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APPLICATION OF SOLAR AND WIND TECHNOLOGIES IN THE ESCWA REGION

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FOREWORD

This technical publication on "Application of solar and wind technologies in the ESCWA region" has been prepared in implementation of programme element 2.2 on "Promotion of mature solar and wind technologies" of the 1986-1987 programme of work and priorities of the Natural Resources, Science and Technology Division.

The main objective of this study is to provide the region's policy-makers, concerned institutions and relevant experts with a technical document on solar and wind technologies of direct relevance to the region's priorities and with applications to rural and remote areas.

The materials covered in the study are, inter alia, energy and economic development, assessment of renewable sources of energy, assessment of renewable energy technologies, potential application of solar and wind technologies and development of renewable energy technologies, infrastructure and institutional setting for the application of solar and wind energy in the ESCWA region.

The study drew heavily on available research data, ongoing renewable energy projects and technical missions undertaken by ESCWA staff and other experts in the region. As such, the study should be seen as a complement to previously published Division reports dealing with new and renewable sources of energy.

It is hoped that this study will be useful and beneficial to the end-users.

MAIN SYMBOLS AND ABBREVIATIONS

A	Cross-sectional area in square metres
AC	Alternating current
CRS	Central receiver system
C	Degree Celsius
c	Concentration ratio
DC	Direct current
DCS	Distributed collector system
GCC	Gulf Co-operation Council
GDP	Gross domestic product
GNP	Gross national product
GWh	Gigawatt hour
GWp	Gigawatt peak
H	Total pumping head in metres
HV	High voltage
Kg.o.e.	Kilogramme of oil equivalent
kWh	Kilowatt hour
kWp	Kilowatt peak
m	Metre
m/s	Metre per second
MW	Megawatt
NPA	Nairobi Programme of Action
NRSE	New and Renewable Sources of Energy
OAPEC	Organization of Arab Petroleum Exporting Countries
P	Power in watt
P-N	Positive-Negative
Pr	Working pressure in bars
PV	Photovoltaic
Q	Quantity of water in cubic metres per day
R	Recovery ratio
R, D and D	Research, development and demonstration
RO	Reverse osmosis
RSS	Royal Scientific Society
SERC	Solar Energy Research Centre
t.o.e.	Ton of oil equivalent
TWh	Tetrawatthour
UHV	Ultra high voltage
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
VHF	Very high frequency
W/m^2	Watt per square metre
WECS	Wind energy conversion system
Wp	Watt peak
M	Efficiency
V	Volt

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I. INTRODUCTION

Energy has become an integral part of modern society. It is perceived as a vital input into economic and social development in all countries. It is indispensable for industrial, agricultural, commercial and household use. The modern industrial era brought with it an increase in consumption of energy and changes in energy sources, from wood and coal to predominantly oil and natural gas. The relationship of economic prosperity to energy consumption has become an essential element of energy policy, economic policy and national welfare.

The energy needs of the ESCWA region raise interesting problems owing to the inclusion of high income oil exporting countries, least developed oil importing countries and countries in between these two extremes. These countries have realized that fossil fuels are finite in extent and that diversification of energy sources other than hydrocarbon is a must for future development.

Concern for current and future energy supplies is reflected in the energy programme development of various national governments of the region and in the efforts being made by a number of regional organizations to assess the national, regional and global energy situation and possible rates of supply and substitution. Egypt(1) and Jordan(2) are two leading countries of the region which have made extensive studies for resource assessment as inputs in their energy planning. However, energy policies to be pursued by countries are influenced by several factors such as the energy resource base, the demographic situation and population growth level, the nature of socioeconomic activity, the relative costs of energy, the adequacy and reliability of supply, the availability of technology and supporting infrastructure, the success of energy conservation programmes and concern about the environmental and safety aspects of the production and use of energy.

While oil and gas contribute a major share of energy inputs into urban industrial production, the shortage of conventional energy sources in the rural sectors of ESCWA countries is one of the main factors that hampers their socio-economic development. With the oil price adjustments since 1973 and the development of various new technologies using renewable sources of energy, there is a general trend in ESCWA countries toward diversifying energy sources, and renewable sources of energy have been considered as a component source of future energy supplies. However, despite the awareness of the inevitable depletion of hydrocarbon resources and efforts to ensure a rational use of energy, the consumption of energy continues to increase at high rates under the pressures of major construction projects and other offshoots of socioeconomic development.

In this context, the development of renewable energy technologies and their application, wherever economically feasible, will help in promoting the socio-economic development of the scattered villages in the rural and remote areas of the region.

In response to this situation, the ESCWA secretariat has embarked on various technical assessments the ascertain the most suitable solar and wind energy applications in the region. The wealth of technical knowledge obtained from such a regional assessment and, in some cases, on-site assessment of the renewable resource base, infrastructure, institutional setting and other relevant materials pertaining to the promotion of mature solar and wind technologies will be the subject of this report. The materials covered in this report will complement other technical reports on renewable sources of energy prepared by the ESCWA secretariat and distributed in the last five years(3, 4 and 5). The report will deal with the potential application of solar and wind technologies, the local capability to manufacture solar and wind energy equipment/components, institutional setting and government involvement in the introduction of an endogenous renewable energy industry in the ESCWA region.

This report also primarily focuses on the "Application of solar and wind technologies in the ESCWA region". As such, the report will provide a background on solar and wind energy which are considered among the most promising renewable energy resources in the ESCWA region.

The report is introduced by a chapter presenting an overview of the energy situation in the ESCWA region and the role of new and renewable sources of energy as a component source of energy supplies in rural and remote areas. Chapter II of the report deals with "Energy and economic development" and the relationship of energy and economic growth to energy consumption per capita. The contribution of renewable energy sources to the development of rural energy will be elaborated with respect to the end-use energy needs of rural and remote communities.

The availability of solar and wind resources to meet requirements of renewable energy technologies is discussed in chapter III, "Assessment of renewable sources of energy in the ESCWA region". In chapter IV, "Assessment of renewable energy technologies", an overview is provided of the following: the state of the art of solar technologies and various utilizations such as space heating and cooling; domestic, industrial and commercial uses of heated water; and electricity generation by thermodynamic conversion and by photovoltaic ells. The utilization of wind technologies for water pumping, water desalination and electricity generation are also elaborated in chapter IV.

Chapter V, "Potential application of solar and wind technologies", reviews the present stage of utilization of solar and wind energy, past and current projects undertaken by member States, and investigates the social and environmental acceptability of these applications with regard to ongoing activities of ESCWA member States. Chapter VI, "Development of renewable energy technologies infrastructure", identifies the research, development and demonstration (R, D and D) activities pertaining to new and renewable sources of energy (NRSE) in the region. The chapter also contains a discussion of the prerequisite infrastructural setting for development and penetration of solar and wind application in the region, such as the role of government, local manufacturing capability, economic viability and opportunities for regional co-operation. In this regard, chapter VII, "Institutional setting for the application of solar and wind energy", outlines the incorporation of renewable energy resources in energy planning, policy co-ordination and the manpower development and training which are fundamental to any successful promotion and commercialization of renewable energy technologies.

The report concludes with recommendations for the acceleration of applications of solar and wind technologies in the short and long term by:

- Building up the renewable energy industry through fully equipped, skilled manpower supported by the necessary infrastructure;
- Inclusion of renewable energy resources in energy planning;
- Promotion of regional and subregional co-operation in R, D and D and in manufacturing renewable energy equipment/components to avoid any duplication and to utilize efficiently the financial resources and skilled labour force in short supply in most countries of the region.

II. ENERGY AND ECONOMIC DEVELOPMENT

There is a tangible recognition of the critical role of energy in the ESCWA countries. Economists and policy-makers of the region have become more aware of the complexity of the relationship between energy consumption and economic and social development. High energy consumption has generally been associated with industrialization, economic development and a high standard of living.

In the past, energy was not explicitly considered in many economic development plans, since it was cheap and abundant either through imports or from domestic sources. However, with the passing of the era of inexpensive petroleum in 1973, the prices of energy and its derivatives will continue to increase as the supply of accessible resources is being reduced. Together with other factors such as labour and capital, energy is now considered one of the essential inputs into the economic process. The level of economic development of a country is therefore related to the energy consumption of its people. In fact, energy consumption has often been used in all developed and developing countries as one of the reliable indices of a country's economic development.

The majority of ESCWA countries are endowed with conventional hydrocarbon resources. The proven and potential oil and gas reserves of these countries can sustain their economic growth for decades to come. Table 2.1 shows the proven oil reserves and natural gas reserves for ESCWA countries(6) for the years 1981-1985. Saudi Arabia has the largest crude oil reserves, followed by Kuwait, Iraq, the United Arab Emirates, Oman, Egypt, Qatar, the Syrian Arab Republic and Bahrain. As for natural gas, the largest reserves exist in Qatar, Saudi Arabia, Kuwait, the United Arab Emirates and Iraq respectively. The rest of the countries mentioned in table 2.1 have natural gas reserves ranging between 35 billion cubic metres and 201 billion cubic metres.

With the exception of oil and gas resources, the region is not largely endowed with fossil fuels such as coal. However, unevaluated coal deposits have been found in Lebanon, the West Bank, Oman and the Yemen Arab Republic. Large lignite deposits in the Mogamaa area near Riyadh in Saudi Arabia are currently being evaluated. Only Egypt has proven coal reserves of 35.5 million tons in the Maghara basin in Sinai.

The hydropower resources are still low in the ESCWA region. However, some ESCWA countries have substantial hydropower potential. For example, as a percentage of the total energy production, total hydroelectricity production is about 40 per cent in Egypt, 11 per cent in Iraq and a very small percentage in Jordan, Lebanon and the Syrian Arab Republic. As such, the region's potential of hydroelectricity has not been utilized fully.

With this information as a background, one may divide ESCWA countries into various subgroups distinguishing their resource and infrastructural endowments. Iraq, for instance, is rich in hydrocarbon and hydroelectricity with a relatively large population to enable the country to embark on industrial and agricultural development projects. The GCC countries are endowed with significant oil and gas resources and produce accordingly, but their population is rather small. Countries such as the Syrian Arab Republic, Egypt, Jordan and Lebanon, though either self-sufficient in oil and gas resources or net importers of oil, have a rather strong infrastructure in comparison with other ESCWA countries. The two least developed countries, the People's Democratic Republic of Yemen and the Yemen Arab Republic, have the lowest per capita gross national product (GNP) in this group. The gross domestic product (GDP) per capita at current prices for the ESCWA region(7) and the real GDP growth in 1983-1984 along with other basic indicators in 1984(8) are shown in annexes I and II respectively. The figures in annex I also show that Qatar, the United Arab Emirates, Kuwait, Bahrain, Saudi Arabia and Oman, which are countries with surplus oil income, have high per capita GDPs. However, the region's GDP, which dropped by 4 per cent at constant prices in 1985, decreased by a further 6 per cent at constant prices in 1986 owing to declining oil prices and the related depreciation of the United States dollar.

In the ESCWA region, the oil sector plays a significant role in generating income and employment for oil exporting countries. The contribution of the oil sector to the GNP of ESCWA countries varies according to the resource base of these countries. Much of the increase in the GDP of these countries is reflected in annexes I and II(9). By the same token, the high consumption of energy in these countries is a reflection of the high income generated by the oil sector.

2.1 Production and consumption of commercial energy

The production of primary energy in ESCWA countries slightly increased during the period 1981-1984, except in Lebanon, Qatar, Saudi Arabia and the United Arab Emirates, which decreased their production. Tables 2.2 and 2.3 show the level of production and consumption of energy in those countries(9). According to recent information(6), production of crude oil decreased by 12.3 per cent in Kuwait, 26.4 per cent in Qatar and 18.3 per cent in Saudi Arabia, while Egypt, Iraq and the United Arab Emirates increased their production by 11.7 per cent, 16.8 per cent and 5.3 per cent respectively; the production levels in Bahrain and the Syrian Arab Republic remained unchanged in 1984-1985.

Table 2.4 summarizes the production and consumption of electricity in ESCWA countries from 1981 to 1984(8). In terms of energy consumption per capita, Qatar was leading with 11,770 kWh, then followed by Kuwait, the United Arab Emirates, Bahrain, Saudi Arabia, Oman and Iraq with 8,336 kWh, 5,288 kWh, 4,966 kWh, 2,878 kWh, 1,418 kWh, and 1,218 kWh respectively. Democratic Yemen had the lowest energy consumption per capita with 10 kWh.

The commercial energy consumption in some ESCWA countries has been rising due to their economic growth and substantial social development as shown in table 2.5(7).

The average annual increase in the energy consumption of ESCWA countries fell from 15.5 per cent in 1965-1973 to 13.3 per cent in 1973-84. One of the main reasons that the oil exporting countries of the ESCWA region have shown a decline in the growth of energy consumption rates in recent years is the decline in oil revenues.

Table 2.1. Proven oil reserves and natural gas reserves in some ESCWA countries

Country	Proven oil reserves (Billion barrels at year end)					Natural gas reserves (Billion cubic metres)				
	1981	1982	1983	1984	1985	1981	1982	1983	1984	1985
Bahrain	0.2	0.2	0.2	0.2	0.16	243	223	210	206	201
Egypt	2.9	3.3	3.5	3.2	3.9	83	203	201	198	200
Iraq	29.7	59.0	65.0	65.0	65.0	773	816	921	921	921
Kuwait	67.7	67.2	66.8	92.7	92.5	981	966	879	1038	1037
Oman	2.6	2.7	2.8	3.5	4.0	76	76	80	209	170
Qatar	3.4	3.4	3.3	3.4	3.3	1699	4249	4249	4249	4193
Saudi Arabia	164.8	168.3	168.9	171.7	171.5	3346	3433	3544	3610	3544
Syrian Arab Republic	1.9	1.5	1.5	1.5	1.4	41	36	36	36	35
United Arab Emirates	32.2	32.4	32.3	32.5	33.0	658	810	884	906	929
Total	305.4	338.2	344.3	373.5	374.76	7900	8319	11289	11373	11230

Source: OAPEC Secretary General's Twelfth Annual Report, AH 1405/AD 1985. Kuwait, 1986.

Table 2.2. Production of energy in the ESCWA countries

Country	Year	Crude oil	Primary energy production (x 1,000 metric tons of oil equivalent per year)				
		1,000 b/d	Solids	Liquids	Gases	Electricity	Total
Bahrain	1981	46	**	2,632	2,694	**	5,326
	1982	44	**	2,517	2,961	**	5,478
	1983	42	**	2,422	2,954	**	5,375
	1984	42	**	2,337	3,375	**	5,712
Democratic Yemen	1981	**	**	**	**	**	**
	1982	**	**	**	**	**	**
	1983	**	**	**	**	**	**
	1984	**	**	**	**	**	**
Egypt	1981	603	**	29,824	1,747	864	32,435
	1982	624	**	33,221	1,947	886	36,053
	1983	682	**	36,459	1,937	888	39,284
	1984	780	**	41,873	2,540	889	45,302
Iraq	1981	897	**	44,288	313	58	44,660
	1982	1,012	**	49,979	318	52	50,348
	1983	1,099	**	54,045	314	51	54,410
	1984	1,222	**	58,718	253	52	59,023
Jordan	1981		**	**	**	**	**
	1982		**	**	**	**	**
	1983		**	**	**	**	**
	1984		**	**	**	**	**
Kuwait	1981	1,130	**	59,038	5,495	**	64,534
	1982	823	**	43,004	4,198	**	47,202
	1983	1,052	**	55,513	4,610	**	60,123
	1984	1,160	**	61,450	5,043	**	66,493
Lebanon	1981	**	**	**	**	72	72
	1982	**	**	**	**	55	55
	1983	**	**	**	**	47	47
	1984	**	**	**	**	49	49
Oman	1981	328	**	16,709	2,816	**	19,525
	1982	336	**	21,409	2,565	**	23,974
	1983	389	**	24,063	3,590	**	27,653
	1984	416	**	25,677	5,294	**	30,972

Table 2.2 (Cont'd)

Country	Year	Crude oil	Primary energy production (x 1,000 metric tons of oil equivalent per year)				
		1,000 b/d	Solids	Liquids	Gases	Electricity	Total
	1981	405	**	20,626	4,553	**	25,179
Qatar	1982	328	**	16,620	4,222	**	20,842
	1983	294	**	14,266	3,572	**	17,838
	1984	402	**	19,695	3,870	**	23,564
	1981	9,808	**	504,713	939	**	505,651
Saudi	1982	6,483	**	337,870	1.173	**	339,043
Arabia	1983	4,569	**	260,310	1,173	**	261,483
	1984	4,079	**	241,100	1,173	**	242,273
Syrian	1981	163	**	8,520	44	225	8,789
Arab	1982	138	**	8,191	46	250	8,488
Republic	1983	161	**	9,359	69	237	9,665
	1984	162	**	9,505	59	243	9,807
United	1981	1,502	**	73,963	8,025	**	81,988
Arab	1982	1,248	**	65,622	3,976	**	69,598
Emirates	1983	1,118	**	60,960	3,495	**	64,455
	1984	1,142	**	61,082	3,494	**	64,576
	1981	**	**	**	**	**	**
Yemen Arab	1982	**	**	**	**	**	**
Republic	1983	**	**	**	**	**	**
	1984	**	**	**	**	**	**

Source: Data extracted from table 2 of the United Nations Energy Statistics Yearbook 1984. New York, 1986.
OAPEC, Secretary General's Twelfth Annual Report, AH 1405, AD 1985. Kuwait, 1986.

