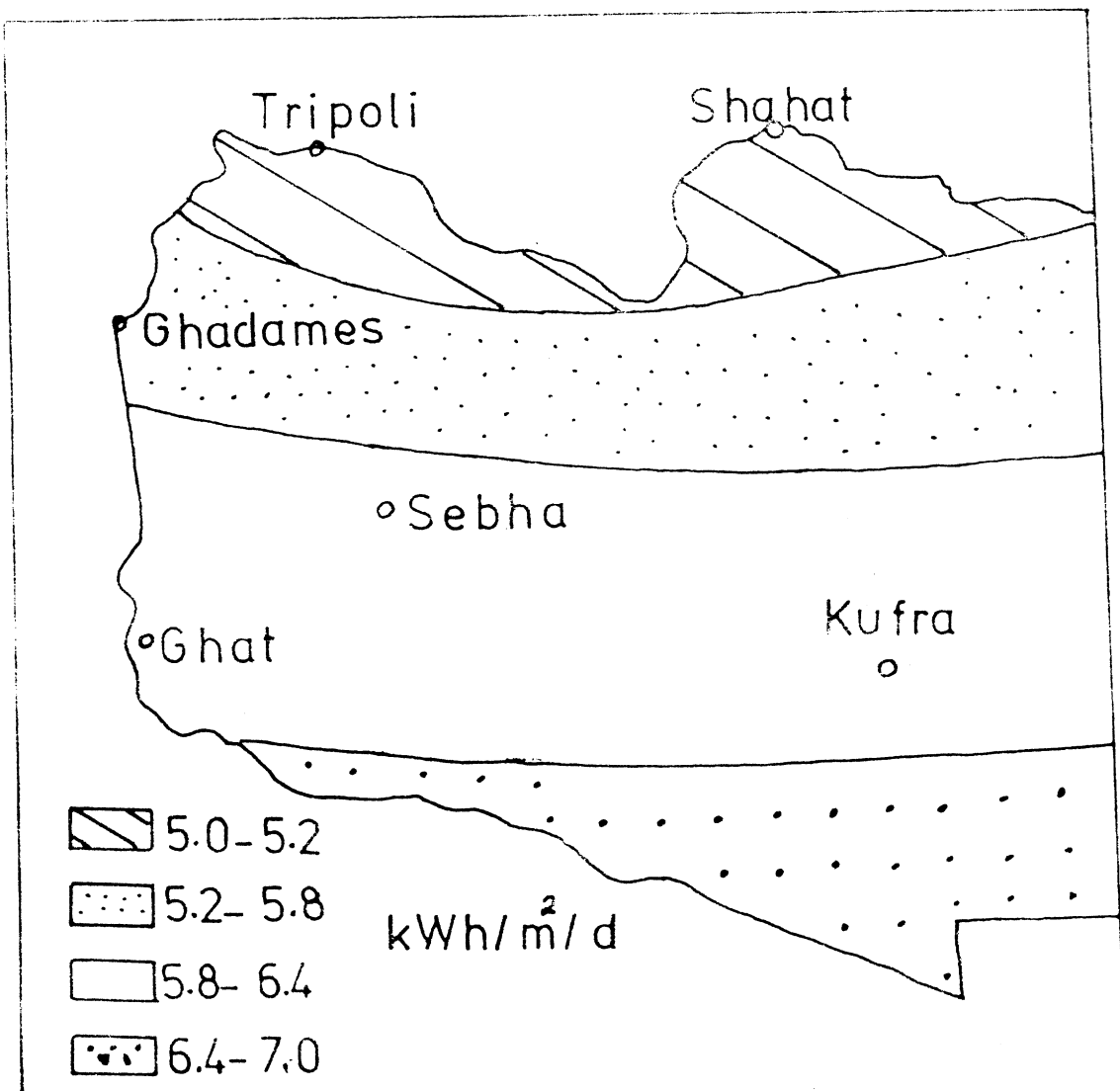


Figure XVII. Isoradiation map of the Libyan Arab Jamahiriya

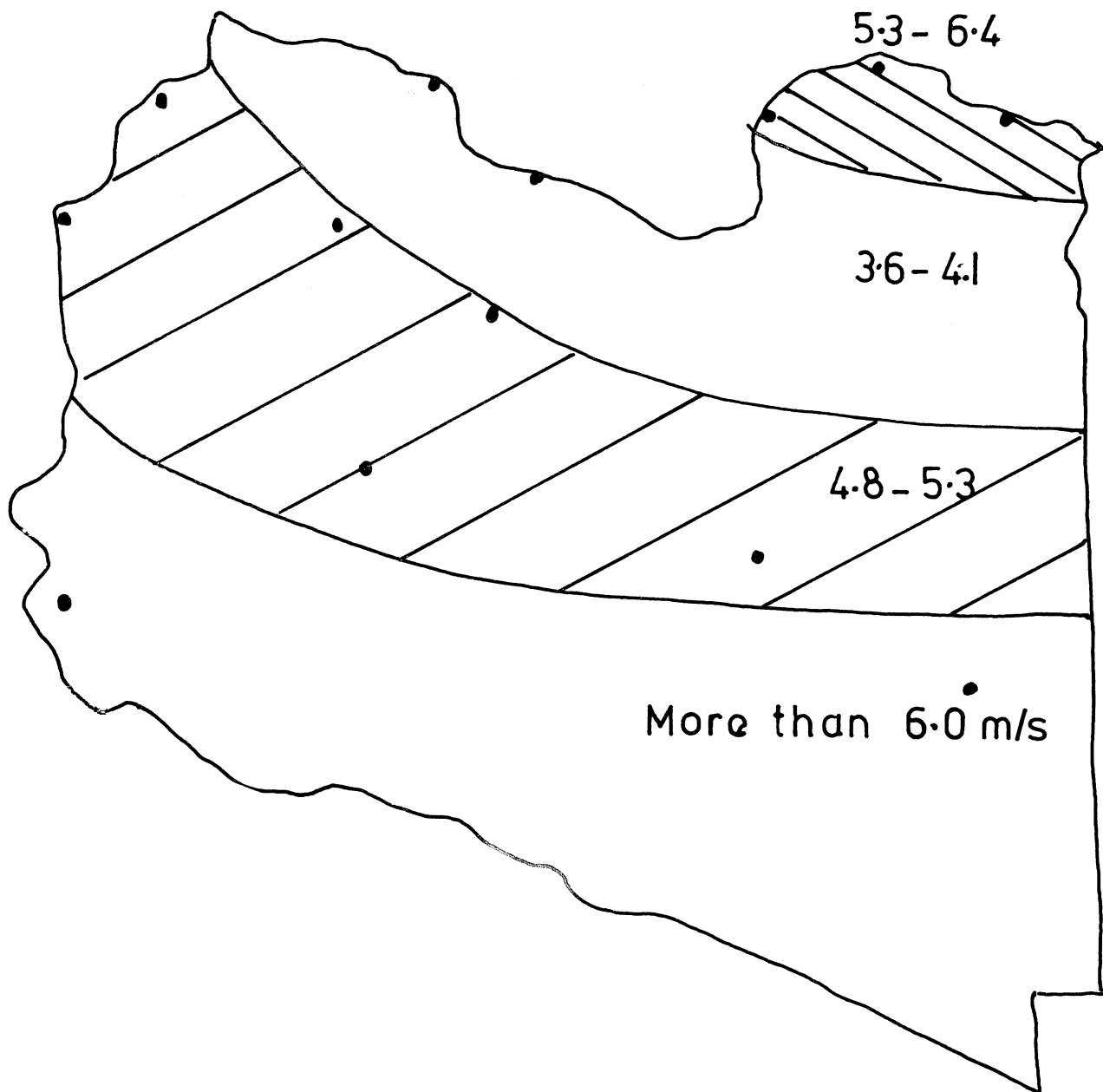


Figure XVIII. Wind Isopaths of the Libyan Arab Jamahiriya

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Part Two

COUNTRY PAPERS

VII. COUNTRY PAPER OF EGYPT: REPORT ON THE ACTIVITIES OF THE
MINISTRY OF ELECTRICITY AND ENERGY IN THE FIELD OF THE
DEVELOPMENT AND USE OF NEW AND RENEWABLE ENERGY

Tlaat El-Tablawy*

A. Introduction

Energy has always played a fundamental role in meeting the requirements of development. At present, given the unprecedented industrial and technological development that affects all aspects of life, this role has become even more important.

The rate of energy consumption in Egypt has increased continuously. During the last few years the increase in consumption of total energy reached 11 per cent per year, while it exceeded 14 per cent with regard to electrical energy. It is therefore probable that national resources of conventional energy will fall short in meeting the requirements of the increasing rate of energy consumption and in achieving the objectives of the economic and social development plans of the State.

For that reason, the Ministry of Electricity and Energy, in pursuit of its objective of providing the energy required for development programmes, and paying due regard to the conservation of the natural resources of the country, has insisted that its strategy includes two major targets:

(a) Achievement of the maximum possible energy conservation and the limitation of the excessive use of energy resources;

(b) The survey and assessment of new and renewable energy sources in Egypt, their widespread utilization and the development of systems that take the potential of local industry into consideration, as well as the fact that this should solve conventional sources of energy as much as possible.

It is worth mentioning that new and renewable sources of energy include natural energy resources such as:

- (i) Solar and wind energy;
- (ii) Biomass energy;
- (iii) Agricultural residues;
- (iv) Geothermal energy;
- (v) Tidal and wave energy.

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Within the framework of these fundamental objectives, the Ministry of Electricity and Energy has designed its strategy for the development and utilization of new and renewable sources of energy, which are expected to contribute about 5 per cent of total national consumption by the year 2005. In order to achieve this, the Ministry of Electricity and Energy has formulated programmes for the development and utilization of new and renewable sources of energy with the objective of:

(a) Establishing the infrastructure required for the survey and assessment of new and renewable energy sources in Egypt, and preparing plans for the development and utilization of these sources;

(b) Setting up and improving executive organs that are capable of taking full responsibility for implementing planned activities in this field;

(c) Undertaking research and technical and economic studies in co-operation with other parties involved in scientific and technological activities that promote the utilization of new and renewable sources of energy;

(d) Implementing several demonstration projects in the field and applied systems for readjusting technologies that are available world-wide to the local capabilities and conditions;

(e) Studying the requirements of standardization and the testing systems of renewable energy equipment;

(f) Preparing and implementing the training and dissemination programmes for the widespread utilization of new and renewable energy;

(g) Providing the required support for the enhancement and expansion of local industry producing renewable energy equipment.

In the context of these programmes, the Ministry of Electricity has implemented several demonstration and application projects with the aid of bilateral agreements with international bodies, and in co-operation with a number of Egyptian organizations involved in research development and demonstration (RD and D) and the application of renewable energy technologies.

This paper consists of two parts: the first includes a presentation of the achievements of the Ministry of Electricity and Energy, while the second deals with projects that have been considered for implementation in the current five-year plan.

B. Achievements of the Ministry of Electricity and Energy in the field of renewable energy

Within the framework of the above-mentioned objectives, the Ministry has implemented many projects in the following field applications:

1. Survey of new and renewable energy resources in Egypt

Since the optimum utilization of energy resources requires a comprehensive survey and assessment of their availability, particularly with regard to

renewable energy sources that vary from one geographical location to another, and from one part of the year to another, the Ministry has paid special attention to the establishment of facilities that are specifically designed to measure and assess new and renewable resources in Egypt. Major achievements in that direction are:

(a) The establishment of a solar measuring network on a national level for the preparation of a comprehensive solar map for Egypt. A central station has already been installed with mobile stations for data collection;

(b) A comprehensive survey of wind resources in Egypt, from which a basic map of wind energy in the country was drawn up;

In addition, a detailed study is being carried out on wind energy on the Red Sea and northern coasts as well as in the eastern Al-Ouwainat area. The study consists of the analysis of data collected during the last two years from 12 stations in these areas;

(c) At present, geothermal resources are being investigated, and biomass resources are being studied to assess the potential of their use in energy generation. In this regard, the Ministry, through the Supreme Council of New and Renewable Energy, co-ordinates with the Ministry of Agriculture and the Academy of Scientific Research and Technology where biomass resources have been studied and assessed within their respective programmes of activities.

2. Development and utilization of renewable energy

Since 1977, the Ministry of Electricity and Energy has launched an ambitious programme for the use of solar energy in many fields, including thermal use for heating/cooling and water desalination, as well as energy generation through the utilization of photovoltaic devices for various applications. The implementation of the demonstration and application projects was completed by a scientific programme for studies, which aimed at assessing the potential of solar energy with regard to the various energy requirements of Egypt.

The study carried out by the Ministry pointed out the necessity of developing the utilization of solar energy for different heating purposes in the household, commercial and industrial sectors. This is because available solar energy technologies may lead to the saving of about 3.5 billion kWh of electricity in the household and commercial sectors by the year 2005, in addition to 2.2 MTOE which could be saved through the utilization of solar energy for industrial heating operating at low temperatures.

Also, systems that generate electricity through the use of photovoltaics, can make a contribution to the attempt to solve the problem of providing remote areas with energy, particularly in the light of the Egyptian programme for the development of desert areas of eastern Al-Ouwainat, the western desert and Sinai. According to the studies carried out, this would lead to a saving of about 0.52 MTOE per year.

The Ministry, which is fully aware of the complexity of the activities that need to be undertaken to achieve these objectives, including the establishment of the required infrastructure to promote the development and utilization of solar energy sources, has carried out the following studies and projects:

(a) Projects involving solar water heaters for the household and commercial sectors

The Ministry started its activities in this field by importing 1,000 solar water heaters with different specifications and sizes from France, Canada and Cyprus. In order to encourage the use of these solar water heaters and experiment with their performance under local conditions, the following steps were taken:

- (i) Thirty-five solar heaters were installed in different experimental sites in several governorates in Egypt, and their performance was tested under local conditions;
- (ii) A number of installation and maintenance crews working in the Electricity Distribution Co. in Cairo, Alexandria and the canal cities, were given training;
- (iii) Solar water heaters were rented to users through distribution networks in order to promote the widespread utilization of these heaters and to follow up their operation and maintenance. The number of heaters installed according to these arrangements, exceeded 800 units;
- (iv) Fifty solar water heaters were installed in public utilities in an effort to benefit the nation at large. Among the solar water heaters designed for that purpose were those installed in the Faculty of Engineering, the Military Hospital in Ghamra, the Governorate of Marci Matrouh and the Metallurgy and Steel Co.

In addition, the Ministry, with the aid of the Franco-Egyptian agreement, installed the following heating devices:

- a. A heater with a capacity of five m³ per day in the cobalt building of the Armed Forces Hospital in Al-Maadi;
- b. A heater with a capacity of 150 litres per day in Al-Wafa and Al-Amal city.

In addition, a number of heating projects for industrial purposes are being implemented as part of programmes to be carried out to the end of the first five-year plan. These projects will be mentioned later.

(b) Experimental projects involving the generation of electricity from solar energy

Electricity can be generated from solar energy through the use of thermal and photovoltaic systems. The Ministry has investigated the possibility of

using all of these systems. It has also paid special attention to their development world-wide. However, owing to the technical and economic constraints that hinder the application of thermal systems, the activities of the Ministry have been concentrated on the utilization and testing of electricity production systems that use photovoltaic devices. It should be noted that, although efforts are being concentrated on photovoltaics, the Ministry continues to pay special attention to the world-wide scientific and technical development of other systems.

Co-operation with the Federal Republic of Germany includes the provision and installation of a number of solar experimental stations that function by mean of photovoltaic cells which have the following uses:

- (i) A navigation warning device installed in the lake of the High Dam. The device has functioned successfully since 1980, and has led to the commercial propagation of this type of photovoltaic application in Egypt;
- (ii) A system to operate the microphones of the Meet Ab-Elkom mosque;
- (iii) A refrigerator with a capacity of 2 kW to preserve medicine in the medical centre of Meet Abu-Elkom village. The refrigerator has functioned successfully since the beginning of 1981;
- (iv) A photovoltaic station that recharges electric batteries which operate insecticide sprays. The device has been operating since March 1981 on the site of the project to improve irrigation methods in El-Mansura;
- (v) A solar water pump with a capacity of 2 kW has been successfully used for irrigation purposes since December 1981;
- (vi) The operation of a colour television by means of photovoltaic cells. The TV is located in a public square in Meet Ab-Elkom village, and has functioned successfully since the beginning of 1983.

A number of Egyptian engineers and technicians have been trained in the installation and proper operation and maintenance of the equipment included in the above-mentioned projects.

The Ministry has also implemented the following projects in co-operation with United Nations Development Programme and a petroleum company:

- a. The installation of a number of wireless communication units in the Abu-Ghousoun, El-Kasir and Ghardba areas on the Red Sea coast, as well as in the oases of Sina and Merci Matrouh;
 - b. The installation and operation of a unit to desalinate water with a capacity of 10 m³ per day in the town of Abu-Ghousoun on the Red Sea;
 - c. The design, installation and operation of the first pumping station to function by means of photovoltaic cells. The station was installed in the Shark El-Ouwainat area, and has a total capacity of 25 kW.
-

(c) Projects that utilize solar energy for cooling and water desalination

Egypt suffers from a lack of drinking water in several coastal areas and in the Western Desert. The provision of cooling stores for food and medicine is also a basic requirement in many remote areas. In an effort to meet these needs, the Ministry has begun to experiment and readapt solar energy technologies through the implementation of the following projects:

- (i) The installation of the first cooling unit to function by means of a solar thermal system in the Sahara area of Aswan. It has a capacity of 10 kW. It was installed with the co-operation of the French Government, and is designed to preserve the fish amassed by dispersed fishermen. An ice maker with capacity of six tons of fish is used to preserve the fish;
- (ii) A solar thermal energy unit for wells being desalinated was installed in 1979 on the site of the Egypt Company of Phosphates in Al-Hamrawin on the Red Sea coast. However, because of a number of technical problems that came to light during operation, this unit is being replaced by another that uses a photovoltaic system. The maximum capacity of the latter 18 kW. It has been provided with 200 kW storage batteries. The unit produces 53 m³ of fresh water from the mines wells which have a salinity that reaches 3,500 parts per million;
- (iii) The installation of a 30 litre refrigerator within the framework of the agreement with UNDP for the preservation of vaccines and medicines in the Egyptian Organization for the Production of Vaccines;
- (iv) The installation and operation of a water desalination and pumping unit that functions by means of photovoltaic cells, and which has a capacity of six kW. It provides the high voltage research laboratory in Al-Haram with potable water. The unit has functioned successfully since 1984.

(d) Projects for the establishment of laboratories to test solar equipment

As it was fully aware of the importance of protecting both the producers and consumers of solar energy equipment and meeting the requirements of solar energy projects, the Ministry of Electricity and Energy has made a special effort to construct specialized laboratories to test solar equipment and to issue certificates of suitability. In this frame, two laboratories that test and evaluate solar flat-plate collectors, have been installed in the high voltage complex of Al-Haram. Locally manufactured solar heaters are tested and their performance is evaluated. The laboratories in question are:

- (i) Laboratory for testing solar flat-plate collectors. In co-operation with the French Government, a complete laboratory has been installed to test and evaluate the performance of solar flat-plate collectors, in accordance with international testing specifications. Locally manufactured heaters are tested in this laboratory;

- (ii) Experiment with nocturnal radiation. A system to test the effects of nocturnal radiation on the performance of solar complexes and to collect data on heat loss caused by nocturnal radiation has been installed;
- (iii) Station for the comparative testing of solar complexes. Within the framework of an agreement between Egypt and the Federal Republic of Germany, a unit to test solar flat-plate collectors at the site of the high voltage laboratory at Al-Haram was imported and went into operation. A number of improvements have been made to this unit in order to undertake a comparative performance evaluation of and to test solar complexes. Engineers of the Ministry have made tests and evaluations of samples of locally and foreign manufactured solar complexes. The unit is characterized by its high degree of accuracy in testing and evaluating, and is therefore in a position to issue certificates of suitability for solar energy equipment.

The co-operation between Egypt and the Federal Republic of Germany in this field has resulted in the design and importation of the seven low-cost heaters listed for the laboratory. Suitable designs were selected for manufacture in Egypt.

(e) Manufacture of solar energy equipment

Following the implementation of a number of solar heating projects by the Ministry in the household and industrial sectors, and the training of the required personnel, it is necessary to establish a strong national industry producing renewable energy equipment that is capable of meeting the needs of the local market. Therefore, the Ministry has been keen to establish the Franco-Egyptian Company of Renewable Energy Equipment (RIFCO), in accordance with investment law No. 43. The capital of the company amounts to 600,000 Egyptian pounds (LE), 50 per cent of which was provided as follows:

	<u>Percentage</u>
Al-Nasr Co. for manufacturing transformers and electrical appliances (ALMACO)	60
French Agency for Nuclear Energy	15
Jordano Co. (French)	15
Societe' Generale	10

The main objective of the company is to manufacture solar energy equipment especially solar and wind energy equipment.

The actual production of the company started in the provisional production workshops of the factories of ALMACO until factories with an area of 15,000 m³ were completed in Ramadan. The plant was brought into operation on 1 October 1986.

The manpower of the company has been trained in the latest developments of the solar heater industry in France. At present the company is executing a number of solar heating projects for several establishments, and has completed others in hotels and hospitals. The plant produces solar heater units of

different sizes, in addition to complex systems. The production capacity of the plant is as follows:

Heaters with a capacity of 150 litres per day	2 150
Heaters with a capacity of 200 litres per day	2 150
Heaters with a capacity of 500 litres per day	900
Number of cells assembled	8 450

When necessary, production can be increased by introducing additional shifts.

C. Projects considered for implementation in the current five-year plan

1. Ministry projects to develop and utilize solar energy

(a) Projects for the use of solar heating in industrial operations

Industrial heating operations represent about 60 per cent of the energy consumption of Egyptian industry. Studies carried out by the Ministry of Electricity and Energy have proved that 14 per cent of these operations use low temperatures, therefore, traditional equipment can be replaced by solar energy equipment. In order to select and evaluate solar heating systems for the different industrial sectors, three projects for the use of solar energy in industrial heating operations have been designed within the framework of the agreement with the United States International Development Agency. In addition, studies have been made of two projects in other industrial fields. The first three projects are being financed from a grant provided by the United States International Development Agency. The total cost of the projects, including training programmes and testing activities, has been estimated at \$US 3 million. The projects in question are:

- (i) Solar heating and waste energy recovery - the automated slaughter of poultry for the General Company at Maser Al-Jadida. The project is designed to utilize solar flat-plate collectors to heat water for scalding basins, in addition to the recovery of waste heat generated by the offal during the slaughtering process. This will lead to a saving of over 30 per cent of energy consumption during slaughtering. The project was expected to operate on an industrial level some time between 1986 and 1987;
- (ii) Solar heating in the Egypt-Halwan Co. for Textiles. The project includes the utilization of solar energy connected to a heat recovery system to provide 200 m² of hot water daily at a temperature of 65 °C required for crushing and bleaching cloth. The project was expected to come into operation during 1986-1987.
- (iii) Crop drying by solar heating in the General Organization for Agricultural Production at Al-Jiza. Air is heated to dry about two to five tons of fresh fruit per day, all the year round. The project was expected to begin during 1986-1987.

(b) Projects to generate electricity by using solar energy

In addition to these projects, an agreement between Egypt and the Federal Republic of Germany includes the implementation of a project for solar water pumping in the Wadi Al-Natroun area, together with other activities that can be summarized as follows:

- (i) The utilization of solar thermal and photovoltaic cell systems in the Wadi Al-Natroun area, which have capacities ranging from 3 to 5 kW. The project includes the installation of a solar thermal unit for pumping water for irrigation, and three water pumping units operated by photovoltaic cells, also for irrigation.

The Ministry of Electricity and Energy, in co-operation with the Institute for Water and Land Research in the Ministry of Irrigation, is presently implementing a project to set up a farm with an area of five fadans (21,000 m²) and experiment with the utilization of solar energy in the development of the desert. In addition, a number of studies have been undertaken to assess the performance of solar complexes with vacuum tubes, to investigate wind sources in the Sinai peninsula, and to implement a project for water desalination in the area. However, these projects have not yet been implemented and negotiations are under way between the two parties for the design of a more detailed study;

- (ii) The utilization of a dual system of solar photovoltaic cells and diesel to produce about 605 tons of ice per day. The project will be undertaken in the fishery areas of the Lakes of Munbabad Wadi Al-Ryah in Al-Faioum Governorate. The maximum capacity of the photovoltaic units will be 35 kW. The system is provided with a set of batteries that have a total capacity of 33 kW of electrical energy. They are connected to 25 kW diesel generator, and is provided with an ice store of 10 to 21 tons which represents ice consumption for 2 to 3 days.

The tender to import the required equipment was put out during August 1986, and the importation, installation and operation of the equipment was expected to be completed by mid-1987.

(c) Projects for cooling and water desalination

The activities being undertaken in co-operation with the United States Agency for International Development and UNDP in the fields of cooling and water desalination include the following:

- (i) The utilization of a dual system of solar energy and diesel for ice making. The project will be implemented on the Al-Masayed site in the Wadi Al-Ryah area (Governorate of Al-Fayoum), and will have a capacity of 14 kW of solar cells connected to a diesel generator with a capacity of 22 kW. The implementation of the project will be undertaken in co-operation with the United States Agency for International Development;

- (ii) The desalination of water from the Roman wells in the village of Kasr, located near the town of Mersa Matrouh. The project aims to produce between 20 and 52 m³ per day of freshwater with a salinity ranging from 1,000 to 12,000 parts per million. The maximum capacity of the solar photovoltaic cells is about 25 kW. The unit will be provided with a set of batteries for storing electric energy and a diesel generator with a capacity of about 10 kW. Both the final design of the unit and the testing of the appropriate technology for water desalination were expected to have been completed in November 1986;
- (iii) The installation of 10 solar distillation units, each producing 10 litres per day of freshwater. Suitable sites for these units are being selected in Al-Isriailya, Suez and Abu-Ghusoun.

2. Projects of the Ministry in the field of wind energy

The Ministry has pioneered the survey of wind energy resources in Egypt. In 1972, in co-operation with the University of Oklahoma, the Ministry undertook a comprehensive survey of wind energy resources in Egypt. As it has been proved that usable wind energy is available on the northern and the Red Sea coasts, the Ministry is implementing a number of projects for the utilization of wind energy in these areas, as well as in Shark Al-Ouainat area. In addition to the survey, the projects include the following:

- (a) Projects implemented within the framework of the agreement of co-operation with the Government of the Federal Republic of Germany
 - (i) Importation and installation of wind turbines with horizontal axes and with a capacity of about 20 kW for pumping water and for irrigation in the Shark Al-Ouainat area. It was expected that this system would be installed and operating by the beginning of 1987;
 - (ii) The German Government will import and install a unit for sea water desalination in the town of Dahab in the Sinai Peninsula. The unit is designed to function with wind energy through the utilization of a wind turbine for the production of one to 10 m³ of freshwater per day;
 - (iii) Importation of equipment to assess wind energy on six sites in Al-Arish, Dahab, Sharm El-Shaikh, Al-Toar, Saint-Katerine and Abu-Radees in the Sinai peninsula.
- (b) Projects implemented within the framework of the agreement of co-operation with the United States Agency for International Development
 - (i) Water desalination utilizing wind energy in the town of Ghardaba on the Red Sea coast. The project is designed to have a desalination unit with a capacity of 200 kW to produce about 980 m³ of freshwater. The unit was expected to have begun operating by the end of 1987;

- (ii) Generation of electricity for a village on the Mediterranean coast in the Governorate of Matrouh. The project includes the installation of a wind turbine to operate an electricity generator with a capacity of 20 kW connected to a diesel generator. The project was expected to have begun operations by the end of 1987;
- (iii) Establishment of a wind farm with a capacity of 250 kW in the town of Raas Gharib to generate electricity. The device will be connected to the local grid in order to study the possibility of generalizing this method. Electricity generation from this wind farm was expected to start in June 1987.

In addition, a wind farm at Al-Ghardaba is being established in co-operation with the German Bank for Reconstruction. This wind farm consists of six units each with a capacity of 30 kW to be connected to a gas station to generate electricity.

(c) Projects undertaken within the framework of the agreement of co-operation with UNDP

- (i) An ice-making unit to produce about three tons of ice per day through the utilization of a dual system of energy generation from wind and diesel, where the capacity of the wind generator is 55 kW. This unit was expected to be in operation in January 1987;
- (ii) A wind farm with a capacity of 1.4 megawatt (MW), is being developed to provide the energy required to pump water and for other purposes.

In addition, the Ministry is negotiating with the Ministry for War Production to co-operate in the manufacture of wind turbines in Egypt.

3. Projects of the Ministry in the field of biomass

The Ministry is supporting and developing the utilization of biomass energy directly, as well as through the Supreme Council for Renewable Energy Sources. This is being undertaken in the following fields:

(a) Co-operation with the National Centre for Agricultural Research in the utilization of biomass and production of biogas. Co-operation is in the field of scientific research and the establishment of experimental units of different sizes, in addition to the conducting of feasibility studies on the utilization of sewage and urban waste.

(b) In the context of the programme of the technological study of renewable energy and its utilization, which is included in the agreement of co-operation with the United States Agency for International Development, the Ministry has conducted a pre-feasibility study of the various ways of utilizing biomass in Egypt. Priorities for the implementation of experimental biomass projects have also been determined in relation to other renewable energy projects. The study focuses currently on the possibility of implementing projects for electricity generation and gas production from sewage waste projects in co-operation with national and international scientific bodies.