** Not applicable

Table 2.3. Energy consumption in the ESCWA countries

Country	Year	Primary energy consumption (x 1,000 metric tons of oil equivalent)					
		Solids	Liquids	Gases	Electricity	Total	Per capita kg o.e.
Bahrain	1981	0	394	2,694	**	3,088	8,507
	1982	0	398	2,961	**	3,360	8,842
	1983	0	355	2,954	**	3,308	8,332
	1984	0	395	3,375	**	3,370	9,106
Democratic Yemen	1981	***	799	**	**	799	419
	1982	***	1,096	**	**	1,096	560
	1983	***	1,176	**	**	1,176	585
	1984	***	1,218	**	**	1,218	590
Egypt	1981	750	12,834	1,747	864	16,195	383
	1982	835	13,835	1,947	886	17,502	403
	1983	585	14,660	1,937	888	18,070	406
	1984	656	16,033	2,540	889	20,118	441
Iraq	1981	1	5,212	313	58	5,585	408
	1982	1	5,235	318	52	5,604	396
	1983	1	5,174	314	51	5,539	378
	1984	1	5,277	253	52	5,582	368
Jordan	1981	**	1,713	**	***	1,713	568
	1982	**	1,917	**	***	1,917	613
	1983	**	2,076	**	***	2,076	639
	1984	**	2,318	**	***	2,318	687
Kuwait	1981	**	1,603	5,495	**	7,098	4,885
	1982	**	2,597	4,198	**	6,796	4,424
	1983	**	3,477	4,610	**	8,088	4,996
	1984	**	2,836	5,043	**	7,879	4,627
Lebanon	1981	4	1,644	**	76	1,723	650
	1982	2	1,092	**	58	1,151	436
	1983	0	1,296	**	51	1,346	511
	1984	0	1,501	**	52	1,553	587
Oman	1981	**	940	2,816	**	3,756	3,654
	1982	**	5,267	2,565	**	7,832	7,259
	1983	**	5,375	3,590	**	8,966	7,927
	1984	**	5,660	5,294	**	10,954	9,275
Qatar	1981	**	429	4,553	**	4,983	19,239
	1982	**	495	4,222	**	4,717	17,470
	1983	**	546	3,572	**	4,118	14,655
	1984	**	531	3,870	**	4,400	15,120
Saudi Arabia	1981	**	20,149	939	**	21,087	2,190
	1982	**	24,205	1,173	**	25,378	2,531
	1983	**	26,955	1,173	**	28,128	2,699
	1984	**	25,923	1,173	**	27,097	2,503

Table 2.3. (cont'd)

Country	Year	Solids	Liquids	Gases	Electricity	Total	Per capita kg o.e.
Syrian Arab Republic	1981	6	7,048	44	221	7,320	803
	1982	7	6,143	46	239	6,435	680
	1983	5	5,935	69	225	6,235	635
	1984	4	6,028	59	232	6,323	621
United Arab Emirates	1981	**	3,560	5,596	**	9,156	8,630
	1982	**	5,555	1,240	**	6,795	6,003
	1983	**	5,536	1,280	**	6,816	5,699
	1984	**	5,723	904	**	6,628	5,281
Yemen Arab Republic	1981	**	433	**	**	433	73
	1982	**	799	**	**	799	131
	1983	**	839	**	**	839	135
	1984	**	869	**	**	869	136

Source: Data extracted from Table 2 of the United Nations Energy Statistics Yearbook 1984. New York, 1986.
** Not applicable *** Not available

Table 2.4. Production and consumption of electricity in ESCWA countries

Country	Year	Production GWh	Consumption	
			Total GWh	Per capita kWh
Bahrain	1981	1,814	1,814	4,997
	1982	2,009	2,009	5,287
	1983	2,026	2,026	5,103
	1984	2,056	2,056	4,966
Democratic Yemen	1981	65	65	10
	1982	50	50	8
	1983	40	40	6 (49)
	1984	70	70	10
Egypt	1981	21,310	21,310	503
	1982	22,576	22,576	520
	1983	22,800	22,800	512 (579)
	1984	22,870	22,870	501
Iraq	1981	10,974	10,974	802
	1982	13,708	13,708	968
	1983	16,200	16,200	1,106
	1984	18,460	18,460	1,218
Jordan	1981	1,237	1,237	410
	1982	1,512	1,512	484
	1983	1,918	1,918	591 (765)
	1984	2,304	2,304	683
Kuwait	1981	10,336	10,336	7,114
	1982	12,016	12,016	7,823
	1983	12,830	12,830	7,925 (8241)
	1984	14,196	14,196	8,336
Lebanon	1981	1,810	1,856	700
	1982	1,290	1,320	501
	1983	1,220	1,260	478 (886)
	1984	1,355	1,385	524
Oman	1981	1,148	1,148	1,117
	1982	1,381	1,381	1,280
	1983	1,623	1,623	1,435 (961)
	1984	1,675	1,675	1,418

Table 2.4 (Cont'd)

Country	Year	Production GWh	Consumption Total GWh	Consumption Per capita kWh
Qatar	1981	2,772	2,772	10,703
	1982	3,089	3,089	11,441
	1983	3,315	3,315	11,797
	1984	3,425	3,425	11,770 (12,679)
Saudi Arabia	1981	25,061	25,061	2,603
	1982	31,014	31,014	3,094
	1983	29,915	29,915	2,871 (3381)
	1984	31,150	31,150	2,878
Syrian Arab Republic	1981	4,564	5,418	495
	1982	5,737	5,608	593
	1983	6,312	6,175	629
	1984	6,757	6,622	650
United Arab Emirates	1981	6,210	6,210	5,853
	1982	6,470	6,470	5,716
	1983	6,570	6,570	5,493 (7320)
	1984	6,636	6,636	5,288
Yemen Arab Republic	1981	228	228	38
	1982	279	279	46
	1983	285	285	46 (251)
	1984	295	295	46

Source: United Nations Energy Statistics Yearbook 1984. New York, 1986.
Note: Data in brackets are taken from M. Al-Emady, "Investment Requirements in Electricity Sectors of the Arab Countries for 1985-2000." Proceedings of the Third Arab Energy Conference, Vol.5, p.67. OAPEC, 1985.

Table 2.5. Commercial energy growth in ESCWA countries

Country	Average annual energy growth (per cent)			
	Energy Production		Energy Consumption	
	1965-1973	1973-1984	1965-1973	1973-1984
Bahrain	**	30.7(a)	**	30.7(a)
Democratic Yemen	**	**	-10.7	7.0
Egypt	10.0	15.6	- 0.7	11.2
Iraq	4.5	- 7.1	6.2	6.4
Jordan	**	**	4.3	14.8
Kuwait	4.3	- 9.1	2.6	2.8
Lebanon	2.4	- 0.7	6.1	- 3.8
Oman	57.2	4.6	89.7	8.5
Qatar	**	47.0(a)	**	47.0(a)
Saudi Arabia	15.7	- 3.0	12.4	7.4
Syrian Arab Republic	164.4	3.3	9.7	11.8
United Arab Emirates	24.1	- 2.2	65.3	18.6
Yemen Arab Republic	**	**	16.5	21.7

Source: Data extracted from table 8, p. 184, of the World Development Report 1986. World Bank, May 1986.

(a) Data taken from Statistical Abstract of the Region of the ESCWA Baghdad 1986.

** Not available

2.2 Role of renewable energy sources in economic development

The above analysis of the energy scene in the ESCWA countries reveals that the excessive consumption of oil and natural gas in the oil-producing countries of the region has a negative effect on the balance of payments of imported oil in the non-oil-producing countries. The level of oil and natural gas reserves has continued to force the countries of the region to take appropriate measures in energy conservation and to adopt a policy of substituting other sources of energy for oil and of meeting a greater part of the essential demand for energy by increasing the utilization of local conventional resources and NRSE.

In fact, at the Regional Preparatory Expert Group Meeting for the Nairobi Conference, held in Beirut from 12 to 16 January 1981, experts supported the policy of energy transition from the current hydrocarbon-based energy mix to a more diversified mix in order to secure balanced and sustained growth of the economy. For the countries of the ESCWA region, such efforts to diversify energy sources would have a twofold effect on the process of national development, that is, energy security and supply to the rural areas through development of traditional energy that was largely new and renewable.

In accordance with General Assembly resolution 36/193, entitled "United Nations Conference on New and Renewable Sources of Energy" and adopted on 17 December 1981, the ESCWA secretariat has carried out numerous activities involving new and renewable sources of energy, with emphasis on the importance and consequences of utilizing renewable sources of energy in this particular region, which aspires to the application of new technologies, including renewable energy technologies. Should there be a transition from conventional-based energy to a new mix of conventional and renewable sources of energy in the early part of the twenty-first century, the ESCWA countries have to embark on serious research, development and demonstration in this area, and at the same time ensure that they do not lose from importing pre-packaged technology, as in the case of hydrocarbon technology for which the region is still dependent on exogenous sources.

The other factor is the question of natural depletability of hydrocarbon resources in the region. Though some countries have tremendous reserves of oil, gas, or both, the actual global demand on hydrocarbons will shorten the life span of such reserves. Actually, the region has no significant other fossil fuel resources, such as coal, and nuclear energy has not been used yet. All these factors increase the regional demand for energy in addition to the global demand and thus hasten the rate of depletion. On the other hand, renewable energy sources, characterized by their low energy densities but nearly universal local availability, require for their collection areas and materials almost in proportion to the capacity size of the installation. However, because renewable energy systems are usually decentralized, they offer the advantage of providing energy options in locations where commercial sources of energy are not available, or available but at very high cost.

It is well known that the majority of people in the ESCWA region live in rural and remote areas where new and renewable sources of energy such as biomass, solar and wind energy could be utilized in order to alleviate the energy shortage.

At the fifth session of the ESCWA Technical Committee held from 31 March to 2 April 1987 in Baghdad(10), the Committee discussed the energy activities of the ESCWA secretariat and stated that it would be necessary "to conserve oil resources and to control oil consumption in the coming decades by developing new and renewable sources of energy with a view to reducing the consumption of oil and gas". However, the development and the acceleration of utilization of new and renewable sources of energy in the region were constrained not only by the state of the art, but also by difficulties related to application of the renewable energy technologies. Even for some technically mature technologies based on new and renewable sources of energy, this application requires that they become commercially viable by overcoming barriers to cost effectiveness, market penetration, social acceptance and that they acquire adequate trained personnel to construct, operate and maintain the equipment(11). Such requirements are especially necessary owing to the heavy state subsidies for energy prices (table 2.6), which make the cost of some NRSE uneconomical(12).

Table 2.6. <u>Electric energy pricing</u>

Country	Currency	Average cost of MWh at the end-user		Total average		Average Government subsidy	
		L.C.	US.$	L.C.	US.$	L.C.	US.$
Democratic Yemen	YD	-	-	47	136	4	10
Egypt	LE	12(UHV) 14(HV) 30(MV) 34(LV)	14.5 17 37 42	13	16	21	26
Kuwait	KD	32	110	2	6.9	30	103
Oman	OR	45	130	20	58	25	72.5
Qatar	QR	260	62	60	14	200	48
Saudi Arabia	SR	170	49	60	17.5	110	32
Syrian Arab Republic	SL	460	84	200	37	260	48
United Arab Emirates	DH	450	135	66	20	384	115
Yemen Arab Republic	YR	1470	318	1140	250	330	68

<u>Source</u>: UNESCWA. Electric Power, Generation and Distribution, and Opportunities for Co-operation in the ESCWA Region. E/ESCWA/NR/85/8. Baghdad, 22 October 1985.

L.C. = Local currency

US $ = United States dollars equivalent

2.3 Energy and rural development

The development, supply and use of energy in rural and remote areas has generated great interest in most ESCWA countries, which have increased efforts to achieve some measure of rural development in order to eradicate rural poverty. Energy is playing an important role in this exercise in which new and renewable sources of energy could be utilized to fulfil subsistence and development needs in rural and remote areas. The basic energy requirements in these areas are as follows:

(a) Energy for cooking and preserving food;

(b) Lighting of homes, schools, community centres and dispensaries;

(c) Mechanical power to supplement and/or replace manual labour indifferent operations like pumping water, plowing, planting, weeding, grinding, harvesting, threshing, drying, and transporting of people and agricultural outputs;

(d) Fertilizer and chemicals, which need to be processed so that they may supplement natural fertilizers;

(e) Electricity for operating transistor radios, educational television sets and small essential household appliances.

The energy resources available in most rural and remote areas in the ESCWA region are biomass, solar and wind energy. However, data available on renewable sources and energy consumption in rural areas are not sufficient in most ESCWA countries, except Jordan, which has built a data base concerning the current status of services in towns, villages and settlements(2) and, to some extent, Egypt and Democratic Yemen, which have carried out studies on energy in rural areas through the use of biogas technology(13 and 14).

For rural and remote communities in the ESCWA region, the energy requirements that could be covered, for example, by solar and wind energy are given as follows(15):

Estimates of annual per capita total energy needs for rural areas

(a) Basic needs	Estimated total energy need in kWh/capita/yr.
- Domestic water pumping and water supply assuming 0.12 cubic metre water consumption/ person/day, total pumping head of 100 m, and overall hydraulic efficiency 50 per cent	24
- Water sanitation	15
- Potable water supply and purification	2
- Lighting (24 watt/person for 4 hours a day and a total conversion and distribution efficiency of 70 per cent)	50
- Education and communication devices	4
Total basic needs	95

(b) Irrigation requirements

The amount of water needed for irrigation depends on the crop, climatic conditions, kind of land and efficiency of water use. This amount ranges between approximately 25 cubic metre/ha/day for drip irrigation (corn, wheat, cotton, millets) and 60 cubic metre/ha/day for flood irrigation (100 cubic metre/ha/day for rice, 70 for sugar-cane, 50 for cotton and 45 for other grains). In addition, the drinking water requirements for animals are as follows:

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

The total daily water needs (Q cubic metre/day) could be estimated by knowing the population, number of animals and the area of land to be cultivated.

Thus, the energy required to cover the needs for water pumping may be approximately calculated as:

$\underline{(Q \times H)/N}$, where N is the hydraulic efficiency (= 0.5 - 0.7); where H is the total pumping head in metres, which is the sum of the pump depth (depth of water resource), storage tank height and the head loss resulting from water flow through pipes.

(c) Long-term energy needs

- Food preservation	42	kWh/capita/year
- Space cooling	91	" " "
- Cooking (one kW for 2.5 hours a day per family with efficiency 70 per cent)	263	" " "
- Basic needs	95	" " "
Total future energy demand	491	" " "

III. ASSESSMENT OF RENEWABLE SOURCES OF ENERGY IN THE ESCWA REGION

3.1 Solar energy

Solar energy users require solar data on global, incident, reflected and diffuse radiation in various forms depending on the exact nature of the application. These data are required for:

(a) Engineering design of collectors and storage systems;

(b) Evaluation of collector efficiency and solar energy system calibration;

(c) Research on short-term and long-term predictions of solar radiation.

The first engineering design calls for solar radiation data in order to choose a suitable site from among several locations and to design the most efficient collector and storage system after the site is chosen. Average values of hourly solar radiation, their extreme values and the standard deviation, which constitutes a good measure of natural variability, and relevant climatological data are required for optimizing the performance of the systems, taking into consideration the inclination of the collector. Storage systems require additional information on the persistence of solar radiation greater than a fixed threshold value. Sometimes climatological data will have to be supplemented by actual measurements at the particular location.

The second requirement calls for solar radiation measurements, taken immediately next to an operating solar collector, from which the efficiency of the collector may be evaluated.

The third requirement calls for very precise measurements of a number of parameters that will enable the scientist to understand the atmospheric and environmental properties that attenuate solar radiation, to determine the amount of it received on the ground and to study long-term trends in the transmission of solar radiation through the atmosphere. Finally, for predictions of solar radiation from one to several days in advance, or on time scales of years or longer, co-ordinated studies by scientists in different disciplines are required.

Estimates of solar energy potential in different parts of a country rely mainly on past data and statistics. The well-marked seasonal variations as well as the day-to-day variability in the global solar radiation received in different parts of the country will find useful applications in system design.

The inclination of the collector and the albedo of the vicinity have to be considered in the case of flat plate solar collectors. Environmental factors such as the ambient air temperature and windspeed are required for calculating the performance of the system, taking into account the heat exchange with the environment.

The following table lists the radiation parameters and associated meteorological factors required for specific problems in solar energy utilization(16, 17 and 18).

Solar radiation parameters and associated meteorological factors

Purpose	Parameters needed
Water heating and space heating	Detailed information on global solar radiation, frequency distribution of solar insolation, air temperature, windspeed, and cross correlation of solar radiation and air temperature or wind speed
Passive house heating systems	Information on direct radiation, reflected radiation, incident radiation, as well as global solar radiation, air temperature, wind speed and air humidity
Solar cooling systems	Global solar radiation, incident and reflected radiation, air temperature, wind speed, frequency distribution of global solar radiation and long-wave radiation
Concentrating systems	Direct and diffuse solar radiation, and its frequency distribution
Solar heat engines and solar thermodynamic generators	Direct and diffuse solar radiation, and its frequency distribution, air temperature and wind speed
Photovoltaic power generators	Global solar radiation, spectral distribution of the radiation, air temperature and wind speed

Source: WMO. Meteorological Aspects of the Utilization of Solar Radiation as an Energy Source. Technical Note No. 172. WMO-No. 557, 1981.

The following paragraphs review briefly the solar data collection activities in the ESCWA countries.

In Bahrain(19), data on global and diffuse solar radiation are collected by the Bahrain Oil Company, which was commissioned by the Ministry of Development and Industry.

In Democratic Yemen(20), a study on solar radiation has been completed by the College of Technology at the University of Aden in order to establish a reliable data base for the assessment of renewable sources of energy in the country.

Egypt(21) has carried out extensive programmes for the assessment of solar resources and established a reliable data base on solar energy.

In Jordan(22), the Solar Energy Research Centre of the Royal Scientific Society has established its own solar measuring network to carry out the assessment of renewable sources of energy of the country. The Jordanian Meteorological Department records all solar energy parameters at their meteorological stations installed at different locations in the country.

In Iraq, the Meteorological Department and some universities and research institutes collect data on solar radiation. The Solar Energy Research Centre intends to expand the solar radiation network in Iraq and to establish a data base for various solar radiation parameters.

In Kuwait(23), a completed solar measurement station has been installed at the Kuwait Institute for Scientific Research to monitor and record solar radiation data and other climatological parameters.

In Lebanon(24), the National Council for Scientific Research is collaborating with the National Meteorological Service to install 12 stations for the measurement of solar radiation in different sites in the country.

In Oman(25), there are 25 meteorological stations in different parts of the country to record solar radiation data. A private firm has commissioned an expert to assess the solar energy source in Oman.

In Qatar(26), the Industrial Development Technical Centre has implemented an important pilot project in the field of energy in which a meteorological and solar measurement station has been installed. Also, there exists a meteorological department which is very well and modernly equipped for solar and wind data collection and processing.

In October 1977, Saudi Arabia(27) and the United States of America signed a Programme Agreement for Co-operation in the field of Solar Energy, entitled SOLARAS. The resource development programme, one of the SOLARAS programmes, involves a data collection programme predominantly of solar and meteorological data within the country and provides the other programmes with quantitative data on solar energy resources that are helpful in developing the systems design necessary in each area of solar technology. A solar map of Saudi Arabia has been published by King Abdul Aziz City for Science and Technology (KACST).

In the Syrian Arab Republic, solar radiation data are recorded at the meteorological stations.

In the United Arab Emirates, solar radiation data are recorded at the country airport and meteorological stations.

In the Yemen Arab Republic(28), various studies on the potential of solar energy were carried out in co-operation with the United Nations and some foreign specialized agencies.

Figure 3.1 shows isopleths of equal daily total incoming insolation averaged over an entire year in ESCWA countries(3). From this map, it is seen that ESCWA countries are located in an area of very high insolation and can be divided in four regions:

(a) Areas of extremely high insolation (between 240 and 280 W/square metre): south-west area of Saudi Arabia;

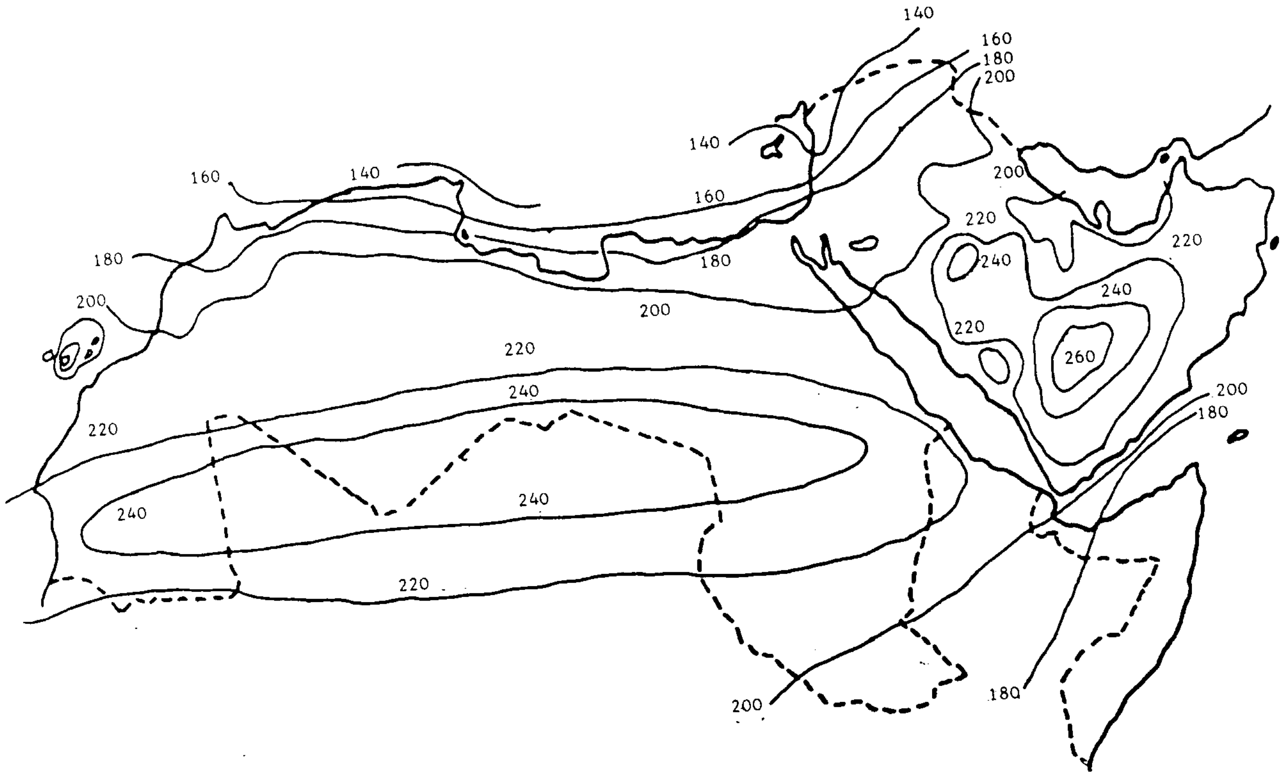
(b) Areas of very high insolation (between 200 and 240 W/square metre): Upper Egypt and most of Saudi Arabia;

(c) Areas of high insolation (between 160 and 200 W/square metre): Lower Egypt, Jordan, most of Iraq, Qatar and the United Arab Emirates;

(d) Areas of moderate insolation (between 120 and 160 W/square metre): Lebanon and the northern part of the Syrian Arab Republic.

Figure 3.1 Yearly average isopleths; equal insolation receive at ground surface

(Values in watt/square metres)



The average insolation received by the ESCWA countries is in the range of 240 to 250 watts/square metre and hours of sunshine are in excess of 3,000 hours per year. Table 3.1 shows the insolation received by ESCWA countries(16).

Table 3.1. Average insolation in ESCWA countries

Country	Insolation watt/square metre
Bahrain	225
Democratic Yemen	280
Egypt	200
Iraq	225
Jordan	200
Kuwait	225
Lebanon	200
Oman	225
Qatar	225
Saudi Arabia	250
Syrian Arab Republic	200
United Arab Emirates	225
Yemen Arab Republic	280

It appears that the practical limit for the use of solar energy devices falls within average insolation values of 172 to 240 W/square metre, which are attained 90 to 100 per cent of the time during the year in the ESCWA countries.

3.2 Wind energy

Wind energy is the kinetic energy associated with movement of large masses of air resulting from uneven heating of the atmosphere by the sun. The total annual kinetic energy of the world's winds is estimated to be about 30 x 10^6 TWh per year. The technically usable potential is assumed to be limited to theoretically 30 x 10^3 TWh per year.

When considering wind-power potentialities, the most important features of wind behaviour are the changes in speed and direction which occur in the first 30 to 50 metres above the ground level in the area where windmills might be located. At no point on the surface of the earth are these constant. The speed varies continuously, though sometimes the fluctuations are a small enough percentage of the mean speed for this to be taken as relatively constant: at other times, in gusty winds, the changes in speed are very rapid and considerable in magnitude. The direction also varies during any appreciable length of time.

The time scale is important for both speed and direction. The annual mean wind speed at a selected site is a measure of the energy available. Variations in this annual mean, from year to year, are usually fairly small, so that the annual energy to be obtained from a windmill can be relied upon up to 10 to 20 per cent. Monthly mean speeds also allow a recognizable pattern in most areas, so that there are certain months in which the mean speed can be expected to be higher than the annual mean and others in which it is lower. The changes in hourly mean windspeed throughout the year may cover the range from zero to perhaps 28 or 35 m/s, while, at the approach of a storm, this mean value may rise from a metre per second to 16 or 25 m/s within the space of an hour or even less.

Changes in the direction of the wind are usually much less rapid. Although swings of perhaps 20 or 30 degrees on either side of a steady direction may frequently occur, this steady direction generally persists for some hours.

For wind-power purposes, wind measurements are made with one of three main objects in mind, as follows:

(a) To determine the wind regime at possible wind power sites and to gather information on the annual energy that might be obtained;

(b) To study the vertical and horizontal distribution of wind at a site;

(c) To study wind structure, including gust measurements, and to provide wind data for the testing of the performance of wind-energy conversion systems.

The power in the wind, proportional to the cube of the speed, is thus also changing continuously, but it can easily be appreciated that measurements of instantaneous wind speeds are not needed. In the first place, a windmill cannot respond, in an easily determinable way, to rapid changes in wind speed and, secondly, the work of analysis following such measurements would be prohibitively lengthy. Hourly mean wind speeds are therefore chosen as a reasonable compromise. The power in a wind stream of a cross-sectional area A, when it is moving at a speed V, is $P = 0.61\ A\ V^3$, where the multiplier 0.61 is determined by considering that air density is equal to 1.225 kgm/cu.m at 15^oC and standard atmospheric pressure at sea level (P in watts, A in square metres and V in m/s).

Information on wind patterns in most ESCWA countries can be found in the records of the national meteorological services, of the oil companies and at the national airport. Although these records do not cover the entire territory of the country, they do provide a general idea of the potential wind resource of the country and are usable when an official assessment is not available.

In Bahrain wind speeds and directions are measured at the national airport by the meteorological service.

The Meteorological Service of Democratic Yemen has collected information obtained from wind speeds and directions measured at the country's airports.

The Egyptian Meteorological Authority(21) has its own weather station network covering almost all the territory to record wind speeds and directions. The oil companies and the Nuclear Plants Authority also have their own measuring stations. However, the wind data recorded by these stations were related to the general wind regime at the sites surrounding the observation stations and not for the requirements of a wind resource assessment.

The Ministry of Electricity and Energy of Egypt(21) has conducted a study on wind resource assessment, in which six measuring stations were installed in different sites along the Red Sea Coast and the Mediterranean Coast. The measurements of wind speeds and directions covering a one year period have already been made available. Six additional measuring stations were installed during 1986 in other locations, including the Sinai region.

In Jordan(22), there are several meteorological stations which measure wind speeds and direction located all over the country and run by the Jordanian Meteorological Department. The Royal Scientific Society also has its own wind data measuring network for wind resource assessment in Jordan.

In Iraq, data of wind speeds and directions are recorded at the country airport by the meteorological service and at some universities and research institutes working in the field of renewable sources of energy.

In late 1983 in Kuwait, a wind resource assessment was conducted by the Kuwait Institute for Scientific Research to compile a computerized wind speed data base to analyse and assess the acquired data for the potential wind energy in the country.

In Lebanon, the National Council for Scientific Research(24) has recorded wind speeds and directions for the study of wind energy utilization in coastal areas.

In Oman(25), there are 25 meteorological stations in different parts of the country to record wind data. A wind resource assessment has been undertaken.

In Qatar, data on wind speeds and directions are recorded at the country airport and at the site of the solar energy project in Um Said.

In Saudi Arabia(27), data on wind speed and directions have been collected under the SOLARAS programme.

In the Syrian Arab Republic, data on wind speeds and directions are measured by meteorological stations and by different departments and research institutes in the field of renewable sources of energy.

In the United Arab Emirates, data on wind speeds and directions are recorded at the country airport.

In the Yemen Arab Republic(28) data on wind speeds and directions are recorded at the country airport and at Sana'a University.

Table 3.2 shows the wind potential in 23 selected sites of the ESCWA region.

Table 3.2 Wind potential in selected sites of the ESCWA region

Country	Site	Lat. N	Longt. E	Source of data	Period	Height (m)	Annual mean Wind speed m/s	Annual mean Wind power density W/m^2	Energy pattern factor EPF
Bahrain	Muharraq	26° 16'	50° 27'	OCWCS	1959-1968	10	4.57	139	2.387
Democratic Yemen	Aden Airport	12° 05'	45 03'	MD	1968-1984	10	4.0	112	2.87
	Riyan Airport	14 38	49 12	MD	1973-1984	10	3.6	102	3.58
	Socotra Island	12 02	54 0	MD	1976-1978	10	6.6	441	2.5
Egypt	Ras Ghareb	28° 22'	33° 04'	EEA	1983	10	6.88	314	1.6
	Hurghada	27 17	33 46	EMA	1943-1975	12	6.3	283	1.13
	Abo Ghossoun	27 -	33 -	EEA/EMA	1983	10	4.93	148	1.23
	East Oainatt	22 54	28 24	GPC/EEA	1984	10	5.6	164	1.53
Jordan	Ras Muneef	32° 22'	35° 05'	RSS	1984	10	6.6	364	2.08
Kuwait	Al-Ahmadi	29° 4'	48° 10'	OCWCS	1960-1972	10	5.3	170	1.87
Oman	Masirah	20° 20'	58° 49'	DGM	1985	10	4.6	139	2.34
	Thumrait	17 40	54 2	DGM	1985	10	5.7	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	1.9
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	2.6
	Abou Kamal	34 05	40 09	MOE	-	10	4.43	151	2.85
	Qarachuk	37 00	42 05	MOE	-	10	4.0	120	3.0
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

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.

Source: United Nations Economic and Social Commission For Western Aisa (ESCWA). Working Paper on "Wind Energy for Rural and Remote Areas in ESCWA Region, Part I, General Issues. E/ESCWA/NR/86/WG.1.3(Part I).

IV. ASSESSMENT OF RENEWABLE ENERGY TECHNOLOGIES

4.1 Solar energy technology

The development of most potentially important solar technologies is just beginning. Basic research is opening up entirely new possibilities, particularly in solid state and photobiochemical conversion processes. It is quite possible that the large scale use of solar energy in the future in the ESCWA countries will be with technologies not yet available and perhaps even with technologies still unknown. At present, the use of small-scale solar energy technologies for the rural and remote areas in the region seems to be very appropriate.

Although the amount of solar energy available on the earth's surface is very large, solar radiation has peculiar properties which have to be considered when applying it to meet specific needs. These properties are the following:

(a) Solar energy reaching the earth's surface has a very low density. It has to be collected and possibly concentrated in order to be technically usable and economically applicable. Some solar energy technologies involve large-scale equipment;

(b) Owing to the physical and technical limitations, the efficiencies in the collection and utilization of solar energy are substantially lower than for other energy sources;

(c) Since the intensity of solar energy varies during the day and the year, proper storage is necessary.

Many solar energy technologies are already mature, and more are under intensive development, utilizing either direct or indirect options in collecting solar energy. Figure 4.1 illustrates a basic scheme of available technologies utilizing direct collection of solar energy. Specific applications determine the choice of technological option in each case(30).

The report of the technical panel set up by the Preparatory Committee of the Nairobi Conference on New and Renewable Sources of Energy gives a broad indication of the status of solar technologies which are in use or could be used in the future (see table 4.1). These technologies are innovative, and investment in new energy technology will create jobs in the high-technology industries(30).

4.1.1 Solar thermal energy

There are basically two distinct approaches to solar thermal energy, namely, the passive systems and the active systems.

(a) Passive solar technology

Passive systems do not use any equipment in their operation. The heated surface (the collector) is close to the area where heat is required. Natural processes such as conduction, radiation and natural convection transfer heat figure 4.1

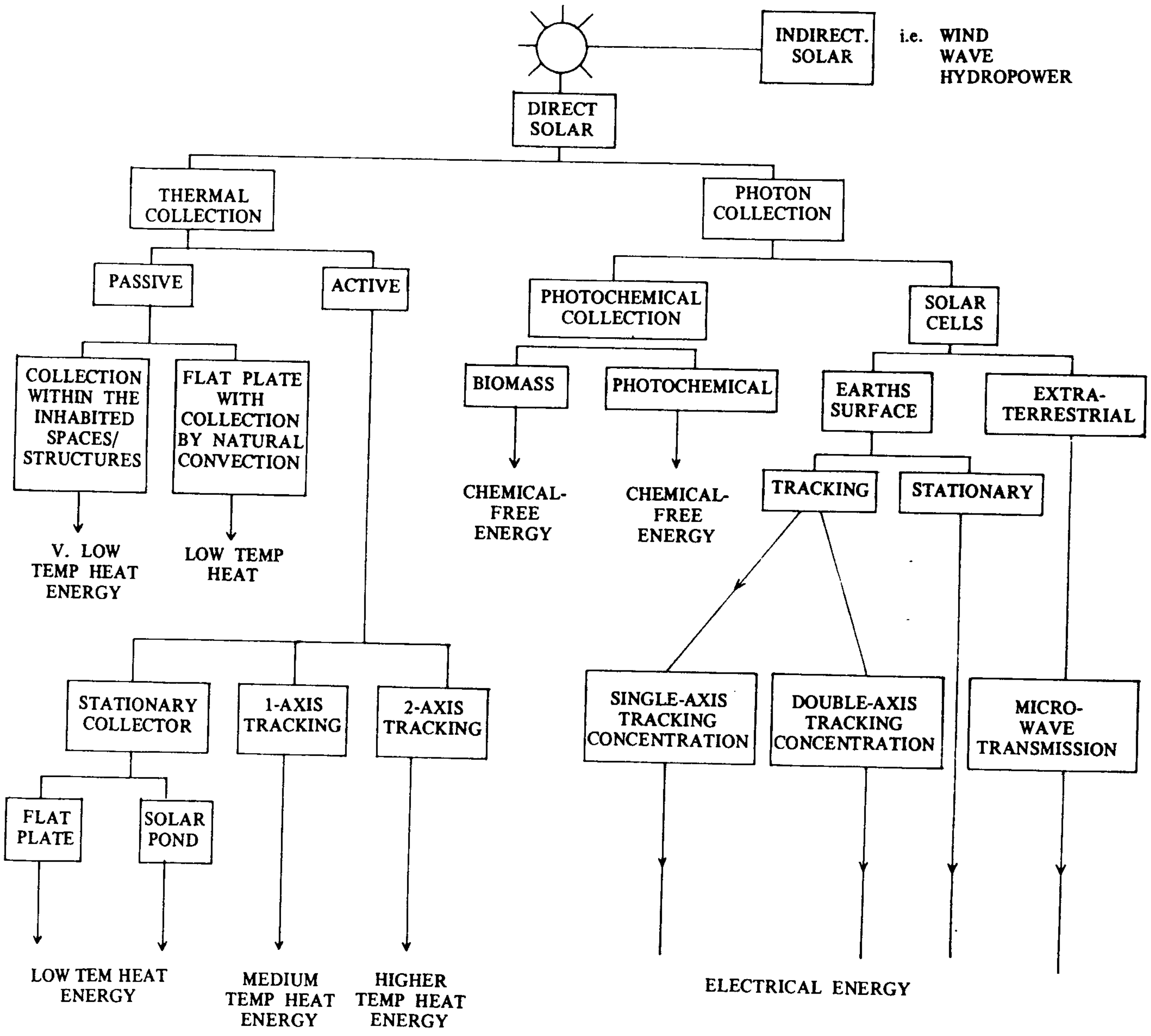


Figure Solar energy collection options

Table 4.1. Mature solar technologies and their applications

Applications	Thermal passive (low technology)	Thermal stationary (intermediate technology)	Solar ponds (intermediate technology)	Tracking collectors 1-axis (Low-to-intermediate technology)	Tracking collectors 2-axis (High technology)	Photovoltaics (terrestial) (High technology)	Satellite power systems (High technology)
Space-heating: agriculture/ building	X	X	X	X			
Water-heating: agriculture/ industry/building	X	X	X	X			
Refrigeration: building/ industry/agriculture		X	X	X	X	X	
Space-cooling: building/ industry/agriculture	X	X	X	X	X	X	
Cooking: building/ agriculture		X		X	X		
Water-pumping: building/ industry/agriculture		X	X	X	X	X	
Water purification: building/industry/ agriculture		X	X	X	X		
Greenhouses: building/ agriculture	X	X	X				
Timber and crop-drying: agriculture	X	X					
Power production (electrical): building/ industry/agriculture			X	X	X	X	X
Power production (mechanical): building/ industry/agriculture			X	X	X	X	
Industrial process heating: industry		X	X	X	X		

Source: United Nations, Report of the Technical Panel on Solar Energy. New and Renewable Sources of Energy (Proc. Conf. Nairobi, 1981), A/CONF.100/PC/27. United Nations, New York, 1981.

to the load. Passive systems are simpler systems. However, they have to be very carefully designed, because there is very little control of the flow of heat in the system. Once the system has been built, there is often very little opportunity to alter it, so great care is needed to ensure that it operates in the desired manner and does not produce conditions that are too hot or too cold.