(c) Installation of scientific testing laboratories for applied research into biomass. These laboratories complement those already existing in other organizations in the country.

4. Activities of the Ministry in the field of training,
increase of awareness and dissemination of information

Programmes for the implementation of renewable energy projects and the utilization of its technologies require the establishment of an appropriate scientific and technical base, as well as adequate training of the personnel on whom the tasks of the development of renewable sources of energy fall. Hence, the Ministry has been keen to implement the following programmes:

(a) Establishment of a data base for renewable energy. A documentation centre for renewable energy has been established under the agreement of co-operation with France. It includes a specialized library and microfilm equipment. However, owing to the development of activities in this field, the agreement of co-operation with the United States Agency for International Development included the establishment of an up-to-date information centre for renewable energy for the use of those involved in this field at a national level.

(b) Training programmes covered by the agreement of co-operation with the United States Agency for International Development include the following:

- (i) Scientific training. This includes the organization of scientific seminars to improve the knowledge of high level professional staff and engineers of the various renewable energy technologies. Such programmes include local training seminars and workshops on training abroad;
- (ii) Practical training crews composed of engineers and technicians involved in the supervision, design, installation and operation of systems are to be trained intensively in the relevant technologies, as well as in operation and maintenance.
- (c) Increasing the awareness and dissemination of information.

Various programmes giving scientific information on the utilization of renewable energy sources and dissemination of the results of the different projects included in the agreement covering social studies related to these projects, are being prepared and implemented.

5. Establishment of the Egyptian Renewable Energy Development
Authority

As a result of the growth in the utilization of new and renewable sources of energy and in the awareness of the role these sources play in meeting the energy needs of Egypt, the Ministry has established the Egyptian Organization for the Development of New and Renewable Energy. It will be financed in co-operation with the European Community (EC) and the Italian Government. The cost of establishing this organization was estimated at over 14 million European currency units (ECUs).

But following the development of a number of applied projects whose requirements can be provided through the utilization of renewable energy technologies, the importance of establishing a specialized sector for the implementation of renewable energy applied projects has emerged. Consequently, the Ministry has taken the necessary measures to establish a specialized organization responsible for the development and improvement of the utilization of new and renewable sources of energy. The specialized organization, which was established by virtue of law No. 102 of 1986, also stated that the Egyptian Organization for Renewable Energy was one of its specialized sectors. In co-operation with other governmental bodies, the authority assumes responsibility for the achievement of national objectives in the field of renewable energy. These include:

(a) The survey and assessment of renewable energy resources in Egypt and studies into the possibility of utilizing them;

(b) The specification and implementation of programmes of applied research and development, and following up on the technological development required at a national level to strengthen local capabilities and to promote the utilization of renewable energy sources;

(c) The establishment of technical specifications and standardization of solar energy equipment, and the issue of suitability certificates for products in co-operation with the concerned authorities of the country;

(d) Work on the establishment and support of the local manufacture of solar energy equipment;

(e) The provision of support for manpower and the technical infrastructure required for the widespread utilization of solar energy equipment, in the form of training programmes and services;

(f) The provision of consultancy, engineering and supervision services for applied projects of a significant size.

6. Sources for the finance of renewable energy projects

Finance for renewable energy projects implemented by the Ministry of Electricity and Energy is obtained from several foreign sources, in addition to contribution from the Egyptian Government.

International bilateral agreements that have been concluded for the implementation of new and renewable energy projects; together with financial allocations and share of the Egyptian Government in each of these, are summarized in table VII-1.

Table VII.1. The finance and sources of renewable energy projects

Agreement/ project	Allocated fund (Millions)	Approved external fund (Millions)	Type of funding	Share of Government (Millions)	Funding Agency	Status Project
Importation of 1,000 solar heaters	\$US 0.75	-	-	\$US 0.75	Ministry of Electricity and Energy	Completed
Franco- Egyptian agreement	FF ^{a/} 7.00	FF 7.00	Loan	LE 0.50	French Agency for Nuclear Energy	In final stages
First Egypt-Federal Republic of Germany agreement	\$US 1.50	-	Grant in kind	LE 0.25	Federal Republic of Germany	Completed
Second Egypt-Federal Republic of Germany agreement	\$US 7.00	-	Grant in kind	LE 0.25	Federal Republic of Germany	Under implementation
Co-operation agree- ment with EEC	ECUs 8.00	ECUs 8	Grant	LE 2.00	EEC	ECUs already spent
Co-operation agree- ment with Italian Government for participation in financing organization	ECUs 2.30	-		LE 4.10	Italian Government	Agreement not yet signed; allocation requested
Co-operation agreement with the United States Agency for International Development	\$US 24.10	\$US 9.70	Grant	\$US 4.46	US Agency for International Development	Commitment to spend \$US 6.7 million
Co-operation agreement with UNDP	\$US 1.065	\$US 0.75 from UNDP \$US 0.235 from AGFUND ^{c/}	Grant	\$US 0.10 and LE 0.20	UNDP GCC ^{b/} / Egyptian Government	Under implementation
Total of proposed finance for agreement under consideration	\$US 12.00	-	Grant	LE 2.00		Negotiations under way

Total: allocated = \$US 29.65 million Proposed = \$US 12 million

a/ French francs (ff).

b/ Gulf Co-operation Council (GCC).

c/ Arab Gulf Programme for the United Nations Development Organizations (AGFUND).

VIII. RENEWABLE ENERGY ACTIVITIES IN JORDAN

H. El-Mulki, R. Ta'ani, M. Kabariti*

A. Abstract

This paper gives a brief review of the solar and wind energy activities of the Royal Scientific Society (RSS), together with those of other Jordanian organizations in the field of renewable energy in general. Activities carried out in Jordan in this field may be classified into three categories, namely: basic research, applied research and final application. Current research and the development work carried out in Jordan has been selected in such a way that it matches Jordan's resources with energy demands, so that given the constraints on manufacturing in Jordan, the equipment needed to utilize these resources can be met by local manufacture.

B. Introduction

Jordan is one of a handful of countries in the world that lacks indigenous sources of readily available energy. In the last five years Jordan has also experienced a great development in its energy sector, while energy demand has increased by approximately 9 per cent annually.

Jordan imports all of its energy needs, and its total oil imports have reached more than 12 per cent of total export earnings over the last few years. Nevertheless, Jordan has good solar energy potential, substantial resources of oil shale, and acceptable levels of wind energy. Thus, it is natural that research and development activities should be directed towards the exploration, development and utilization of these resources.

Activities carried out in Jordan in this field may be classified into three categories, namely: (i) basic research, which is carried out in Jordanian universities into the field of solar thermal and photovoltaics; (ii) applied research, development and demonstration which is carried out by RSS into solar water and space heating and water pumping that utilizes wind energy conversion systems (WECS) and photovoltaics; (iii) applications in the field of solar water heater for domestic and industrial utilization, agricultural greenhouses and potash recovery from evaporating ponds. It is worth mentioning that among the many organizational measures that have been taken in the last five-year plan, the energy sector has been organized to cope with rapid development through the establishment of the Ministry of Energy and Natural Resources (MENR). MENR takes the planning and general policy action that the sector requires. The newly established Ministry has given considerable consideration to renewable energy and energy conservation, and a separate department to deal with this matter has been incorporated into its organizational structure.

A brief presentation of renewable energy activities in Jordan will now follow.

* Royal Scientific Society of Jordan.

C. Past activities

RSS has conducted several projects in the field of solar and wind energy research, development and demonstration. The main projects were as follows:

1. Sea water desalination using the heat pipe principle

This project, supported by the Government of the Federal Republic of Germany, and conducted jointly by RSS and the German Agency for Technical Co-operation (GTZ), aimed at studying the possibility of utilizing solar energy in water desalination.

A pilot research plant was constructed at the solar energy experimental station in Aqaba to study the behaviour and performance of the system and to modify its various components.

The findings were presented in a final report. ^{1/} In addition, RSS compared the above-mentioned method of water desalination with that of solar stills, a widely accepted and well-known method. It constructed 20 m² of stills of different design for this purpose. The results show that the output of these stills is much higher than that of the original heat pipe system design.

2. Design and installation of mini photovoltaic systems

This joint project was conducted by RSS, the Public Security Department, the Civil Defence Department and the Jordan Meteorological Department. RSS carried out a survey on several types and brands of solar cells which are available on the international market. It chose two types for field testing and experimentation on the behaviour of the system, together with other types of system control and storage. The findings were distributed to the concerned departments, with a recommendation that Jordanian-made batteries be used for storage.

3. Study on the potential of solar and wind energy applications in Jordan

The project aimed at identifying the potential applications of solar and wind energy technologies, in line with Jordan's current and future needs. It was supported by the Government of the Federal Republic of Germany and conducted jointly by RSS and GTZ. Information pertaining to the subject was collected from various ministries and agencies. It was then analysed, evaluated and presented in the following volumes: ^{2/}

1/ Jordan, Royal scientific Society, (3) 80 (23) (December 1980).

2/ Ibid., The Potential of Solar Energy Application in Jordan, vol. I, General Background (3) 83/29, vol. II, Assessment and Analysis of Basic Energy Needs to be Supplied by Solar Energy, (3) 83(31), vol. III, Assessment and Analysis of Available Energy Resources, (3) 83(32), vol. IV, (3) 83(33), vol. V, Possible Application of Solar Energy in Jordan, (3) 83(30), (May 1983).

- (i) Energy situation in Jordan;
- (ii) Assessment and analysis of basic energy needs to be supplied by solar energy;
- (iii) Assessment and analysis of available energy resources;
- (iv) State of the art survey on solar and wind energy related to Jordan's needs;
- (v) Possible applications of solar energy in Jordan.

4. The solar house

This project, which was carried out jointly by RSS and the Kuwait Institute for Scientific Research (KISR), aimed at conducting research and experiments on solar space and water heating, as well as studying the various solar heating systems, solar collectors, storage systems and media and auxiliary systems. In addition to the technical study, the project aimed at studying the economic feasibility of the house. The outcome of the first year of operation on the solar house has been evaluated and presented in a technical report published by RSS. ^{1/}

The results of the first year show that the thermal load was high and that the storage tank efficiency was low. Measures were taken to remedy these weaknesses. The house was subjected to a second year of testing. In the second year, new heating load devices that were used in the first year of testing were utilized again. The results demonstrate that the thermal load was reduced to about 46 per cent and that the integrated efficiency of the collector array was maintained at approximately 22 per cent.

Accordingly, a booklet on the findings of the solar house will be published and distributed to engineering offices and specialists.

D. Current activities

1. Flat plate collectors

In the area of flat plate collectors (which was one of the first activities carried out by RSS), the Society worked on the development of domestic solar water heaters according to the criteria that guarantee the low cost of a unit, ease of installation and maintenance, and the utilization of materials that are normally available within the country.

RSS designed and produced pilot systems in its workshop, and signed three agreements with local manufacturers for mass production to meet the local market as well as exports.

^{1/} Jordan, Royal Scientific Society, The Potential of Solar Energy Application in Jordan, vol. IV, (3) 83 (33).

In its efforts to develop flat plate collectors for medium and high temperature requirements, RSS is currently conducting a project with aid from GTZ that aims at upgrading its previous design of a flat plate collector. The project involves the establishment of an indoor-outdoor test facility with a total area of 4 m². This will allow these collectors to be tested according to international standards, and will consequently speed up their development.

Parallel with the above-mentioned project and in co-operation with UNIDO, RSS is currently testing a large solar water heating system manufactured in its workshops. It has been installed at one of the leading dairy factories in Jordan. The collectors are used to preheat water entering the steam generator.

2. Wind energy

RSS designed and constructed two prototype windmills (one mechanical and one electrical) for aerofoil demonstration and testing purposes. In co-operation with the Water Supply Corporation and Natural Resource Authority, it ordered a 12 kW WECS to pump water and installed it at a deep well (60 m) at Jurf El-Darawish in Ma'an district. The system was tested for two years. The weak points of the system, mainly in the control system, were determined and remedied. The modified and developed system was then transferred to Al-Kharana Station, as water demand in Jurf increased drastically owing to the connection of the well with the water network.

RSS is implementing a project using wind energy to pump water. The main aim of the project is to strengthen RSS capabilities in wind energy technology so as to enable it to develop technology in accordance with Jordan's wind resources and energy demands for pumping water, with the ultimate aim of producing WECS locally. In the framework of this project, different wells with dynamic levels varying between 30 m and 190 m, and water demand of between 30 m³/d and 150 m³/d will be equipped with various types of WECS. Mechanical, medium technology, and advanced technology electrical wind convertors will be utilized. A wind farm consisting of three windmills will be used to pump water from the deepest well, where the maximum water supply is required. In conjunction with this, 16 measuring stations including an advanced data logger will be used to determine wind energy potential in different parts of Jordan.

3. Photovoltaics

Research, development and demonstration activities in this field are being carried out by the photovoltaic group at RSS. In 1983, in co-operation with the EEC, an outdoor testing facility capable of testing photovoltaic systems and their components was established. This testing facility helped RSS to select PV components and to design the project which follows.

In the field of water pumping, RSS, in a contract with the Jordan Water Authority, completed the design and erection of three pumping systems. Each photovoltaic system consists of 1.6 kWp photovoltaic cells, an AC reversible pump and the necessary invertors.

In the field of remote electrification, one location has been supplied with 1.5 peak of photovoltaics to supply its basic energy needs. The electrical energy that is generated will be used to power a small refrigerator

for the clinic, light the main streets, educational television and an emergency telephone. The project was offered under contract to RSS by the Jordan Valley Authority.

4. Geothermal energy

In the last few years, the Natural Resources Authority (NRA) has started a survey to determine the availability of geothermal resources in Jordan. In 1985, NRA was able to determine the sites of two geothermal wells and is currently making preparations to drill these locations to a depth of about 1,500 m. Based on the technical and economic feasibility of these wells with relation to their use in generating electrical power, other sites will be explored.

5. Energy conservation programme

The Department of Renewable Energy in MENR is currently conducting studies on insulation and passive features that could be applied to residential buildings. Studies are also being undertaken on the conservation of energy in both the industrial and transportation sectors.

E. Activities planned for the future

1. Photovoltaics

In co-operation with GTZ, RSS is planning a project that aims to design mini-photovoltaic systems that will supply the minimum electrical requirements of remote areas and selected purposes. The project will involve the design, installation and testing of three different photovoltaic systems at three locations. These tests will determine the technical and economic feasibility of the systems.

2. Wind-photovoltaic hybrid system

The development objectives of this project are to enhance social and economic development in remote and rural locations in Jordan by meeting basic energy needs and making use of the opportunities resulting from the local manufacture of simple energy producing equipment and other related activities.

The project, which will be implemented by RSS with the aid of a grant from AGFUND, UNDP and other Jordanian authorities, involves the installation of WECS and photovoltaic systems that will be used to provide electrical power to pump water together with electricity for a particular location. The project would lead to acquiring local skills impact to widen the scale of application of renewable energy technology in Jordan and other countries.

3. Wind energy for the generation of electricity

The project aims at the installation of a wind farm with an approximate power output of 100 kW, which will be connected to the national grid. It also involves the erection of five additional wind speed classifiers. The project will determine the feasibility of wind farms in selected windy areas of Jordan.

4. Thermal insulation

The project aims at studying the possibility of utilizing thermal insulation in building, together with the possibility of encouraging local production from locally available raw materials. Within the scope of this project it is proposed to establish a laboratory to test watertight materials and insulation.

F. Renewable energy applications in Jordan

1. Radio telephone system powered by photovoltaic cells

Jordan has installed 88 radio telephone units in rural and remote desert locations. These units were purchased directly from the United States of America. Additional units are required for a large number of villages and long desert roads in Jordan. The system provides an efficient, reliable and cheap method of communication.

2. Solar evaporation ponds for potash recovery

The Jordanian potash project utilizes the brine reserves of the Dead Sea and solar energy to recover about 1.2 million tons per year of potash and other by-products. Three evaporation ponds have been constructed with a total area of 76 km². Water from the Dead Sea is pumped into these ponds where brine concentration and the precipitation of salts take place. The total solar energy utilized in this process is estimated to be 3.73×10^{10} kWh per year. This energy is equivalent to that available in 3.25 million tons of crude petroleum at a cost of \$US 749.1 million.

3. Solar water heaters

Solar water heater technology could be considered to be new. The utilization of solar energy for domestic hot water began in Jordan after the oil crisis of 1973. In 1973, two Jordanian workshops began to produce 50 solar water heater units annually. In the years that followed, solar water heaters have become popular and widely accepted and utilized. In 1984, the number of workshops increased to 37, and real production reached 12,284 units/year (each consisting of three collectors with an area of about 3.2 m², a storage tank and the necessary piping). Total production capacity is 43,924 units (therefore the utilized capacity is currently 28 per cent). Total aggregate investment in this industry, as of 1985, is 1.63 million Jordanian dinars (JD).

At the end of 1984, the total number of houses utilizing solar water heaters in Jordan was estimated to be 44,700 (or about 13 per cent of all the houses in Jordan).

4. Agriculture greenhouses

The utilization of solar energy for agriculture in Jordan started late in 1970. Greenhouse cultivation in Jordan started with 50 acres in 1970, and an estimated 25,000 acres were being cultivated at the beginning of 1985. The main area is concentrated in Jordan Valley, but with improvements in technology

and the validation of the economic feasibility of these applications, the greenhouse is now spreading all over the country. A number of manufacturers are currently producing the plastic covers needed for greenhouses and irrigation pipes, and are able to meet local demands.

RSS is conducting a joint project in this field with the Iraqi Solar Energy Research Centre. In the framework of this project a complete station has been established. It consists of 48 houses and has an advanced measuring capacity.

G. Conclusion

This paper has covered some of the main activities related to renewable energy in Jordan. It is hoped that these activities will pick up momentum in the near future. The RSS programme is flexible in its approach, and is subject to revision as new results or fresh knowledge are developed. RSS has placed great emphasis on R and D.

IX. COUNTRY PAPER ON THE SOLAR ENERGY RESEARCH PROGRAMME IN LEBANON

A. Azouk, M.B. Ouaida*

Abstract

Lebanon is a dependent country in terms of its energy needs. However, it is endowed with a very attractive new source of energy: the sun. The country receives 6,500 MJ/m²/year of solar radiation. Many projects are currently exploiting this free source of energy in order to reduce the energy bill.

A. Introduction

The energy bill presents a real problem for the Lebanese Government. More than 90 per cent of energy consumption in Lebanon is imported in the form of petroleum products and is used for all kinds of purposes. The only local resource to be exploited up till now is water that produces 155 MW of electricity, which is shared by a number of hydroelectric power stations all over the country (Litani 130 MW, Nahr Ibrahim 8 MW, Kadisha 6 MW, Nahr El-Bared 5 MW, others 6 MW).

Efforts are now being made to benefit from the geographical situation of the country which receives an average of 6,500 MJ/m²/year from solar radiation. The aim is to reduce the energy bill in a town planning programme that uses solar thermal applications in many sectors, particularly in construction (passive and active systems) and agriculture (greenhouses, drying, etc.). At the same time, a programme is proposed to design the solar map and to establish some energy-saving instructions, according to the geographical site, for use in building (insulation of walls, double glazing, etc.).

This paper will review the status of energy consumption in Lebanon and will discuss fields where solar energy could be of use in reducing the energy bill. A number of examples of applications of solar systems, the different areas of research going on in the country, as well as prospects for the future, will also be presented.

B. Structure of energy consumption

Energy in Lebanon is shared between the sectors as follows: 43 per cent for domestic use and agriculture, 25 per cent for industrial use and 32 per cent for transport. Table IX-1 shows the distribution of energy consumption distribution in these sectors.

* National Council of Scientific Research of Lebanon.

Table IX.1. Energy consumption by different sectors

Petroleum products	Percentage	Energy consumption in different sectors
Fuel oil	36	80 per cent electricity production + 20 per cent industry
Diesel	25	10 per cent electricity production + 90 per cent domestic, agriculture, international trucks
Gasoline	23	100 per cent transport
Kerosene	12	90 per cent air transport + 10 per cent domestic
Butane	2	100 per cent domestic
Losses	2	
Electrical power		80 per cent domestic + 20 per cent industry

Electricity is used in the domestic sector for lighting, heating, air-conditioning and house appliances. This sector also absorbs butane for cooking and a large quantity of diesel for heating and hot water. The industry sector uses 20 per cent of electrical power for machinery and lighting and 20 per cent of fuel oil for its heating needs. The transport sector takes virtually all the gasoline and a small quantity of diesel for international trucks.

The increase in energy demand is estimated to be between 10 and 15 per cent per year by the Electricity Company of Lebanon (EDL). Needs over the next few years will be covered by thermal power stations. This is a short-term solution; an electronuclear choice would be very expensive and would exceed needs (the smallest electronuclear station in the market is about 650 MW, equivalent to the whole of present consumption). However, this solution should be borne in mind for the end of the century.

C. Solar energy applications

This dependence on imported energy dictates that another local source be found to diminish the energy bill and permit the country to benefit from solar energy. The sun is an ideal energy source for thermal applications. It could be used in many important sectors, particularly the domestic and agriculture sectors (hot water, heating, air-conditioning, cooking, electricity production, greenhouses, biomass, drying, etc.). However, it should be accompanied by a studied programme to develop the use of this free source of energy.

This programme logically starts with a study of solar energy availability at the site or region of interest. For this reason, a number of meteorological stations have been set up to measure solar radiation. Preliminary results have been extracted from measurements taken by the National Meteorological Service and the Ksara and Lee observatories of the American University of Beirut. The average monthly global radiation and dry bulb temperature are represented in figures XIX and XX.

Figure XIX. Monthly average global radiation

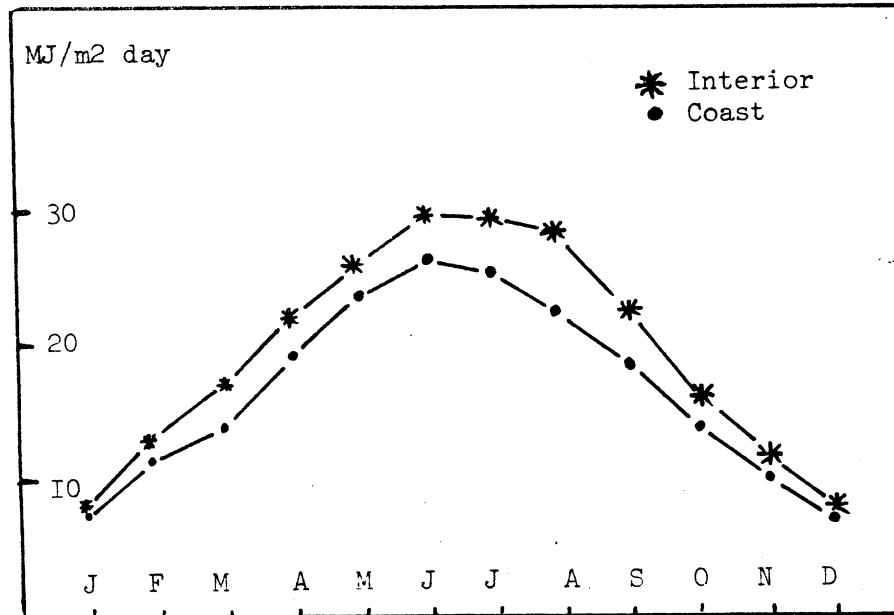
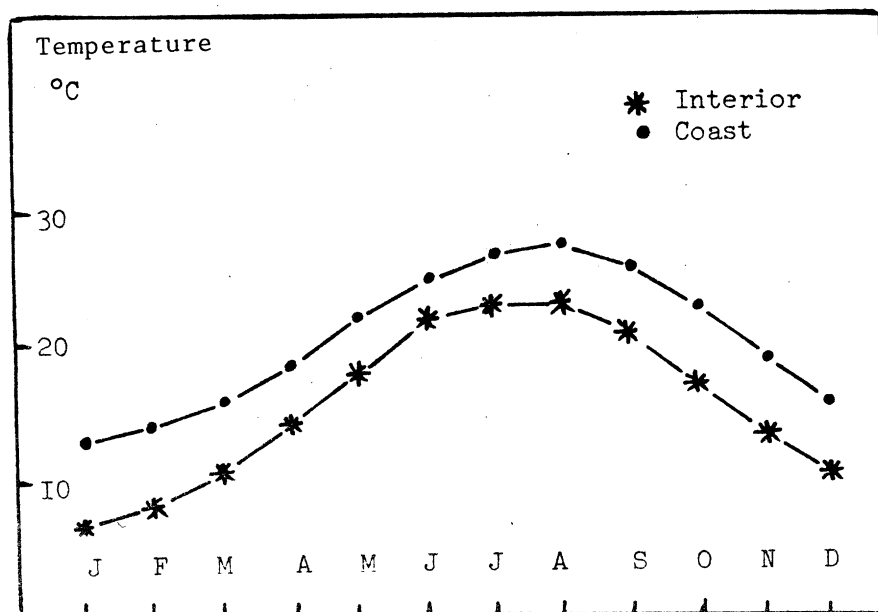


Figure XX. Monthly average dry bulb temperature



1. Thermal applications

The best applications in Lebanon are in the field of low temperature thermal solar energy. Seventy per cent of water heating could be covered by solar energy. Greenhouses could easily be installed for agriculture. Unfortunately, the situation in the last 10 years (the period in which the exploitation of solar energy was really developed) has not allowed the large-scale extension of this new technology, as has occurred in neighbouring countries. Efforts are now going on to develop applications for water heating systems. In addition, norms to save energy are followed in construction through the use of new techniques like insulation of external walls, regulation and automation of internal climate systems, and the benefits to be gained from sunshine using a bioclimatic architecture concept.

The first large solar installation was completed in 1981 in a hospital near Beirut to supply 30 m³ of hot water at 50° C, with 480 m² of flat plate collectors imported from France. This kind of installation was extended to a number of hotels in Tripoli and Beirut, individual houses, as well as buildings in the mountains and near the coast. In a number of special applications, absorbers with selective coating, vacuum tube and concentrating solar collectors were used. All of these collectors were imported from industrialized countries.

The local industrialization of this sector is now in the initial stages. Some industries produce thermosyphon solar water heaters that are mainly manufactured by craftsmen. Any development in this sector needs to take into consideration the experience already obtained and should try to improve the collectors so that they can be adapted to local use. On the other hand, tangible proof of the technical and economical viability is important for people to be encouraged to look forward for this energy. This industry is expected to develop in the future, particularly if it is possible to extend the market to neighbouring countries.

2. Photovoltaic and wind applications

With regard to photovoltaic conversion, there is only a limited market in Lebanon. However, the market could be open to low-power modules for use in isolated houses, mountain chalets, station repeaters, transmitter-receivers and beacon lights. Solar lamp-posts are now used to light car parks and gardens. If markets in neighbouring countries are opened, solar cell technology could be developed on a large scale.

Wind energy has been used for some time to pump sea water from saline ponds on the coast. It was abandoned when diesel pumps came into use in the 1960s. Using existing techniques this energy source could be developed to take advantage of the available wind potential on the site.

D. Research and prospects

The National Council for Scientific Research (NCSR) is the executive arm of the Lebanese Government in the field of research and development. The aim of the Solar Energy Group of NCSR is to promote solar energy applications in Lebanon. In collaboration with the National Meteorological Service, 12 solar radiation measuring stations are being installed on different sites. The data

that is acquired will provide more information on the different micro-climates and will lead to the establishment of a solar map of Lebanon. It could be possible to install solar energy systems in buildings. With regard to water heating, a number of configurations (individual, collective, etc.) could contribute to save imported energy. A study of the performance of a number of solar water heating installations under local atmospheric conditions is presently under way. This includes the previously mentioned installation of 480 m² of flat plate collectors in a hospital near Beirut. The purpose of the study is to determine the performance of each part of the installation: collector fields, heat exchangers, storage, piping systems, control devices, etc. The performance test requires the measurement of 39 experimental variables such as:

- (i) Global solar radiation at the collector area;
- (ii) Temperature variation of the heat transfer fluid between each collector field outlet and inlet;
- (iii) Mass flow rate of the heat transfer fluid;
- (iv) Ambient air temperature;
- (v) Fresh water temperature;
- (vi) Temperature variation of the heat transfer fluid between each heat exchanger outlet and inlet;
- (vii) Hot water average temperature in each storage tank;
- (viii) Voltage of pump and electro-valves in order to observe the behaviour of the regulation system.

All these parameters are recorded in a data bank (Fluke, type 22340B) and can be handled on a micro-computer (APPLE IIe). From the measurements, the following can be deduced:

- (a) Incident solar radiation;
- (b) Thermal energy supplied by each collector field;
- (c) Verification of regulation function;
- (d) Global and instantaneous efficiencies of collectors;
- (e) Global and instantaneous efficiencies of heat exchangers;
- (f) Time function of pumps and electro-valves in order to calculate auxiliary electricity consumption;
- (g) Evaluation of storage temperature versus solar gain and water pumping;
- (h) Heat losses from each part;
- (i) Useful solar energy rate.

X. COUNTRY PAPER ON THE EXPERIENCE OF MOROCCO IN THE FIELD OF RENEWABLE ENERGY

(Photovoltaic Conversion Applications)

Mohammad Al-Bardai*

A. Introduction

Morocco is located in the north-western part of Africa and covers an area of 710,850 km². The population of Morocco has been estimated at 22 million, of which 57 per cent live in rural areas.

In 1984, total energy consumption in the country reached 4,836 MTOE, 70 per cent of which was imported.

In order to handle such a critical situation, Morocco adopted a national energy plan aimed at mobilizing local energy resources, including renewable energy sources. A public body, the Centre for the Development of Renewable Energy Sources, functioning under the auspices of the Ministry of Energy and Minerals, was established. One of the main functions of the Centre is to undertake studies and research, organize meetings and conclude agreements that promote the development of renewable energy sources, particularly in the field of manufacturing, marketing and the utilization of renewable energy systems.

The activities of the Centre are organized as follows:

1. Research and development (sources and technologies);
2. Studies and implementation of pilot projects and the follow-up on their performance;
3. Dissemination of experience, provision of technical staff and training of personnel in the relevant institutions.

The objective of the Centre is to promote the use of raw and renewable sources of energy in remote and rural areas through the introduction of renewable energy technology in order to improve living standards.

The implementation of projects and follow-up are carried out with the co-operation of people in rural areas in order to ensure a broader dissemination of renewable energy technologies.

This paper will focus on the experience of Morocco in the field of solar photovoltaic and other applications.

* Centre for Renewable Energy Development, Ministry of Energy and Minerals of Morocco.

B. Solar energy

1. Sources

A study, based on solar radiation data in the cities of Casablanca and Beni Milal, together with the percentage of insolation available in the different meteorological stations in Morocco, indicates that the average solar radiation available in Morocco ranges between 4.7 and 5.6 kW/h per m² daily.

In order to make more accurate data available, the Centre is now involved in the preparation of a solar atlas through the provision of the meteorological stations with instruments and devices for measuring solar radiation and analysing data (see annex I to this chapter).

2. Thermal conversion

Among the major activities of the Centre in this field are the following:

(a) An instrument to test locally manufactured or imported flat-plate collectors;

(b) An instrument to test solar water heaters;

(c) The study and construction of a unit for heating water in the compounds of the Air Force base;

(d) A study is being carried out on the marketing of solar water heaters at a national level.

3. Photovoltaic conversion

Noticeable progress has been achieved in Morocco in the field of photovoltaic conversion. Applications can be found in areas such as communications, water pumping, rural lighting and the protection of metal pipes from rusting.

4. Communications

Because of its advantages, the solar generator has attracted the attention of a large number of companies and national institutions that use diesel engines to provide communication systems that are mounted in remote areas with the power they require, in spite of the high cost of repair, maintenance and spare parts.

Solar energy was first employed by the radio and television transmission station in Marrakesh district, when a 300 watt solar generator was installed. In view of the encouraging results of this project, the radio and television station of Morocco provided 200 units for long-range broadcasting and transmission, and 33 units for medium-range broadcasting and transmission. They were composed of solar generators that had a total power capacity of 60 kW.

The second national institution to show in this field was the National Office for Railways. Considering the need to establish continuous telephone

connections between railway stations, the Office replaced traditional diesel engines with solar generators to provide the external telephonic connection units with the power they required. Eleven devices of this kind have been installed along the national railway network, while another project to provide power for railway crossings (480 watts for each station) is being considered.

Benefiting from the experience of the Moroccan television and radio station and the National Office for Railways, the National Office for Post and Communications has also utilized solar energy to provide receiving and transmitting systems with the power they require. At present, two projects aim to provide 20 solar generator units that have a total power capacity of about 100 kW. It is worth noting that all of these systems function with batteries that have a significant storage capacity. The batteries are manufactured locally.

5. Water pumping

The second significant photovoltaic conversion application in Morocco is water pumping. Within the framework of a policy to develop and disseminate the technology of renewable energy, the Centre for the Development of Renewable Energy has installed and tested different types of solar water pumping systems throughout Morocco. In fact, 9 projects have been implemented since 1983. One of these projects is the demonstration station at the School of Minerals in Marrakesh (see annex II).

The technical follow-up on these projects is of great importance to ensure the efficiency and benefits of the various systems, as well as to identify a special programme to study water pumping stations that use solar energy. Table X-1 shows the achievements of the Centre in this field.

Demonstration experience indicates that water pumping by solar energy requires little maintenance (of generators), and that it does not create any operating problems provided that the initial study is thoroughly prepared, particularly with regard to:

- (a) The hydraulic characteristics of the well;
- (b) The preparation of the well (digging, deepening, construction, etc.).

A study carried out by the Centre to compare the cost of one m³ of water pumped by a diesel engine, together with that of wind and solar energy, revealed that when wind energy is used, particularly at speeds of less than three metres per second and a pressure head of under 20 metres, solar energy is therefore competitive up to the limit of pumping 20 m³ of water per day at a cost of two to three dirhams for one m³.

Solar water pumps of this size can also meet the potable water needs of rural communities (with an average of 1,000 inhabitants). The use of such pumps is advantageous in rural areas owing to the fact that there are no major difficulties in their operation and maintenance.

Table X.1. Sites and types of solar water pumping systems

Site	Type of pumping engine	Number of pumps	Electric power (Watts)	Total height of pressure (Metres)	Quantity pumped per day (m ³)
Wijda	Continuous current	1	2 600	35	50
Tarodant	Intermittent current	5	7 000	35	150
Marrakesh	Continuous current	1	1 400	35	30
	Intermittent current	1	1 400	35	30
	Continuous current	1	1 400	35	30
Rabat	Continuous current	1	752	32	10
Al-Aiyoun	Continuous current	2	2 350	40	50
Kalaat Al-Saraghma	Continuous current	1	752	25	30
Wirgagat	Continuous current	1	900	25	20
		1	900	25	20
		1	1 500	35	30

It is worth noting that many solar water pumps have been installed in several locations in Morocco. The electric power generation capacity of these systems ranges from 600 to 1,500 watts required to pump 20 to 30 m³ of water per day.

In addition, the Ministry of Interior is now working on a programme to provide 300 water stations with solar water pumping systems. At present, the first stage of this programme covering 75 solar water pumps is being implemented. The second phase covering 225 solar water pumps is under study.

6. Rural lighting

In order to solve the problem of rural migration, it is necessary to improve living standards and conditions in rural areas, and to meet the basic energy needs of the rural population. The characteristic possibility of spreading economic and social benefits in rural areas makes photovoltaic conversion technology appropriate for pumping water, lighting public facilities (schools, mosques, etc.), and powering television sets and small-size refrigerators. The Centre for the Development of Renewable Energy has implemented three projects to light three villages. One is Debaibigat village (population 400) in the Governorate of Kalaat Al-Saraghma. The technical characteristics of the project are as follows:

- (a) Pump 20 m³ of water per day;
- (b) Light a primary school consisting of three halls;
- (c) Light the halls of the mosque;
- (d) Recharge batteries (see annex III to this chapter).

The economic and social benefits of the project are being investigated. In view of the pressing need to use photovoltaic conversion and the significant number of users, it is necessary to devise ways and means of reducing the price of these systems in order to boost their marketing. The Centre for Development pays special attention to this issue in order to:

- (i) Stimulate a local power transfer industry and other related suitable devices;
- (ii) Encourage the establishment of units for the local assembling of photovoltaic conversion systems;
- (iii) Study the possibility of financing photovoltaic projects through the banks.

C. Wind energy

Morocco has significant wind energy resources, particularly in coastal areas and in the southern part of the country. The Centre for the Development of Renewable Energy has carried out a detailed study of wind resources in Morocco by analysing the available data in the national meteorological stations over a period of five years (see annex IV). The importance of this kind of energy in Morocco is reflected in the substantial number of windmills (5,000 to 10,000) that were installed during the period 1930 to 1960. Most of these windmills, however, no longer function owing to a lack of proper maintenance. In order to address the problem, a special programme was set up in conjunction with the concerned authorities in several parts of the country to repair the windmills. Specialized teams were formed for that purpose.

As regards the dissemination of technology, the Centre is in the process of manufacturing an efficient windmill which will be demonstrated shortly.

It is worth mentioning that in the field of power generation from windmills, a project at the co-operative level was implemented in 1985 near the coastal town of Souaira, and other projects are under study (see annex V to this chapter).

D. Biomass energy

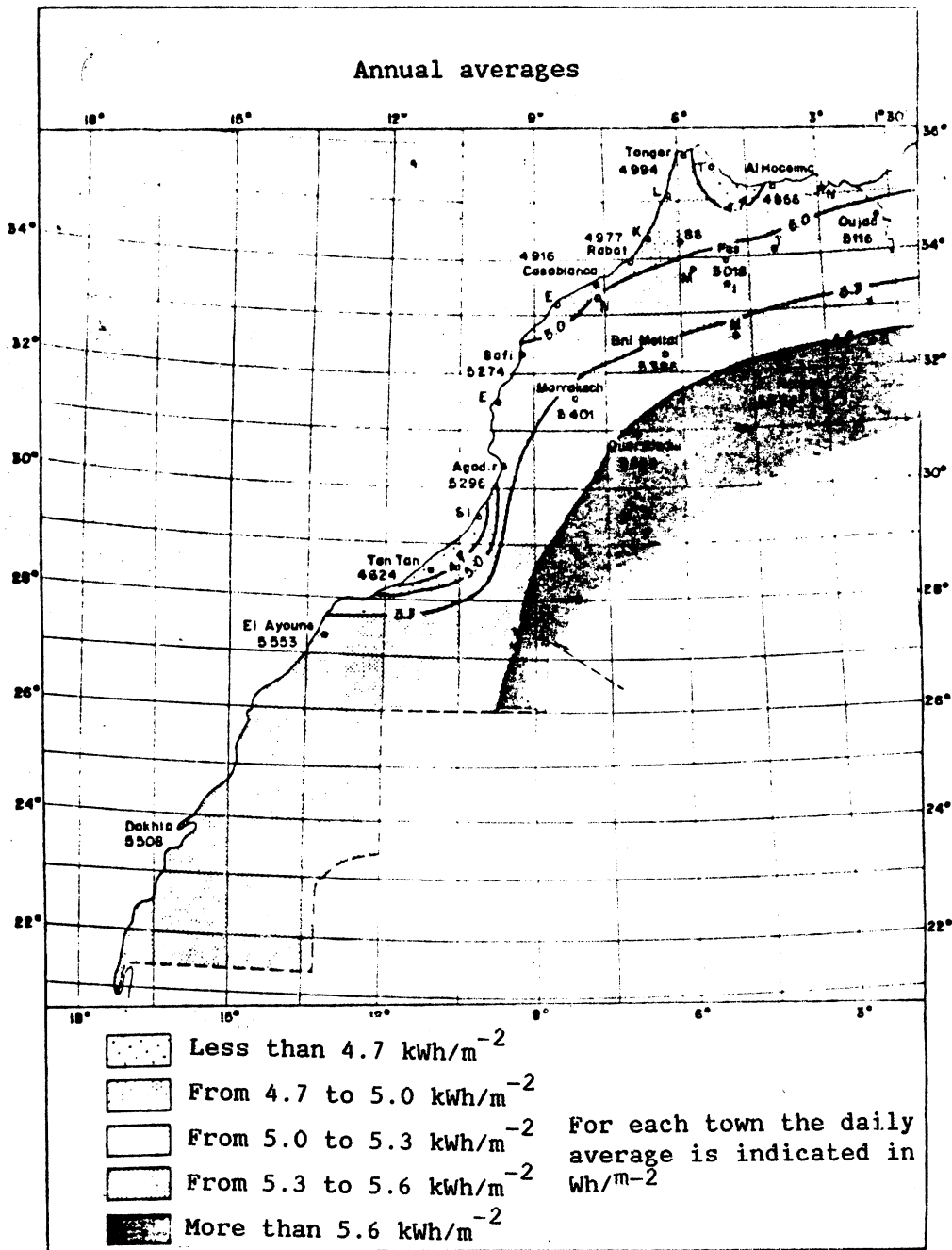
Morocco has a substantial source of biomass energy in view of its extensive areas of forest (15.5 million hectares), agricultural residues and animal dung.

In spite of the fact that the Centre for the Development of Renewable Energy is concerned with the different applications of biomass energy technologies such as greenhouses, pumping water and water desalination, its main activities are focused on the development and promotion of the utilization of family-size biogas digesters for lighting and cooking. Several types of digesters (Chinese, Indian, etc.), have been developed in Morocco. More than 60 biogas units ranging from 10 to 20 m² and producing from one to five m³ of biogas per day have been constructed.

Research is also being carried out into the possibility of improving small-size digesters for use in comparative cost-benefit studies on various other types, in addition to studying the beneficial effects of a heat factor on digesters at large.

Annex 1

DAILY GLOBAL IRRADIATION



Annex 2

SOLAR ENERGY LABORATORY

A. Solar Irradiation

1. Introduction

The Centre for the Development of Renewable Energy established a solar energy laboratory in the Teacher Training College of Marrakesh. The laboratory was provided with modern instruments for measuring the climatic elements needed to study solar potential in Marrakesh. The data and information are compiled and processed and then analysed for final use.

2. Characteristics

(a) Measuring

The following elements are measured in the laboratory:

- (i) Global solar irradiation through four different types of solar collectors;
- (ii) Direct solar irradiation: direct solar collector;
- (iii) Diffused solar irradiation: indirect solar collector;
- (iv) Temperature: temperature measuring;
- (v) Pressure: meteorological measuring.

(b) Collection of data

Data are collected by the following means:

- (i) Registration of information sheets;
- (ii) Informatin Programming Centre;
- (iii) Computers for data analysis.

(c) Refitting of measuring instruments

The refitting of all measuring instruments is carried out once a year through the use of a number of devices.

(d) Implementation

The laboratory was set up within the framework of the agreement concluded between the United States Agency for International Development and the Centre for the Development of Renewable Energy, in addition to the co-operation between the Centre and the Teacher Training College of Marrakesh.

(e) Cost

The total cost of instruments amounted to 350,000 dirhams, which was borne by the Centre.

B. Apparatus for testing the flat-plate solar collectors

1. The site

The site is located at the Teacher Training College of Marrakesh.

2. Objectives of the device

(a) To study the thermal characteristics of flat-plate solar collectors.

(b) To undertake research aimed at promoting the local manufacture of flat-plate solar collectors.

3. Description of the project

A study of the thermal characteristics of flat-plate collectors, whether manufactured locally or imported from outside the country, makes it possible to measure the following elements:

- (a) Ambient temperature;
- (b) Temperature on the inner and outer sides of the collector;
- (c) Solar irradiation on the slope of the collector;
- (d) Extent of the flow;
- (e) The flow of pressure.

The instruments used for measuring are as follows:

- (i) Thermometers;
- (ii) Solar collector to measure the relative solar irradiation;
- (iii) Various other instruments and equipment such as those used to measure the extent of the flow and level of pressure of pumping water and cooling. The computerized equipment needed to compile data is also available.

4. Financing

The project was financed by the United States Agency for International Development, within the framework of the co-operation agreement with the Centre for the Development of Renewable Energy.

5. Total cost

The total cost of the project amounted to \$US 20,000.

C. Station for photovoltaic experimentation

This station represents a pilot project to demonstrate several solar electric energy applications (pumping, cooling, lighting, etc.).

In addition, the station provides facilities to test solar electric equipment, as well as training.

1. Applications

(a) Pumping water to irrigate the garden of the school (90 m³), and for other purposes;

(b) Providing various pieces of equipment with electricity (lightbulbs, refrigerator, engines), with a total capacity of 4 kWh per day.

2. Technical materials

(a) Solar generator

(i) Total power: 4,320 watts;

(ii) Three different generators;

(iii) Arscolar: mono single/crystal (1,440 watts);

(iv) Solarex: poly-crystal (1,440 watts);

(v) Mobil: amorphous (140 watts).

(b) Batteries

(i) Total capacity: 450 Ah (48 volts);

(ii) Two sets of batteries, each of a different type: coated 225 Ah.

3. Charges

(a) The pumps

(i) Number: three;

(ii) Type: A pump with one engine run by intermittent current; two pumps with two engines run by continuous current;

(iii) The power of each pump is 1,000 watts.

(b) Other charges

(i) An engine run by continuous current with a power of 1,000 watts and 48 volts;

(ii) An engine run by intermittent current, 1,000 watts and 48 volts;

- (iii) A 230 litre and 48 volts refrigerator;
- (iv) Six lightbulbs.

4. Beneficiaries

The school of Minerals in Marrakesh and the Centre for the Development of Renewable Energy.

5. Cost

Equipment and support: \$US 110,000 (grant from the American Agency for International Development).

Engineering work: 100,000 dirhams (Centre for the Development of Renewable Energy).

Annex 3

**PRESENTATION OF THE PROJECT FOR THE ELECTRIFICATION
OF AL-DUBAIBIYAT VILLAGE**

1. Name of the project

Electrification of Al-Dubaibiyat village by solar energy.

2. The site

Al-Dubaibiyat village, Akrama group, province of Kalaat Al-Saraghma.

3. Description of the project

The Centre for the Development of Renewable Energy implemented a pilot project for the electrification of rural areas by solar energy in Al-Dubaibiyat village in order to meet their basic needs, mainly to:

- (a) Provide the population with a supply of drinking water;
- (b) Charge batteries to provide television sets with power;
- (c) Light the school;
- (d) Light the halls of the mosque;
- (e) Light streets and other public utilities.

The total combined electrical power is estimated at 1,504 watts.

4. Technical description

(a) Water pumping

- (i) Quantity of water pumped daily: 20 m³;
- (ii) Combined electrical power: 752 watts;
- (iii) Total pressure head: 25 m.

(b) Lighting the school

- (i) Number of light bulbs: 12 (four for each compartment);
- (ii) Duration of lighting: three hours per day;
- (iii) Electric power: 188 watts.

(c) Lighting the mosque

- (i) Number of light bulbs: seven (five for afternoon prayer and two for the reading hall);
- (ii) Duration of lighting: three hours per day, in addition to a microphone;
- (iii) Combined electric power: 188 watts.

(d) Public lighting

- (i) Number of light bulbs: four;
- (ii) Duration of lighting: four hours per day;
- (iii) Combined electric power: 188 watts (47 watts for each pole).

(e) Charging of batteries

- (i) Combined electric power: 188 watts;
- (ii) Number of batteries that can be charged in one day: two.

5. Measuring instruments

Instruments to measure the various data relating to equipment will be made available so that the technical performance of the latter can be assessed.

6. Technical follow-up

The Centre for the Development of Renewable Energy will take responsibility for the technical follow-up of the project.

7. Maintenance and surveillance

The concerned authorities in the Governorate of Kalaat Al-Sarghma will take responsibility for the maintenance and surveillance of all the equipment that is installed. The Centre for the Development of Renewable Energy has already provided these authorities with the relevant information and explanation about the operation and maintenance of the equipment.

8. Repairs and spare parts

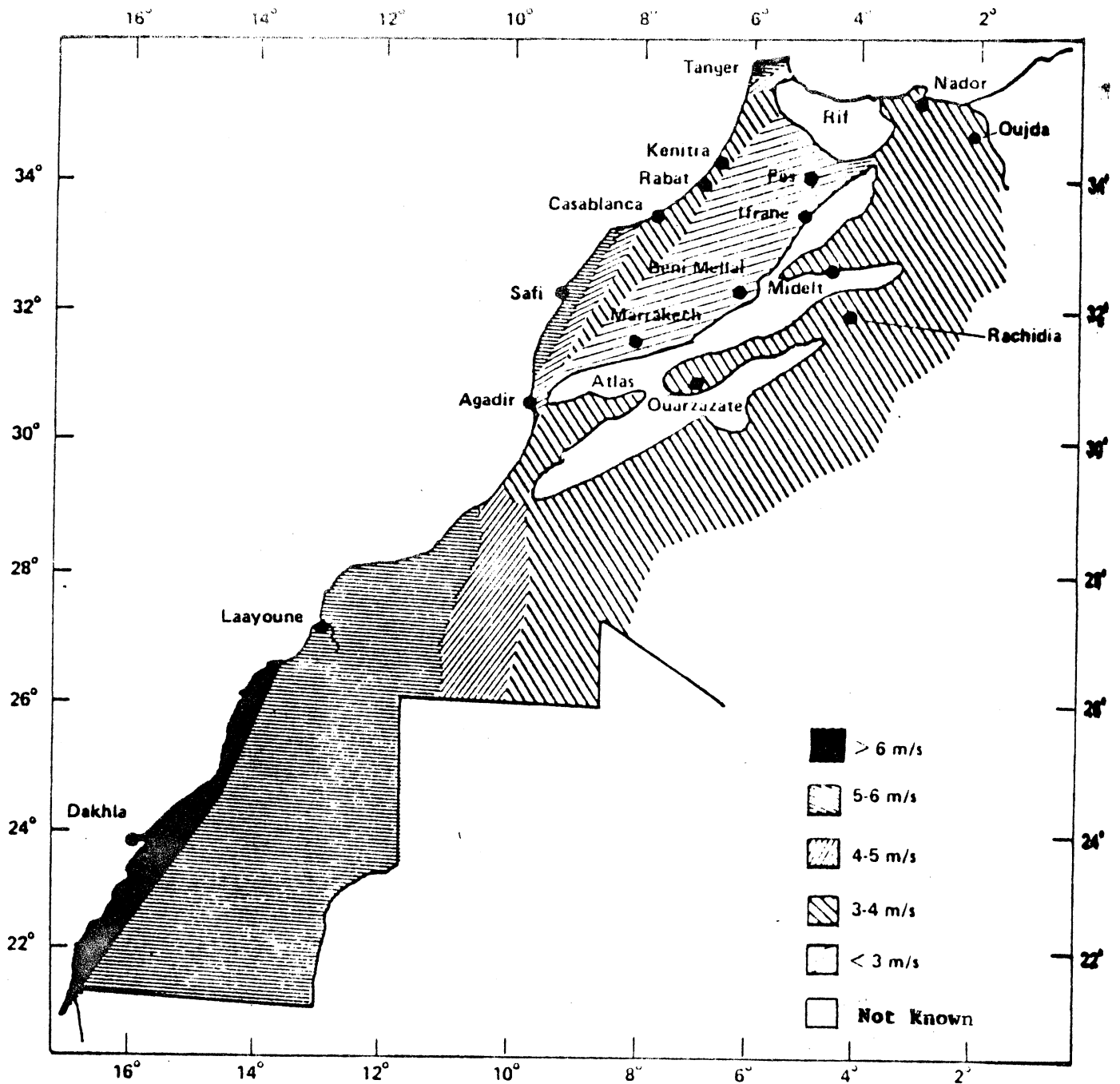
After the period of expiry of the guarantee given by the supplier, the cost of repairs and spare parts will be borne by the concerned authorities in the Governorate of Kalaat Al-Saraghma under the supervision of the Centre for the Development of Renewable Energy.

9. Cost

Equipment: 400,000 dirhams.

Annex 4

MAP OF DISTRIBUTION OF WIND SPEEDS IN MOROCCO



Annex 5

SIDI BULNOIR PROJECT

1. Name of the project

Wind power generator.

2. Objectives

Provision of electricity (water pumping for drinking and irrigation) for a rural co-operative of five houses.

3. Technical data

Wind power generator: Wind MB 916 type with two blades:

(a) Circumference: 9 m;

(b) Height: 24 m;

(c) Power: 10 kW when the wind speed reaches 10 metres per second and 16 kW at 14 metres per second.

4. The site

The Bulnoir Had Dri Group rural co-operative (about 30 km from Sulvaira).

5. Energy needs

80 kWh per day, with an average wind speed of 5.4 metres per second.

6. Concerned authorities

The Centre for the Development of Renewable Energy and the Provincial Directorate of Agriculture.

7. Installation

The Centre for the Development of Renewable Energy and North wind, starting date 30 April 1986.

8. Remarks

The Centre for the Development of Renewable Energy will take responsibility for the technical follow-up of the station and preparation of an evaluation report on the project. If necessary it will assist in the dissemination of this technology.

9. Social aspects

The project will contribute to the amelioration of living standards of the population of the co-operative.

10. Cost

Equipment and technical assistance: \$US 90,000, given by USAID.

Preparation for the project: 10,000 dirhams.

XI. COUNTRY PAPER ON THE USE OF SOLAR AND WIND ENERGY IN RURAL AND REMOTE AREAS OF OMAN*

Solar energy is considered to be one of the most important potential energy alternatives in Oman. However, its use is limited mainly to telecommunication services, particularly in remote districts. It is also used for some experimental water pumps.

Solar energy becomes economically viable when the price of electricity reaches 50 baizas per kilowatt/hour. The cost of one kilowatt/hour of solar energy is estimated to be 45 baizas. These estimates could change in the future when further progress in the conversion of solar energy has been made.

Oman is situated in the south-eastern part of the Arabian Peninsula between latitude 26° north and 17° south and longitude 52° west and 60° east. Oman has about 300,000 square kilometres with between one and 1.5 million inhabitants.

Most of Oman is mountainous and difficult to penetrate. It has also desert areas, in addition to many remote villages where a large number of inhabitants live. There are many scattered and small villages distant from each other that are situated in areas which are difficult to reach.

It is difficult to supply these villages with electricity because the cost would be high compared with the requirements of each village, taking into consideration the fact that many villages have no more than 200 persons each.

It would be possible to use solar and wind energy resources in these remote areas. Despite the efforts that have been made, greater priority must be given to this subject in development plans. The Sultanate can benefit from the expertise and results of research in development that have been accumulated by ESCWA and by other developed nations.

Before conducting these experiments and activities it will be necessary to study the present condition of the activities of renewable energy. Different types of data on energy resources must be collected for the purposes of evaluation, and in order to study the economic viability and extent of the applications.

About 25 meteorological stations in different parts of Oman are run by solar energy. The Directorate General of Meteorology of the Ministry of Communications operates these stations.

About three stations are run by solar energy. Petroleum Development Oman (PDO) operates the remaining companies.

* Ministry of Petroleum and Minerals and the Ministry of Electricity and Water of the Sultanate of Oman.

The functions of the station are centred on the collection of data related to the sun's rays and the speed and direction of winds. It is worth mentioning that Oman has a very hot summer season in which the average heat of the sun reaches five kilowatts per square metre per day.

The Ministry of Communications collects data on wind energy speed and direction from the various stations for the purposes of study and evaluation.

These studies have revealed that the yearly speed of winds in some areas in the south and south-east are between nine and 12 knots, and that they reach about 10 metres high. The best areas for the exploitation of wind energy are Thamreet and Masira, where the force of the wind ranges between 130 and 250 kilowatts per square metre.

Before embarking on any activity, a consulting company has been given the responsibility of carrying out additional studies to obtain more accurate information so that the technology of this renewable energy source can be utilized.

Many microwave telecommunication stations belonging to PDO are operated by energy collected from the sun by panels. In addition to this, a water pump operated by solar energy has been installed in an agricultural institute in Nizwa, in the interior of Oman.

Water heaters operated by solar energy are used in some residential areas near the refinery or oilfields. PDO is studying the possibility of using solar energy to heat crude oil in the oilfields in order to separate the associated gas. Furthermore, PDO is studying the use of solar energy to generate the steam that is injected into heavy oil wells.

Solar and wind energy resources could play an important role in the different regions of Oman in places where electrical power is not available, in order to fulfil the requirements of the inhabitants.

XII. COUNTRY PAPER ON THE SOLAR PILOT PROJECT IN QATAR

M.M. Haruni*

Abstract

This paper is intended to give some data on the components of the first stage of the Qatar pilot project. The project consists of: a meteorological and solar measurement station, test benches for thermal collectors (low and high temperature), photovoltaic tests for cells and panels, a flat thermal collection concentrating system, a solar pond energy collection and storage system, a heliostat mounted normal photovoltaic two-axis tracking generator, a flat thermo-photovoltaic hybrid concentrating collecting system, a thermal solar distillation desalination unit, and a small experimental farm that makes use of sand, sea-water and solar energy, where water vapour from the solar-heated sea water condenses directly onto plant roots.

A. Introduction

This project was planned after long and painstaking contact with, visits to and evaluation of the state of the art, as well as the claims of the various manufacturers of solar collecting systems and the different small and large solar stations. It was clear that solar energy collection and utilization has reached a turning point. Many systems already have or will soon become obsolete. Continuous progress results in solar energy collection becoming more simple and efficient. The fewer moving parts there are in the solar collecting system, the more promising its economic applications.

Each of the technologies in this project were chosen after a thorough study and evaluation was made.

The first stage of the project is now under construction in the industrial area at Umm Said so that the available infrastructure and living facilities can be utilized. Figure XIII-1 shows the various units of this project.

The size and scope of each unit was chosen in order to give the required data which can be utilized to design a commercial unit. This is an important step before any system is adopted for large-scale implementation.

B. Solar measurements

The solar measurements bench consists of six sensors (anemometer, pyranometer, pyrgeometer, pyrliometer, psychrometer and thermometer) mounted on an aluminium frame and placed outdoors under optimal measuring conditions.

The connections between sensors and measuring units are made through a junction box fixed to the frame.

* Qatar, Industrial Development Technical Sector.

The measuring instruments (transmitters and amplifiers) and the recorders are mounted in a 19 inch rack.

Pyranometer - model Friedrichs type 6021.

Pyrgeometer - model Kipp and Zonen type CM7.

Pyrheliometer - type CM-5 equipped with an aluminium tube with a ratio diameter/length of 1/10, fixed to an equatorial mounting with an Atlantic-type tracking system.