There are two main applications for passive solar systems: building climatization and protected agriculture. In all cases, system configurations will be dependent on climatic conditions, availability of solar radiation and requirements of the system. Passive solar systems are classified according to the following concepts:

- Direct gain passive systems used for solar heating of buildings; they comprise two main elements: thermal mass and glazing windows;

- Indirect gain passive systems for solar heating and cooling of buildings; they are comprised of thermal mass and roof ponds;

- Greenhouse passive systems for agricultural applications and space climatization.

(b) Active solar technology

In active systems, the energy is used or stored in a location away from the collectors. Therefore, pumps or fans are used to transport the fluid or air heated by the collector from the collector to the storage unit and from the storage unit to the load.

Active systems, although more complicated, have the advantage of being easily controlled by simply turning pumps on and off. When heat is available from the collectors, a pump is turned on and the energy is collected. When heat is required by the load and energy is available from the solar systems, another pump is turned on and energy is delivered to the load. The basic components of an active system are: an array of collectors; a heat storage system; pumps and controls; an auxiliary heating system; and a load.

A substantial number of different kinds of solar collectors have been in use. The temperature at which energy is used for any heating application is the most important factor in assessing the solar collector option. The application-dependent temperature largely dictates which type of collector is most appropriate.

The main uses of direct solar energy are:

(i) Domestic and commercial uses

a Space heating, whereby solar energy can supply economically 30-50 per cent of the space heating load operating in combination with back-up heating systems based on non-renewable energy sources;

b Warm water supply;

c Space cooling and refrigeration, by passive and active systems;

d Solar cooking;

e Water purification and distillation.

However, independent of additional back-up systems, solar thermal systems must include some kind of heat storage which may be obtained either as sensible heat associated with the ordinary working fluid without phase change, (hot water storage, rock storage, storage for steam systems), or as latent heat associated with the phase change of chemically well-defined substance.

(ii) Industrial and agricultural uses

a Water heating or pre-heating used in industry for cooling, washing, bleaching or anodizing;

b Low pressure steam at temperatures below 200 C degrees which represents a sizeable proportion of the thermal energy requirements of some industries. Such temperatures are easily attained by concentrators, and major developments are continuing in this area;

c Hot air for drying and dehydration;

d High temperature direct process heat, which represents the bulk of the thermal energy used in some industries in the form of heat (petroleum refining, metal opening, cement glass). However, the desired temperatures correspond to the upper limit of what can be provided by current solar technologies.

At present, low temperature collector systems are used for space heating and cooling and water heating (domestic, industrial, agriculture). They are economically competitive with conventional energy for heating swimming pools, providing hot water especially in bigger pre-heating systems (100 sq.m) and heating systems in the northern climates. There are also advanced collector types for improving the useful energy per square metre but they are still too expensive since the market is too small(31).

The use of solar energy for producing electrical or mechanical power and high temperature process heat requires very high temperature collector systems. Many types of concentrating collectors technically are available such as:

- Compound parabolic concentrators, c $\simeq$ 3-5 (where c is the concentration ratio);

- Cylindrical parabolic troughs, c = 10-80;

- Circular Fresnel lenses, c $\simeq$ 100-900;

- Parabolic dishes, c $\simeq$ 200-1000.

4.1.2 Solar energy for electricity generation

Electricity can be produced from solar energy in two different ways: by thermodynamics and photovoltaics. For very small amounts of power (to 5 kW), photovoltaics are definitely the more appropriate.

(a) Electricity generation by thermodynamic conversion

The techniques of electricity production by thermodynamic conversion must be based on high temperature collection of solar radiation to achieve high cycle efficiencies, and the availability of high, direct radiation levels is an essential requirement. Concentrating collectors (one-axis and two-axis tracking) and solar tower systems (central receiver system) are the most suitable for high temperature collection. There are two alternatives for thermodynamic electricity generation: the solar farm and the solar tower radiation collecting system. The solar farm, that is, the distributed collector system (DCS), works with decentralized collectors, uses thermofluids for transporting the collected heat and reaches a concentration of 30-50 and temperatures of 100-300^{o} C. The solar tower, that is, the central receiver system (CRS), has a central absorber. The concentration of radiation is by optical transport, works between 500-1200^{o} C and reaches a concentration of 400-1000.

Central receiver technology has likewise been successfully demonstrated in at least five countries. The world's largest operating solar plant is a 10 MW water/steam unit in southern California. Heliostats have moved beyond second generation design, and automated, integrated plant control systems are now being developed. Heliostat production capacity now exists in Spain, Japan, France, the Federal Republic of Germany and the United States of America.

In power levels up to 2 MW the distributed collector system (DCS) seems to be the most promising. In power levels from 10 MW to 70 MW, the central receiver system (CRS) seems to be the most suitable.

(b) Electricity generation by photovoltaic cells

The solar cell or photovoltaic cell which is the main component of any photovoltaic system converts the incident solar radiation into direct electrical current and operates on a principle called the photovoltaic (PV) effect. This produces a voltage in a non-homogeneous semi-conductor, such as silicon, by the absorption of light quanta or other electromagnetic radiation. The PV cell consists of a positive-negative (P-N) junction which is formed between two electrical semi-conductor materials. When light is absorbed near a junction, mobile electrons and holes (positive and negative charges) are produced. The movement of these charges causes an electric potential (voltage) to develop across the junction. When an external circuit is connected, electrical energy is produced.

There are numerous materials being investigated for use in PV cells. Accordingly, the PV cell types are grouped into three categories depending on their stage of development. The first category includes cell types which are manufactured and marketed. These include single crystal silicon wafers and polycrystalline silicon. While silicon ribbon cells are still under development, recent laboratory progress indicates the possibility of starting mass production in the near future.

The advanced cell research types have been sufficiently demonstrated in laboratory prototypes to indicate promise for commercial products. Thin-film cadmium sulphide and polycrystalline silicon are prime candidates for rapid advancement.

The last category entails research for new cells. Emerging materials are those the intrinsic properties of which indicate potential for low cost and greater than 10 per cent efficiency in thin-film form. Without modification or concentration of the incident spectrum, the maximum theoretical efficiency of a single-crystal silicon is around 25 per cent(32). The achieved laboratory efficiencies of various types of cells are shown in table 4.2.

Table 4.2. Photovoltaic cell efficiency

Cell type	Achieved laboratory efficiency (percentage)
Existing solar cells	
Bulk polycrystalline silicon	16
Single-crystal silicon	18
Silicon ribbon (shaped sheet)	15.5
Thin-film cadmium sulphide	9.2
Advanced cells	
Thin-film polycrystalline silicon	9.75
Thin-film copper indium selenide/cadmium sulphide	9.4
Cadmium-zinc sulphide/copper sulphide	10.2
Amorphous silicon	5.5
Single-crystal gallium arsenide	23
Polycrystalline thin-film gallium arsenide	6.5

Source: Electric Power Research Institute, Assessment of distributed photovoltaic electric power systems, AP-2687, October 1982. Research Reports Center (RRC), Palo Alto, CA, 1982.

The performance of PV cells is dependent on the operating temperature. Gallium arsenide cells exhibit only small decreases in efficiency with increasing temperature, while silicon solar cells are affected more severely by higher temperatures. They have very low efficiencies at about 200^{o} C, and are virtually unusable at 300^{o} C. For temperatures less than 200^{o} C, the silicon cell efficiency is affected by 0.04 to 0.06 percentage points per degree centigrade. Cadmium sulphide cells have a much smaller temperature dependence below room temperature than other types of devices.

The energy density on a PV device can be increased by using optical concentrators (lenses). Sunlight can be concentrated by a factor of several hundred on silicon cells and by a factor of several thousand on gallium arsenide cells.

The electrical and physical characteristics of PV devices lead to the designing of PV arrays for basic building blocks. The PV cell is the basic device which generates electricity when illuminated. A number of PV cells are used in the manufacturing of a module. The module is the smallest environmentally protected assembly of PV cells. Several modules are usually factory assembled and wired into a panel, which is the basic unit that is field installed. A number of panels are normally installed to build an array.

Individual PV cells, limited in size by manufacturing considerations, are a few square centimetres in area and produce a fraction of one watt per cell. The output voltage varies with cell type and radiation intensity, but is usually in the neighbourhood of 0.5 V. The basic PV cell is relatively fragile and must be environmentally protected.

The module provides structural integrity, environmental protection, electrical connections and mechanical mounting provisions. The cells are connected in parallel and series combinations to achieve various electrical and reliability requirements. Most module designs vary from about 0.2 to 3 square metres. The number of parallel strings in a module varies from one to eight or more. By-pass diodes are normally used around each series block to provide an electrical path around failed strings.

Several modules are usually assembled into panels, which in turn are assembled to produce an array. The panels have a rating of 1.5 kW per panel. All PV systems must include a power conditioner subsystem to perform the following duties: accomplish basic DC to AC conversion, provide an interface to the PV array and provide interfaces to the load and utility.

There are numerous photovoltaic systems which have already been proven to be economically viable and technologically feasible for many commercial applications in remote stand-alone operations, such as navigation aids, VHF and microwave repeaters, railway signalling, wireless communications and cathodic protection. Over the last few years, a number of photovoltaic demonstrations have been made all over the world. Package lighting units, stand-alone street lighting units, solar powered television sets and refrigeration and water pumping systems are among the systems being demonstrated in many ESCWA countries with the financial support of local government or international agencies. The studies done for the UNDP/World Bank project, which give the present and projected costs of solar pumps (see table 4.3), are among the most comprehensive efforts in the field.

At present, the photovoltaic technology is more or less proven as far as the production of materials, mainly silicon (mono- and polycrystalline or amorphous), is concerned. The following silicon materials leading in efficiencies in series production are:

- 13 per cent for monocrystalline;
- 11 per cent for polycrystalline;
- 7 per cent for amorphous.

These are only economical in very small and special applications. In the near future, the rapid development of photovoltaics is dependent upon the following:

Table 4.3. Present and projected solar pump costs

	Electrical rating of pump (W)	Present (1985)	Projected (1987)	Potential (1993-1998)
Module Cost ($/Wp)	All	8	5	2
Motor/pump	200	3.5	1.8	1.8
Cost (Fob)	400	2.2	1.1	1.1
($/Wp)	600	1.8	0.9	0.9
	1000	1.4	0.7	0.7
Miscellaneous	200	6.5	5.7	5.7
Costs ($/Wp)	400	4.0	3.9	3.9
	600	3.2	3.2	3.2
	1000	2.5	2.8	2.8
Total	200	18	13	10
Installed	400	14	10	7
Solar pump	600	13	9	6
Cost ($/Wp)	1000	12	8	5

Source: UN ESCAP: Proceedings of the Regional Expert Seminar on Solar Photovoltaic Technology, Bangkok, 10-14 June 1985.

- Different types of semiconductors;
- Ways of material production;
- Cell configurations;
- Stock cells;
- Concentrating cells.

According to the assessment of photovoltaic conversion conducted by the Commission of the European Communities, the industrial applications of the process and its importance in isolated locations could open up a large world market.

The total capacity of 15 and 40 MWp photovoltaic cells has been installed in 1985 and 1986 respectively. It is expected that in the year 2000 the potential capacity of 4,5 GWp could be reached.

At the Regional Expert Seminar on Solar Photovoltaic Technology held from 10 to 14 June 1985(33) in Bangkok, the current world status of photovoltaic manufacturing technology and its applications were reviewed and the cost estimates of modules were given (see table 4.4).

Table 4.4. Cost estimates of crystalline and amorphous silicon

(a) Crystalline silicon

	Plant capacity	Silicon wafer	Module efficiency (percentage)	Module cost
1985	0.5 - 5 MW	US$2 - 2.5/Wp	11 - 13	US$5 - 5.5/Wp
1990	3 -10 MW	US$1.2-1.5/Wp	13 - 15	US$2 - 3/Wp
1995*				

a/ Watts peak.

(b) Amorphous silicon

	Cost	Remarks
1985	US$ 8-15	Commercial plants for manufacturing modules for power applications are only now becoming available. The cost is based on solar cells for pilot plant applications.
1992-93	US$1.5-3	Plant capacity of 10-30 MW. The cost will depend upon the extent to which the capital investment required for equipment will be reduced.**

However, the main barriers to a widespread market penetration are the high investment costs not only for the photovoltaic modules but also for other conventional components(31).

4.1.3 Solar energy for chemical energy production

The collection of energy from solar radiation is also possible through the photochemical processes that are naturally carried out through the photosynthesis used by plants to convert sunlight to storable and nonrenewable sources of energy. Research is being conducted throughout the world to improve understanding of the photosynthetic efficiency of plants. The prospects for improving photosynthetic yields for agricultural production are

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* No estimates exist. If ribbon crystal and/or spin crystal technologies succeed, the cost may be around US$1.5/Wp. However, it may be difficult to make the cost lower than US$1.5/Wp except in the case of thin films.

** It was noted that balance-of-systems costs currently were US$5 to US$8/Wp in general, except in some cases such as water pumping where the cost was much lower. Structure costs and power conditioning had the highest possibility for cost reductions, but battery costs could limit cost reductions for stand-alone systems.

promising. Important research is under way, especially regarding the use of solar radiation to produce hydrogen from water. For example, hydrogen produced from renewable resources has been proposed as energy for rural Alaskan communities. Application of the hydrogen system would take into consideration Alaska's unique resources, supply logistics, demographics, and economics. Integration of hydrogen production with transportation distribution, storage and utilization of equipment was discussed for the representative rural village of Old Harbor on Kodiak Island. A six and a half year demonstration programme to convert this village from diesel fuel to hydrogen was anticipated(34). The objectives of this study were to assess the prospects of reducing Alaska's dependency on fossil fuels by producing hydrogen from renewable resources and easing the burden of transporting fuel to remote sites.

4.2 Wind energy technologies

Technologically, windmills have been a proven source of energy in the past and for centuries a useful source of power for pumping, grinding, sailing and milling purposes. The first windmills were probably simple vertical-axis panemones, such as those used in Egypt as early as about 3600 B.C. for grinding grain. The use of windmills was widespread throughout the Arab world by the eleventh century; they were introduced into Europe in the thirteenth century. Although not an indigenous technology, they soon took on an unprecedented importance in medieval Europe, first for grinding grain and later for sawing wood, making paper and draining water from low-lying farmlands. In the seventeenth century there were about 10,000 windmills in England. By the early nineteenth century, with the invention of the steam engine, the advent of petroleum fuels and rural electrification programmes, windmills abruptly declined in importance(35). The post-1973 era of energy consciousness and the increased pollution associated with energy production have revived interest in windmills. Today, windmills have become the subject of extensive development and the machine now emerging makes use of major technological developments that have taken place in recent years in the area of structural design, materials and control, taking advantage of an improved understanding of wind loading and rotor aerodynamic performance(36).

Wind energy systems are now seen to have major potential applications in rural and remote areas especially for:

- Domestic water supply;

- Crop irrigation;

- Performing agricultural tasks;

- Pumping saline water for salt farming;

- Aeration and water supply for aquaculture;

- Generating electricity to operate water pumps for large scale irrigation and for water pumping for small communities in combination with diesel back-up and/or energy storage systems;

- Generation of electricity to assist rural electrification;
- Water desalination;
- Ice-making.

Wind energy conversion systems (WECS) are classified into two main types, namely, wind electric systems and wind mechanical systems.

(a) Wind electric systems

Wind electric systems may be classified according to size into the following categories:

(i) Small wind electric systems

Small wind energy systems vary in size from a few watts to 100 kW; rotor sizes range from 3 to 39 m. Currently, small wind generators can produce either direct current (DC) or alternating current (AC) power and can be used as dependent or independent systems. A dependent system operates only in connection with another source of electricity, such as a diesel generator, a photovoltaic system or an electrical grid. An independent system has its own energy storage facilities and does not need to be connected to any other energy source. The independent system is best applied in remote areas. To make use of the advantages of both systems, a combined system is also possible. Such a system may utilize battery storage and a dual function inverters, which can operate both when connected or disconnected from the grid power line.