Recorder - model Camille Bauer, type 3 ARH6/144.

Potable thermometer - model Friedrichs type 2017.1.

Weathercock and anemometer with an indicator and recorder - model Friedrichs type combined.

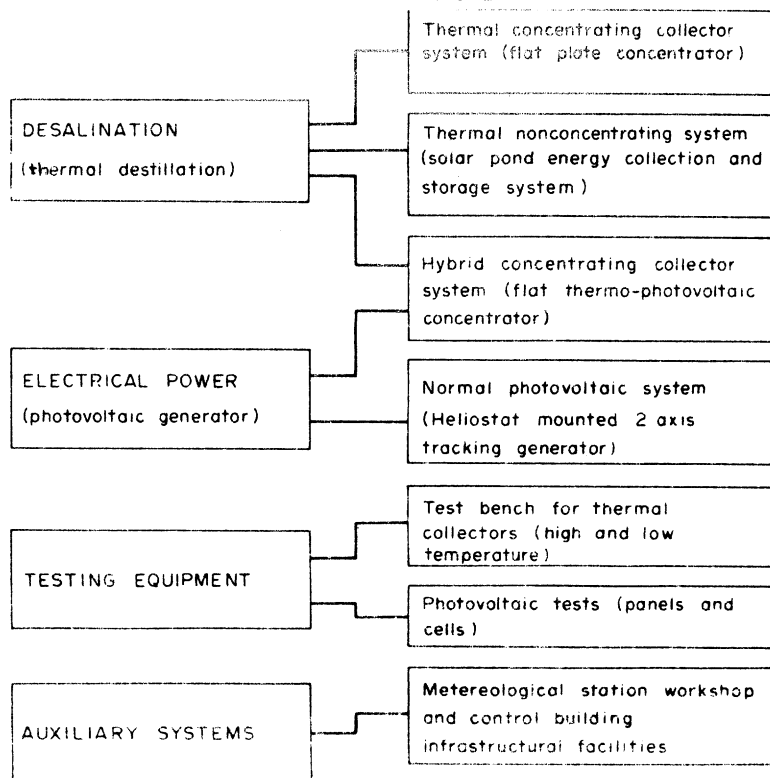
Humidity meter and hydrometer - model Friedrichs.

Potable meter for measuring direct radiation - model Haenny-type solar 118.

C. Low temperature collector test bench

The use of solar collectors to satisfy energy demands in a way that is both economical and environmentally safe is steadily on the increase. Since the solar energy density measured on the earth's surface is rather low, solar plants are still relatively expensive and the efficiency and durability of solar collectors are extremely important to achieve an economic application.

Figure XXI. Test bench



Precise, time-consuming procedures are required to test collectors according to the regulations contained in DIN 4757, Part 4 (Deutsche Institute für Normung, Federal Republic of Germany).

ASHRAE 93-77 (American Society of Heating, Refrigerating and Air-Conditioning Engineers, United States of America), and AFNOR P 50-501 (France).

In order to obtain more accurate data, a test unit that can be employed universally was developed. It is distinguished by the following features:

- (i) The equipment is mobile for use in indoor and outdoor tests;
- (ii) It carries out optional tests according to DIN, ASHRAE or AFNOR;
- (iii) It makes comparative tests of two collectors;
- (iv) It can test radiators;
- (v) It has a low staffing requirement because of its electronic controls and computerized evaluation of the measurements.

The test bench includes a thermostat control box, the frame for the collectors, the sensors, which are mounted in the frame, and part of the instrumentation, which is in the collector data panel. The current panel is mounted at the rear of the collector frame. Data recording is not performed on a printer, but by means of a Hewlett-Packard computer with a printer-plotter.

In order to operate the test bench properly, the following parameters are indicated in analogue form in the instrumentation panel, which is located at the back of the test frame:

- (a) Temperature;
- (b) Flow rate;
- (c) Solar radiation.

Other parameters can also be indicated in analogue form, but they are not necessarily needed for the operation.

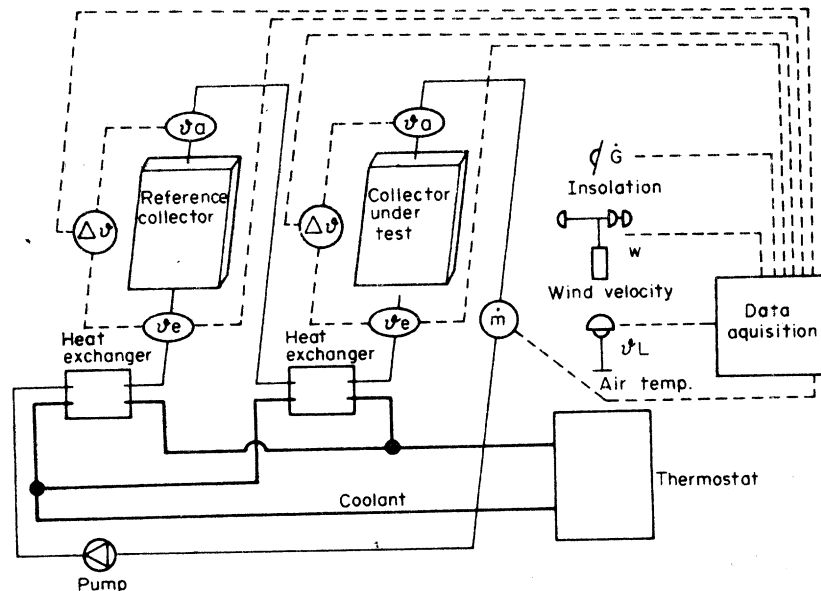
The test bench frame is constructed of zinc-coated steel frames that are screwed together; it requires practically no maintenance. The angle of the collector can be varied between 0° and 90° . The steel frames are reinforced at the corners with iron angles in order to reduce torsional problems. The entire test bench is mounted on four wheels, with two acting as brakes. The test bench is designed for two flat-plate collectors, and has a weight capacity of 200 kg. In a vertical position the test bench has the following dimensions: height 250 mm; depth 1,200 mm; width 2,200 mm. The maximum size of the test collector that can be accommodated on the test bench is about 2 x 2.2 m.

The heat exchanger, pump and flow rate controller are enclosed in a well insulated stainless steel box. All of the connections to the test bench are made by quick-disconnectors for convenience.

1. Performance and operation description

Figure XXII shows the schematic diagramme of the collector test bench. The reference collector and test collector are connected in series by a closed circuit. A constant but adjustable collector inlet temperature is achieved by using heat exchangers with large dimensions that are connected to a heating and air-cooled thermostat (on the right in figure XXII). The operating temperatures range from -20° to $+150^{\circ}\text{C}$. Electrical resistance thermometers (Pt-100) and a temperature difference amplifier are used to measure the temperature differences between the collector outlet and inlet.

Figure XXII. Schematic diagramme of the collector test bench



The thermostat (Solartest St 8,000) is a thermostatic circulator used to heat and cool the closed consuming devices within a temperature range of -20 to $+150^{\circ}\text{C}$. The temperature is controlled by an electronic PID controller with a simple electrovalve with an accuracy of $\pm 0.05^{\circ}\text{C}$.

With temperatures of up to $+80^{\circ}\text{C}$ the instrument operates without pressure and uses tap water as a heat transfer liquid. With higher temperatures, a solenoid valve automatically closes and the thermostat operates in temperatures up to $+150^{\circ}\text{C}$ as a compressed water instrument.

Solartest St 8,000 can be moved by means of four rollers running in ball-bearings. An air-cooled cooling aggregate, low-noise and maintenance-free, has been installed in the lower part.

The electric controls are thermally insulated. The pressure of the system, pump and tap water are indicated by three manometers.

If a comparison of two collectors is required, it is usually only necessary to note the relative difference between the two efficiency curves. If the two test collectors are connected in series, the instrumentation and testing time can be reduced. A temperature-regulated heat exchanger for each collector allows them to operate at almost identical entrance temperatures. The working fluid can be heated to the required entrance temperature either by means of solar insolation, or by preheating it by electricity.

It is not necessary to measure the flow rate or to determine the specific temperature of the fluid, since it is the same for both collectors. All that is required is to measure the temperature difference between the outlet and inlet of each collector. The ratio of the two temperature differences gives a relative comparison of the two collectors, provided that there is an efficiency curve for the reference collection.

2. Registration and data acquisition

The flat-plate collector test bench is equipped with an analogue measurement system for the following eight channels:

- One for air temperature;
- One for wind velocity;
- One for solar insolation (global);
- Two for temperature measurement;
- Two for temperature measurement;
- One for flow rate measurement.

The operator is able to read the temperature, flow rate and insolation measurement values at the collector test bench. All other values are collected by a data-logging system which is the same for both the flat-plate collector test bench and parabolic collector test bench. The data-logger includes a data acquisition control unit with a 20 channel relay multiplexer assembly and personal computer HP 85 F together with a printer-plotter type 2671 G.

D. High temperature collector test bench

1. Test bench description

In order to perform thermal performance tests on parabolic collectors, a test bench that can operate at a relatively high temperature level (maximum outlet temperature of 400°C) must be provided. In addition, it must provide the necessary flow rates so that the collector can operate at various temperatures. The test bench can operate with both linear and point-focusing parabolic collectors. The test bench can test parabolic collectors with a total aperture area in the range of 18 to 100 m², in addition to testing two collectors in parallel.

In general, the test bench consists of a closed loop that uses heat transfer oil. The main mechanical components are the feed pump and an air-cooled heat exchanger that can extract the maximum incoming thermal energy. The loop is operated manually in order to increase flexibility, and can operate at various preselected collector inlet temperatures, with various collector temperature differentials.

An overall view of the test bench is shown in figure XXIII. The test bench frame is manufactured from stainless steel and has three doors on the front side for easy access to the hydraulic components. The right side contains the control cabinet, which has all the necessary gauges in an analogue form so that the operator can run the test bench directly. In addition, the test bench has ring bolts at the top for transportation purposes, together with wheels for manoeuvring the test bench to the collector. The wheels can be removed for transport and storage purposes.

Figure XXIV shows the preliminary installation view of the test bench with all the relevant components.

A flow schematic of the test loop is shown in figure XXV. The loop shows that it is possible to test two mirrors in parallel at the same time as long as the total collector area does not exceed 100 m². A coarse adjustment of the flow rate is achieved by using the bypass control valve V12.

Figure XXIII. Overall view of the test bench

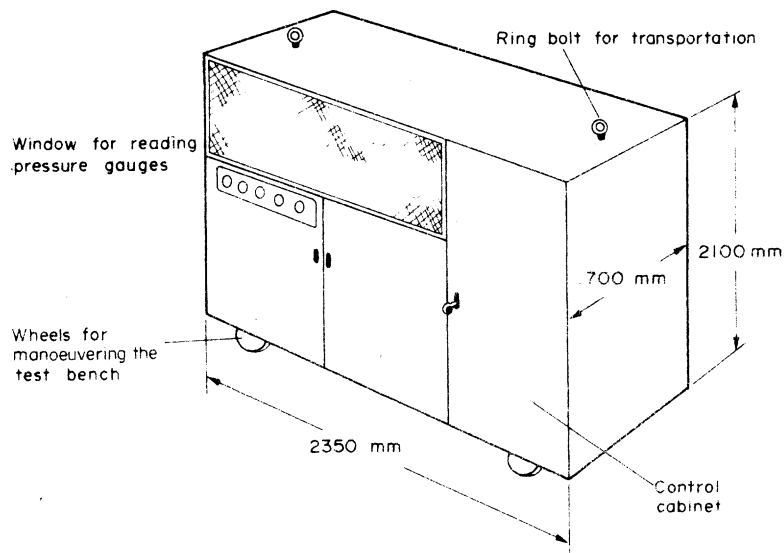


Figure XXIV. Preliminary installation view of the test bench

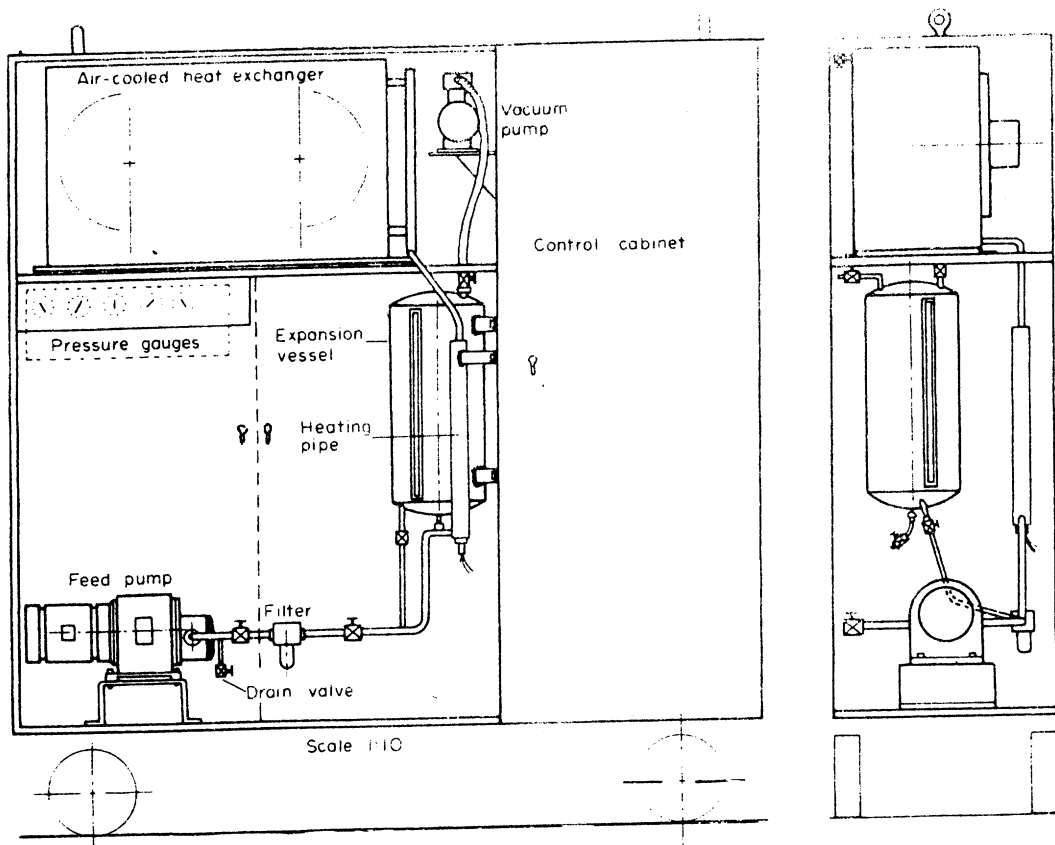
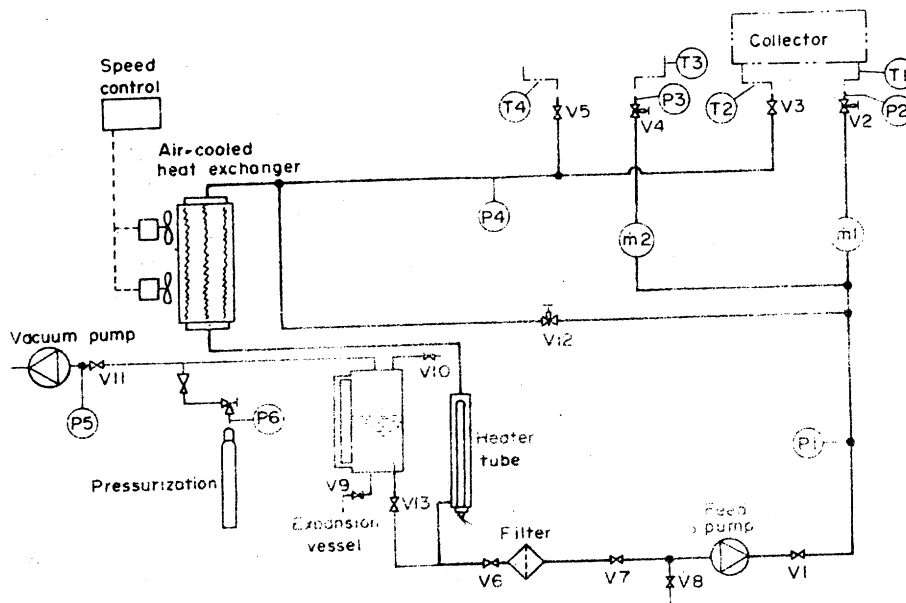


Figure XXV. Schematic flow of the test loop



2. Design and performance description

Figure XXV depicts a simplified flow schematic of the test loop. A gear pump driven by a constant speed electric motor delivers the heat-transfer oil to the collector or collectors. The oil heated in the collector is then cooled by an air cooler speed-controlled ventilator. The working fluid enters a larger tube where it is preheated by a rod-type electric heater to the required temperature, as is indicated by T1 and T3. Either the collector or the heater can be used to preheat the working fluid.

The flow rate to the collectors is controlled by two (or three) hand-operated control valves. Coarse adjustment is obtained through the bypass valve V12, and fine adjustment is made through valves V2 or V4 (when two collectors are being tested). These valves also serve as shut-off valves when the collector is disconnected from the test bench.

Owing to the fact that some heat transfer oils have a high vapour pressure at higher temperatures, an N₂ pressurization system is provided in order to prevent vaporization of the fluid.

A vacuum pump is provided largely for initial filling purposes or for occasional evacuation between depressurizations. After filling has been carried out in a vacuum, the pump can be disconnected from the test loop through valve V11, and pressurization can then take place.

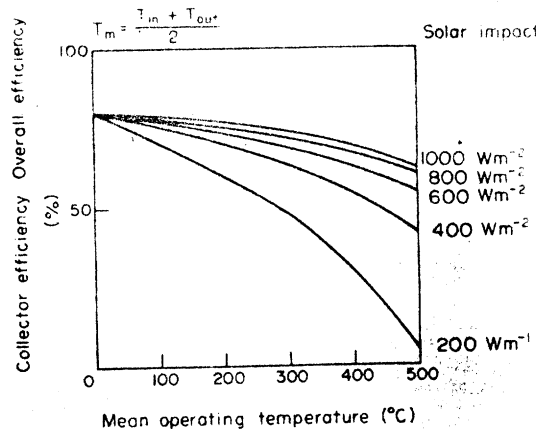
Owing to the relatively high temperatures and flow rates, it is more difficult to achieve exact control of the test parameters than with a flat-plate collector system. Consequently, manual control of the test parameters was preferred, in view of the high flexibility available to the test operator.

In order to achieve the required inlet temperature of the collector, the heater can be preset. The feed pump is then started, and the bypass valve is set in position so that the flow rate to the collector has a nominal desired value. This can be determined by means of estimates or from calibrations. When the desired inlet temperature is reached, the collector efficiency can then be evaluated according to ASHRAE specifications by noting the flow rate, the inlet and exit temperatures of the collector and solar insolation. The method of evaluating efficiency is very similar to that used for flat-plate collectors. A sample of a collector efficiency curve is given in figure XXVI.

When two collectors are compared, flow rates are adjusted by means of the throttle valves until the flow rate for each collector is identical. A relative comparison of the efficiency of each collector can be made by comparing temperature differentials with the reference collector.

The speed-controlled cooler is adjusted so that it extracts from the collector the exact energy input needed to reach the required inlet temperature.

Figure XXVI. Collector efficiency curve



3. Instrumentation and data acquisition

The parabolic collector loop is equipped with an analogue measurement system for the following 10 channels:

- One for air temperature;
- One for wind velocity;
- One for solar radiation (global);
- Two for temperature measurement;
- Three for temperature measurement;
- Two for flow rate measurement.

The operator is able to read the temperatures, flow rates and pressures at the collector test bench. All other values are collected by a data logger system, which is the same as that used by both the parabolic collector and flat-plate collector test benches. The data logger includes a data acquisition/control unit with a 20 channel relay multiplexer assembly and personal computer HP 85 F, together with a printer-plotter type 2671 G.

E. Photovoltaic performance tests

1. Solar cell tester

The complete solar cell tester I system consists of a newly developed xenon lamp, a flash generator and a software-based data processing system that offers such options as memory access, an intensity-voltage (I-V) curve shape factor, as well as other features (see figure XXVII).

The solar cell tester I produces accurate results for determining solar cell output. The system takes advantage of the quick response time of photovoltaic devices, which illuminate and characterize the samples within a few milli-seconds. During the flash-pulse, the Solar Cell Tester measures the complete I-V curve of the cell by imposing predetermined values of current. In the meantime it measures the irradiance level, cell voltage and also corresponding current in order to lower the quantification errors coming from AC-DC and DC-AC conversions. Just after the flash-pulse, a low voltage is fed into the cell in order to determine the shunt resistance current.

- (c) Converting the binary values needed by AC-DC and DC-AC converters to measure the voltage or current in volt (V) or ampere (A) decimal values;
- (d) Measuring the I-V curve correction as a function of the temperature discrepancies;
- (e) Automatically computing cell behaviour at different temperatures;
- (f) Measuring the I-V curve correction as a function of irradiance variations during the flash;
- (g) Computing the open circuit voltage variation of the cell as a function of instantaneous irradiance;
- (h) Computing the maximum power point and corresponding voltage and current levels;
- (i) Calculating typical parameters such as I_{sc} , V_{oc} , efficiency, R_{sh} and R_{se} ;
- (j) Transmitting the category range to the electronic measuring equipment;
- (k) Tape recording the average values at the end of an array.

3. Panel power measurement

The equipment is designed to measure the power produced by photovoltaic panels under natural sunny conditions. The variable load is designed to measure one to four normal photovoltaic panels (30 to 50 watts). To measure special generators that have larger current intensities, other variable loads must be chosen. The voltage, current and power values are permanently registered on a three-channel recorder.

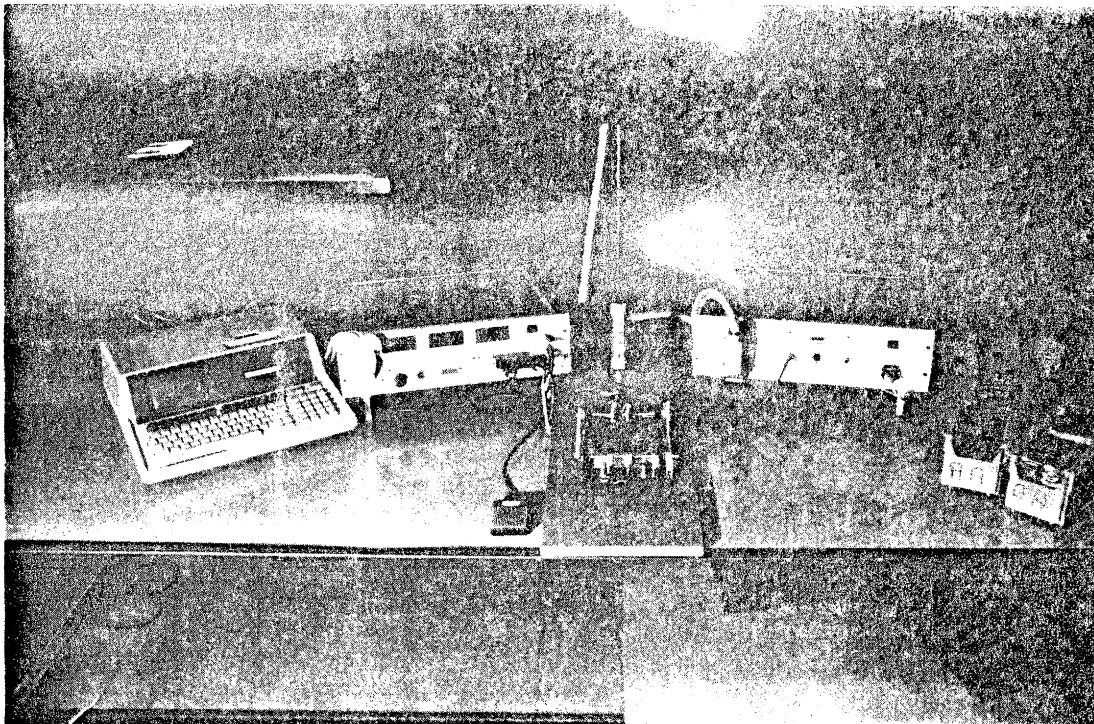
F. Solar (MSF)-fluidized bed (FB) self-regulating desalination unit

The MSF-fluidized bed desalination unit was designed to operate with a solar power source, in conjunction with a heat storage system (figure XXVIII).

Sea water is pumped by a vacuum pump to a de-aeration unit which has a self-regulating level. Once de-aerated, the sea water is pumped into a compact vertical condenser made up of a large number of titanium tubes. These tubes contain a glass particle bed which fluidizes as the sea water flows through. This fluidization results in a high turbulence, which leads to an improved vapour condensation rate on the outer surface of the tubes.

Brine that is pre-heated by this vapour condensation enters the main heater, which also contains a number of titanium tubes incorporating a fluidized bed turbulence system. In the brine heater, however, the glass particle fluidized bed permits not only an improved heat exchange rate. It also develops an abrasive de-scaling capability that avoids the use of chemicals and simplifies maintenance.

Figure XXVII. Complete solar cell tester I system



The data are taken in steps in order to allow solar cells to react over varying impedance levels (too many measurements within such a short time would produce inaccurate values). The data are then transferred to a computer that calculates the efficiency, short-circuit current (I_{sc}), open-circuit voltage (V_{oc}), fill factor, shunt and series resistances (R_{sh} and R_{se}). It also calculates the new averages of the array after each measurement for all of the data. These are made available on both printed tape and a graphic I-V curve. They show: cell type, test temperature, irradiance level, flash power and the digital output of data points.

At the end of the calculation the cell category fixed with information is displayed on the front panel (15-LEDs).

2. Computer data processing

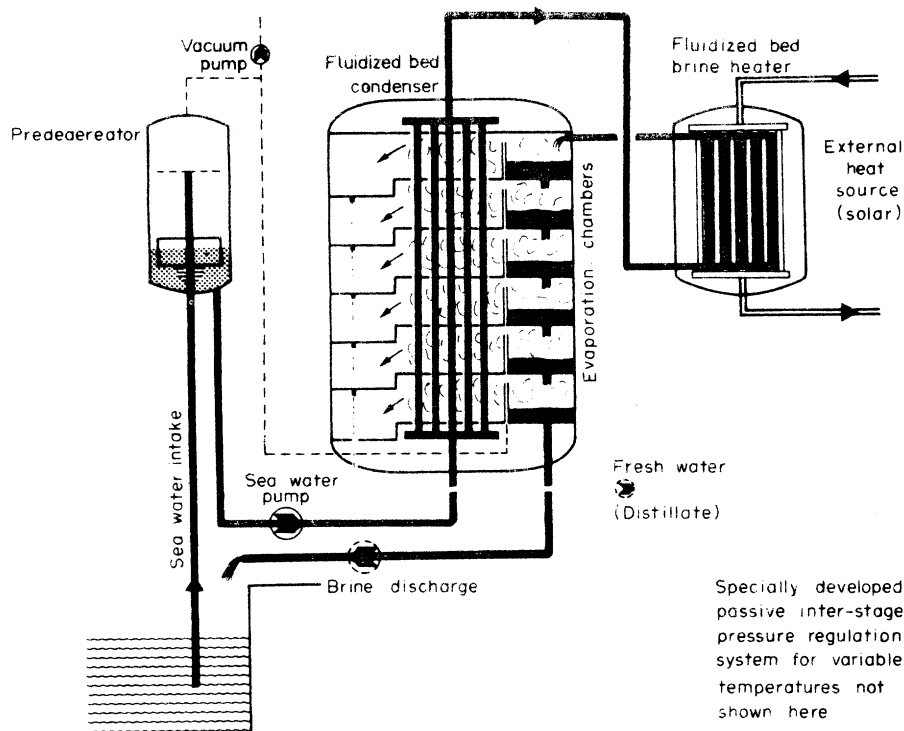
When connected to a HP 85 computer an additional data processing capability is available.

The primary data processing functions performed by the computer are as follows:

(a) Transmitting the desired point distributions and scale range to the electronic measurement equipment (performed only at the beginning of a new cell array);

(b) Recording the measurement points along the I-V curve and dark current of tested cell;

Figure XXVIII. MSF-fluidized bed desalination



The fact that the condenser and brine heat exchanger are both made of a large number of parallel, straight tubes, with a very slow flux speed, eventually results in a small pressure loss. Therefore, only limited pumping power is required.

Once heated, the brine enters the first of the evaporation stages where distillate production starts. Thereafter, it passes through a specially developed passive inter-stage pressure regulation device.

All of the stages are built on top of each other, so that the complete cascade results in a compact unit surrounding the vertical condenser. The vapour that is produced at each stage is condensed and the distillate is collected at the bottom of the unit. The distillate passes from stage to stage through similar passive inter-stage control devices.

All of the evaporation stages, together with the condenser tubes, the inter-stage pressure regulation devices and the collection chambers, are assembled together and enclosed in a steel vessel.

The brine and the distillate collected at the bottom of the vessel may be evacuated by hydrostatic pressure when placing the unit at an elevation of 10 m or by using electrical pumps when placed at ground level.

1. Sea-water intake

A comparison of the chemical analysis of sea and underground water is considered to be basic data for any final design, and it led to the decision to feed the complete desalination system with sea water taken directly from the sea, rather than underground water.

A submersible pump feeds the zero-level de-aerator tank by means of a PVC pipe and a battery of three parallel filters.

An injection pump alongside the filters is activated for a few minutes once or twice in a week, in order to introduce a chemical substance which inhibits the proliferation of marine life into the water stream.

2. Thermal collector field

A total of 76 modules of east-west tracking Atlantis flat thermic concentrating collectors will be used as the main power source for the desalination system. Each module consists of:

(a) A glass slat mirror assembly (2 x 58 mirrors, 200 cm long) with a tracking mechanism which is incorporated into the aluminium frame.

(b) A black-coated absorber tube with a square cross-section (5.5 x 5.5 cm) of thermal insulation is mounted on the two sky-facing sides. Two-way fluid channels (supply and return) are incorporated into the tube. A de-aereating safety valve is mounted on the top.

(c) An autonomous solar cell-powered sun sensor and tracking system with a thermostatic de-focusing switch to prevent overheating.

3. Hydraulic connections

The collectors are mounted on a common supporting structure made of steel profiles which stand on concrete foundations. They are arranged in two fields with one each containing 19 parallel rows, each of which has two collectors connected in series (directly coupled absorber tubes).

Distribution and collection pipings run along the bottom of each field. They are each designed with a reverse place for two additional collectors (a total of four additional collectors can be mounted).

The design of the interconnecting pipework between the collectors, as well as the main piping to the heat storage tank is constructed in such a way as to minimize heat losses during the night and the power requirements of the

pumps. The water in this pipework must first be heated to the right temperature in the morning before the collector field starts to supply power for the desalination unit and to charge the heat storage tank. For this purpose, an electrically driven three-way control valve is installed in the loop of the collectors in order to bypass the heat storage tank. Only when the temperature of the heated volume is higher than that in the storage tank can the water flow enter into the tank.

A circulating pump with an automatic control is installed in the loop of the collectors. A differential temperature control (with respect to the top of the storage tank) is used for this purpose.

Technical description and specifications: Design operating temperatures (under the most favourable conditions):

- (i) Mean thermal collector outlet temperature: 92°C ;
- (ii) Mean thermal collector inlet temperature: 79.5°C ;
- (iii) Mean temperature difference input/output: 12.5°C ;
- (iv) Mean thermal collector operating temperature: 85.7°C ;
- (v) Mean ambient temperature: 25°C ;
- (vi) Insolation time (direct solar radiation in the direction of the sun) from 0700 to 1700 hours: 850 Wm^{-2} ;
- (vii) Average direct solar radiation intercepted (with tracking): approximately 760 Wm^{-2} ;
- (viii) Mean efficiency (at $T_M = 85.7^{\circ}\text{C}$ $T_{\text{amb}} = 25^{\circ}\text{C}$) : 0.45;
- (ix) Average specific thermal power (0700 to 1700): 342 Wm^{-2} ;
- (x) Mean energy yield (0700 to 1700): $3,420\text{ Wm}^{-2}$;
- (xi) Active area/collector: 5.9 m^2 ;
- (xii) Number of collectors: 76;
- (xiii) Total active area: 448 m^2 ;
- (xiv) Total energy yield/day: $E_t = 1,533\text{ kWh day}^{-1} = 1,318,834\text{ kcal day}^{-1}$.

4. Sea-water de-aeration

The formation of air bubbles along the water columns in the fluidized bed tubes may result in a low heat transfer coefficient for recuperation. In addition, during the condensation of water vapour at each temperature and pressure level, the partial pressure of air contained in the water vapour increases around the condensing walls, thus forming a barrier through which

the vapour must be diffused in order to continue condensation. For these reasons, water must be de-aereated in a first stage before it enters the heat recuperator. The remaining air is later sucked out from the condenser chambers after vapour condensation.

A barometric de-aerator is used for the first stage of de-aeration. The barometric sea-water column is achieved with the aid of a vacuum pump until the water has reached the appropriate height, which is dependent on barometric pressure. As soon as the sea-water pump is put into operation, the necessary flow rate is established by means of a swimmer system which opens and regulates the inlet of sea water to the de-aerator. A bed of small plastic bodies is used to amplify the area of water flux inside the de-aerator.

After de-aeration at a nominal pressure level of 30 millibars has taken place, sea water is pumped into the fluidized bed condenser tubes.

At nominal power, only one 1.1 kW pump is used to run the desalination unit. A second pump is used as a stand-by or for the start-up procedure.

A motor powered bypass valve is installed between the delivery and suction of the pumps in order to regulate the flow rate. Each of the pumps has its own electrically-driven outlet valve.

5. MSF FB desalination unit

The MSF-FB desalination unit consists of a large number of titanium tubes, each containing a glass particle bed that fluidizes as the sea water flows through. This fluidization results in a high turbulence, which gives a high heat transfer coefficient for vapour condensation on the outer surface of the tubes.

The unit consists of 22 evaporative stages, each of which flashes the remaining hot sea water (after evaporation) into the next pressure-temperature level. All of the stages are built on top of each other in a configuration that produces a complete cascade in a compact unit.

The pressure difference regulation between the stages is achieved by means of specially developed passive inter-stage devices.

All of the evaporation chambers, together with the condenser tubes, inter-stage pressure regulation devices and the collection chambers are assembled together and enclosed in a steel vacuum vessel.

The brine and distillate are collected at the bottom and evacuated by hydrostatic pressure.

6. Brine heater

Sea water, which is pre-heated by vapour condensation in the different states, leaves the MSF-FB unit through a polyvinylidenefluoride (PVDF) pipe in the direction of the brine heater.

Before entering the brine heater, a bypass allows the brine to return immediately to the de-aerator. This bypass is limited to start-up procedures and must never be used at higher temperatures. This first bypass is controlled by an electrically-driven valve that opens and closes the bypass. A second manual valve opens the inlet to the distribution chamber of the brine heater; it only serves for assembly purposes.

The brine heater is a vertical, counter-flow heat exchanger with a fixed tube-handle design. Sea water (brine) flows through its primary side, which consists of a large number of vertical titanium tubes, each containing a glass particle bed. This has two purposes: first, it originates high turbulence at low liner speeds and secondly it reduces the need for chemicals to prevent calcium formation by producing an abrasive effect over the walls of the tubes. At the outlet of the brine heater, sea water can again return to the de-aerator by bypassing the evaporator, or it can enter the first stage of the evaporator by closing the bypass and opening the return pipe to the MSF-FB unit. Two electrically-driven valves achieve this.

Hot water flows through the secondary side of the brine heater. It is taken from the upper layer inside the heat storage tank with the aid of a circulating pump. As the heat exchanger has a counterflow, hot water flows downwards while sea water travels upwards.

There is a special device for the chemical treatment of fresh water on its way from the brine heater to the cold water distribution tank.

7. Heat storage tank

A 35 m³ heat storage tank will be used. It is made of steel and can be fed with hot water either from the thermal collector field, the hybrid collector field or, eventually, the solar pond.

The entire construction of the tank acts as a supporting structure for the desalination system, including the two platforms.

Hot water enters the tank by three independent inlets that are connected to a common swimmer on the inner side. The function of this swimmer is to permit the injection and collection of the hot water in the upper layer, regardless of the temperature level and heat content of the tank. The total amount of fresh water that circulates in the two collector loops (thermal and hybrid) and the initial cold capacity of the heat storage tank increase in capacity as the temperature rises. The upper part of the heat storage tank therefore acts as an expander. The water surface inside the tank will be covered with a cork plate in order to prevent excessive evaporation.

The hot water outlet from the heat storage tank, connected on its inner side to the swimmer, also has the three inlets.

Independent pipework is designed to allow overflows at the maximum allowed level of hot water inside the tank.

The complete tank is insulated with a foam layer and covered with an aluminium sheet for protection.

G. Concentrating photovoltaic array

The flat concentrating solar collectors constitute a new generation of concentrating collectors that were developed as a result of long experience with concentrating collector systems.

1. Construction and working principle

A large number of long, flat, glass mirror slats (the back side is silver-coated and protected) are arranged within a common modular aluminium frame and suspended along their turning axes.

All of the mirror slats (heliostats), once they have been adjusted individually to focus onto the receiver tube (thermal or hybrid), are turned by a common lever mechanism so that they follow the sun and keep focusing on the receiver as the sun moves from east to west (whereby mirrors are arranged in a north-south direction) or change their elevation (where the mirrors are arranged in an east-west direction).

As soon as the sun appears, a special autonomous (solar cell powered) sun tracking system commands and powers an electric micro-motor and reduction gear. This activates the lever mechanism and secures the precise focusing of the mirror slats on the absorber. The turning angle of all of the mirrors is the same, always being half of the moving angle of the sun.

The individual mirrors and lever mechanism were designed to reduce friction losses to a minimum and are enclosed within the frame to protect them from environmental influences.

A sliding coupling connects the individual mirrors to the lever mechanism (for safety and easy adjustment), and also connects the lever mechanism with the reduction gear.

The concentration of solar radiation (the effective concentration factor) on the receiver depends on the number of mirror slats that are selected and on the level of direct radiation that is intercepted and directed onto the receiver.

The upper limit for the effective midday concentration factor is in the order of 20 (geometric concentration in the order of 40).

2. The hybrid receiver

The hybrid receiver is triangular-shaped. Solar cells of a particular type are fitted onto the sides facing the mirror, and are encapsulated and electrically connected to each other.

In order to achieve a specified voltage output and to avoid power losses from cell shadowing effects, groups of solar cells connected in series are connected in parallel with the corresponding cells of other groups.

Four fluid channels are incorporated into the receiver in order to extract thermal energy. Depending on the temperature level that is chosen, useful thermal energy is gained, while at the same time the cell temperature is stabilized (cooling effect).

The hydraulic design was optimized for minimal pressure losses and maximal cell cooling (cell temperatures are never more than 3 to 6° C above the fluid temperature, depending on the level of radiation received during the course of the day).

3. Collector field

The hybrid collector field consists of two arrays (fields), each with 14 double modules of the Atlantis-hybrid flat concentrating collector. The modules are designed to deliver electricity and thermal power simultaneously. The exact amount depends on the operating temperature and on the level of direct radiation. Each photovoltaic array consists of 140 photovoltaic cells that are encapsulated by a special glass cover and fastened onto an absorber tube which also contains the fluid channels.

Solar radiation is collected by the absorber through reflection on the flat glass mirror slat assembly which is incorporated in an aluminium frame.

An autonomous solar cell-powered tracking system drives the mirror mechanism, which focuses the reflected radiation onto the absorber.

the 14 double modules of each array are mounted on a common supporting structure made of steel profiles, which stands on concrete foundations.

Each of the two modules are electrically and hydraulically connected in series. All of the double modules within one field are also connected in series. The two fields are connected in parallel.

The hydraulic distribution and collecting pipework runs along the bottom of each field. A place for one reserve double module on each array is foreseen.

4. Specifications of the array

Each array consists of 140 photovoltaic cells of type C10 from AEG. The cells are monocrystalline of a space-technology quality and have proved to function better under concentration than all of the other cells tested to date.

The 140 cells in series are interconnected in parallel on the absorber so as to increase reliability and to avoid shadowing effects.

5. Summary of the specifications

- (a) Number of modules: 56;
- (b) Module voltage at power peak: 7 V;
- (c) Field voltage at power peak: 196 V;

(d) Peak array output power (at 880 W/m^2 direct radiation perpendicular to the collector plane and 85° C fluid temperature): 14.5 kW;

(e) Operated at a lower temperature, the voltage and power increases, e.g., 30° C fluid temperature;

(f) Field voltage: 270 V;

(g) Peak array output power: 19.5 kW.

H. Normal solar photovoltaic generator

The two-axis tracking system consists of a photovoltaic array mounted on a heliostat structure. The photovoltaic array consists of a square array of 256 40 W Arco M-51 modules. The modules are assembled at the factory as rectangular sub-assemblies each of 16 M-51 modules, wired, tested and shipped in special wooden fixtures. Sixteen of these sub-assemblies are installed on the tracker structure in two sections. Each of the two sections is supported by a truss rack, which is fitted to a 12.5 cm diameter torque tube.

The two truss racks supporting the 256 Arco M-51 modules are fastened to the gear drive with bolts. The gear drive is the decisive part of the tracker and provides the motion for the collector array to keep the plane of the photovoltaic cells perpendicular to the direction of the solar radiation. The motion is provided by two electrical motors in azimuth and elevation. The tracking signals are provided by a computer placed in the control room.

If there is a storm, a signal given by an anemometer will instruct the computer to place the collector array in a horizontal position. The pedestal of the tracker is fitted to the concrete basement block by a twelve-bolt base flange.

1. Summary of the specifications

(a) Number of modules: 256;

(b) Structure: heliostat type;

(c) Orientation: 2-axis tracking;

(d) Electric connection, 16 modules in series; 16 groups in parallel;

(e) Peak electrical power output: 8.95 kW;

(f) Nominal module voltage: 14.5 V;

(g) Nominal generator voltage: 232 V;

(h) Yearly electrical energy yield: approximately 21,000 kWh. Under the most favourable conditions:

(i) Solar radiation: $1,000 \text{ W m}^2$;

(ii) Ambient temperature: 28° C .

2. Maximum power point tracker and inverter system

The power line from the photovoltaic array is connected to a direct current/alternating current (DC-AC) regulator, or maximum power point tracker (MPPT), whose function is to continually match load resistance characteristics to the working point on the voltage-current characteristic of the array in order to produce the maximum amount of energy. This load resistance characteristic is a function of the battery load, which depends on the relationship between the amount of energy produced by the array and the amount of energy consumed by the inverter.

The inverter transforms DC into AC current at 240 V with a frequency of 50 Hz.

The complete power optimization and transformation system for the normal solar photovoltaic array is installed on two boards in the control room.

The MPPT and the inverter blocks are mounted into the first board on individual frames that can be removed for the purpose of maintenance and checking.

The electronic command circuits are mounted on printed cards that are plugged into a drawer in the first panel. The heavy inductance coils and transformers are mounted on the second panel.

3. Battery system

The function of the battery is to store electrical energy whenever available energy from the photovoltaic generator exceeds demand. If the available energy from the photovoltaic generator is lower than the load, the battery will supply the differential power.

Accordingly, the state of the charge of the battery commands the output voltage of the MPPT and the input voltage of the inverter.

The battery is located in a well-ventilated room of its own. The floor, walls and ceilings should be protected by a special coating. The accumulator elements are placed on three steel racks.

I. Solar pond collector and storage system

Salt gradient solar ponds that combine collection with seasonal storage are considered to be one of the cheapest solar energy systems available today. They have widespread potential applications in solar heating and cooling, as well as industrial process heating (e.g., desalination).

The solar pond is non-convecting. Salt is dissolved in the water; the salt concentration and, therefore, the density of the water increases with depth. The warm water heated by solar energy that penetrates into the pond stays at the bottom of the pond and acts as an accumulator. It may reach temperatures of up to 100° C. If special care is taken, the hot brine can be drawn off without disturbing the density and salt gradient in the pond layers.

In order to keep the heat losses as small as possible, there must be sufficient distance between the ground-water level and solar pond. By elevating the pond 2 m above the soil with the aid of dry sand, heat losses from the base can be reduced without having to retain the ground water. At the same time, a heat storage system should be built (sand below the pond).

1. Temperature and salt gradient

In order to establish the salt gradient of the non-convecting layer, it is necessary to ascertain the highest temperature gradient of the solar pond. When the temperature gradients and climatic conditions of Qatar are known, it is possible to define and create a stable salt gradient.

Several Schmitt-diagrammes were developed and drawn for the Solar Pilot Laboratory (the thickness of the non-convecting zone was thereby varied).

After static and dynamic stability have been considered, the solar pond of Qatar will receive a salt concentration difference between the two convection zones of approximately 150 kg m^{-3} .

2. Salt diffusion

The diffusion of salt tends to equalize the difference in salt concentration over the years. Although the rate of diffusion is fairly small, the total salt consumption of a large pond could reach about 20,000 tons a year for a one km^2 pond if no special measures are taken. Salt diffusion depends on the difference between the concentration at the top and bottom, on the thickness of the non-convecting zone and on temperature.

3. Falling pond

Although the velocity of salt flux is very low, the $1,500 \text{ m}^2$ solar pond in Qatar would lose 30 tons of salt a year from the convecting layer at the top. IDTC, however, has experimented with a design for the falling pond, which does not lose salt and, therefore, which does not need a salt production pond.

The basic idea of a falling pond is that by extracting the brine from the bottom of the non-convecting zone, the water in the pond develops a downward velocity. At the point when this downward velocity offsets the upward salt diffusion, the net salt flux becomes zero. As a result, no make-up salt is needed. Obviously, freshwater has to be separated from the hot brine that is extracted, and it must be returned to the top of the pond. The concentrated brine must be injected into the bottom of the pond.

A falling pond is shown in figure XXIX. Through the extraction of brine in the solar pond, a downward velocity that equals the upward salt flux velocity is created. The concentrated brine (recovery of salt) is returned to the pond.

4. Energy considerations

With the aid of a Schmitt-diagramme, heat losses as a function of time were calculated. If the non-convecting zone reaches a temperature of 85° C, surplus energy (useful energy) has to be drawn off, otherwise the temperature in the convecting zone rises above 85° C and it can disturb or devastate the salt gradient.

Figure XXX shows the useful power that can be drawn off when maintaining a temperature level of 85° C. Obviously, more energy can be drawn off when the temperature is below 85° C (thus releasing stored energy).

During the winter, the upper temperature level of 85° C may not represent the optimum operating temperature for the pond.

5. Filling system for the solar pond

Two systems were developed by Atlantis to fill the pond:

(a) Filling through adding layers. Through the use of valves a high salt concentrate from a salt pond can be mixed with water to produce the required concentration. By this means one layer after another will fill the pond. Each layer has to be placed on the surface and it rests on the previous layer (like fuel on water), because the concentration of the layers should be made thinner and thinner;

(b) Injection system. The amount of salt needed for the pond is diluted to reach the concentration that has been determined for the convection zone. Water is then injected into the pond. Because water is lighter than the salt concentration, it rises to the surface and on its way mixes with the high salt concentration above the injection valve to produce a lower concentration. When the layer reaches a uniform concentration, the process is halted, the injection valve is adjusted, and the process begins again on a higher level. In this way the desired salt gradient is created. The injection system was chosen for the Solar Pilot Laboratory pond.

J. Master control system and electrical wiring

The master control system (MCS) was designed to achieve the following: a very high degree of flexibility between the different operational modes within the pilot solar laboratory and its complex subsystems; the maximum easy accessible data on the status of each of the subsystems, including the actual mode of operation and the necessary input/output data of the two electrical power plants; a flexible system, in the sense that changes to MCS can always be carried out at a low cost. The concept and hardware chosen have both been designed from this point of view.

The MCS is easy to operate and requires little personal training to make the best use of it. However, the functioning of each of its elements must be understood in great depth. The MCS controls the following subsystems:

(a) An Acro heliostat photovoltaic power module, which incorporates the flow of electrical power through the maximum power tracker, to and from the electrical power storage (batteries) to the inverter and the connected loads;

(b) An Atlantis hybrid collector field incorporates the flow of both the thermal and electrical power, which are transported by means of a hydraulic circuit into the storage facility;

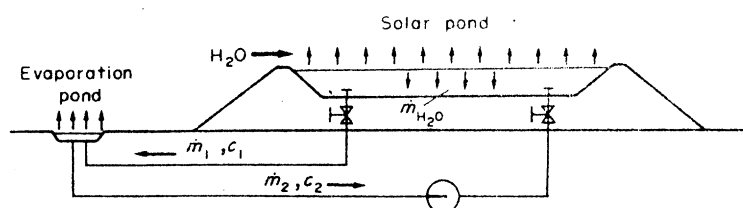
(c) The power is transmitted from the power substation to the control room, and from there to the other subsystems;

(d) A record of solar radiation on the collector field and the measurement of actual wind velocity of 6 m above the level of the control room;

(e) A functional mode (operating or not in use) for the desalination system;

(f) A storage subsystem to monitor the power and water level in the tank itself.

Figure XXIX. Falling pond



$$\dot{m}_{H_2O} = \dot{m}_1 - \dot{m}_2$$

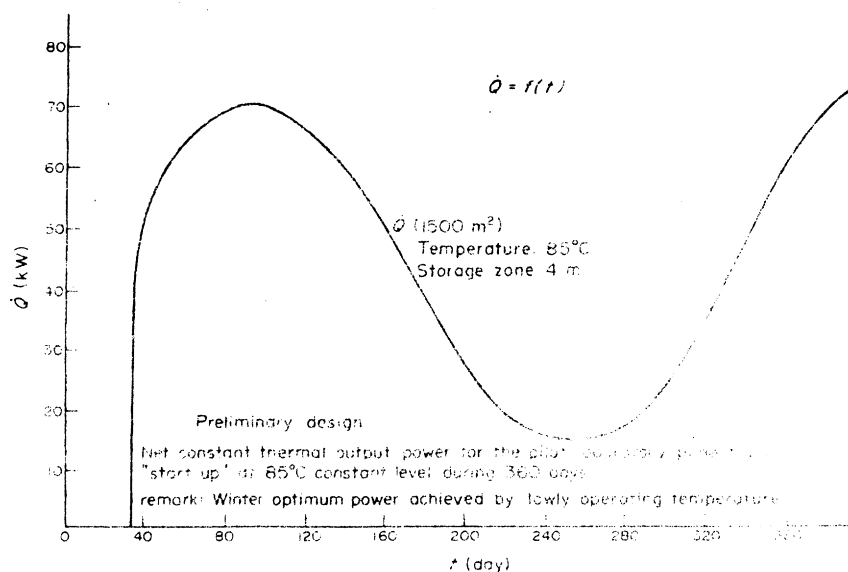
$$\dot{m}_2 = \dot{m}_1$$

$$c_2 = c_1$$

\dot{m}_1, \dot{m}_2 substance flux

c_1, c_2 salt concentration

Figure XXX. Useful power at 85° C



Within the description of the master control function, the term control means both display and command. Some elements/components/subsystems in the plant are controlled by displaying the status of its important characteristics; others are controlled in the sense that a parameter of the element can be changed by a simple push-button action.

The master control system is located in the control room at the end (west) of the control building. The master control system is combined with other important components of electrical hardware. It was designed in such a way that all the important lines are centralized in the control room. The reason for this will be explained later.

There is, however, another reason for centralizing all the power and control functions of the solar pilot laboratory into one main control room: it is the only air-conditioned room that has adequate working conditions for both the plant personnel and the electronic hardware. It has been assumed that the plant personnel will always be on site whenever all or parts of the IDTC solar pilot laboratory are operating. The goal was to structure all the control functions of the supervising plant personnel in such a way that they would not be subject to stress from having to carry out normal routine checks.

1. Priority level of controls

In order to achieve the highest degree of flexibility, most of the functions of the subsystems or components are monitored manually from the MCS. A number of control functions have been automated as they would require the constant attention of the staff, and because the chosen hardware logic that performs the commands will carry out the specified duty much more efficiently. Safety interlocks are required to protect the system, subsystems, components and elements in case of malfunction of other elements, or because of the incorrect manipulation either of the control panel or of the hardware.

2. Safety concept for the MCS power supply

Plans have been made to power the MCS with electricity from the Qatar public grid. If, for any reason, this power supply should fail, it would be possible to switch to one of the AC power bus bars of the photovoltaic power plants. Evidently, this means that the PV plant is working. It should be mentioned that any failure in the power grid does not change the status of the operational mode of the PV plant. This means that if the PV power plants are not working, they cannot supply power to the control panel. However, the PV plant can be started manually by a simple push-button action on the switchboard.

In summary, a failure in the public grid will be detected and an acoustic alarm will sound. The operator can start up one of the PV power plants manually. Within a few seconds, they will release AC power. The MCS can then be connected to this AC power, which means that the solar pilot laboratory can again be controlled from the main control panel.

K. Closing note

The data that is obtained from this first stage will help to shape the second stage of the project. However, solar cooling and refrigeration will be included.

It is hoped that this project will serve as a training school to create national experts, technologists and the skilled labour who can take over the task of implementing further R and D programmes, as well as commercial applications.

The pilot laboratory will provide local means for the evaluation of any solar collector system and measurement of its efficiency.

All concerned organizations, especially in the Gulf area, are invited to co-operate with the pilot project. The project could be extended to include the study of any new developed systems of solar collecting and their applications.

XIII. PROPOSALS FOR A SOLAR ENERGY PROGRAMME IN THE YEMEN ARAB REPUBLIC

M. K. Al-Motawakel*

A. Introduction

Solar energy promises to provide the solution to problems that characterize other energy technologies: the depletion of non-renewable resources, economic dependency on a few countries that have reserves of fossil fuels, environmental pollution, deterioration and the safety hazards associated with nuclear power.

Solar energy systems are not thought to be competitive with other non-renewable energy systems (e.g., fossil fuels). This is a valid assumption if energy production is considered exclusively in terms of dollar costs. If non-renewable energy systems are evaluated in terms of energy losses during energy production and other associated factors, a completely different picture emerges, a change-over to solar energy systems is desirable in view of the fact that sunlight is readily available and costs nothing.

For Yemen, solar energy is thought to be the most promising way of solving the country's energy shortage. This problem has been considered in a number of different ways.

In 1981, the Yemen Co-operative Association (YCA) and the American Solar Energy Corporation studied the possibility of transferring silicon solar cell technology to Yemen.

The aim was to provide rural areas with electricity generated by the photovoltaic process. This project never materialized because of the overestimation of costs and the commercial outlook (see table XIII-1).

In 1982, the United Nations Environment Programme (UNEP), acting upon a request from Yemen, commissioned an expert to study and make recommendations on the possible application of appropriate solar energy technology (1).

On an academic level, in response to a request from Sana'a University (the only research centre in solar energy in Yemen) for a specialist in solar energy to assess the progress made in this field by the Physics Department, and in order to help the development of an undergraduate syllabus in solar energy, Mr. J. C. McVeigh was sent on mission (2). Table XIII-2 summarizes the solar energy applications suggested by Mr. McVeigh. In three categories that were in addition to this, a number of research papers have been published or accepted for publication (3).

* Faculty of Science, Sana'a University, Yemen Arab Republic.

Table XIII.1. Proposed cost of electrifying a rural house in Yemen

(Proposed daily consumption = 4.65 kWh/day)

Distribution			
Function	Daily use (h)	Power (W)	Consumption (kWh/day)
Lighting	7.0	300	2.10
TV	7.0	200	1.40
Washing	0.5	200	0.10
Water pumping	1.0	300	0.30
Proposed cost			\$
System (32-12V photovoltaic array + storage batteries)			1 617.0
Transportation			1 522.0
Taxes (30 per cent of system cost)			5 885.0
Installation			1 087.0
Local storage + profit (20 per cent of system cost)			1 961.7
Total			30 072.7

On the applied level, the Ministry of Transportation and Telecommunications, the first user of solar energy in Yemen, has already introduced a number of photovoltaic-powered telecommunication stations. Sana'a University generates 1.6 kW (peak value) of electricity and uses it to power the solar research laboratory and occasionally the computer in the faculty of science.

B. Energy consumption

The main sources of energy in Yemen are imported oil, locally produced wood, agricultural residues and animal power. It has been estimated that petroleum products constitute about 32 per cent of the country's total imports. This demand is expected to rise annually by 10 per cent in the years 1980 to 1990 (1).

Table XIII.2. Solar applications suggested for Yemen by J. C. McVeigh

System	Applications with existing skills	Future applications
Thermal	Solar water heating ^{a/}	Higher temperature collectors
	Solar distillation	Absorption cooling
	Solar crop drying	Large active systems
	Solar cooking	Many small units for domestic applications
	Passive solar heating/ cooling	Distillation plants Industrial solar water heating Application of passive heating/ cooling of large buildings, offices and schools
Photovoltaic	Telecommunications ^{a/}	Widespread use of PV systems
	Irrigation pumping	
	Small-scale power for remote villages	
Solar ponds		First small 100 kW solar pond
		First 5 MW solar pond
Wind power	1-3 MW windmill tried in mountain location	

^{a/} Work already in the field.

An annual increase of more than 25 per cent in electricity consumption is expected in coming years. At present, the total installed capacity is about 90 MW, and this is expected to reach 320 MW in 1990 and 500 MW in the year 2000. The lack of adequate and reliable data on the consumption and costs of non-commercial sources of energy in Yemen makes it difficult to estimate the actual contribution of these sources to the energy balance.

It has been reported (6) that firewood consumption per head of population ranges from 1.5 to 2.0 cubic metres. In a recent study (7) the average annual per capita consumption of firewood was estimated to be 760 kilograms (kg) or about one cubic metre.

Yemen has a considerable potential in terms of crop residues. They are currently used to meet household needs. Animal power is mainly used in agriculture and transport in rural areas.

C. Potential of solar energy applications

The amount of solar energy available in the country is so large that its potential as a future energy resource deserves to be exploited. As can be seen from table XIV-3, the average daily solar radiation in Sana'a, the capital, is 22 megajoules (MJ)/m². This is equivalent to an annual energy supply of 8,167 MJ/m² (4).

The deficiency in all conventional sources of energy and the total dependence of Yemen on imported oil makes the development of any indigenous source of energy, particularly solar energy, not only important, but also essential. In view of these factors, the state of the art of different solar applications will be considered.

1. Solar water heaters

According to a recent survey, water heating accounts for 30 per cent of the daily consumption of electricity. Although it is difficult to estimate the exact cost of installing a solar water heater in Yemen, it would repay its costs within two years. The overall cost of solar water heaters in Yemen ranges from \$300/m² to \$350/m². This cost could be reduced by half if solar water heaters were manufactured locally.