There is a growing interest, particularly in Denmark and the United States, in the use of wind turbines in the 2-100 kW range interconnected to the electric grid. Wind farms have been progressing in a number of developed countries. In 1986, there were approximately 16,000 wind energy converters (WEC) with 1.1 GW installed capacity in different parts of the world.

(ii) Large wind energy electric system

Large wind energy systems have been built ranging from 100 m in diameter and power output of 4 MW to 128 m in diameter with 7.2 MW power output. Most modern wind turbines have horizontal axis rotors like traditional windmills, but with only two or three relatively slender aerofoil-shaped blades. They are mainly used for generating electricity.

(b) Wind mechanical systems

Water pumping is the only widely used mechanical application for wind machines. There are three basic categories of mechanical wind pumps commercially available in addition to the electric wind pumping systems. They are as follows.

(i) Traditional multi-bladed farm wind pumps

Among the commercially produced mechanical-drive windmills, the multi-bladed type are the most widely distributed wind pumps and have been imported and/or adapted by several developing countries. They are reliable, have a high starting torque and operate well even in low winds. They are usually designed to have many blades, low rotation speeds, moderate size and rigid steel construction. Since they have a high starting torque, they are well suited to drive water pumps which generally have a high starting torque. Typically, multi-bladed windmills begin pumping water at wind speeds of 2.2-2.7 m/s, speeds which are suitable for the arid and semi-arid areas in the ESCWA region.

(ii) Modern light-weight wind pumps

Although several multi-bladed windmills are being used in developing countries, they have the following limitations:

- Conventional multi-bladed design is beyond the scope of local manufacture in several developing and least developing countries;

- Costs are too high for subsistence farmers and loans and subsidies have not generally been available;

- Maintenance and repair are problems despite the basic reliability of the machine, especially when local maintenance service remains unorganized.

In view of these problems, new multi-bladed windmill designs suitable for small-scale manufacture in the developing countries have been developed(37, 38 and 39). The new designs have several advantages:

- They are considerably lighter in weight, more simple to construct and have a slightly higher overall efficiency;

- They can be constructed by using locally available materials and manufacturing them in simply equipped workshops;

- They are cheaper than commercially available windmills manufactured by the developed countries;

- The resulting savings in foreign currency expenditure are appreciable.

(iii) Low cost windmills

A wide variety of simple handcrafted water pumping windmills are now in seasonal use in various parts of the world, especially in the least developed countries. Both horizontal axis sailwing windmills and vertical axis Savonius designs have been developed for irrigation or drainage requiring relative low lift.

The Savonius rotor has received attention as a simple windmill with a large potential for application in developing countries. Although its efficiency of design is low, its ability to accept wind from any direction, the simplicity of its construction and the widespread availability of materials to construct it are technical advantages that make Savonius rotors suitable for wind energy applications in developing countries.

Sailwing windmills are perhaps the most attractive in design for rural level construction. This fact has been demonstrated in various developing countries. The windmills can be constructed of locally available materials (often wood and cloth) and are produced with local skills, using simple hand tools.

Such windmills have been built in a number of countries, but their activation does not seem to have resulted in adequate dissemination of these technologies, possibly because of lack of sufficient promotion and extension services.

(iv) Wind electric pumping systems

High-speed wind electric generators currently available in a wide variety of model and sizes(40) have a number of potential advantages:

- Greater flexibility in placing the wind machines in relation to the well;

- Use of high capacity submersible of shaft type turbine pumps instead of piston pumps;

- Availability of pumping powers up to 100 kW or more which can be used in large irrigation projects;

- Flexibility of use in conjunction with a rural electricity grid so as to permit continuous pumping, but with reduced electricity.

Despite these advantages, electric pumps have not been used in developing countries because of the high capital cost of wind electric generators. Also, there is the problem of secondary storage, particularly when the aerogenerator has to be used not only for running the pumps but also for feeding power to a variety of other machines run on electricity.

In remote and rural areas, electricity generation by wind power is already competing with diesel systems.

Small-scale wind energy conversion systems of up to 50 kW are nearly competitive and in widespread use, while medium-size WECS (approximately 1 MW) are most promising for large-scale electricity generation. There are also a dozen large-scale WECS prototypes installed in various developed countries, and their technical and economic problems are still under investigation(31).

V. POTENTIAL APPLICATION OF SOLAR AND WIND TECHNOLOGIES

5.1 Objectives of solar energy development and application

The development and utilization of solar energy in the ESCWA countries would be a contribution to a number of important goals of the region. In the first place, in the case of oil importing countries, an increased use of solar energy would reduce, to an extent, their dependence on imported fuels. For the case of oil exporting countries, an increased use of solar energy would save, to an extent, their oil consumption and hence increase their foreign hard currency earnings.

Secondly, solar energy is an ideal source of energy for small-scale and decentralized applications and therefore its development would be particularly appropriate for rural and remote areas.

The direct benefits of solar energy to ESCWA countries would, or could, mean more energy available for industry; an improved balance of payments because of reduced oil imports; better environmental conditions from reduced reliance on polluting fossil fuels; and the introduction of a technology for which the equipment can be manufactured locally.

Thirdly, through the introduction of renewable energy sources in their energy programmes, ESCWA countries would have an opportunity to master, in the longer term, the technological development needed to promote their endogenous industries.

In this context, the main objectives of solar energy development and application to be promoted by ESCWA are the following:

(a) Increasing the reliance of ESCWA countries on endogenous energy sources;

(b) Strengthening the technological capacity of ESCWA countries in the energy sector;

(c) Providing suitable energy forms for both urban and rural industrial development;

(d) Developing programmes for the improvement and commercialization of solar energy technologies through co-operative action by ESCWA countries;

(e) Exchanging experiences among ESCWA countries in research, development and demonstration and application of new solar energy technologies;

(f) Promoting solar process energy in rural industries in the context of an integrated rural development programme;

(g) Providing the basis for ESCWA countries to formulate and implement appropriate policies in regard to solar energy applications and the integration of solar energy with overall energy policies on national, as well as regional and international levels;

(h) Promoting the local manufacture of solar energy equipment for urban and rural application in ESCWA countries;

(i) Exchanging and disseminating information on all aspects of solar process energy technology.

5.2 Potential application of solar technologies

(a) Domestic hot water

Domestic hot water solar systems are the best known and commonest application of flat-plate solar collectors. A solar water heater consists of one or several collectors, a storage tank, circulation and control systems and, in some cases, an auxiliary heating element. These systems may be classified, according to size, as single or collective systems or, according to the type of circulation for the heating media, as thermosyphon or forced systems.

In addition, simple models of solar water heaters made of plastic and polymer materials have been developed for use in heating swimming pools in cold countries and other limited temperature applications below 35° C.

(b) Industrial process heat application

The industrial sector is the largest energy user in developed and developing countries, where solar energy can provide direct thermal energy. The main areas of solar thermal applications in industry are process hot water, drying/dehydration and process steam.

(i) Process hot water

Large amounts of heated water at temperatures between 50 and 100° C. are used for cooking, washing, bleaching and anodizing or concentrating collectors.

(ii) Process steam

Steam is used in industry; 80 per cent of this process steam is at temperature below 175° C. and can be supplied by solar collectors in three ways as follows:

- By using a high transferring fluid in the collectors and then transferring the heated fluid to an unfired boiler;

- By circulating pressurized water in the collectors and flashing it to steam in a flash tank;

- By boiling water in collectors.

Although steam is used widely in industry to transport heat, it is probably better to combine solar energy with hot water. If hot water supplies heat to a process, a solar collector can be used without unfired boilers and without the disadvantages of flash systems. Thus, if solar energy is being considered for a new plant, some consideration should also be given to using pressurized hot water in place of steam.

(iii) Power generation

The use of solar energy to generate electricity can be achieved either through thermal or photovoltaic applications. In the thermal application, solar heat is used to replace other sources to power a conventional steam cycle. This can either be done by using a vast array of relatively sophisticated collectors - usually parabolic in shape and able to track the sun - or a field of photovoltaic cells in arrays can be used to generate power directly.

For power generation on a small scale, solar energy can already be useful. In particular, photovoltaic cells can be used for telecommunications in remote areas where it would be expensive to build traditional power lines for connection to national grid systems. Photovoltaic or thermal solar power can also be used to run small desalination plants, pumps and irrigation systems.

(iv) Drying and dehydration

The agro-industries are the main consumers of industrial hot air for crop drying, for the textile industry and for metal products industries. The two most common ways to supply solar heated air are to heat the air directly in the collectors and to heat a liquid in the collectors and then use a liquid to air heat exchange.

Simple solar driers have been demonstrated in different countries for use by farmers or on a limited industrial scale.

(v) Greenhouses

The use of active and passive thermal power for heating and cooling in greenhouses is the most profitable application of solar energy in the ESCWA countries, since the concept of a greenhouse is to provide and maintain desirable growing conditions for various crops during different seasons of the year, in order to provide horticultural production for people living in dry or semi-arid areas.

(vi) Solar water desalination

Solar energy is used for distilling saline or brackish water in many countries around the world. Different processes are used for saline water desalination. These processes are as follows:

- Distillation processes (flash type distillation, single or multiple effect distillation and vapour compression distillation);
- Membrane processes (reverse osmosis (RO));
- Electrodialysis.

Solar desalination processes which are in use today are mainly solar stills and reverse osmosis. With regard to solar desalination, the present situation is as follows:

a If the demand is lower than 20 cubic metres per day, the basic solar stills appear to be good choices when there is an adequate insolation for an isolated community and especially when there is a limited availability of skilled manpower to operate more sophisticated water desalination plants.

b If the demand is higher than 20 cubic metres per day, it is advisable to associate solar and conventional resources as follows:

- For sea water: multistage flash associated with flat plate in addition to pre-heating of boiler feed-water in industry. These applications account for about 5 per cent of industrial energy consumption, but it could be supplied by higher temperature waste heat. Collective solar water heater systems are used for these applications, using either open or closed loop systems depending on process conditions.

- For brackish water, reverse osmosis systems provide the best solutions.

The RO desalination plant consists usually of an energy conversion system and desalination equipment. The energy required to produce one cubic metre of fresh water by an RO desalination plant is given approximately as:

> $E \doteq Pr/25 \times R$, where Pr 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 70 per cent efficiency for the pump.

For brackish water, RO membranes can operate at recovery ratios as high as 0.75-0.9 and at a pressure of about 30-40 atmosphere (one atmosphere $\doteq$ 0.9869 bars). For sea water, the recovery ratio is 0.2-0.3 and the pressure ranges from 60-70 atmospheres. If the RO plant is provided with an energy recovery device, the energy consumption may be reduced to 25-30 per cent. Therefore, the energy required to produce one cubic meter of fresh water from very low salinity brackish water is estimated to be 1.3 kWh per cubic metre, and from very high salinity sea water it is estimated to be 13.8 kWh per cubic metre. With an energy recovery system, these values may be reduced to about 1 kWh per cubic metre and 10 kWh per cubic metre respectively.

(c) Solar thermal water pumping

Solar heat can be used directly to vapourize a working fluid which can then drive a piston (a Rankine engine). There are several types of small-scale solar water pumps which are installed and tested in various countries around the world. Pumping can also be done using a variety of direct and indirect solar energy sources in addition to the photovoltaic generation of electricity.

(d) Space heating and cooling

The use of direct solar energy for space heating is a well established technology and heating is required for some ESCWA countries at some time during the year. It can be achieved either through active systems involving solar collectors and conventional heating equipment or more simply through passive systems which depend mainly on careful building design. The same applies to space cooling systems which in many ESCWA countries are even more vital than heating. A combination of active and passive systems can give best results.

(e) Solar refrigeration

Solar refrigerators are based on the absorption principle with solar heat replacing that normally generated by more conventional sources. It can be either direct solar heat or produced by photovoltaically generated electricity. To operate continuously it needs either some form of heat storage or a conventional back up system for periods when the sun is not shining.

Table 5.1 summarizes the specific potential applications of solar technologies(40) which can already be exploited or will be developed in the near future by taking account of the following geographical, social and development considerations:

- Development of small rural communities, particularly desert communities;
- Extension of urbanization;
- Supply of fresh water needs for bedouin communities and remote areas;
- Provision of energy for rural industrial development with special attention to the promotion of small agro-industries;
- Space climatization.

5.3 Activities in the field of solar energy in the ESCWA region

Various applications of solar energy are found in the ESCWA countries. The best known applications are the use of solar energy for domestic water heating, saline water desalination and electricity generation using the photovoltaic system in rural and remote areas.

The use of solar energy for space heating has been demonstrated in Jordan, Iraq, Saudi Arabia and Kuwait. The application of solar energy for air conditioning systems is more vital to all ESCWA countries than heating, and some demonstration houses with solar cooling systems have been built in Iraq, Jordan, Kuwait, Saudi Arabia and Lebanon.

Water heating by solar power is fairly widespread and is already commercially competitive with other more conventional methods in Egypt, Jordan, Lebanon, Kuwait, Iraq, Saudi Arabia and the Syrian Arab Republic.

The operation of solar thermal pumps is at present demonstrated in Egypt, Saudi Arabia and the United Arab Emirates.

Most of the current work on water desalination uses solar stills, which have been installed in Iraq, Jordan, Kuwait, Lebanon, Egypt and Saudi Arabia.

Table 5.1. Potential applications of solar technologies in the ESCWA region

Application Country	Space Heating	 Cooling	Solar Heating	 Pumping	Solar drying	Refrige-ration	Green-houses	Desali-nation	Power generation	Telecommu-nications
Bahrain	1 2 3	1 2 3	1 2 3	3 4	1 2 3	1 3	1 2 3	1 2 3 4	3 4	4
Democratic Yemen	1 2 3	1 2 3	1 2 3	3 4	1 2 3	1 3	1 2 3		3 4	4
Egypt	1 2 3	1 2 3	1 2 3	3 4	1 2 3	1 3	1 2 3	1 2 3 4	3 4	4
Iraq	1 2 3	1 2 3	1 2 3	3 4	1 2 3	1 3	1 2 3		3 4	4
Jordan	1 2 3	1 2 3	1 2 3	3 4	1 2 3	1 3	1 2 3	1 2 3 4	3 4	4
Kuwait	1 2 3	1 2 3	1 2 3	3 4	1 2 3	1 3	1 2 3	1 2 3 4	3 4	4
Lebanon	1 2 3	1 2 3	1 2 3	3 4	1 2 3	1 3	1 2 3		3 4	4
Oman	1 2 3	1 2 3	1 2 3	3 4	1 2 3	1 3	1 2 3		3 4	4
Qatar	1 2 3	1 2 3	1 2 3	3 4	1 2 3	1 3	1 2 3	1 2 3 4	3 4	4
Saudi Arabia	1 2 3	1 2 3	1 2 3	3 4	1 2 3	1 3	1 2 3	1 2 3 4	3 4	4
Syrian Arab Republic	1 2 3	1 2 3	1 2 3	3 4	1 2 3	1 3	1 2 3	1 2 3 4	3 4	4
United Arab Emirates	1 2 3	1 2 3	1 2 3	3 4	1 2 3	1 3	1 2 3	1 2 3 4	3 4	4
Yemen Arab Republic	1 2 3	1 2 3	1 2 3	3 4	1 2 3	1 3	1 2 3	1 2 3 4	3 4	4

Source: Extracted from table 8 of the Solar and Other Alternative Energy in the Middle East. The Economist Intelligence Unit, Special Report No.108, September 1981.

Notes: 1 = Active system; 2 = Passive system; 3 = Thermal; 4 = Photovoltaic
Blank = Not applicable or low probability of utilization.

The use of active and passive solar thermal power for heating and cooling of greenhouses is widespread in Iraq, Jordan, Kuwait, Lebanon, Bahrain and the United Arab Emirates. Solar heat can also be used for soil sterilization.

Research on solar drying of food, agricultural products and fish has been carried out in Egypt, Iraq, Jordan and Lebanon.

Solar refrigeration has been investigated in Bahrain, Egypt, Kuwait and Saudi Arabia. Such systems may be used for the preservation of food, animal, agricultural and fish products, either by cooling air in cold storage or by producing ice to preserve the food.

The use of direct solar power to generate electricity can be either thermal or photovoltaic. Egypt and Kuwait have investigated the use of solar thermal power generation. The most important photovoltaic conversion system used in the ESCWA region was the power plant in Al-'Uyaynah in Saudi Arabia; it uses silicon cells with concentrators and has a capacity of 350 kW. Research on photovoltaic cells is also being carried out in Iraq, Jordan, Egypt and Saudi Arabia.

Iraq and Saudi Arabia are producing photovoltaic systems on a commercial scale.

Jordan and Saudi Arabia have installed hundreds of photovoltaic emergency telephones on their highways. Egypt has installed a number of telephone and TV repeater stations in remote areas.

The following summarizes some selected solar applications and other relevant activities in the ESCWA countries.

(a) Bahrain(19)

Bahrain has been involved in solar research since 1977 through the Bahrain National Oil Company which co-operated closely with the Kuwait Institute for Scientific Research (KISR). The following activities have been undertaken:

(i) An educational exhibition through slides, models and photographs of various solar energy applications was organized in 1977;

(ii) Data were collected on the performance of a flat plate collector which was partially assembled at KISR;

(iii) Two pyranometers have been installed to monitor global and diffuse radiation on the horizontal plane. Climatological data obtained from the meteorological stations in Bahrain are being analysed at KISR;

(iv) Research on solar desalination is mainly restricted to academic institutes, in order to improve the efficiency of different designs of solar ponds and solar stills. Other projects are concerned with the quality of condensate and its possible application in agriculture and as a source of potable water;

(v) The Physics Department at University College of Bahrain has started a programme to prepare the hydrogenated amorphous silicon using R.F. flow discharge and to study its electrical and optical properties. Hydrogenerated amorphous silicon solar cells using different structural designs are also programmed;

(vi) Bahrain hosted two major solar energy exhibitions in 1978 and 1980 where all the main companies involved in solar research displayed their products. In February 1986, Bahrain hosted the Second Arab International Solar Energy Conference. Courses on solar energy are offered by the Physics Department at University College of Bahrain and by the Mechanical Engineering Department at the Polytechnique.

(b) Democratic Yemen(41)

The Ministry of Energy and Minerals in Democratic Yemen believes that its future plan of action in the NRSE areas should concentrate on the following priorities:

(i) Developing national policy in line with the NPA to develop NRSE;

(ii) Continuing compilation of data pertaining to technical and economic aspects of NRSE, while following up on current activities undertaken by Arab countries and other global developments with regard to the utilization of such NRSE technologies;

(iii) Seeking foreign expertise (in the context of co-operation programmes) to undertake preliminary surveys and assessments to outline (or define) ongoing projects in Democratic Yemen and provide information for evaluation and course correction of similar NRSE projects or plans in the republic;

(iv) Promoting the utilization of appropriate renewable energy technology through, *inter alia*, increasing the awareness of the public with regard to the positive social, economic and environmental impacts of the application of such technologies.

(c) Egypt

Egypt has one of the biggest renewable energy programmes in the ESCWA region, but it is also, as well as all ESCWA countries, heavily dependent on expertise and equipment from developed countries.

All Egypt's major universities are involved in renewable energy research but much work is also done at the National Research Centre (NRC) of Egypt in its Solar Energy Laboratory and Solid State Laboratory. In 1976, the Ministry of Electricity and Energy set up a Solar Energy Commission to co-ordinate research as well as to initiate projects and a Supreme Council for Renewable Energy Sources was set up in 1979. Now the Ministry of Electricity has set up the Egyptian Renewable Energy Development Authority.

The Solar Energy Laboratory at NRC carried out the following projects:

(i) In co-operation with the United States, a 5 kW solar thermal power generation project made up of three heliostats having a total area of 108 sq. m with paraboloidal concentration;

(ii) A 10 kW solar thermal power generation project, a solar cooling project with 1.5 tons of cooling load and a solar water desalination project were implemented in co-operation with the Federal Republic of Germany;

(iii) A solar drying project in co-operation with the International Development and Research Centre (IDRC) of Canada.

The following major projects were implemented by the Ministry of Electricity and Energy:

(i) Reverse osmosis project: a solar reverse osmosis unit supplied by the French Atomic Energy Commission for testing, operating and maintenance by Egypt;

(ii) Franco-Egyptian project: feasibility study of local manufacturing of solar energy equipment; deep freezing of fish caught in Lake Nasser; water heating and air conditioning for a 100-room hotel on the northern coast. This project included the supply of three solar water heaters of different sizes equipped with flat plate collector, a 5 kW solar pump with a cooling and freezing unit, and a complete solar energy and meteorological station including measuring and calibration instruments, testing and maintenance equipment, and a complete energy information centre. Training of Egyptian engineers and technicians in France on installation, operation and maintenance of the above-mentioned equipment was also provided.

An educational solar energy laboratory has been established at the Faculty of Science of Cairo University and a solar energy course at Master's degree level has also been introduced into the curriculum. Research on other fields of solar application was carried out by various departments.

Solar energy data in Egypt are recorded by the Department of Meteorology. There is a solar measurement laboratory in the HV laboratory of the Ministry of Electricity and Energy and solar measurements are also recorded by the NRC.

Solar water heaters are locally manufactured in several factories owned by both the public and private sectors, and sold for domestic consumption.

The Egyptian Government has formulated a National Strategy for the Development and Utilization of New and Renewable Sources of Energy. This was done with assistance from the United Nations Development Programme and the United Nations Department of Technical Co-operation for Development. The strategy is for targets by the year 2000 to supply 5 per cent of national commercial primary energy through the application and development of renewable sources of energy. Table 5.2 shows the important renewable energy projects which are implemented or under implementation by the Ministry of Electricity and Energy.

Table 5.2. Renewable energy projects implemented or under implementation by the Ministry of Electricity and Energy in Egypt

No.	Agreement/Projects	Allocated fund	Approved external fund	Type of funding	Government share	Funding agency	Status of project
1	Importing of 1,000 solar water heaters	US$ 750,000	-	-	US$ 750,000	M.O.E.	Completed
2	Egyptian-French Agreement	FF 7 mn	FF 7 mn	Loan	LE 500,000	FAEA	Last phases
3	Egyptian-German Agreement(I)	US$ 1.5 mn	-	Grant	LE 250,000	FRG	Completed
	Egyptian-German Agreement(II)	US$ 1.0 mn	-	Grant	LE 250,000	FRG	Ongoing
4	Egyptian-EEC Agreement	ECU 8 mn	ECU 8 mn	Grant	LE 2 mn	EEC	ECU 1.4 mn spent
5	Egyptian-Italian Agreement as a share in financing	ECU 2.3 mn	-	Grant	LE 4.1 mn	Italian Government	Agreement not signed yet
6	Egyptian-USA Agreement	US$ 24.1 mn	US$ 9.7 mn	Grant	US$ 4.36 mn	USAID	Obligated 6.7 mn
7	Egyptian-UNDP Agreement	US$ 1.065 mn	US$ 730,000 (UNDP) US$ 335,000 (AGFUND)	Grant	US$ 100,000 LE 200,000	UNDP Gulf countries	Ongoing
8	Total proposed agreements under study	US$ 12 mn	-	Grant	LE 3 mn	-	Under negotiation

Total allocated 39.65 mn US$
Total proposed under negociation US$ 12 mn

Source: United Nations Economic and Social Commission for Western Asia, Seminar on Small-scale Solar and Wind Technologies for Rural and Remote Areas in the ESCWA Region: Country Paper of Egypt (Ministry of Electricity and Energy), Amman, 29 November to 3 December 1986.

Notes:
LE: Egyptian pound
US$: United States dollars
FF: French franc
ECU: European currency unit
USAID: United States Agency for International Development
FRG: Federal Republic of Germany
FAEA: French Atomic Energy Agency
EEC: European Economic Community
AGFUND: Arab Gulf Fund

(d) Iraq

Research on solar energy is carried out in most universities in the country. A building to house the Solar Energy Research Centre (SERC) at Baghdad has been constructed on the premises of the Scientific Research Council, covering an area of 3,000 square metres. The whole building acts as a laboratory for solar air conditioning and hot water supply. The solar guest-house inaugurated in 1982 was the first full-scale project undertaken by SERC in the field of air-conditioning. It has a total area of 600 square metres and a solar air-conditioned area of 400 square metres.

In collaboration with the Ministry of Housing and Construction, work has started on building an expressway rest area, which will be cooled, heated and supplied with hot water and some electricity by solar energy. The application of solar technology lends itself to such areas in view of their remoteness from the main grid. Solar energy is also used in the air conditioning and hot water supply in locally made prefabricated flats.

A solar greenhouse project was the first joint Arab project in the field of solar energy application in agriculture. It was jointly implemented by SERC and the Royal Scientific Society of Jordan and was located in the Fudailia district north-east of Baghdad. It has 42 plastic greenhouses of 500 sq. m each and has already been planted with tomatoes, cucumbers and green peppers.

Photovoltaic water pumping, photochemical conversion and storage and water desalination are being implemented by SERC.

(e) Jordan

The Jordanian Government is supporting the development of solar energy. Its application is included in the Five Year Plan. Activities in Jordan in the field of solar energy may be classified into three main categories, namely:

(i) Basic research, which is being carried out at the Jordanian universities in the field of solar thermal systems and photovoltaics;

(ii) Applied research, development and demonstration, which is being carried out by the Royal Scientific Society and the Renewable Energy Department of the Ministry of Energy and Mineral Resources in the field of solar water heating, space heating, water pumping by photovoltaic cells and solar passive architecture;

(iii) The applications of solar water heaters for domestic and industrial utilization and agricultural greenhouses.

The Solar Energy Research Centre of the Royal Scientific Society has undertaken several projects, namely, sea water desalination using the heat pipe principle; design and installation of mini-photovoltaic systems, solar houses and study on the potential of solar and wind energy application in Jordan in co-operation with the Federal Republic of Germany.

The major research, development and demonstration activities on photovoltaics are being carried out by the photovoltaic group at the Royal Scientific Society in co-operation with the Federal Republic of Germany. Flat plate collectors for water heating and for medium and high temperature requirements are being used by the solar energy group at the Royal Scientific Society.

Standard specifications of locally manufactured solar water heaters and thermal insolation are prepared by the Renewable Energy Department.

(f) Kuwait

Solar energy data are recorded by a weather monitoring station installed at KISR which is responsible for solar research, development and demonstration in the country. Four main areas of interest were identified: (i) solar heating and cooling of buildings, (ii) desalination, (iii) power generation, and (iv) agricultural applications.

A 100-kW solar thermal power plant has been installed by KISR with technical assistance from the Federal Republic of Germany.

(g) Lebanon

The National Council for Scientific Research is the executive arm of the Lebanese Government for research and development. The Solar Energy Group of the Council aims at promoting solar energy applications and has collaborated with the National Meteorological Service in installing 12 stations for the measurement of solar radiation in different locations in Lebanon.

(h) Oman

There are several applications of solar energy in Oman, such as photovoltaic cells for telecommunication systems and solar heating crude oil. They are conducted by foreign private and commercial companies and also by academic staff. The Government has shown increasing interest in the development of solar energy, especially for remote areas.

A private company has commissioned an expert to assess the solar and wind potential in Oman.

(i) Qatar

Activities in the field of solar energy are undertaken by the Industrial Development and Technical Centre (IDTC) and Scientific and Applied Research Centre of the University of Qatar.

The solar pilot project at Umm Said consists of: a meteorological and solar measurement; test benches of thermal collectors (low and high temperature); photovoltaic tests for cells and panels; a flat plate thermal collecting concentrating system; a heliostat mounted normal photovoltaic axis tracking generator; a flat thermo-photovoltaic hybrid concentrating collector system; a thermal solar distillation/desalination unit; sea water and solar energy system, in which the water vapour from the solar-heated sea water directly condenses on the plant roots. The aim is to use this solar pilot project as a training school for creating national experts, technologists and skilled laborers to take over the task of implementing further research and development programmes and as a source for actual commercial applications of solar energy in Qatar. The Umm Said project was carried out by IDTC in co-operation with the Government of France in 1980. The Scientific and Applied Research Centre (SARC) of the University of Qatar has installed a PV-driven reverse osmosis water desalination plant with technical assistance from UNESCO.

(j) Saudi Arabia

Solar radiation data are recorded by the Meteorological Service. A radiation atlas has been developed from data collected over the past 13 years for more than 40 weather stations covering the Kingdom.

Saudi Arabia is deeply involved in solar energy development in terms of investment and participation of most major developed countries. The first university to become involved was the University of Petroleum and Minerals at Dhahran, which organized an international solar energy conference in 1975. Areas of research at the University are insolation, desalination, storage, photovoltaics, collectors, water heating and solar ponds, and electricity generation.

Riyadh University is also involved in a solar research project on desalination, water heating, collectors, storage, space heating and cooling, and greenhouses.

King Abdel Aziz University in Jeddah has taken up solar research on desalination and its agricultural and industrial applications and solar pumps.

King Faisal University also has a special interest in industrial and agricultural applications of solar energy.

All four universities mentioned above and other institutions are involved in testing solar air conditioning units and solar power stations as part of the joint Saudi-US SOLARAS programme, which, in financial terms, is the biggest solar project in the Kingdom.

There are new projects under investigation such as solar cooling systems guidelines, solar-powered agricultural produce processing, a 50 kW solar membrane concentrator project, solar hydrogen production and utilization, a solar powered highway device project, tunnel lighting, overheight detection and diversion, traffic counters, illuminated steep grade warning signs, sign lighting at two interchanges and lighted warning signs at pedestrian crossings (42).

(k) Syrian Arab Republic

Solar radiation data are recorded by the Meteorological Service. The Syrian Arab Republic enjoys relatively long sunshine time with a daily average energy reception of around 5.87 kWh/sq. m. In spite of the fact that government interest in the development of solar energy resource dates back to 1974, only a small number of projects, whether experimental or operational, have been implemented. The major pioneers in the experimental efforts in this field have been the Ministry of Electricity and the Scientific Studies and Research Centre. The former already has in operation a photovoltaic electricity generating facility with an output of about 2 kW, used together with a wind-driven electricity generator having a rated output of about 1 kW to supply the necessary power for operating a relay station. The Scientific Studies and Research Centre has embarked on a number of projects. One is the measurement and comparison of the efficiencies of various types of flat-plate collectors, with a view to establishing performance standards as well as criteria for the further development of such collectors in domestic and small-scale industrial applications. Another is the establishment of an experimental flat-plate collector assembly facility aiming at furthering the technological aspects of collector construction and maintenance.

The Ministry of Industry has established a factory for solar water heaters. There are also several private factories producing solar water heaters.

Research is also under way on a limited scale at various institutions, including the universities of Damascus and Aleppo.

(l) United Arab Emirates

Solar radiation data are recorded by the Meteorological Service. Solar energy has been used since 1960 at an integrated food-power-water complex in Saadiyat.

The United Arab Emirates are still in the stage of planning solar research and have no research body of their own. The only solar installation so far is at Al-Ain where a 1 kW pump has been installed by the French company CFP/Sofretes to pump water. There are numerous foreign companies which have begun demonstrating their solar equipment. So far, the main market has been for water heaters and swimming pool heaters. Air conditioning systems and photovoltaic generators may have a good future in this country.

(m) Yemen Arab Republic

Solar radiation data are recorded by the Meteorological Service. In 1981, the Yemen Co-operative Association studied with the American Solar Energy Corporation the possibility of transferring the solar technology of silicon solar cells to Yemen. However, this project was not implemented due to the high cost of a photovoltaic system. In 1982, the United Nations Environment Programme, upon the request of the Government, commissioned an expert to study and make recommendations on the possible application of appropriate solar energy technology.

A solar programme is offered at Sana'a University. The Ministry of Transportation and Telecommunications has already introduced photovoltaic-powered telecommunication stations. At Sana'a University, a photovoltaic system of 1.6 kW generates electricity to power a solar research laboratory and sometimes even the computer of the Faculty of Science.

There are also several companies working on solar water heaters by manufacturing or importing the equipment needed.

The Confederation of the Yemen Development Association has carried out experiments to use photovoltaic systems for lighting and house appliances. In co-operation with the United Nations Development Programme, the Confederation has also carried out a study aimed at establishing two stations for power generation using a photovoltaic system: the first to light a school and a teachers' residence, and the second to establish four pumping stations to pump water for irrigation in Taiz and Hudeidah. The Tahama Development Committee and the Federal Republic of Germany have carried out a study to construct 84 pumping stations in the Moor Valley.

Table 5.3 summarizes regional activities in the field of solar and wind energy, and Table 5.4 shows the photovoltaic application in the ESCWA countries(43).

5.4 Objectives of wind energy development and application

Wind energy has been one of the few forms of renewable energy which traditionally has been cost-effective and practical in previous eras. Wind energy has also been frequently cited as a prime contender for decentralized water pumping applications in remote areas, therefore meeting one of the most basic and widespread energy needs in development. However, there are no accurate and reliable data on wind pump and wind generator performance in the ESCWA countries. Furthermore, the available data on wind resources are insufficient. Hence, neither policy makers nor water users currently have the information necessary to support investment decisions.

Therefore, the main objectives of wind energy development and application to be promoted by ESCWA are the following:

(a) Increasing the reliance of ESCWA countries on endogenous and renewable energy sources in ESCWA countries, in line with the Nairobi Programme of Action;

(b) Strengthening the technological capacity of ESCWA countries in the energy sector;

(c) Developing a reliable data base on the design, operation and maintenance of windmill pumping systems to supply water for human consumption, livestock and irrigation; and to generate power and end-uses such as water desalination and ice-making in small-scale rural level applications;

(d) Exchanging and disseminating data and information among concerned ESCWA countries;

(e) Promoting the local manufacture of wind energy equipment for applications in rural and remote areas in ESCWA countries.

5.5 Potential applications of wind technologies

There are four specific potential applications of wind technologies in the region, namely, water pumping, small-scale electricity generation, water

Table 5.3. Status of solar and wind energy applications in the ESCWA region
(By Country)

	Bahrain	Democratic Yemen	Egypt	Iraq	Jordan	Kuwait	Lebanon	Oman	Qatar	Saudi Arabia	Syrian Arab Republic	United Arab Emirates	Yemen Arab Republic
Solar													
Flat plate collector	X	X	X	X	X	X				X	X		X
Solar drying			X	X	X								
Solar water heating		X	X	X	X	X	X	X		X	X		X
Solar cooling	X		X			X				X			
Solar green-houses	X			X	X	X						X	
Solar distillation			X	X	X	X							
Solar pumping		X	X		X			X		X		X	X
Solar insolation	X		X	X	X	X	X	X	X	X			X
Photovoltaic power generation		X	X		X	X			X	X			X
Solar thermal power generation			X		X	X				X			
Solar industry			X		X						X		
Storage of energy			X			X							
Courses in solar energy			X	X			X			X			
Resource assessment			X		X								
Wind													
Windmills for pumping water		X	X										X
Aerogenerators			X		X						X		
Resource assessment			X		X								

Table 5.4. Photovoltaic applications in the ESCWA countries

No.	Country	Type of application	Remarks
1	Bahrain	Pumping of petrol in a gas-station	A car filling station in the centre of Manars uses 3kWp for its pumps and a refrigerator.
2	Democratic Yemen	Lighting and refrigeration	The University of Aden utilizes 1.5 kWp for some lighting and a small refrigerator which can be used for medicine in remote area.
3	Egypt	Water pumping	A pumping unit in El-Mansoura, near Cairo, is installed by AEG/ Germany. It has two centrifugal pumps and produces 100 sq.m/day. The power is 2kWp. Another unit is being installed near Mit-Abo-Elcom with 5kWp as part of USAID programme.
4		Refrigeration Microphone, battery charger, TV and telephone repeater stations	Several small unit PV-refrigerators are being used in the rural area for medical purposes (5kWp). Used in remote areas.
5	Iraq	Street Lighting	Two sets of 40 lighting units near Baghdad, 75W each. 40 units are stand-alone while the other 40 units are centrally operated. This is an EEC project with SERC of Iraq (6kWp).
6		Water Pumping	Two pumps in farms near Baghdad (10kWp).
7		Telecommunication and light signals, railway and sea	At various parts of Iraq (20kW).