2. Solar pumps

The recent expansion of agriculture in Yemen can only be met by the further extension of irrigation from wells. Therefore, the need for devices to lift water will increase, and solar pumps could have a wide use.

3. Generation of electricity

Electricity generated from solar cells is now used in Yemen. It is expected to be used to pump water, for refrigeration and for other low-power equipment (e.g., TV).

For the large-scale production of electricity, thermal generating plants appear to be more practical in view of their considerable impact on the energy balance in the country.

4. Other systems

Solar dryers, solar refrigeration and solar cooling have a promising market potential.

Table XIII.3. Experimental observations and deductions for Sana'a, Yemen

	Average daily global insolation (MJ m ⁻²)	Average daily sunshine hours	Average daily ambient temperature (° C)	Mean of daily peak insolation during month (W m ⁻²)	Maximum value of insolation during the month (W m ⁻²)	Average monthly global insolation (GJ m ⁻²) _{a/}
January	19.4	9.1	18	803	886	0.601
February	20.9	9.9	18	886	1 025	0.585
March	23.4	9.0	19	750	1 025	0.725
April	24.8	9.1	23	914	1 163	0.744
May	24.8	8.9	23	803	997	0.769
June	24.1	8.8	25	914	1 025	0.723
July	23.8	7.1	23	720	914	0.738
August	23.9	7.4	21	803	970	0.725
September	23.8	8.7	18	914	970	0.714
October	22.3	10.1	18	942	997	0.691
November	19.4	9.7	18	886	914	0.581
December	18.4	9.0	18	831	914	0.570

a/ Gegajoules (GJ).

Table XIII.4. Distribution of mean monthly wind speed at Sana'a International Airport (1977-1981)

Mean monthly wind speed

Month	1981	1980	1979	1978	1977
January	9.0	3.5	4.5	3.9	4.3
February	3.5	5.5	5.0	4.0	5.5
March	4.5	4.5	4.0	3.0	4.0
April	4.5	4.0	4.0	4.5	5.0
May	7.0	5.0	4.0	4.0	4.0
June	4.0	4.0	6.5	5.0	6.0
July	4.0	5.0	5.0	4.0	5.0
August	5.0	4.5	4.0	5.0	5.0
September	7.0	12.0	5.0	4.0	5.0
October	3.0	3.0	4.0	3.5	0.5
November	3.5	7.5	4.5	3.0	2.0
December	6.0	7.0	5.2	8.0	2.0

Source: Compiled from data collected at Sana'a International Airport by the Meteorology Department.

D. Proposals for a solar energy training programme

Manpower training and the provision of current research activities at Sana'a University in the field of solar energy, together with the necessary testing and recording equipment, are considered to be the first steps in the utilization of solar energy in Yemen.

This suggests that training should go in two directions:

1. Local academic training

(a) The course on solar energy that has been introduced in the physics department needs additional support and the provision of laboratory equipment and small-scale demonstration experiments;

(b) Current research activities at Sana'a University lack financial and technical support. Help is needed from international and national bodies and individual countries to promote these activities. The University needs the following:

- (i) A reliable solar workshop;
- (ii) Testing, simulating and data collecting (recording) equipment;
- (iii) Periodicals with up-to-date information in the field of solar energy.

2. Training facilities

- (a) Long-term postgraduate studies;
- (b) Short-term training courses;
- (c) Training for technicians;
- (d) The participation of local researchers in international and regional conferences, seminars and workshops;
- (e) Joint research projects sponsored by international organizations and national universities.

Annex

A SOLAR PROGRAMME FOR THE YEMEN ARAB REPUBLIC

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Immediate existing operating skills in the following fields:

Solar water heating (small)
Solar distillation
Solar cooking
Solar crop drying
Passive solar heating and
Telecommunications
Irrigation pumping
Small-scale power for remote villages, e.g. TV, lighting, refrigeration

Biogas digester - gas for cooking
Trees/plants for energy crops
Radiation measurements - a reference year
energy use and needs
wind survey data

Over five to ten years with training programmes:

Higher temperature collectors for industrial processes, e.g. food processing (210° C), focusing systems
Absorption cooling
Large active systems
Many small units for domestic applications
More systems, large arrays, more applications

Windmills - first units for pumping
Initially a larger unit for electricity - 200 kW
Initially few energy crops show results - more planting
Large biogas units
Initially a small solar pond - 100 kW

Data analysis leading to energy projections - reference year modified

Long-term prospects:

Additional fresh water distillation plants at the village level
Establishment of industrial solar water heating
Construction of larger buildings with passive heating/cooling and active hot water e.g. offices, government buildings, schools
Additional small heating units for domestic water
Widespread use of PV systems

1-3 MW windmill to be tried in best mountain location

Wide acceptance of biogas units
Major replanting associated with tree cropping for both charcoal and direct power/electricity

Construction of 5 MW solar pond

Source: Compiled from data prepared at Sana'a University by Mr. Cleland McVeigh, on behalf of the British Council, May 1982.

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Part Three

PAPERS PRESENTED BY REGIONAL AND INTERNATIONAL ORGANIZATIONS

XIV. THE ROLE OF OAPEC IN NEW AND RENEWABLE SOURCES ON ENERGY IN ARAB COUNTRIES*

A. Introduction

The Arab homeland covers more than 13.7 million square kilometres, about 75 per cent of which lies in Africa and the remainder in Asia. The population of the Arab world is over 180 million, of which 70 per cent lives in Africa.

Total commercial energy consumption in the Arab world in 1984 amounted to 1.04 billion barrels of oil equivalent, of which 86.5 per cent came from oil, 12.5 per cent from gas and 1 per cent from coal and water resources. Average per capita commercial energy consumption is about 5.8 barrels of oil equivalent which, according to 1984 statistics, is less than half of world per capita consumption. Moreover, 80 per cent of the Arab population lives below this average.

The Arab world's consumption of commercial energy varies from one country to another, depending upon the welfare situation and per capita income. In some countries such as Qatar and Kuwait, per capita consumption is more than 80 times that of Sudan or Mauritania, as is indicated in table XIV-1.

The average annual income of an individual is about \$US 2,200, as is indicated in table XIV-2, but 76 per cent of the Arab population lives below this average. Furthermore, there are marked differences in average income between one country and another: annual per capita income in the United Arab Emirates and Qatar reached over \$US 20,000 according to 1984 statistics, while that in Yemen, Somalia and Sudan was less than \$US 600. Assuming that there is a correlation between an individual's standard of living and his level of energy consumption, it can be concluded that many of the inhabitants of the Arab world, particularly those in Sudan, Mauritania, Yemen, Morocco, Egypt and Tunisia, still use non-commercial energy produced from wood, dung and other residues.

Table XIV-3 shows an estimate of total energy available from the different energy sources in the world, and compares them with sources in the Arab world. It appears that new and renewable sources such as solar, biomass, wind and thermal energy are plentiful. However, their use on a large scale is not yet economical. Continued research and development is required, and the same applies to wave, tidal and hydropower energy.

B. OAPEC activities

OAPEC activities in energy were initiated with the First Arab Energy Conference, held in Abu Dhabi on March 1979, with ministerial participation. The objectives were to establish an institutional framework for energy issues with the purpose of co-ordinating and harmonizing the development and planning

* Paper presented by the Organization of Arab Petroleum Exporting Countries.

of the Arab energy policies. Participants from 22 Arab countries and representatives of international and foreign institutions attended the Conference. Most of the papers dealt directly with energy supply and demand in the Arab world, and with future energy policies. They also discussed the effects of international development on the Arab energy situation.

Table XIV.1. Comparison between annual commercial energy consumption per capita and annual biomass energy per capita

	Commercial energy consumption per capita (BTUs x 10 ⁶)	Biomass energy available (BTUs x 10 ⁶)			Total Biomass energy available (BTUs x 10 ⁶)
		Forests	Agricultural production	Dung	
Qatar	748.0	..	..	..	..
Kuwait	213.2	0.03	-	0.80	0.83
Bahrain	259.0	..	..	..	..
United Arab Emirates	219.0	0.07	-	2.68	3.38
Saudi Arabia	146.0	2.46	0.30	1.46	4.22
Libyan Arab Jamahiriya	96.0	3.00	1.00	3.78	7.78
Oman	52.2	-	0.06	3.00	3.60
Iraq	55.0	1.90	1.38	4.66	7.94
Lebanon	35.0	0.38	0.27	0.86	1.57
Syrian Arab Republic	27.0	2.58	3.27	2.43	8.28
Jordan	28.0	0.64	0.01	0.92	1.57
Algeria	31.0	5.30	1.29	2.07	8.66
Tunis	22.6	1.32	1.64	3.58	6.54
Egypt	19.1	-	2.76	1.29	4.05
Morocco	8.8	8.33	2.46	4.58	15.37
Democratic Yemen	13.5	20.50	0.60	2.22	23.32
Djibouti	9.0	..	..	..	13.64
Mauritania	3.9	164.00	0.27	22.90	187.00
Yemen Arab Republic	6.0	1.29	3.27	5.96	10.50
Somalia	2.8	55.40	0.60	32.70	88.70
Sudan	3.0	208.00	3.34	3.43	8.28

Sources: Economic Commission for Western Asia, ECWA Report on Biomass Energy in the Arab World, ECWA/NR/WG.1/3 (Beirut, 1980); Organization of Arab Petroleum Exporting Countries, Eleventh Annual Statistical Report (Kuwait, 1984).

Table XIV.2. Population and GNP/capita for Arab countries (1983)

Country	GNP/capita	Population
Algeria	2 400	20 569
Egypt	700	45 364
Iraq	..	14 600
Jordan	1 710	3 244
Kuwait	18 180	1 664
Lebanon	-	2 624
Libyan Arab Jamahiriya	7 500	3 334
Mauritania	440	1 637
Morocco	350	20 801
Oman	6 240	1 133
Saudi Arabia	12 180	10 437
Somalia	250	4 611
Sudan	400	20 807
Syrian Arab Republic	1 680	9 810
Tunisia	1 290	6 846
United Arab Emirates	21 340	1 208
Yemen Arab Republic	510	7 696
Democratic Yemen	510	2 009
Qatar	21 170	282
Bahrain	10 360	422
Djibouti	460	352

In the First Arab Energy Conference, OAPEC presented a survey of solar energy research, development and applications in the Arab world. The information contained in that survey formed part of a comprehensive study that was conducted under the direction of OAPEC to cover all kinds of solar energy activities in Arab countries. Prior to the study a special team of two solar energy experts visited all the Arab countries and made a detailed report of the exact status of solar energy activities in each country.

Table XIV.3. Estimated energy available in the world
and in the Arab world
(BTUs)

Source	World	Arab world	Percentage
Fossil	22.4×10^{18}	3.28×10^{18}	14.60
Solar	$3.8 \times 10^{23}/\text{year}$	10.2×10^{19}	0.27
Wind	$7.6 \times 10^{20}/\text{year}$	5.5×10^{19}	7.20
Waves	$17.1 \times 10^{16}/\text{year}$	-	-
Biomass	$3.8 \times 10^{16}/\text{year}$	5.8×10^{15}	1.20
Geothermal	7.6×10^{18}	7.5×10^{16}	0.98
Tidal	$4.7 \times 10^{16}/\text{year}$	-	-
Hydro	$2.8 \times 10^{16}/\text{year}$	-	-
Nuclear	2.8×10^{21}	-	-

In an effort to maintain the momentum for examining energy-related activities in the Arab world and to keep up with new developments in energy technology, the First Conference decided that the Arab Energy Conference would be held once every three years. Therefore, OAPEC, in co-operation with three other Arab organizations, ^{1/} convened the Second Arab Energy Conference, which was held in March 1982 in Doha, Qatar. The theme was "Energy for development and Arab integration". More than 400 people were invited, including official delegations from all Arab countries. A total of 64 research papers, together with other articles were presented. The status of alternative energy in the Arab world was reviewed and information was updated. It was found that in many Arab countries some solar and wind energy applications and research were being duplicated. Most of the applications and studies of solar energy were found to be in solar heating, solar cooling and solar desalination. Countries were interested also in solar energy for drying crops, pumping, greenhouses, photovoltaics and solar insolation. Solar energy was also being used in telecommunications along highways and in remote areas. Wind, geothermal and biomass energy receive less attention in both research and application.

^{1/} The Arab Fund for Economic and Social Development, the League of Arab States and the Arab Industrial Development Organization.

OAPEC has taken note of the great interest of all Arab countries in alternative energy research and development, as well as the interest in other energy resources. OAPEC has also noted the lack of co-operation between Arab countries in the planning of their national energy programmes. Therefore, in accordance with the Second Arab Energy Conference recommendation to establish an Arab scientific centre to develop energy resources, collect the necessary data and study energy-related projects, OAPEC formed the Arab Centre for Energy Studies. The main functions of the Centre are to monitor all kinds of activities in alternative energy in Arab countries and also world-wide, to monitor the latest technology and know-how in the developed countries, and to transfer appropriate applications to the Arab world. The Centre should also redress the lack of information exchange on energy-related subjects among Arab countries. It might also act as a regional energy consulting and servicing Centre.

The centre contains two departments: the Economics Department and the Energy Resources Department.

The Third Arab Energy Conference was held in May 1985 in Algeria. It was organized by five Arab organizations, of which four had organized the Second Arab Energy Conference. Over 500 people attended the Conference and about 65 papers on different energy topics were presented, in addition to a number of national papers. Many recommendations were made at the end of the Conference, including one calling for the diversification of research into alternative energy. OAPEC will follow up the recommendations and pursue contacts with the other organizers in an effort to implement them.

The information on alternative energy collected by the Energy Resources Department of the Arab Centre for Energy Studies is summarized in the following pages.

C. New and renewable sources of energy

As stated before, Arab countries enjoy plentiful resources of alternative energy. This paper will consider only four of them: solar, wind, biomass and geothermal.

1. Solar energy

The solar energy activities of Arab countries are summarized in column two of table XIV-4 which shows the present and future areas of interest in solar energy in Arab countries. These areas vary widely so as to cover most solar energy activities with a potential that is recognized by the developed countries, as can be seen in table XIV-5. The progress of research in these areas depends to a large extent on the availability of finance and expertise. Leading Arab countries in solar energy research and development are Saudi Arabia, Kuwait, Algeria, Jordan, Egypt, Tunisia, Iraq and Sudan. Their main interests are summarized in table XIV-5.

The budgets allocated to solar energy projects vary considerably from country to country. Saudi Arabia has invested a lot of money (over 100 million dollars) on solar energy projects, while Democratic Yemen and the Yemen Arab Republic have no significant budget allocations for these projects. Budgets for other Arab countries which might engage in solar energy activities were difficult to trace.

Table XIV.4. Fund and research activities in the Arab world

	Areas of interest	Starting date	Outside funding (US dollars)	No. of local organizations	No. of Arab organizations	No. of foreign organizations	No. of research projects	Solar industry
1. Algeria	15	1955	..	12	-	5	11	Water solar heater
2. Bahrain	8	1977	..	1	1	-	5	-
3. Egypt	12	1975	17m	12	-	12	11	Water solar heater
4. Iraq	10	1963, 1972	..	4	1	-	-	Water solar heater
5. Jordan	10	1971	..	5	2	3	10	Water solar heater
6. Kuwait	14	1975	..	2	2	5	12	-
7. Lebanon	4	1973	..	4	-	-	3	Water solar heater
8. Libyan Arab Jamahiriya	8	1977	..	4	-	2	2	-
9. Mauritania	1	1973	..	3	-	1	1	-
10. Morocco	2	1976	..	5	-	1	2	-
11. Yemen	2	-	..	1	1	1	-	-
12. Oman	3	1979	..	1	-	4	2	-
13. Qatar	5	1977	27.5m	2	-	3	2	-
14. Saudi Arabia	20	1970s	500m	11	-	26	12	..
15. Sudan	9	1970s	2.8m	4	-	7	6	-
16. Syrian Arab Republic	3	1970s	..	4	-	1	2	Water solar heater
17. Tunisia	11	1963	..	11	-	11	7	Water solar heater

Table XIV.5. Areas of interest and existing solar applications

	Air-conditioning	Drying	Desalination	Distillation	Collectors	Furnaces	Greenhouses	Hydrogen production	Insolation	Ponds	Photovoltaic	Power generation	Precipitation of metals	Pumping	Refrigeration	Reverse osmosis	Space cooling	Space heating	Storage	Telecommunications	Water
1. Algeria		R	I	R	R	R	I		R	R	R	R,W,W	I	I,S,W			R	R	R		R
2. Bahrain	I				I		R		R		R	R,S		I,S			R				I
3. Egypt		R	R		R				R	R	R	R,S,W,H		I,R,S,W,H	R	I	R		R		R
4. Iraq		R	R	R	R		R		R			I,S,W,H		I,S,W,H			I	I			R
5. Jordan		R	R	R	R		R		R		R	R,S,W,H		I,S,W			I	R		R	R
6. Kuwait	R	R	R		R		R		R		R	R,S,W		I,S,W			R	R	R	I	R
7. Lebanon									R	I	I	I,S,W,H		I,S,W,H				R			R
8. Libyan Arab Jamahiriya		R	R		I				R			I,S,W		I,S,W	I			I	I		R
9. Mauritania									R			I,S,W		I,S,W							
10. Morocco									R		R	I,S,W		I,S,W							
11. Yemen										I	I	I,S,W		I,S,W							
12. Oman									R			I,S,W		I,S,W				I			I
13. Qatar			I						R		R	I,S		I,S	I	I				I	
14. Saudi Arabia	R	I	I,R	I	R		I,R	R	R	I	R	R,I,S,W	I	R,I,S,W			R	R	R	I	I
15. Sudan		R	I						R	I	I	I,S,W,H		R,S,W,H	I		R	R			R
16. Syrian Arab Republic											R	I,S,W,H		I,S,W							R
17. Tunisia	I		R		R		I		R		R	I,R,S,W		R,S,W	I				R		R
18. United Arab Emirates	I	I					R			I	I	I,S		R,S	R		I				

Key: H = hydropower; R = research; W = wind; I = area of interest; S = solar.

2. Wind energy

Researchers into the utilization of wind energy find that man has been using this source of energy for more than 2,000 years. It was used to power sailing ships and windmills, to pump water and to carry out other tasks. The most significant impact of wind energy was perhaps in spreading the human race to the far reaches of the earth. It can be claimed, therefore, that wind has been and still is a very useful renewable energy source.

The sun is one source of wind energy: an estimated 2 per cent of solar energy that reaches the earth is transformed into wind energy.

European countries and the United States of America have succeeded in harnessing wind energy, and the ancient Arabs also obtained encouraging results.

Researchers in industrial countries are trying to improve the machinery and equipment required for utilizing wind energy. In the Arab world, two major experiments are now under way. They will be considered in some detail later.

3. Geothermal energy

Data obtained from drilling and mining operations show that underground temperatures rise gradually as drilling gets deeper. This increase varies between 9° C and 45° C or more per kilometre. This difference in temperature is called the geothermal gradient. This gradient causes thermal energy to move towards the surface by means of three main processes: (a) thermal conduction through solid rock; (b) the movement of molten magma, and (c) the movement of hot water towards the surface.

This movement naturally applies to all thermal energy phenomena in different parts of the world. In the Arab world, this can be divided into three types according to the source or thermal energy or the heat content (enthalpy) produced from the thermal energy that is required for useful work such as power generation.

(a) Low enthalpy source

Low enthalpy ascending water has a temperature of less than 80° C, as is the case with some mineral and non-mineral hot springs and also with water produced from shallow wells. Even at such a low temperature, energy from these sources may be used to generate electricity by heating gases with low boiling points such as freon. If a station of this type is to be built, it should be sited near the source of the hot water, as hauling water from remote places is costly, and ultimately results in heat loss.

The areas where such thermal sources might exist are the northern coasts of the Libyan Arab Jamahiriya and Egypt, the southern part of Morocco, the Gulf area and the eastern part of Yemen.

(b) Medium enthalpy source

In this case, the temperature of the ascending water or vapour varies between 80° and 150° C. This is enough to generate electricity and can be used in remote areas. This source can supply energy to power generating stations with output capacities of between 20 and 1,000 kilowatts per unit. Sources of this type could exist in northern Morocco, Algeria, Tunisia, the occupied territories, Jordan, Northern Iraq and south-eastern Saudi Arabia.

(c) High enthalpy source

In this case, the temperature exceeds 150° C, when water appears in the form of vapour and can be used directly to generate power. Units with output capacities ranging between 5 and 30 megawatts or more may be installed at each location. This type of energy is present in Djibouti, Yemen and Algeria, and may also exist in Morocco and Saudi Arabia.

(d) The economic advantage of geothermal energy

The cost estimate of building a transformation unit to produce electricity from geothermal energy varies between \$150 to \$500 per kW of installed capacity.

Countries like Mexico, the United States of America and Japan have proved that geothermal energy is an additional source of energy, and have used it for drying and cooling processes, in addition to generating electricity. The geothermal energy utilized in these countries competes with other sources.

In Arab countries, no project has yet been executed for the commercial utilization of geothermal energy, but plans have been drawn up in Djibouti and Algeria. Since the geothermal energy that appears on the surface in the form of water or water vapour in most Arab countries is often of only low or medium enthalpy, electrical power would be costly to produce.

4. Biomass energy

Most biomass sources are carbohydrate in origin, and have varying degrees of moisture content. Biomass is often impure as it contains many ingredients that differ in their physical, chemical and biological properties.

Biomass sources include fuelwood, charcoal, dung, crop and other plant residues, industrial wastes, as well as the wastes of society. The use of all sources, while technically possible, is rarely of commercial advantage.

Certain Arab countries depend heavily on biomass energy, known also as non-commercial energy. For example, Yemen, Somalia and Sudan consume more than three times as much biomass energy as commercial energy. Mauritania's consumption of biomass energy is two and half times its commercial energy consumption. In Democratic Yemen, Egypt and Morocco, the use of biomass energy respectively forms 70 per cent, 35 per cent, and 21 per cent of the total energy consumption, which means that a significant proportion of the Arab world's population depends on biomass energy. If any shortages in providing this source were to be encountered, the population would suffer

seriously. Therefore, a study of the annual supply of the principal sources of biomass energy in the above-mentioned countries is needed in order to assess their total energy demand. Furthermore, before establishing any industry that depends on these sources, it is essential to take into account the extent of the changes that could arise in the continuity of supply of this vital energy source.

In table 1, it can be seen that the amount of biomass energy available per capita in Democratic Yemen, Yemen Arab Republic, Sudan, Somalia, Morocco and Mauritania exceeds the consumption of commercial energy. However, the problem is how to obtain and utilize this energy efficiently.

(a) The economic advantage of biomass energy

It is not easy for the researcher to provide a general study on the economic advantage of utilizing biomass energy in Arab countries as the types of sources, availability and ease of procurement differ widely. However, some data are available on the conversion of certain types of biomass energy into ethanol, methanol, natural gas, ammonia and other products.

The cost of an energy unit produced from biomass can vary from one country to another. For instance, the average cost of one million British thermal units (BTUs) of energy in the form of ethanol in the United States of America exceeds that produced in Brazil from the same biomass source by 30 per cent. This is because it is easier to obtain abundant sources of biomass from nearby localities.

D. Major activities in solar, wind, geothermal and biomass energy in Arab Countries

This study will review the major activities in solar, wind, geothermal and biomass energy in Arab countries.

1. Solar energy activities

The major solar energy activities in Arab countries can be summarized as follows:

(a) Algeria

- (i) A solar village to accommodate 2,000 persons:
- (ii) A solar furnace to be enlarged by installing tubular boilers:
- (iii) Massive cooling and heating for a solar housing project;
- (iv) A 10 kW solar thermal conversion unit.

(b) Bahrain

A solar powered petrol station.

(c) Egypt

- (i) Solar cells;
- (ii) Experimental work on Nile Delta villages to supply solar power for televisions, pumps, ovens and water heating;
- (iii) Several power generation projects;
- (iv) A solar cooling project;
- (v) A desalination unit;
- (vi) Solar drying projects;
- (vii) A reverse osmosis project;
- (viii) Feasibility studies on the local manufacture of solar equipment;
- (ix) Feasibility study for a power generation project in the Qatarah depression;
- (x) Storage of solar energy using alloys with low melting points, organic compounds and salts;
- (xi) Installation of water heaters in a new town in Sinai.

(d) Iraq

- (i) Water desalination for remote areas;
- (ii) Crop drying and greenhouses with the co-operation of the Royal Scientific Society (RSS);
- (iii) A solar house and solar cooling system for the solar energy centre.

(e) Jordan

- (i) A desalination plant at Aqaba;
- (ii) A solar still (portable);
- (iii) Solar collector testing and licensing;
- (iv) An experimental solar house with active and passive features;
- (v) Manufacturing of solar water heaters;
- (vi) A pumping station powered by photovoltaic cells;
- (vii) Power generation stations.

(f) Kuwait

- (i) A solar mobile home, solar house and kindergarten project (40 ton solar refrigeration);
- (ii) Installation of a 100 kW solar thermal conversion unit;
- (iii) Experimental unit to integrate water desalination and power generation, and the redesign of greenhouses.

(g) Libyan Arab Jamahiriya

Solar water houses, solar drying system, greenhouses and cathodic protection for oil pipelines.

(h) Oman

Telecommunications systems powered by photovoltaic cells.

(i) Qatar

- (i) A photovoltaic station to power cathodic protection units;
- (ii) A desalination plant.

(j) Saudi Arabia

- (i) Several desalination plants, solar powered desalination equipment, solar water pumps;
- (ii) Solar housing studies (traditional houses);
- (iii) Solar power heating complex for a school at Tabuk;
- (iv) SOLERAS Programme:
 - a. Solar-assisted air cooling system;
 - b. 350 kW solar power station using photovoltaic cells (solar village);
 - c. Solar desalination plant;
 - d. Solar-powered control units for agricultural use.
- (v) Telecommunications project to link Jeddah with Port Sudan.

(k) Sudan

- (i) Solar pumps for irrigation and solar refrigeration units;
- (ii) Solar heating systems especially designed for building in northern Sudan;

- (iii) A plan to build a solar village at Umm Safari which involves solar desalination, power generation and water pumping.

(l) Syrian Arab Republic

Solar water heaters and solar space heating.

(m) Tunisia

- (i) Plan for a demonstration solar village;
- (ii) Fabrication of flat-plate collectors and solar cookers;
- (iii) Solar water heating for a school and mosque;
- (iv) Building some stills for water desalination.

(n) United Arab Emirates

- (i) A solar water pump at Al-Ain;
- (ii) A solar desalination plant;
- (iii) Solar-assisted air-conditioning for the Al-Omeira apartment block;
- (iv) Greenhouses at Saadiyat Island.

2. Wind energy activities

Most Arab countries are involved in wind energy activities, particularly in the area of collecting wind speed data. Research institutes and universities have set up short- and long-term programmes to harness wind power. The leading Arab countries in the field of testing wind power for pumping water and generating electricity are Jordan and Tunisia. These countries have each designed and constructed two prototype windmills for aerofoil demonstration and testing purposes. Jordan has also installed a 12 kW unit to pump water from a well 60 m deep and then transferred it to another location after modification.

Other Arab countries such as Saudi Arabia, Kuwait, Iraq, Sudan and Egypt have devised a number of wind energy programmes, but most are in the study phase.

3. Geothermal activities

At present Arab countries are engaged in few activities related to geothermal energy as significant resources have only been discovered in Djibouti, Algeria, and Yemen. Djibouti is the most active Arab country in geothermal exploration, and there is evidence that it has significant geothermal energy potential.

Four areas have been identified in Djibouti as having the most promising potential for geothermal activities: the Asal rift, Hante, Gaggade and Lake Abhe. In the Hante area in the south-west of the country, three shallow temperature gradient holes have been drilled as part of an organized programme to investigate the country's geothermal resources. The information that is collected is being used as a guide, prior to embarking on a deep drilling exploration programme.

At present the Government is calling for tenders to drill four new holes to a depth of 2,000 metres. The objective is to obtain vapour with sufficient energy to generate electricity. The country has an ambitious plan to generate electricity, and the authorities believe that the whole country can be electrified using geothermal energy as the main source. The authorities also believe that entire electricity demand can be met by one or two small geothermal plants with a capacity of about 30 megawatts of electricity (MW_e) each.

4. Biomass energy

In spite of the great difficulty in finding reliable estimates of the biomass energy in Arab countries, some figures have been collected and listed in table XV-1. From these figures it can be seen that biomass energy could meet all the energy requirements of Mauritania, Somalia, Morocco, Sudan, Djibouti and Yemen, and a good percentage of the needs of Tunisia, Egypt, Algeria and the Syrian Arab Republic, as well as some of the needs of other Arab countries.

Morocco, Sudan and Egypt are the most active Arab countries in the field of biomass energy. In Morocco, several activities have been undertaken, including the following:

(a) The design and testing of an Indian digester with the following specifications: volume 6 m³, biogas production 0.6 to 1.8 m³/day, feed-stock dung, cost about \$US 1,000;

(b) The design and testing of another type of digester that utilizes other feedstocks, for comparison purposes;

(c) The testing of many small capacity Chinese digesters.

In addition, an extensive programme has been planned to increase the volume of digesters in current use and to utilize all other kinds of biomass material that is available in large amounts in the country.