Table 5.4. (Cont'd)

No.	Country	Type of application	Remarks
8		Production of PV panels	With Siemens (300kWp per year).
9	Jordan	Repeater station	For civil defence and police in remote areas, 5 stations, each has 160 Wp, storage battery of 240 Ah at 12V. The daily load is 460 Wh (800 Wp).
10		Water pumping	a. Umari Well: Static water level 21m, casing 10 in., storage tank height 5m, storage tank capacity 55 cu.m, daily water requirement 40 cu.m. PV-system consists of 42 modules of polycrystalline silicon and has power rating of 1612.8Wp, inverter 105 V DC input and 3-phase 70 V output. Variable frequency. Submersible motor pump of 1150W. Actual pumping 37.3 cu.m/day. b. Jafer Well: Static water level 15.7 m, casing 10 in., storage tank height 5 m, storage tank capacity 55 cu.m, daily water requirement 40 cu.m All PV-system is the same as in (a) with power rating of 1344 Wp. Actual pumping is 37.6 cu.m/day. c. Hazeen Well: Static water level 12.5 m, storage tank height 5 m, storage tank capacity 55 cu.m. PV-system consists of 42 modules of monocrystalline silicon, with power rating of 1622 Wp. Actual pumping 62 cu.m/day.

Table 5.4. (Cont'd)

No.	Country	Type of application	Remarks
11		PV-testing station	As described in text.
12		Electricity supply for villages	This is part of the co-operation with Germany to supply PV-systems to remote areas for selected purposes, such as clinic refrigerator, electric lighting, educational television and emergency telephones. One village has a 4.5 kWp central system, with battery capacity of 3600 Ah at 24 V, with inverter to provide different AC-load. Another village has a decentralized 1 kWp system and battery storage of 1500 Ah at 12 V.
13		Train Crossing Signal	This is to control and operate a relay station at Fayan; 44 modules of 1760 Wp power, a shunt regulator, a battery storage 800 Ah at 24 V. The daily energy load is 6.24 kWh.
14		Radio transmitter	This is situated at the Dead Sea, for the Arab Potash Company. 8 modules of 370 Wp with battery storage of 300 Ah at 24 V. The daily energy load is 840 Wh.
15	Kuwait	KISR - Solar house	This is 2 kWp system of monocrystalline silicon cells to operate pumps for the 7.5 tons absorption cooling machine for the solar house and its lighting.
16		School lighting	This is as described in previous text.

Table 5.4. (Cont'd)

No.	Country	Type of application	Remarks
17		Battery charges	Several units of 0.5 kWp each with lead acid batteries were used to charge vehicles for fire-engines and police cars, total power 10 kWp.
18		Traffic light and seaport beacons	Traffic light signals at three different locations in Kuwait were installed in 1983, 240 Wp each (720 Wp) with battery storage of 800 Ah with each system. 2 kWp is used for various beacons.
19		Cathodic protection	Few pumping stations are using PV for corrosion protection (1 kWp).
20		Water pumping	There are more than 5 pumps operated by PV-panels, one in KISR, (6 kWp) and 4 in various agricultural farms near Kuwait city, (5 kWp) each. The combined power of the 5 pumps is 26 kWp.
21	Lebanon	Park lighting, sea-shore beacon lighting and few water pumping	Estimated capacity 30 kWp.
22	Oman	Telecommunications, cathodic protection and water pumping	Because the area is mountainous and scarcely populated - 15-/200 inhabitants per village - several PV-projects were installed. Estimated power 50 kWp.
23	Qatar	Solar energy research station	This was explained in the previous text.
24		Desalination	This is a reverse osmosis unit operated by the Physics Department of Qatar University. Power is 11 kWp. Uses Mobil Tyco ribbon type solar cells with an area of 100 sq m

Table 5.4. (Cont'd)

No.	Country	Type of application	Remarks
25	Saudi Arabia	Solar village	As in previous text.
26		Fence electrification	The 80 km long King Khalid Military City utilises 59 arrays of PV to electrify its fence and prevent camels from wandering in (30 kWp).
27		Jeddah car park	The international airport car park in Jeddah uses 20 kWp for lighting.
28		Abha-tunnel lighting	This is to light a tunnel in the mountainous region of Abha (10 kWp).
29		Cathodic protection	Since 1965, Saudi Arabia utilized PV units in most remote areas for oil pumping stations. Estimated power 100 kWp.
30		Short wave transmission	5-short-wave transmission stations in various parts of Saudi Arabia, total power 80 kWp.
31		Highway telephones	Highway telephones between the capital Riyadh and each of the following towns: Dhahran, Medina and Taif. total capacity 50 kWp.
32		Desalination unit	This is a reverse osmosis unit built by Mobil Tyco for their employees working in Jeddah. The unit is installed in their club by the Red Sea. The power is 10 kWp. Uses ribbon type cells.

Table 5.4. (Cont'd)

No.	Country	Type of application	Remarks
33	Syrian Arab Republic	Park lighting, sea-shore beacon lighting and few water pumping	Estimated capacity 30 kWp.
34	United Arab Emirates	Street lighting	An installation of 10kWp is used to light a tunnel and its entrance near Jabal Abu Ali in the UAE.
35		Cathodic protection	Several PV units are used in the pumping and refinery oil stations, with capacity of 25 kWp.
36	Yemen Arab Republic	Sana'a University project	This is a PV project to supply electricity to the weather station and provide some emergency lights. Its capacity is 22 kWp.

Source: A.A.M. Sayigh. Present Application of Photovoltaic in the Arab Countries. Paper presented at the conference: "The Role of Alternatives in the World Energy Scene", 'Energy Options', IEE-University of Reading, U.K., 7-9 April 1987.

desalination and ice-making. Table 5.5 illustrates the ready and potential applications of wind energy in the ESCWA countries.

(a) Water pumping

Small-scale wind energy technologies can play an important role in pumping water for household applications, animal husbandry and irrigation.

(b) Small-scale electric power generation

By small-scale wind electric energy conversion systems is meant those 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) with either two or three blades. These are low torque high rational speed wind turbines using mainly gears for power transmission. These systems may generate direct current (DC), variable frequency alternative current (AC) or constant frequency AC power, depending on the type of the electric generator coupled to the wind turbine and on the power conditioning unit associated with the system, if any.

(c) Water desalination

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

(d) Ice-making

Several fishing villages are scattered on the long coasts of the ESCWA region. One of the serious problems facing the fishermen in these remote villages is how to preserve fish until they are transported to consumers. 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. This ice can be produced during periods when there is enough power available in the wind, and stored at relatively low cost until it is required.

Energy consumption for fresh water ice-makers varies from 65 kWh/ton for small plants (3 tons/day) to 40-50 kWh/ton for larger plants (6 tons/day)(44). Energy consumption for sea water ice-makers is from 33 per cent to 67 per cent greater than for fresh water ice-makers. The component that consumes the major part of energy in an ice-making plant

Table 5.5. Potential application of wind technologies in the ESCWA region

Application Country	Water Pumping	Power Generation	Water Desalination	Ice Making
Bahrain			X	X
Democratic Yemen	X (M,E)	X	X	X
Egypt	X (M,E)	X	X	X
Iraq	X (M,E)	X	X	
Jordan	X (M,E)	X	X	X
Kuwait			X	
Lebanon	X (M,E)	X	X	
Oman	X (M,E)	X	X	X
Qatar				
Saudi Arabia	X (M,E)	X	X	
Syrian Arab Republic	X (M,E)	X	X	
United Arab Emirates	X (M,E)		X	
Yemen Arab Republic	X (M,E)	X	X	

M: Mechanical E: Electrical
Blank: Not applicable or low probability of utilization.

is the compressor (about 70 per cent of the energy) followed by the sea water pump (about 10 per cent of the energy) and then the other components and auxiliaries.

5.6 Activities in the field of wind energy in the ESCWA region

Wind energy research, development and demonstration are carried out by most institutions in the ESCWA region. These activities involve basic theoretical work, gathering of wind data, creation of prototype devices, modification or adaptation of wind system components to operate satisfactorily in local conditions, and field testing of individual components or integrated wind systems. Assessment of wind energy utilization, planning for wind energy research and development projects are also considered within the scope of research and development programmes, which may be carried out simultaneously in one institution since they are closely interrelated.

Since wind is an important energy source for water pumping and generating electricity in rural and remote areas, a brief review of wind energy research and development for some ESCWA countries is given below. It is also worth noting that as early as 3600 B.C., the ancient Egyptians used windmills for grinding grain and for pumping water from the Nile River to irrigate the surrounding arable lands. In the nineteenth century, wind energy had been utilized again in Egypt for water pumping. In the late 1940s and early 1950s windmills were extensively used for the same purpose in such countries of the ESCWA region as Democratic Yemen, Egypt, Lebanon, Kuwait, Saudi Arabia and the Syrian Arab Republic.

(a) Bahrain

No wind maps have been prepared in Bahrain, although wind velocity is measured at the airport by the country's Meteorological Service.

(b) Democratic Yemen

The Meteorological Service of Democratic Yemen measures wind velocity and direction at the national airport. The Public Corporation for Electric Power had installed an 18 kW wind energy conversion system as a pilot experiment in December 1979. Due to some mechanical difficulties, and perhaps due to low wind potential at the site, this system was dismantled.

(c) Egypt

Wind data of the country are recorded by the Meteorological Service. The Ministry of Electricity in 1972 initiated a wind assessment programme, financed by the National Science Foundation of the United States of America. Phase I of the programme included a resource availability study in which the already existing wind data from meteorological records were collected and analyzed in order to define the most promising locations for wind utilization. During Phase II of the 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). Phase III was intended to improve the time accuracy of the recording 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 meters. However, this phase was not implemented. In 1984, a wind resource assessment for Egypt was conducted by Battele Pacific Northwest Laboratories. In 1985, six measurement stations were installed in three sites on the Red Sea coast (Ras Ghareb, Hurghada and Ras Golan) and in three sites on the Mediterranean coast (El-Kasr, Obied and Ras El-Hekma). In addition, six wind measuring stations are being installed in six sites, including the Sinai.

Since 1984, a team from the National Research Center has implemented a project on utilizing solar and wind energy in the Sinai. The raw wind data collected from the records of the Meteorological Authority for several years before 1967 in three sites in Sinai (El-Arish, El-Torr and Abo-Rdais) and some additional data measured by mobile measuring instruments were analyzed.

To evaluate the wind potential a wind classifier was installed jointly by the Ministry of Electricity and General Petroleum Corporation in East-Oainatt about 1500 km to the southwest of Cairo.

Two wind energy conversion systems (one a 20-kW horizontal axis wind turbine and one a 20-kW Darrieus type vertical axis turbine) are being installed in the first experimental farm of East-Oainatt to test the wind regime of this site. In the same region, six wind energy conversion systems of 40 kW each are planned for installation in the solar village of East-Oainatt where an integrated energy system (solar-wind-biogas energy system) was used as a demonstration project financed by the Government of Italy.

A 55 kW wind energy conversion system financed by UNDP and executed by the United Nations Department for Technical Co-operation (UNDTCD) has been installed in Abo Ghossoun on the Red Sea coast to provide energy for an ice-maker.

Three WECS each of capacity 100 kW are being installed in Ras Ghareb on the Red Sea coast as a nucleus for a wind farm. This wind farm is financed by the Egyptian/USAID renewable energy project.

A 250-kW wind energy conversion system is proposed in the Development of East-Oainatt project for water pumping.

(d) Jordan

Wind data in Jordan are recorded by the Meteorological Service. In 1983, the Royal Scientific Society undertook a study on the inventory and processing of the available wind data collected from 30 measurement stations operated by the Jordanian Meteorological Department, the Natural Resources Authority and the Jordan Valley Authority, in order to assess the wind energy potential in Jordan. From 1983 to 1986, the Royal Scientific Society has set up four measurement stations and data acquisition systems to monitor wind data in Ras Muneef, Jesr Al-Ruwaished, Kharana, Jarf Al-Darawish and Al-Tayeba. Two wind electric pumping systems (one 20 kW wind generator, one 17.5 kW system) were installed in Jarf Al-Darawish. Another wind electric pumping system is being installed in Jesr Al-Ruwaished to pump 150 cubic metres per day from a depth of 180 m. and another wind electric pumping system with a pumping rate of 100 cubic metres per day from a well of 55 m. depth is installed in Al-Twana. A mechanical wind pump with a rotor diameter of 4 m, designed and manufactured by the Royal Scientific Society and including the pump and gear box, has been installed in El-Mudawara with a daily output of 50 cubic metres per day from a depth of 13 m.

(e) Kuwait

Late in 1983, wind energy research activities at the Kuwait Institute for Scientific Research were initiated by a wind assessment study. Its objective was to compile a computerized wind speed data base and to analyse and assess the acquired data for potential wind energy in the country. The Institute installed a network of wind measuring stations to record wind speed at various heights. Later, making use of the recommendations of the wind assessment study, Kuwait plans to install, operate and monitor a prototype wind turbine generator.

(f) Lebanon

The National Council for Scientific Research of Lebanon had studied wind energy utilization in the coastal areas. There is already a tendency to use large wind systems. However, owing to the present situation in Lebanon, further collection of wind data is not possible.

(g) Oman

There are 21 stations run by the Directorate General of Meteorology and three stations run by Petroleum Development of Oman. In 1986, the OMZEST

Group Companies, a private sector organization, undertook a wind resource assessment.

In 1980, Petroleum Development of Oman financed the manufacturing and installation of a 12-blade fan wheel-type windmill for water pumping at the location of the Khabourah Agricultural Development Project near Muscat. However, this windmill experienced many operating problems and the system was dismantled.

(h) Saudi Arabia

The Mechanical Engineering Department of the University of Riyadh in Saudi Arabia had three projects on wind energy, namely: (i) assessment of wind energy potential all over the Kingdom, (ii) utilization of locally manufactured small wind turbines to clean dust and sand from solar collectors installed in desert areas, and (iii) combined solar wind power generation.

The Institute of Meteorology and Arid Land at King Abdel Aziz University of Jeddah strongly recommended the utilization of wind energy, whenever possible, to pump underground water in any of some five thousand settlements, scattered all over the Kingdom and at distances more than 200 km from central power systems.

A new project, "Saudi Arabia Wind Assessment", is carried out by King Abdul Aziz City for Science and Technology (KACST). Its purpose is to carry out a wind solar power assessment survey leading to the development of a wind atlas and the identification of up to ten promising locations for near-term demonstrations. The survey would also include simulation and analysis of all weather data.

(i) Syrian Arab Republic

Wind data are recorded and were published in the Climatic Atlas of Syria by the Meteorological Department of the Ministry of Defence in 1977. In 1979, the Ministry of Electricity installed a solar wind power system in Erda to supply power to a communication station. In 1984, the Directorate of Research of the Ministry of Electricity published an overall assessment of the wind potential in Syria. There are about 4500 wind pumping systems, mostly locally manufactured, in operation in and around Nabek, and 2,000 wind towers in the Kalamoun area (north of Damascus). A 2 kW combined solar photovoltaic-wind energy system was installed in Edra by the Ministry of Electricity. The system was supposed to supply a communication station with electricity.

(j) United Arab Emirates

Wind data are recorded by the Meteorological Service at the country's airport. The Department of Technical Co-operation of the Ministry of Planning in Abu Dhabi has encouraged all Emirates to create a National Center for Science and Technology which will be concerned, *inter alia*, with new and renewable energy research.

(k) Yemen Arab Republic

In the early 1970s, the Ministry of Agriculture provided a few windmills for water pumping. They were installed around Taiz and other isolated areas.

5.7 Mature solar and wind technologies

The ESCWA secretariat has carried out an analysis that attempts to identify technology/applications in the region. It takes into consideration the capability of local technologies to manufacture system components with local materials. In total, 40 technology/applications options were evaluated based on solar, wind and hybrid technologies for urban sectors. For further elaboration of the methodology and criteria used in this evaluation, refer to document E/ESCWA/NR/86/5/Add.1. The results of this analysis can be categorized as follows:

(a) Mature candidates for commercialization in 1986-1990:

(i) Flat plate collector for a temperature range below 80° C using either water or air as the heating medium;

(ii) Greenhouse solar facilities for agricultural applications, either drying or protected agricultural technique;

(iii) Solar stills for capacities up to 10 cubic metres per day for Bedouin and desert communities;

(iv) Passive solar technologies for hot arid climates and climates with the need to develop appropriate building materials;

(v) Wind mechanical pumping using horizontal axis wind turbines.

(b) Maturing candidates for industrialization in 1990-1995

(i) Photovoltaic technologies for electric power generation and pumping applications.

(ii) Moderate tube and parabolic troughs for high temperature application.

These results could apply only in urban areas. However, for rural and remote communities, some renewable energy technologies need further investigation to set up an order of priorities adequate for these areas.