Sudan and Egypt depend on biomass as a major source of energy, especially in rural areas. Preliminary statistics show that in Sudan per capita consumption of biomass energy is more than three times the consumption of commercial energy; Egypt's dependence on biomass energy is also high at 35 per cent. Forests constitute the highest percentage of biomass energy in Sudan. Although Sudan depends mainly on biomass energy, the care it takes of its sources appears to be poor, and grows worse yearly.

At present there are more than 20 different proposals to increase the efficiency of current biomass utilization. More than seven Sudanese organizations are working together on biomass projects. These organizations feel very strongly that national authorities must give their utmost attention to the question of the depletion of biomass sources in view of their extensive use (81 per cent of total energy) in the country.

In Egypt, where more than a third of the population uses non-commercial energy obtained from agricultural residues and animal wastes, many studies are being undertaken in different institutes, universities and scientific organizations with the object of augmenting production. But as yet no studies that deal with how to improve the ways of utilizing biomass energy have been published, and this source is still being used in a primitive way.

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XV. ENERGY ACTIVITIES OF THE UNITED NATIONS ECONOMIC AND SOCIAL COMMISSION FOR ASIA AND THE PACIFIC (ESCAP)

(E/ESCWA/NR/86/WG.1/4)

ESCAP Secretariat

A Objectives of the ESCAP programme on energy

The primary objective of ESCAP with regard to energy resources is to provide assistance to its developing member and associate member countries in developing and managing their energy resources on a systematic and comprehensive basis. ESCAP also aims at playing a catalytic role in promoting and co-ordinating new initiatives in the energy field in the region.

In view of the current energy situation, the principal components of the ESCAP programme and activities in this field are in the areas of energy assessment and planning, accelerated development and the use of new and renewable sources of energy, and the integrated investigation, development, conservation and efficient use of overall energy with emphasis on conventional sources of energy.

B. ESCAP activities on energy

Pursuant to these objectives, the ESCAP secretariat has undertaken a series of activities under the different subprogrammes mentioned above. The scope of activities covers research studies, technical publications, technical assistance through advisory services and organizing meetings/workshops/seminars/training courses in areas of current interest.

The multi-disciplinary energy activities of the secretariat are implemented by the Energy Resources Section of the Natural Resources Division. In addition, this section also backstops technically, as necessary, and implements some of the activities of regional programmes: the Regional Energy Development Programme (REDP), the Pacific Energy Development Programme (PEDP) and the regional network on Biomass, Solar and Wind Energy (BSW).

1. The Regional Energy Development Programme (REDP)

This is an intercountry project for Asian countries funded by the United Nations Development Programme (UNDP) for the 1982 to 1986 cycle. ESCAP is the executing agency of the project. Most of the project activities are being carried out by the ESCAP secretariat itself, while some are entrusted to other specialized agencies which include the United Nations Industrial Development Organization (UNIDO), the International Labour Organization (ILO), the Food and Agriculture Organization of the United Nations (FAO), the United Nations Educational, Scientific and Cultural Organisation (UNESCO) and the Asian Development Bank (ADB). Resources and expertise are also drawn from the United Nations Department of Technical Co-operation for Development (UNDTCD) and institutions like the Asian Institute of Technology (AIT) and the East-West Centre (EWC). ESCAP provides technical backstopping for these activities.

Under REDP phase 1 (1982 to 1983), the activities carried out included a rural energy planning seminar, the assessment of energy manpower requirements and training, an Association of South-East Asian Nations (ASEAN) coal development study, assistance given to the Regional Mineral Resources Development Centre (RMRDC) in coal advisory services, support to the regional network on small hydropower, two training workshops on mini-hydro, two training courses in biogas technology in China, support for a regional network for fuelwood, a workshop on charcoal production and technology, the ASEAN coal development project and a meeting on wood energy development.

The sub-programmes included in phase II (1984 to 1986) are as follows:

(a) Energy planning, policy analysis and management, including an energy pricing strategy, energy conservation in small/medium-scale industries and energy planning and modelling;

(b) Large-scale energy systems, including studies on natural gas, coal utilization and development and on transcountry power exchange development;

(c) Rural energy systems and new and renewable sources of energy, including rural energy planning studies, support for a regional network for small hydropower and the utilization of surplus agricultural residues as an energy source for productive activities.

2. The Pacific Energy Development Programme (PEDP)

PEDP is a regional programme to assist the Pacific countries in securing the energy needed for their development, and in facilitating a significant reduction in their reliance on imported petroleum. This programme was also funded by UNDP between 1982 and 1986 under the managerial responsibility of ESCAP. So far several assistance missions, surveys, reviews and training courses have either been completed or initiated in various countries of the Pacific region. A workshop on petroleum supply and pricing was also organized. In March 1984, a Pacific Energy Programme Review Meeting reviewed and amended the PEDP work plan and programme. The following six broad areas were decided upon as priorities: a review of training needs, energy planning, electricity sector planning and legislation, petroleum supply and pricing, energy auditing and management, and wood and charcoal stoves.

3. New and renewable sources of energy (NRSE) activities and the regional network on biomass, solar and wind energy (BSW)

(a) New and renewable sources of energy activities

In the implementation of the Nairobi Programme of Action (NPA), ESCAP initiatives in the field of NRSE are mainly directed toward bringing about greater intercountry co-operation. An assessment of NRSE and integrated energy planning, co-operative research, development and demonstration, transfer, adaptation and application of mature NRSE technologies, are some of the main areas where the activities of ESCAP are concentrated during the medium-term plan 1984 to 1989. While the tasks involved are enormous, the resources available to the secretariat are limited. However, based on an

expert group meeting on NRSE held at Colombo in 1982, and with generous assistance from the Governments of Japan and Australia, a regional network on Biomass, Solar and Wind Energy was established in ESCAP in 1983.

In the implementation of regional programmes, the active participation of countries is crucial. In this regard, the ESCAP secretariat has developed fruitful communication channels among countries through their designated national focal points. In June 1984, the first meeting of the representatives of national focal points for NRSE was held at Bangkok. This meeting formulated and recommended a regional programme of action.

In order to tackle the issue of finance, a High-level Regional Consultative Meeting for the Mobilization of Financial Resources for NRSE was held at Bangkok from 4 to 10 September 1984. An opportunity was provided for country representatives to present the main thrust of their respective national NRSE programmes in the form of project proposals for which they required support from funding agencies or donor countries.

The High-level Regional Consultative Meeting endorsed a regional NRSE development programme and discussed the various multifaceted activities regarding the development and utilization of NRSE within the region. It selected 13 project groups after a careful scrutiny of 41 regional project proposals of the "NRSE package" submitted by the ESCAP secretariat, ILO, UNIDO, FAO and the Asia Pacific Regional Network on Small Hydropower (RNSHP) for priority action. The meeting endorsed the secretariat's approach in developing and implementing the regional NRSE programme.

The meeting also identified a number of other strategies required to accelerate the development and utilization of NRSE.

The 13 priority projects have been consolidated and submitted to concerned agencies for comment, and to potential donor countries and funding agencies for consideration. Missions to Europe and Asia were carried out in 1985 to promote these projects and to solicit funding.

The combined proceedings of the High-level Meeting and the Focal Point Meeting were published in December 1985.

A training course on renewable energy planning: methodological aspects of assessment of NRSE and integrated planning, was held at Bangkok from 5 to 30 August 1985, and was attended by 22 participants from Afghanistan, Bhutan, Burma, China, the Cook Islands, India, Indonesia, Kiribati, Pakistan, Republic of Palau, the Philippines, the Republic of Korea, Sri Lanka, Thailand, Vanuatu and Viet Nam, and nine observers from ILO, FAO (which sponsored two participants from Nepal and Sri Lanka), the Asian Institute of Technology, and the Gesellschaft fur Technische Zusammenarbeit GmbH (German Technical Co-operation Agency, GTZ, which sponsored one participant from Nepal, and Chulalongkorn University).

The proceedings of this training course will be published in due course.

(b) The regional network on biomass, solar and wind energy (BSW)

Since the establishment of the network, several activities have been completed and some are under implementation.

As for information-related activities, the network has collected information relating to the three energy fields that feature in its name, and has disseminated it in the form of a newsletter (ESCAP Energy News), six issues of which have been published. In relation to a data base on NRSE research projects for strengthening the network's information services, work on the compendium of new and renewable sources of energy projects has commenced, with the initial preparation of a compendium on solar photovoltaic projects in the region.

As part of the specialist networking arrangements, a seminar was held in June 1985, with the co-operation of the Government of Thailand, on solar PV technology. The seminar made recommendations about PV training programmes, PV networking activities related to co-operative research and technical co-operation among developing countries (TCDC) operational plans of action. The BSW network also organized a roundtable at the Asian Institute of Technology in December 1984 on the establishment of capabilities for the manufacture of photovoltaic systems. In connection with the ESCAP tripartite project on regional co-operation in the R,D and D of solar photovoltaic power systems for rural areas, the BSW network is assisting in the organization of training courses in Pakistan and Indonesia.

An ESCAP/AIT training course on solar hot water systems was held at AIT from 19 to 20 December 1985, which brought together 45 participants from 12 countries. It was recommended that co-operation in this field should be focused on two areas, i.e., the adaptation of standards to suit regional conditions for solar collector testing and the performance evaluation of solar systems. Based on these recommendations, BSW is planning to conduct study missions to establish regional co-operation between countries in this field.

With regard to advisory services, the network has conducted missions to the following countries: Australia, Bangladesh, Burma, China, Fiji, Indonesia, Japan, the Maldives, New Zealand, Pakistan, the Philippines, the Republic of Korea, Sri Lanka, Thailand, Tonga and Western Samoa.

Further activities of the network are expected to focus on the establishment of networking mechanisms on research, development and demonstration co-operation in areas such as solar photovoltaic technology, solar thermal utilization, biomass combustion technology and wind water pumping.

C. Interregional co-operation on new and renewable sources of energy

The meeting of the Executive Secretaries of regional commissions in Addis Ababa on 25 to 26 February 1985, adopted the recommendations of a preparatory technical meeting (as contained in documents ECO/MRC/1/7 and ECO/MRC/1/7/Rev.1). The Executive Secretaries placed particular emphasis on

concrete proposals for interregional co-operation, on relations with other United Nations entities and specialized agencies, and on relations with the Group of 77.

The importance of concrete projects was underscored by the central role assigned to regional commissions by the Economic and Social Council (ECOSOC) and the General Assembly, in the promotion of interregional projects on economic co-operation among developing countries (ECDC)/TCDC (as stipulated in ECOSOC resolution 1983/66 and the recent General Assembly resolution 39/216). It was also noted with appreciation that ECOSOC had decided, upon the joint recommendation of the Executive Secretaries, that interregional co-operation in ECDC/TCDC will be the theme of its discussions on regional co-operation.

ESCAP has been selected as the leading commission in dealing with NRSE. In this connection, ESCAP has prepared an interregional new and renewable sources of energy development programme, a summary of which is given below.

The immediate objective of the interregional NRSE development programme, as proposed by ESCAP in consultation with other regional commissions, is to enhance the utilization and development of NRSE for national socio-economic development and, in particular, for rural development. More specifically, it should consist of regional projects that contain the following activities:

- (a) Conducting surveys and studies of existing and potential resources of NRSE;
- (b) Carrying out studies on the transfer, adaptation and implementation of mature NRSE technology for rural energy use;
- (c) Assisting least developed countries in formulating and executing rural energy projects;
- (d) providing technical advice on the development and use of NRSE;
- (e) Enhancing the flow of field information by organizing technical meetings, seminars, conferences, study tours and the like on NRSE applications and on integrated energy planning;
- (f) Promoting interregional co-operation in ECDC/TCDC among regional commissions;
- (g) Mobilizing financial resources for the implementation of these projects.

This interregional NRSE development programme should enhance technical and economic co-operation between the participating regional commissions. This will enhance their collective self-reliance in various fields which are to their mutual benefit in such areas as the exchange of information, joint ventures in project development, joint efforts in research, development, demonstration and adaptation of technologies on NRSE, with emphasis being placed on rural energy.

The programme should serve as a framework for regional NRSE activities and projects, reflecting the long-term and immediate needs and priorities of the member countries of each regional commission. The programme should provide guidance for the planning, design and implementation of all regional NRSE projects, so as to assure orderly progress in the NRSE sector, and full use of the available resources in fulfilling some of the priority needs of the regions. The structure of the programme should also be flexible in view of the experience gained in recent years, the uncertainties and the present level and sources of funding, together with other factors.

The regional projects of the programme are designed to promote the use of standardized methodologies for energy assessment and resource evaluation, as well as the gathering of statistical information for energy planning, in order to have comparable data that could be shared with other developing countries.

The programme and projects will foster TCDC through the exchange of experience and knowledge attained in the NRSE field by the developing countries, making the fullest use of national and regional institutions, as well as the maximum utilization of the expertise available in the region.

The proposed project covers a wide spectrum of activities and energy resources that are considered to be important within priority areas such as solar, wind, biomass, biogas, hydropower, fuelwood and charcoal, ocean and peat energy. The priority activities, as agreed at the Nairobi Conference, are: energy assessment and planning; research, development and demonstration; transfer, adaptation and application of mature technologies; information flows; education and training.

The proposed projects respond to several recommendations of the Nairobi Programme of Action, of the Regional Expert Group Meeting in Colombo, of the Meeting of Focal Points on NRSE, and the High-level Regional Consultative Meeting for the Mobilization of Financial Resources for NRSE, together with the recommendations of TCDC and ECDC.

As a concrete example of suggested interregional projects, outlined below are some ideas for practical ways of achieving ESCAP/ESCWA co-operation.

D. Co-operation on NRSE between ESCAP and ESCWA

ESCAP initiatives in the field of NRSE have been mainly directed toward bringing about greater intercountry co-operation, take cognizance of the emphasis laid down in the Nairobi Programme of Action for regional-level action. It is quite evident that the developing countries of the five regions face common problems in the development and utilization of NRSE. Despite the somewhat easier oil price and supply situation at present, energy continues to be a major problem confronting nearly all countries, and for this reason development of the energy sector is a major concern.

As the main aim of interregional co-operation between the regional commissions would be to develop institutions and implement programmes to accelerate the development of NRSE in their respect member countries, it would be beneficial to both ESCWA and ESCAP if consideration could be given to the following ways of implementing interregional co-operation:

(a) Exchange of NRSE information (newsletter/publications) between substantive divisions/units of ESCWA and ESCAP;

(b) Joint meetings/seminars/workshops/training courses between ESCWA and ESCAP. This form of co-operation will be useful for the exchange of ideas and information on specific NRSE subject areas. The interregional seminars and training courses would provide useful opportunities for government officials to learn more of the programmes and facilities on NRSE in the two regions;

(c) An intensive way of implementing interregional co-operation would be to devise interregional projects that could be carried out simultaneously. These projects may take the form of research, development and demonstration, information and training.

One of the first initiatives taken by ESCAP on interregional co-operation in NRSE, was the preparation of the project entitled "Interregional TCDC-ECDC in New and Renewable Sources of Energy (NRSE)", which was subsequently submitted to all five regional commissions for comment and further discussion.

Another initiative of interregional co-operation with which ESCWA could participate with ESCAP would be in the field of research, development and demonstration and training of photovoltaic systems for rural areas. This would form part of the tripartite photovoltaic project being implemented by ESCAP, together with the Governments of Japan, Indonesia and Pakistan. The background of this project is as follows: at the fortieth commission session held in Tokyo from 17 to 20 April 1984, a resolution on the Tokyo programme on technology for development in Asia and the Pacific was adopted. An ESCAP Plan of Action on Technology for Development was also adopted as a guideline to further activate technology-related activities in the Asian and Pacific region, in order to accelerate the socio-economic development of the countries in the region. It was stressed that co-operative and tripartite activities in research, development and demonstration projects in selected facets of technologies were a useful and innovative approach to enhancing regional co-operation. Indonesia and Pakistan agreed to the proposal that their solar photovoltaic power generation demonstration facilities and activities could be utilized for demonstration projects implemented by ESCAP. The Government of Japan agreed to provide support for the implementation of the selected PV demonstration projects (in Indonesia and Pakistan), and for training programmes for ESCAP developing member countries.

It would be worthwhile for ESCWA to participate in the scheduled training courses under this project with a view to formulating specific interregional activities that could be followed up in the field of photovoltaics. This could be tied to a demonstration project in an ESCWA country that could be formally linked to the ESCAP projects, if an interest was declared and if sources of finance could be secured.

XVI. ESTABLISHMENT OF CGSERA: UNIDO ISSUE PAPER*

A. International trends in solar energy research and application

In spite of the changing scenarios of prices and the availability of alternative fuels, research and development relating to the utilization of solar energy is proceeding, and the cost of solar energy components and equipment are declining. Neither of these developments is taking place at the required pace, but it is clear that, notwithstanding the present relatively high cost of solar energy, countries have to prepare themselves for the large-scale utilization of solar energy, though within a somewhat uncertain time-frame. In the meantime, solar energy research and applications seem to have reached a crossroads.

In the case of photovoltaics (for which more information is available than for other categories of application or research), actual world-wide shipments, which up to 1984 were increasing, now appear to be stagnant. It is clear to industry and to its observers that earlier projections of the growth of markets for solar photovoltaics were too optimistic. Long-term forecasts for the year 2000 and beyond, however, continue to be optimistic, especially in view of rapidly increasing conversion efficiencies (from 1 to 2 per cent in 1976 to 11 to 12 per cent in 1985). ^{1/}

With regard to solar thermal energy, a 1986 report of the United States Solar Energy Industries Association came to the conclusion that few in the industry expect the market to develop until energy prices rise or federal subsidies for conventional energy technologies are removed, and the major question is whether they will rise soon enough to save the industry from dissolving and the technology base from evaporating. ^{2/}

Trends on an international level relating to research and expenditure on solar energy are worth noting.^{3/} In the case of the United States of America, where substantial public spending on solar research and development (R and D) took place, there is now a trend towards reduction and to setbacks in public sector R and D. These fell from 561 million in 1980 to a forecast of 52 million for 1987. The development of solar technology in the major producing countries relied heavily on public sector support on three main levels: support for R and D, the provision of markets, and raising public awareness of

* The United Nations Development Organization secretariat.

^{1/} Figures quoted in this paragraph are taken from different issues of the Solar Energy Intelligence Report.

^{2/} Solar Energy Intelligence Report, 25 February 1986.

^{3/} Figures in the rest of the paragraph are taken from a draft report prepared for UNIDO by K. Hoffman entitled "Technological and commercial trends in photovoltaics".

the technology. Support for R and D was conducted in the form of national programmes, and the expansion of the market involved international agencies and led to the application of photovoltaic technology in developing countries. While R and D programmes set price goals in the levels of efficiency to be achieved over specific time scales, the expansion of markets provided finances, as well as operating experience, that were subsequently used in R and D. Most R and D in the United States, Western Europe and Japan has been done through complex links between government-industry, industry-university and government-university. While the quantity of publicly-funded R and D in the United States has declined, different trends are visible in Europe and Japan. Under the auspices of the European Economic Community, countries of Western Europe launched a major programme in the late 1970s that involved state agencies, universities, industry and public enterprises. Photovoltaics R and D accounted for \$US 15.5 million over the period 1975 to 1979, and was increased by some 190 per cent to reach \$US 59 million in the period 1979 to 1983. Work in Europe was subcontracted to universities, research institutes and industry in various European countries. Like the United States of America, the EEC programme carried out R and D with the aim of reducing selling costs through the use of improved processing and alternative materials. Various European countries also undertake photovoltaic R and D through national programmes. France, for example, set aside \$US 154 million for photovoltaic development over the period 1982-1986. The Government's contribution amounted to \$US 52 million. The Federal Republic of Germany's Federal Ministry for Research and Technology spent the following amounts on photovoltaics research: in 1972 to 1977, 10 million deutsche marks (DM) (i.e., 4.5 per cent of total appropriations for research on non-nuclear energy); in 1978 to 1982, this was increased to DM 95 million (9 per cent of total appropriations); from 1983 to 1987, research expenditure on PV reached an all-time high of DM 300 million (28 per cent of the total); forecasts for the period 1988 to 1992 expect a decline in non-nuclear research funding from DM 1.1 billion in 1988 to DM 810 million in 1992, with a corresponding reduction in PV research from DM 270 million in 1988 to DM 160 million in 1992 (respectively 26 per cent and 20 per cent of total appropriations).

Photovoltaic R and D in Japan is conducted under the "sunshine project" which was launched in 1974. The funding for photovoltaics has increased rapidly. For example, funding was raised over 140 per cent during the period 1980 to 1982 alone, bringing the total allocation to \$US 30 million. By 1984, Japan was spending some \$US 16 million on photovoltaic R and D which was shared equally by industry and the Government.

Even with the recent reductions in some national R and D budgets, it has been estimated that about \$US 100 million per annum is spent world-wide on PV research.

Information is also available on trends in developing countries. Photovoltaic applications in developing countries were made primarily through the efforts of a number of companies and international agencies. The United Nations Development Programme, for example, funded a World Bank-executed project on photovoltaics. In workshops recently organized by UNDP, it has been shown in numerous demonstration projects during the period 1975 to 1983 that photovoltaics can operate in remote locations and even under harsh

conditions. ^{1/} Photovoltaics is an economically competitive source of electric power for many applications and in many locations. Applications have particularly improved remote power for clinics, schools and other buildings, refrigeration for medicinal vaccines, water pumping for livestock, irrigation and clean drinking water and communications. Financing institutions such as the World Bank, the African Development and Asian Development Banks are prepared to finance economically sound uses of photovoltaics that form a component of a rural, agricultural energy development programme or a rural health scheme.

In regard to production in the developing countries, some progress has been made, though there has been no significant commercialization of photovoltaic systems from local R and D. So far output in these countries has only changed from 0.2 MW in 1983 to 0.70 MW in 1984. ^{2/} The largest growth rate appears to have taken place in India, followed by Brazil and Singapore, which both have assembly facilities. Saudi Arabia has set up a single custom module plant which aims at supplying local and regional markets. At the same time, developing countries are still targets of photovoltaic commercialization, despite disappointing sales in the last five years. The European Community is a major supplier of modules to these countries as part of its aid programme. Individual countries such as Italy and France ship over half of their photovoltaic output to developing countries, mainly to Africa.

B. Trends in solar research and development in developing countries

A review of research institutes in developing countries carried out by UNIDO in 1982 and updated in 1985 and 1986, showed that of 115 institutes included in the most recent review, ^{3/} 43 were involved in research on photovoltaics (solar cell technology and systems), and 25 on solar thermal (flat-plate and concentrating) collectors; 15 on solar thermal systems and six on selective coatings. The main applications were for solar drying (47), water heating (33), cooling and refrigeration (24), solar cooking (16) and water pumping (13); six were engaged in research in industrial heat processing. Expenditure on research and development does not, however, appear to be considerable. An analysis of the research budgets of the institutes listed in the above review for the period 1984 to 1985, shows that they ranged from \$US 10,000 to several million dollars. At the lower end of the scale are Iran, Trinidad and Tobago and Cameroon, while Singapore and Saudi Arabia are top of the list with 12 and eight million dollars, respectively. The great majority, however, have a rather modest budget of 100,000 to 200,000 dollars and have an average professional staff of five.

^{1/} See reports of the UNDP Renewable Energy Information Programme-Photovoltaic Symposia and Information Workshops, Nairobi, Kenya, 13 to 18 April 1986 and Chaing Mai, Thailand, 20 to 25 April 1986.

^{2/} Draft report prepared by K. Hoffman for UNIDO, "Technological and Commercial Trends in Photovoltaics".

^{3/} United Nations Industrial Development Organization, Directory of Solar Research Institutes in Developing Countries (UNIDO/IS.341/Rev.2).

Annex 1 gives a list of research institutes in developing countries, together with the areas of research and the co-operation they currently share with institutions in other countries. Table XVI-1 clearly shows that a certain amount of co-operation already exists in solar energy research. Such co-operation has taken different forms, such as co-operation with aid agencies, with non-governmental development-oriented organizations, Governments and United Nations organizations. It is interesting to note that there are several cases where co-operation between developing country institutions themselves has also taken place.

At the same time it is clear that the developing countries face constraints with regard to research, and more particularly with commercialization, which appears to be a weak link. Even with regard to the manufacturing activities undertaken by developing countries, many applications appear to be based on imported technologies. One recent Swedish study noted that the lack of contact and co-operation between many scientists in the developing world is a major obstacle to a more rapid introduction of solar systems. Countries such as Egypt and Kenya, both have highly regarded research institutes and local manufacturers, but contacts between these parties are few and occasional. ^{1/} Nevertheless, it is evident that a great deal of interest in further co-operation exists, as can be seen from annex 2, which presents the information collected by UNIDO on the interest shown by institutions in various countries in co-operating with other institutes outside. Interest in co-operative research has been expressed in photovoltaic systems by 14 countries: by 11 in solar drying, 10 in solar cells, 9 in water heating and 5 in solar collectors.

C. Some existing forms of co-operation

In regard to international co-operation in general, it is useful to note some of the existing attempts at co-operation which are, however, primarily at the regional level.

The European Network for Solar Energy Co-operation was formally launched in September 1983, on the initiative of the United Nations Educational, Scientific and Cultural Organization (UNESCO). UNIDO is also a member of the network. Bulgaria, the Union of Soviet Socialist Republics (USSR), Hungary, Romania, Poland, Yugoslavia, Israel, the Federal Republic of Germany and France are reported to be on the Network committee. Working groups with focal points in different countries have been set up in regard to solar water heating, heat storage, solar drying, and another working group on photovoltaics and its applications has also been established. The types of activities identified relate to the exchange of personnel, working in participants' laboratories and an impartial assessment. It has been agreed that the collective knowledge of the European Network will be available to encourage the developing countries, and that the wasteful duplication of individual projects could be eliminated by co-operation.

^{1/} Swedish International Development Agency (SIDA), Solar Water Heating in Developing Countries (March 1984), p. 36; and Commission of the European Communities, Building the Renewable Energy Market in Developing Countries.

In regard to the ESCAP region, projects are reported to have been implemented on a regional level in research, development and demonstration on solar photovoltaic systems, in co-operation with the Government of Japan.

Based on the expertise in photovoltaic power generation acquired through national and bilateral projects in Indonesia and Pakistan, assistance is being provided to developing countries in the region, together with the sharing of experience, as well as the training of engineers and technicians in the establishment, operation and evaluation of solar photovoltaic systems. The Indonesia-Japan photovoltaic power generation system project has been proposed for use as a regional research, development and demonstration project.

A Silicon Technology Development Institute has been established in Pakistan by means of a project funded by the Government of Pakistan and UNFSSTD, and implemented by UNIDO. It provides an excellent nucleus for training, research and pilot production of complete PV arrays, starting from quartz. It can be extended to include co-operation with other developing countries.

In the ESCWA region, a network on new and renewable sources of energy (mainly solar) is being established. A meeting on solar and wind energy in the ESCWA region was scheduled for November 1986.

In regard to the African region, the Solar Energy Society of Africa was established in November 1983. Its research priorities include solar crop drying, water supplies for irrigation, solar maps and air-conditioning, including passive heating and cooling. The envisaged activities of this Society include the organization of seminars, the exchange of personnel, material and equipment, the establishment of links with other proficient organizations, development of co-operative programmes and preparation of directories, etc.

The International Solar Energy Society, a non-profit making organization founded in 1957, with more than 90 members world-wide, is widely regarded as the premier body of its type to operate in the solar energy field. It has consultative status in the United Nations as a non-governmental organization. Among its members are most of the leading figures in solar energy research and development.

The society convenes biannual world congresses as a multi-disciplinary forum for experts to review and compare notes on the latest developments in solar technology. It also organizes an international solar equipment exhibition in conjunction with each congress. After Brighton, United Kingdom (1981), Perth, Australia (1983), and Montreal, Canada (1985), Hamburg, in the Federal Republic of Germany was selected for the 1987 congress.

The rather brief and limited review of some of the existing efforts of co-operation show that useful beginnings have been made. However, nowhere is it evident that the resources available for solar energy research and applications have been significantly increased, or that they are being co-ordinated in the way that is necessary to impart a decisive thrust to this field. This is of particular importance to developing countries and to global energy issues in general.

A number of aid agencies have met informally from time to time to discuss their support for research related to energy in developing countries. ^{1/} The first two informal meetings were organized by the International Development and Research Centre (IDRC), in April 1982 and September 1984. A third was held at GTZ headquarters in May 1986. It should be noted that these were informal meetings for the energy sector as a whole, and that no particular focus was put on solar energy. Developing countries do not appear to have been represented at such meetings. It may also be noted that while global networks have been created for biomass (Biomass Users' Network), no such network exists for solar energy. It is reported that the participants in the informal donors' meetings expressed concern that, as a result of the volatile energy market, developing countries should not be discouraged from taking the necessary energy investment decisions. The participants also decided that donors should increasingly focus their support on research into energy-related development constraints and opportunities. The final results of IDRCs Energy Research Group were also discussed. Among other things attention was drawn to the following: research must be demand oriented; user-oriented strategies are needed; energy research priorities must evolve as a result of policy decisions; and research capacities must be built up in developing countries.

D. Need for a Consultative Group on Solar Energy Research and Application (CGSERA)

The foregoing makes it clear that a stage has been reached where a more decisive thrust towards co-operation is needed. Among the factors contributing to this result are the following: the relatively stagnant trends in solar energy equipment production and shipments; the somewhat conflicting trends in regard to the quantum of research funds that are being channelled into the field of solar energy; the availability of a certain amount of experience in the utilization of solar energy equipment by the developing countries; the existence of a large number of institutions in developing countries that are doing research in the field of solar energy; and the expressed desire for international co-operation. This, together with the ongoing, though limited, co-operation at the regional level provides the scope for the establishment of a Consultative Group on Solar Energy Research and Application (CGSERA) at the international level, with the aim of promoting a critical mass of international effort that is related to solar energy research and application, in particular for the benefit of the developing countries.

The context of UNIDO involvement in promoting the Group may be set out at this stage. UNIDO has been working in the field of solar energy by way of information collection and dissemination, the preparation of studies and directories and specific technical assistance projects (for example in Afghanistan, the Comoro Islands, Cuba, Ethiopia, Jordan, Mali, Niger and the Sudan). As part of its programme for strengthening the technological capabilities of developing countries in the field of new and emerging technologies, the UNIDO secretariat brought up the subject of solar energy at the International Forum on Technological Advances and Development, held in

^{1/} GATE, questions, answers, information (September 1986) No. 3/86.

Tbilisi, USSR in April 1983. In its report ^{1/} the Forum recommended the establishment of a Consultative Group on Solar Energy Research and Application (CGSERA). The particular interest of UNIDO is that solar energy research must not only be accelerated as a long-term energy imperative, but the beginnings of a solar energy industry have to be nurtured in many developing countries and matched by the strengthening of relevant scientific and technological capabilities. The growth of such an industry is likely to be substantially hampered if developing countries do not have a measure of research and application capacity. The building of systems for local use requires essentially local knowledge and local research capabilities. These will then have to be related to local manufacturing capabilities. This is not to argue that work in developing countries should be confined to applications, or that they should not go into the field of research in fundamental areas. The creation of an international group will actually open up the possibilities of co-operation and will avoid duplication and accelerate results where a certain measure of excellence has already been achieved.

In the activities of such a group at the international level, it should, however, be borne in mind that existing regional networks must be utilized; national capacities should be fostered and the activities at the international level should not be at the expense of those at the national level; there should be no attempt to "reinvent the wheel", and stress should be put on avoiding duplication. This would be consistent with the growth of national capacities in the manner that is desired by individual countries, so that research is translated into actual application and production. A consultative group, however, can function effectively only if sufficient funds are available and if its members are key factors in this area (including donor agencies and several "centres of excellence" or high-level institutions in developing countries). It is in this context that attention should be given to the experience of the Consultative Group on International Agricultural Research (CGIAR), the set-up of which is explained later in this paper. The UNIDO secretariat believes that next to agriculture, solar energy is an area that deserves attention in view of its renewable nature and importance to all countries, in particular developing countries. Hence, a group modelled on CGIAR, though not necessarily an exact replica of that body, would be useful.

A Consultative Group on International Solar Energy Research and Application could take various forms. Typically, it could have several activities such as information exchange, training, joint research and development, periodical review of the state of the art, measures to promote the commercialization of developed technologies, etc. A consultative group of this type could also promote specialized "centres of excellence" that have regional or international scope in specific subject areas. In addition, it could be directly linked with the funding for research, following the pattern of CGIAR. The last element is critical if the group is to achieve the desired results.

^{1/} Report of the High-level Expert Group Meetings Preparatory to the Fourth General Conference of UNIDO, International Forum on Technological Advances and Development, Tbilisi, USSR, 12 to 16 April 1983, (ID/WG.389/6) (April 1983) para. 71.

E. Experience with the Consultative Group on International Agricultural Research

CGIAR was established in 1971 under the joint sponsorship of the World Bank, UNDP and the Food and Agriculture Organization of the United Nations (FAO). It is an informal association of Governments, international and regional organizations and private foundations that are dedicated to supporting a system of agricultural research centres and programmes around the world. CGIAR operates without any legal charter, written rules, protocols or by-laws; it functions instead on the basis of common consent, shared interest and the good will of its members. Members of CGIAR meet annually to consider programme and budget proposals, policy issues and other matters referred from the centres. The initiative was taken on the belief that long-term support for an expanded international agricultural research system should be provided. It is widely recognized that this experiment has been highly successful. Table XVI-1 shows, for example, that CGIAR contributions for the first 10 years of its operation increased fivefold from \$US 20 million in 1972 to \$US 190 million in 1980.

F. Proposal for a Consultative Group on Solar Energy Research and Application

Based on the foregoing, it is suggested that careful consideration be given to the establishment of a Consultative Group on Solar Energy Research and Application. It would be composed of R and D institutions (particularly those from developing countries), and donor agencies. The aim would be to impart direction and cohesion, as well as to increase the size and accelerate the speed of international research efforts in the field of solar energy, particularly applications in developing countries. It will draw upon the experience of CGIAR, but need not necessarily be identical to that organization. CGSERA could also place a certain amount of emphasis on industrial production and application. It should, however, be remembered that such a group need not be an intergovernmental group, but could be organized on an informal basis by those donors and research institutions that are willing to participate. The Group would not indicate what needs to be done in individual countries. Rather, it would try to harmonize individual national efforts with international research concerns and the wishes of the donor countries. It would have to function with a minimum of legal or bureaucratic constraints. However, certain "rules of the game" would have to be observed, and there would need to be a minimum level of obligation on the part of the donors, as well as on the part of the participating research institutions, particularly in regard to the provision of information and willingness to discuss the results of efforts and experience, especially that relating to developing countries. CGSERA would not preclude any bilateral co-operation, either now or in the future, nor would it substitute the individual efforts of countries or hinder or replace existing commercial flows. On the other hand, this group could contribute both to the creation of a solar energy industry in developing countries by promoting more concentrated research and linking it to industrial application, as well as to the opening up of potential markets for international commerce. The Group would also establish links with agencies in the United Nations system.

Table XVI.1. CGIAR contributions 1972-1981*

(millions of dollars)

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
African Development Bank	-	-	-	-	-	-	0.025	0.030	0.040	0.050
Arab Fund	-	-	-	-	-	0.310	0.310	-	0.255	0.255
Asian Development Bank	-	-	-	0.300	-	0.500	-	0.700	-	-
Australia	-	0.005	1.015	1.215	1.745	1.790	2.580	2.650	2.955	3.315
Belgium	0.140	0.600	0.380	0.620	1.740	2.250	2.720	3.085	3.265	3.530
Canada	1.160	1.780	4.675	4.340	5.390	6.800	7.370	7.544	6.875	7.620
Denmark	0.250	0.225	0.370	0.400	0.455	0.615	0.760	1.045	1.210	1.170
EEC	-	-	-	-	-	2.500	2.240	3.790	4.545	5.480
Ford Foundation	5.315	3.675	3.000	2.800	2.000	1.590	1.000	1.000	1.300	1.300
France	-	-	0.130	0.410	0.510	0.415	0.340	0.675	0.855	1.099
Federal Republic of Germany	-	1.805	3.040	3.935	4.475	5.350	6.760	8.475	10.100	10.000
IDB	-	-	2.030	4.120	5.000	5.700	6.185	6.200	6.700	7.400
International Development and Research Centre	0.175	0.345	0.645	0.990	1.780	1.305	1.045	1.818	1.530	1.075
International Fund for Agricultural Development	-	-	-	-	-	-	-	1.550	3.570	6.570
India	-	-	-	-	-	-	-	-	-	0.500
Iran	-	-	-	-	1.975	2.000	1.000	-	-	-
Ireland	-	-	-	-	-	-	-	-	0.200	0.200
Italy	-	-	-	-	0.100	0.030	0.100	0.100	0.700	1.250
Japan	0.105	0.230	0.265	0.675	1.200	2.500	3.500	4.845	7.000	8.400
Kellogg Foundation	0.155	0.290	0.280	0.290	0.300	0.310	0.320	-	-	-

Table XVI.1. (continued)

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Leverhulme	-	-	-	-	-	-	-	-	0.490	0.585
Mexico	-	-	-	-	-	-	-	-	0.495	1.000
Netherlands	0.375	0.430	0.555	1.235	1.500	1.720	1.785	2.430	2.600	3.070
New Zealand	-	-	-	-	0.105	0.025	0.025	0.025	0.025	-
Nigeria	-	-	-	0.645	0.645	0.620	0.790	0.825	1.976	1.720
Norway	0.075	0.185	0.445	0.810	1.120	1.510	1.880	1.975	1.995	2.000
OPEC Fund	-	-	-	-	-	-	-	-	0.900	1.000
Philippines	-	-	-	-	-	-	-	-	0.150	0.500
Rockefeller Foundation	3.990	4.545	3.500	2.885	2.165	1.595	1.250	1.220	1.600	1.000
Saudi Arabia	-	-	-	-	1.000	1.000	-	-	-	-
Spain	-	-	-	-	-	-	-	-	-	0.500
Sweden	1.000	0.150	1.490	2.290	2.255	2.240	2.725	3.115	3.390	3.525
Switzerland	-	0.410	0.140	0.460	0.855	1.205	1.350	1.850	2.450	2.580
United Kingdom	0.690	1.110	1.920	2.410	2.890	3.515	4.765	6.395	6.790	7.140
UNDP	0.850	1.000	1.465	2.165	1.930	3.500	4.400	3.995	4.615	4.981
UNEP	-	-	-	0.600	0.340	0.340	-	0.150	-	-
United States	3.770	5.390	6.805	10.755	14.870	18.140	21.145	24.800	29.000	35.000
World Bank	1.260	2.780	2.375	3.195	6.525	7.850	8.765	10.200	12.000	14.600
Others	0.750	-	-	-	-	-	-	-	-	-
Total	20.060	24.955	34.525	47.545	62.870	77.225	85.045	99.487	119.576	138.391

Source: Compiled from the Consultative Group on International Research, programme, budget papers and accounts, 1974-1981.

* Contributions as pledged at November 1980. Values will vary depending on the date of disbursement.

It would appear that, in view of the present stage of solar energy research and application and the need for a more concerted effort, as well as for the long-term support of a critical mass, the creation of a Consultative Group on Solar Energy Research and Application that draws, among other sources, on the experience of CGIAR, is both timely and essential. Based on the input provided by various participants in the workshop, it should be possible to establish CGSERA after appropriate consultations with all the interested donor agencies, and with as many developing country institutions as possible after the elaboration of its proposed institutional framework. The present workshop has necessarily been limited to a few expert participants and observers, the intention being to concretize the thoughts a little more in this respect before reaching out to a wider level of participation.

The workshop may like to discuss the foregoing and arrive at proposals for further concrete action in this matter, and in particular for UNIDO to do the following:

(a) Prepare and convene a meeting of all interested institutions in order to establish CGSERA. This would include the surveying and identification of interested R and D institutions, detailed consultation with donor agencies, and the elaboration of the framework of the Group.

(b) Identify subject areas of research and application where efforts at international co-operation may be primarily directed; and

(c) Concurrently build up a portfolio of R and D projects in developing countries that could be promoted and assisted by international co-operation. (It is requested that participants bring concrete proposals for co-operation in research and application to this workshop.)

Annex 1

**POTENTIAL RESEARCH, DEVELOPMENT AND DEMONSTRATION OF NEW
AND RENEWABLE SOURCES OF ENERGY**

<u>Country</u>	<u>Suggested areas of co-operation</u>	<u>Joint research</u>
Algeria	Solar cells (including amorphous silicon a-Si)	
Argentina	Solar cells (+a-Si) PV systems Collectors Solar drying Energy conservation	Brazil (R and D)
Caribbean	Exchange of information	GATE Voluntary International Technical Assistance (VITA)
China	PV Solar cell design (a-Si and polycrystal) Collectors Solar drying Solar thermal Space heating Water heating Energy conservation Desalination	
Brazil	Solar cells (MIS + SIS technology) (a-Si)	
Burundi	Solar drying	USAID EEC Federal Republic of Germany UNESCO-ANSTI Belgium (R and D, Government)
Cameroon	Solar drying refrigeration	France (R and D)
Egypt	Desert development	USAID United Kingdom United States of America (USA) (R and D)
Ethiopia	Solar drying	African Regional Centre for Technology
Fiji	PV Solar radiation measurement Refrigeration	United Nations Pacific Energy programme

<u>Country</u>	<u>Suggested areas of co-operation</u>	<u>Joint research</u>
Ghana	Solar pumping (PV) Solar drying Solar cookers	GTZ Togo Benin (R and D)
India	Solar distillation Solar drying Solar cells Solar cooker Solar pumping Industrial process heat Desalination Refrigeration Flat-plate collectors Selective coatings Steering engine	Indian Institute of Technology (IIT) Federal Republic of Germany (Government) United Kingdom (R and D) International Rice Research Institute (Philippines) Swiss Development Corporation Peru (R and D) United Nations University (UNU) UNESCO United Nations Financing System for Science and Technology Development (UNFSSTD)
Indonesia	Solar cells Water pumping (thermal) PV systems Solar drying Solar water heater	Federal Republic of Germany (R and D) UNFSSTD
Iran	Desalination	
Iraq	Desalination Water pumping (PV) Solar cells Refrigeration	Jordan (R and D)
Jordan	Solar water heating Flat-plate collectors Desalination	GTZ Kuwait Institute for Scientific Research (KISR)
Kenya	Solar drying	Commonwealth Science Council (CSC) (African Energy Programme)
Madagascar	Solar cells Solar thermal	France (R and D) Planned: Indian Ocean countries

<u>Country</u>	<u>Suggested areas of co-operation</u>	<u>Joint research</u>
Malawi	Solar drying Solar still	
Malaysia	Solar thermal Solar dryers Solar radiation PV Solar drying	New Energy Development Organization, Japan JILA, Japan Korean Advanced Institute of Science and Technology (KAIST) France (Government) France (R and D) USA (commercial)
Mali	General	France (R and D) USA (commercial)
Mexico	Water pumping (thermal + PV) Concentrating collectors Cooling	France (Government)
Morocco		France (R and D)
Nepal	Solar water heating Space heating	
Nigeria	Exchange of information/visits Energy conservation Passive solar	
Pakistan	PV Solar cell materials Passive solar Rural energy	USA (R and D) Turkey (R and D) Arab Industrial Development Organization (AIDO)
Papua New Guinea	Solar drying	
Philippines	Solar grade silicon from rice husks	USAID UNDP UNESCO Federal Republic of Germany (Government) Association for the Growth of Systematized Agricultural Technology (AGSAT)
Korea, Republic of	PV Passive solar Active solar	France (commercial)

<u>Country</u>	<u>Suggested areas of co-operation</u>	<u>Joint research</u>
Saudi Arabia	General	USA (R and D) KISR
Seychelles	Rural energy Water pumping (PV) Desalination	Mali France (commercial) Reunion (R and D)
Singapore	Energy conservation (computer simulation) Air-conditioning Passive solar Water pumping (PV) Solar ponds	
Sri lanka	Water heaters	
Syria Arab Republic	Air-conditioning Water heating Solar cells (encapsulation) PV systems Selective coatings	Algeria
Tanzania, United Republic of	Rural energy Refrigeration Water pumping Solar cooker Solar drying PV	CSC Canada (R and D) Uganda (R and D) Kenya (R and D)
Thailand	Solar pond Collectors (water heating) Solar still Rural electrification Solar drying Distillation	Japan (R and D)
Trinidad and Tobago		Canada (R and D) Caribbean Agricultural Research and Development Institute (CARDI) Grenada
Turkey		
Uganda		CSC: Kenya Tanzania Zambia, Malawi Zimbabwe, Mauritius Seychelles, Cyprus

<u>Country</u>	<u>Suggested areas of co-operation</u>	<u>Joint research</u>
Venezuela	Energy conservation Passive cooling Simulation of thermal processes	Mexico (R and D) France (Government)
Yugoslavia	Solar cells	
Zambia	Solar radiation	
Zimbabwe	Solar drying Water heating Water pumping (thermal)	

Source: Compiled from UNIDO, Directory of Solar Research Institutes in Developing Countries document (UNIDO/IS.341/Rev.2) (February 1986).

Annex 2

CO-OPERATIVE RESEARCH SUGGESTIONS

Solar cells

Algeria
Argentina
Brazil
India
Indonesia
Madagascar
Pakistan
China
Syrian Arab Republic
Yugoslavia

Solar drying

Argentina
Burundi
Cameroon
Ethiopia
Ghana
India
Indonesia
Kenya
Malaysia
Tanzania
Zimbabwe

PV systems

Argentina
Fiji
Ghana (pumping)
Iraq (pumping)
Indonesia
Mexico (pumping)
Malaysia
Pakistan
China
Senegal (pumping)
Singapore
Syrian Arab Republic
Tanzania
India (pumping)

Water heating

India
Indonesia
Jordan
Nepal
China
Sri Lanka
Syrian Arab Republic
Zimbabwe
Thailand

Collectors

Argentina
India
Jordan
Mexico
China

Source: United Nations Industrial Development Organization, Directory of Solar Research Institutes in Developing Countries, (UNIDO/IS.341/Rev.2) (February 1986).

ANNEXES

Annex I

KEYNOTE ADDRESS OF THE
EXECUTIVE SECRETARY OF ESCWA

Excellency,
Ladies and gentlemen,

I am glad that this Seminar recognizes, at the outset, the importance of renewable sources of energy in the ESCWA region, in spite of the abundance of hydrocarbon resources in many member countries and the recent trend of falling oil prices. This is because the changes in the prices of conventional energy, on the one hand, and the availability of oil resources in the region on the other, have often been used as a justification to explain the limited resources allocated to the promotion of the widespread use of renewable energy technologies.

In fact, the use of renewable energy technologies depends on various other factors which may be of more relevance than the changes in conventional energy prices.

Let us, first of all, not lose sight of the fact that ESCWA countries, directly or indirectly, remain heavily dependent on finite petroleum resources. A more diversified energy consumption mix which also relies on renewable and other alternative sources of energy can substantially benefit those countries where energy costs still constitute a considerable burden on the national economy and contribute to the conservation of the region's greatest material wealth.

During the last 15 years or so, the consumption of commercial energy has considerably increased, though in various degrees, in all countries of the ESCWA region. In contrast, owing to the important achievements of developed countries in using energy substitutes, implementing strict and efficient measures for energy conservation and developing alternative sources of energy, the rate of increase in commercial energy has been considerably reduced. Moreover, energy intensity has consistently declined in many countries, including a number of developing countries, whereas the intensity of energy consumption has risen in most economic sectors in the ESCWA region.

The distance from national electricity grids and distribution networks of conventional fuels, the availability of repair and maintenance requirements and the impact of different technical options, are also among the main factors in the use of renewable energy technologies.

It should be noted that fuelwood, charcoal, agricultural residues and other traditional energy sources still occupy an important place in the energy consumption patterns of most developing countries.

According to some estimates, more than two billion people rely on biomass energy to meet their basic energy needs. Figures published in recent studies indicate that "supplies from fuelwood and charcoal are estimated to have provided the equivalent of some 380 million tons of oil in 1984". It has also been estimated that, on the average, the share of renewable sources of energy in developing countries might exceed 28 per cent. This percentage varies from one region to another, and from one country to another. In Asia, the share of renewable sources of energy, particularly fuelwood and agricultural residues, is around 22 per cent, but in Africa the figure may exceed 50 per cent. In certain African and Asian countries, the share of traditional sources of energy has reached 80 per cent. The related figure for the ESCWA region may not have reached similar proportions, but traditional energy resources are also extensively used in a number of countries.

In the ESCWA region, attention is being turned to solar and wind technologies and it is believed that this trend should be strengthened.

The increasing use of fuelwood, agricultural residues and other traditional energy resources has resulted in serious environmental degradation, particularly rapid desertification and soil depletion. These issues have particularly serious consequences for the ESCWA region, where arid and semi-arid zones cover large areas. In several countries in the region, most of the population live in areas where fuelwood is already scarce.

However, the most important factor is that ESCWA countries are situated in areas of profuse insolation and the profuse solar energy can supply a substantial part of the energy needs of the region. An encouraging factor is that the technology for the use of solar energy is progressing rapidly.

Wind energy is also promising and, according to estimates, many zones in the region have a significant wind energy potential.

The United Nations Conference on New and Renewable Sources of Energy, held in Nairobi in August 1981, adopted a comprehensive Programme of Action whereby special emphasis was placed on the need to identify and implement projects for the promotion and development of solar and wind technologies.

The ESCWA secretariat, in addition to its other activities in the field of new and renewable sources of energy such as the establishment of a regional network on new and renewable sources of energy and the promotion of mature solar and wind technologies, has paid special attention to the utilization of solar and wind technologies for rural and remote areas in the ESCWA region, in order to meet the basic energy needs of scattered rural and remote communities and to contribute to the development of the agricultural sector which is often hampered by an inadequate power supply.

However, no projects can be effectively implemented without being fully aware of the difficulties facing ESCWA countries in the development of solar and wind technologies, and a clear perception of the various technical, economic, social and environmental implications of their application.

As these difficulties and implications will be examined thoroughly in the Seminar, I would only like to outline here the major ones.

In many ESCWA member countries, adequate policies for the development of solar and wind technologies are still lacking. It should be noted that, with only a few exceptions, the projects carried out so far for the widespread utilization of solar and wind systems are often pilot ones, and there is a wide gap between the projects that are formulated and the actual use of solar and wind technologies.

Another example of the inadequacy of renewable energy policies is the fact that ESCWA countries are particularly attracted to the sophisticated devices developed in the industrialized countries used in the region for experimental purposes. The high technology research undertaken in the developed world is primarily aimed at promoting the development of a commercially viable industry, regardless of the particular situation of the countries of the region. Close co-ordination of research and development programmes is therefore needed if the development of indigenous solar and wind industries is to be promoted. This, of course, requires that special attention be given to the building up of the presently inadequate industrial infrastructures for the manufacture of solar and wind system components and other infrastructural requirements such as transport and storage.

In many cases, the lack of know how and technological capabilities considerably limit the scope of the implementation of costly projects undertaken for the development of solar and wind energy resources.

In spite of the significant progress achieved in a number of countries in the field of research and demonstration, the required support for such activities is still insufficient, and in some cases virtually inexistent. For certain countries, the issue of finance is overriding, and close regional co-operation is needed to overcome the difficulties resulting from insufficient financial allocations for the development and utilization of solar and wind technologies, which often require substantial investment.

The inadequacy of information and data on various aspects of the development and utilization of solar and wind energy systems is often the origin of the failure to implement solar and wind energy development projects.

I am fully aware that I am preaching to the converted when I stress the importance of careful long-term energy planning and the need to establish adequate institutional infrastructures for the management and operation of solar and wind energy systems.

You may agree with me that, with a number of exceptions, scant attention has been paid to the development of solar and wind energy technologies to meet the basic needs of rural and scattered remote communities in the region, and intensive efforts are to be deployed in that direction. This Seminar is therefore organized with a view to the following:

(a) Examining issues of relevance to the development of suitable solar and wind technologies for rural and remote areas in the ESCWA region and north African Arab countries;

(b) Considering practical proposals for the utilization of solar and wind energy systems in specific rural and remote areas, and for well-defined purposes;

Drawing conclusions from the findings of the research that has been undertaken and from your discussions in order to come up with recommendations for appropriate policies for the promotion of solar and wind technologies in rural and remote communities.

I am confident that in seminars like the present one, where experts can meet together and discuss issues, problems and solutions and concrete proposals for the application of effective and efficient solar and wind energy systems will be formulated.

I would like to conclude my address by expressing my deep appreciation to the United Nations Development Programme Headquarters in New York for the invaluable support provided for the organization of this Seminar. I am also grateful to the Ministry of Energy and Mineral Resources of Jordan for the excellent arrangements and facilities it has provided to host the Seminar and to facilitate the task of the participants.

Annex II

LIST OF PARTICIPANTS

A. Representatives of ESCWA member States

Bahrain

Mr. Nazar Al-Baharna
Solar energy expert
Bahrain University

Mr. Shawqi Al-Dallal
Solar energy expert
Bahrain University

Democratic Yemen

Mr. Mohammed Abdul Aleem Alwan
Director-General
Public Corporation for Electric Power

Egypt

Mr. Talaat El-Tablawi
Director
Egyptian Renewable Energy Development Organization

Iraq

Mr. Subhi Najm Ibrahim
Ministry of Industry and Minerals

Mr. Falah Sadek Hassoun
Scientific Research Centre
Solar Energy Research Centre

Mr. Sabih Salim Thabet
Ministry of Oil, Advisory Committee on Energy

Jordan

Mr. Ali Anani
Director
New and Renewable Sources of Energy Department
Ministry of Energy and Mineral Resources

Mr. Mohammad Amr
Chief
New and Renewable Sources of Energy Department
Ministry of Energy and Mineral Resources

Mr. Suheil Kiwan
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Ministry of Energy and Mineral Resources

Mr. Shaher Zoumot
Wind energy engineer
Ministry of Energy and Mineral Resources

Mr. Faisal Abu Allan
Solar energy engineer
Ministry of energy and Mineral Resources

Lebanon

Mr. Ali Mounzer
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National Council for Scientific Research

Mr. Aref Zaouk
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Oman

Mr. Said Mohammad Al-Nabhani
Hydrologist
Ministry of Electricity and Water

Mr. Abdul Kahar

Qatar

Mr. Musud Mustafa Al-Harouni
Chairman
Solar Energy Committee
Industrial Technical and Development Centre

Mr. Fahd al-Nuaimi
Chief
Solar Energy Research Station
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Saudi Arabia

Mr. Mohammed Ibrahim Al-Husseini
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Syrian Arab Republic

Mr. Hisham Samaan
Director of Planning
Ministry of Petroleum

Mr. Ali Maghout
Ministry of Petroleum

United Arab Emirates

Mr. Ahmad Said Majed
Ministry of Oil

Yemen

Mr. Muhammed Kassim Al-Motawakel
Professor
Faculty of Sciences
Sana'a University

B. Representatives of non-member States

Morocco

Mr. Mohammad Berdai
Centre de development des energies renouvelables

Tunisia

Mr. Bennaceur Raouf
Professor
Faculty of Sciences
Tunis University

C. Representatives of United Nations organizations and agencies

ESCAP

Mr. Clive Hughes
Solar energy expert
Biomass, Solar and Wind Network
Natural Resources Division

UNDP

Mr. A. Bruce Harland
Deputy Assistant Administrator and Director
Energy Office

Office of Development and International Economic Co-operation (DIEC)

Mr. Ahmedou Ould Abdallah
Chairman
Inter-Agency Group on New and Renewable Sources of Energy

UNIDO

Mr. Anthony Bromley
First Industrial Affairs Officer
Development and Transfer of Technology Division

D. Representatives of regional and international organizations

Organization of Arab Petroleum Exporting Countries (OAPEC)

Mr. Adnan Abu-Shihada

Royal Scientific Society of Jordan (RSS)

Mr. F. A. Daghestani

Islamic Development Bank (IDB)

Mr. Abdul Razzak Kamel
Head
Operations Department
Islamic Banks Units

Arab Fund for Economic and Social Development (AFESD)

Ms. Mervat Badawi

European Economic Community (EEC)

Mr. Jorg W. Fromme
GOPA-EEC Energy Planning Expert
Ministry of Energy and Mineral Resources of Jordan

Federation of Arab Scientific Research Councils (FASRC)

Mr. Malek Al-Kabarity
Head of Solar Collectors Department - RSS

E. Regional experts

Mr. Ali Sayigh
Solar energy expert

Ms. Anhar Hegazi
Director of Solar Energy Department
Egyptian Renewable Energy Organization

Annex III

**LIST OF INSTITUTIONS ACTIVELY INVOLVED IN RESEARCH,
DEVELOPMENT AND DEMONSTRATION, IN THE FIELD OF
SOLAR AND WIND ENERGY IN THE ESCWA REGION**

<u>Country</u>	<u>Name of Institution</u>
Bahrain	Engineering Department Gulf Polytechnic Isa Tower
	Physics Department Bahrain University Manama
Egypt	Renewable Energy Authority Ministry of Electricity Cairo
	Supreme Council of NRSE Cairo
	National Research Centre Academy of Scientific Research and Technology Cairo
	Faculty of Engineering University of Cairo
	Mechanical Engineering Department University of Assiut Assiut
Iraq	Solar Energy Research Centre Scientific Research Council Baghdad
	College of Science
	College of Engineering University of Basra Basra
	College of Engineering University of Mosul Mosul

<u>Country</u>	<u>Name of Institution</u>
Jordan	New and Renewable Sources of Energy Department Ministry of Energy and Mineral Resources Solar Energy Research Centre Royal Scientific Society (RSS) Amman University of Jordan Amman Yarmouk University Irbid
Kuwait	Solar Energy Department Kuwait Institute for Scientific Research (KISR) Kuwait University Safat
Lebanon	National Council for Scientific Research, Solar Energy Group Beirut Faculty of Engineering and Architecture American University of Beirut Beirut
Oman	Ministry of Petroleum Muscat
Qatar	Solar Research Centre Umm Said Solar Energy Committee Industrial Technical and Development Centre
Saudi Arabia	King Abdul Aziz City for Science and Technology Riyadh Solar Energy Commission Research Institute University of Petroleum and Minerals Dhahran

<u>Country</u>	<u>Name of Institution</u>
Syrian Arab Republic	Solar Energy Committee Scientific Studies and Research Centre Damascus
United Arab Emirates	United Arab Emirates University Al-Ain
Yemen Arab Republic	University of Sana'a Sana'a