In a United Nations Development Programme study(45) carried out in 100 developing countries (including Bahrain, Democratic Yemen, Egypt, Iraq, Jordan, Lebanon, Oman, Qatar, Saudi Arabia, the Syrian Arab Republic and the United Arab Emirates) and completed in 1981, some 31 non-conventional technologies were reviewed with respect to the status of their commercial readiness in various applications. The technologies were grouped into nine broadly defined categories: draught animals, biomass, passive solar, active solar, wind, ocean systems, hydro, geothermal and fossil fuels. These technologies provide energy in the form of mechanical motion, heat, electricity and liquid fuels. Their applications are residential, commercial, agricultural, industrial, and transportation. The following tables were extracted from this study for comparison with the secretariat study.

It can be seen from tables 5.6 to 5.9 that there is a wide spectrum of solar and wind technologies for a number of applications that have a potential for commercialization in the near future.

Table 5.6. Current, short- and long-term uses of solar technologies to the year 2000

Energy use	Thermal		Electric		
	Temperature		Communication	Other dispersed application	Local power system
Technologies	Low 18-70° C	High 70° C			
PASSIVE SOLAR Architecture/ water bags/ greenhouses/ Trombe wall	C				
ACTIVE SOLAR Non-tracking solar thermal collectors flat plate/solar ponds/water bags/ simple concentrating	C			C	N
Tracking solar thermal collectors (distributed systems)		N		N	N
Heliostats--central receiver systems					L
Photovoltaic: silicon/ flat plate			C	C	N
Photovoltaic: thin film/high concentration	N		N	N	L
Photoelectrolysis			L	L	L

Source: United Nations Development Programme. New and Renewable Sources of Energy. Evaluation Study Number 5, May 1981.

C: Current availability N: Near-term availability, 1980-1990
L: Long-term commercial availability, 1990-2000
Blank: Not applicable or low probability of utilization

Table 5.7 Current, short- and long-term solar energy sectoral application

Solar Applications	Residential			Commercial Buildings			Agriculture		Industrial	
Technologies	Cooking	Heating	Cooling	Heating	Cooling	Direct lighting	Small farm	Large farm	Light industry	Heavy industry
PASSIVE SOLAR Architecture/Water bags/Greenhouses/ Trombe wall		C	C	C	C	C	C	N		
ACTIVE SOLAR Non-tracking solar thermal collectors: flat plate/solar ponds/Water bag/ simple concentrating	C	C	N	N		N	N	N		
Tracking solar Thermal collectors (distributed systems)		N	N	N	N	N	N	N	N	
Heliostats--central receiver systems										
Photovoltaic: silicon/ flat plat			C	C	C	C	C	L		
Photovoltaic: thin film/high concentration									L	
Photoelectrolysis		L	L	L	L	L	L	L		

Source: United Nations Development Programme. New and Renewable Sources of Energy. Evaluation study Number 5. May 1981.

C: Current applicability; N: Near-term applicability, 1980-1990; L: Long-term potential commercial applicability 1990-2000; Blank: Not applicable or low probability of utilization

Table 5.8 Current, short- and long-term wind energy sectoral application

Wind applications	Residential	Commercial		Agricultural		Industrial	
Technologies	Cooking heating cooling	Heating/ cooling	Direct lighting	Small farm	Large farm	Light industry	Heavy Industry
WIND Small electric/ mechanical	N		N	N			
Intermediate 100-1000KW		C	C	C	C	C	
Larger than 1MW		C	C	C	C	C	C

Source: United Nations Development Programme. New and Renewable Sources of Energy. Evaluation Study Number 5, May 1981.
C: Current applicability; N: Near-term applicability, 1980-1990; Blank: Not applicable or low probability of utilization

Table 5.9. Current, short- and long-term uses of wind technologies to the year 1990

Energy Use Technologies	Mechanical	Low temp. 18-70°	High temp. greater than 70°C	Communication	Other dispersed application	Local power system	Central power system
Wind Small Electric/ Mechanical	C	N	N	C	C	C	N
Intermediate 100-1000KW				N	N	N	N
Larger than 1MW			N		N	N	N

Source: United Nations Development Programme. New and Renewable Sources of Energy. Evaluation Study Number 5 May 1980.
C: Current availability; N: Near term availability, 1980-1990; Blank: Not applicable or low probability of utilization

VI. DEVELOPMENT OF RENEWABLE ENERGY TECHNOLOGIES INFRASTRUCTURE

6.1 Research and development institutions in the ESCWA countries

In most ESCWA countries, different activities in the field of solar and wind technologies are performed at universities, research institutes or departments within the competence of different ministries. Leading institutions of independent organizational structure that specialize in the field and that have widespread activities extending beyond research and development are the Royal Scientific Society of Jordan (RSS), the Kuwait Institute for Scientific Research (KISR), the Solar Energy Research Center (SERC) of Iraq, King Abdul Aziz City for Science and Technology (KACST), the National Research Centre of Egypt and the Egyptian Renewable Energy Development Organization (EREDO).

Most of the solar and wind energy budgets in ESCWA countries are drawn from educational budgets of universities or from budgets of governmental agencies. Some countries make special budget allocations for renewable energy research and development. These vary according to funds available and the importance attached to renewable energy.

6.2 National projects on solar and wind energy in co-operation with international communities

Solar energy and wind energy are clearly the two priority sources of renewable energy chosen by ESCWA countries. Interest in renewable energy in this region began in 1960 in various universities and institutions. Only after 1973 have national governments, in co-operation with major developed countries, become increasingly involved in the research and development of renewable energy. Table 6.1 shows projects undertaken by ESCWA countries during the past years that have been attracting an awareness and a serious consideration of promoting the use of new and renewable sources of energy by the countries of the region.

6.3 Role of government in strengthening the infrastructure

The role of government in the promotion/diffusion of mature renewable energy technologies is naturally related to the role of government in the economy generally. But these technologies should be considered in the broader context of the energy sector development.

The main activities which the government may undertake in the diffusion process are classified as follows:

- Information to consumers and manufacturers
- Taxes and subsidies
- Credit services
- Support of the distribution system
- Government participation in equipment manufacture
- Raising the public awareness via different mass-media channels.

Table 6.1. Solar energy projects in ESCWA countries

Country	Institution	Project	International Involvement
Bahrain	Bahrain National Oil Company (Banaco)	Feasibility study; greenhouses	Kuwait Institute for Scientific Research
Egypt	Cairo University	Research lab. collectors	
	American University (Cairo)	Silicon cells; social aspects of solar energy as applied at Al-Busaisa village	
	Alexandria University	Storage; collectors; water heating; water cleansing	
	Al-Munya University	Storage; collectors	
	Al-Mansoura University	Various	Florida University; USAID funds expected
	Al-Azhar University (Cairo)	Water heating; desalination	
	National Research Centre (Cairo) 1. Solar Energy Lab.	1. Power generation (heliostats and steam-powered generator up to 5 KWe)	USAID $150,000, 1975-78
		2. Power generation (cylindro-parabolic collectors and turbo-generators up to 10 KWe)	Swiss (Leibi) collectors W German aid, DM 5 mn 1976-79 (Dornier)
		3. Cooling; refrigeration	W German aid, DM 2 mn, 1976-79
		4. Desalination	W German aid, DM500,000, 1977-79
		5. Drying	Canadian aid, CS10,000, 1978-80
	2. Solid State Lab.	6. Photovoltaics	French scholarships & aid FF 180,000
	Solar Energy Commission (Electricity and Power Ministry)	1. Reverse Osmosis	French Atomic Energy Authority; French aid and FF 250,000
		2. Feasibility studies on application and supply of equipment, laboratories and testing stations.	FAEA and Sofretes $1.5 mn
		3. Qattara Depression project feasibility study	W German aid, DM 11.3 mn 1977-79 (Sweco, Sweden)
		4. Solar village plans; electricity for rural areas; tenders to be issued for photovoltaic cells, water heaters and irrigation pumps	Solar collectors purchased from MEA (Linz, Austria)
		5. Feasibility studies	USA
	Renewable Energy Development Organization		EEC funds ECU 10.3 mn
	Ministry of Electricity and Energy		USAID Project US$ 24.1 mn UNDP Project US$ 1.065 mn

Table 6.1 (Cont'd)

Country	Institution	Project	International Involvement
Iraq	Scientific Research Council (Baghdad)	Thermal conversion; desalination; agricultural drying; greenhouses; housing	
	1. Solar Energy Research Center		
	Baghdad University	Insolation; feasibility studies	
	Al-Mustansiriya University	Solar radiation; flat-plate	
	2. Building Research Centre (Baghdad)	Water and space heating	
	Arid Zone Research Institute	Water heating; desalination	
Jordan	Royal Scientific Society (RSS) Solar Energy Centre	1. Al-Aqaba desalination plant (heat-pipe system); windmill; photovoltaic plant	W German aid, DM 3 mn, 1977-79 and DM 3 mn (training) Dornier systems
		2. Photovoltaic plant (3 KW) Small distillation plant for army; solar still (Aqaba) cooking; power generation (planned); collector testing facility; water heaters (Jordan Oil Company)	EEC
		Space heating and cooling	KISR (Kuwait), JD 75,000
	Jordan Telecommunications Corps (Amman)	Telephones in rural areas	Telecom (USA)
	Jordan University (Agriculture Faculty)	Soil sterilization;	
Kuwait	Kuwait Institute for Scientific Research (KISR)	Heating and cooling building Thermal conversion unit (100 KW) collectors; storage; desalination; food purification, greenhouses, photovoltaics planning; agriculture	Five-year co-operation agreement with FRG, 1980-85, MBB (FRG), US$1.7 mn contract; Delaware University Bahrain National Oil Co.
	Kuwait University	Photovoltaics	

Table 6.1 (Cont'd)

Country	Institution	Project	International Involvement
Lebanon	National Council of Scientific Research (CNSR)	Insolation, distillation, photovoltaics	
	American University of Beirut	Water heating (CNSR grant)	
	St. Joseph University	Distillation (CNSR grant)	
	Lebanese University	Heating	
	National Solar Energy Council	Co-ordination and funds	
Qatar	Industrial Development Technical Centre	Desalination plant Desalination plant	Kobe Steel (Japan) Alpha Solarco (USA)
	General Petroleum Company	Feasibility study Photovoltaic generator (cathodic protection, Research Centre).	Lucas Services (UK)
	Applied and Scientific Research Centre, University of Qatar	Photovoltaic driven reverse osmosis water desalination plant	UNESCO
Saudi Arabia	Solar Energy Commission (SEC)	Co-ordination	
	Saudi Arabian National Centre for Scientific Technology (SANCST)	Co-ordination; funding; SOLERAS project involving solar villages, desalination, cooling, education & training	Five-year US$ 100 mn (Soleras) project with US Dept. of Energy (Solar Energy Research Institute); US$ 16.5 mn contract to Martin Marietta for solar power plant (350 KW) for villages
	Petroleum and Minerals University (Dhahran)	Helohydroelectric generation study; insolation; desalination; precipitation of magnesium chloride; storage; photovoltaics; housing collectors; hydrogen production water heating; solar ponds; GTEC	US$ 600,000 to Terraset School (Virginia, USA)

Table 6.1 (Cont'd)

Country	Institution	Project	International Involvement
	Riyadh University	Distillation; water or space heating; crop drying; space cooling; collectors; desalination; storage; housing; hydrogen production; greenhouses; geothermal power	Air-conditioning unit from Georgia Institute of Technology
	King Abdul Aziz University (Jeddah)	Solar pump; desalination	Sotec (Swiss), desalination plant (SR 1.5 mn), Sofretes (France) pump;
	King Faisal University (Dammam)	Agricultural and industrial applications; desalination	
	Saudi Technology and Research Consulting Committee	Air conditioning; agriculture; power; generation; industry; weather modification	US$ 5 mn grant to Sydney University Science Foundation for Physics (1977)
	Al-Diriyya Institute (Geneva)	Heating, cooling; water pumps; research funding	US$ 100,000 cartoon film; US$ 125,000 to Terraset School (Virginia, USA)
	Ministry of Industry and Electricity	Solar power station and pump with SEC and Riyadh University	US$ 5 mn agreement (1978) with EdF involving supply FF 5.4 mn 45 kW Sofretes pump and FF 6 mn 30 kW Seri-Renault photopile; US$ 1.5 mn 240 kW power plant (Solfrance)
	Meteorology Department	Insolation data (Jeddah)	
	Agriculture Ministry	Insolation data	
Syrian Arab Republic	Petroleum Ministry	Domestic equipment and application	
	Electricity Ministry	Space heating	
	Aleppo University	Syrian Solar Energy Society but no programme yet	
	Damascus University	Water heating; storage; cooling photovoltaics	
United Arab Emirates	Trade and Industry Government	Desalination plant Pump (1kW), Al-Ain, Al-Saadiyat complex (food/water/power) Feasibility study	Japan CFP/Sofretes (France) Arizona University (USA) Italy;
	General Enterprise Company	Agent for foreign firms	Solahart (Australia); Dornier (FRG) Solarex (USA); and Solar Industries (USA)
Yemen Arab Republic	Sana'a University	Feasibility study photovoltaic system (1.6 kW)	Georgia Institute of Technology (USA)

Source: J. Perera, Solar and Other Alternative Energy in the Middle East.
The Economist Intelligence Unit. Special Report No.108, September 1981

(a) Information to consumers and manufacturers

Governments can aid the diffusion process by providing information to manufacturers on the options available and by monitoring design performance at independent testing and certification centres. These activities may already be done at existing research institutions; however, the links between industry and research in most developing countries are not effective or nearly nonexistent. The results of applied research should be made available to industry for commercial applications.

Information to consumers can take the form of publicity of new technologies and their costs, benefits and reliability. It can involve the assessment of resource and site evaluation. This type of information to consumers can be channeled through existing technical extention services attached to government offices(46).

(b) Taxes and subsidies

Governments should also review economic policy and assess the appropriate place for renewable energy technologies in their fiscal and trade regime. It may consider a protective tariff for domestic manufacture of the equipment/components concerned. The reduction of import tariffs on materials and components used to manufacture these systems may be one suitable option, or the governments may wish to consider subsidies to consumers to make renewable energy competitive with subsidised petroleum products. Another option is to restrict alternative technologies, forcing all new consumers to adopt the new technology. It is also possible to compel all existing consumers to retrofit their appliances(47).

(c) Credit services

Governments should provide credit or soft loans to consumers and manufacturers.

(d) Support of the distribution system

Governments may be able to use existing organizations to distribute equipment. For example, consumers of hot water will be already paying the local electricity utility for the use of electricity, and it may be convenient to make the electricity company a distributor of solar water heaters and also be responsible for repair and maintenance.

Governments can also give manufacturers tax subsidies in order to compensate for remaining market risks; or they can eliminate risk entirely by purchasing an agreed number of units of new equipment--possibly over a period of years--and by assuming all responsibility for the distribution of such equipment (e.g., installing solar water heaters in government owned housing and office buildings).

Governments could also become involved in developing the infrastructure necessary for the diffusion process. The ability of purchasers to maintain and repair their own equipment may be very limited, and governments can help by establishing repair facilities and technical training programmes for specialized technicians(47).

(e) Government participation in equipment manufacture

Instead of contracting to purchase specified quantities of renewable energy equipment, governments can help make production more attractive by investing equity in the producing firm. Such firms would then be maintained as public entities responsive to the market and could invest their profits in market development. The attraction to government of a joint venture is that it does not have to take all the risk--some is borne by private capital. This may be important if public funds are limited, although governments can also establish a completely state-owned company to produce the technology, if they have sufficient resources of capital and manpower(47).

(f) Raising public awareness via mass-media channels

In the case of renewable energy technologies, both public and private organizations have come to recognize the compelling national interest in hastening the commercial availability of renewable energy. The major barriers against accelerating the utilization of renewable energy are: high initial cost; limited public awareness of, and information about, economically competitive technologies and difficulties in the early stages of technology development. It is useful if industry's and government's renewable energy development programmes are complemented by the activities of many individuals, community groups and non-profit organizations to disseminate information about renewable energy and to make people familiar with renewable technologies. Television, mass-media and education programmes are the best tools to raise public awareness on renewable technologies.

6.4 Availability of local materials

Promoting the use of solar and wind technologies that have been proven appropriate for the ESCWA region is dependent upon many factors. As stated in previous sections, a number of ESCWA countries have already started to manufacture some solar and wind components, while importing the rest of their systems from developed countries. The material requirements for most solar and wind devices for current and near-term uses are available in most ESCWA countries, since any solar and wind system incorporates a number of conventional elements which are essential for the system to function.

In the case of a solar water heating system, the materials used for the solar collector, storage and heat exchanges, circulation and controls, piping networks and back-up system can be found in most local markets. The common materials used in a solar system are copper, aluminium, steel, stainless steel, galvanized steel, glass, plastic, fiberglass and wood.

The construction, operation and decommissioning of solar facilities used in the future at the multiterawatt level will create substantial requirements for materials such as steel, glass and concrete. For the photovoltaic system, most of the material requirements are imported. In the case of wind energy conversion systems (WECS), steel, galvanized steel, aluminium, fiberglass and wood are locally available.

Solar water heating systems utilizing flat plate collectors have been developed and tested in Egypt since 1962. The first firm to produce these was established late in 1980, and its rated capacity is 10,000 heaters annually. The number of companies manufacturing these systems has increased rapidly over the last five years. However, although more than 15 companies were initiated, only eight are now actively producing, installing and operating solar water heaters in Egypt.

In 1983, two companies in Amman manufactured solar water heaters for domestic use: Hanania Heaters*, a subsidiary of Solar King, USA, and Solar Energy Delux, a Jordanian company with a factory at Ayn Al-Bashah, run by the Solar Energy Company (SECO). The production capacity of each company was about 30 heaters a day.

The number of workshops for local production increased in 1984 to a total of 37, with a real production rate of 12,284 units/year (consisting of three collectors with an area of approximately 3.2 square meters, storage tank and the required piping), and a total production capacity of 43,924 units (the utilized part of the production capacity is currently 28%). The total aggregate investment in this industry as of 1985 was JD 1.63 million.

The total number of houses utilizing solar water heaters in Jordan by the end of 1984 was 44,700 (approximately 13% of the total houses in Jordan).

The local manufacture of flat plate collectors for water heating in the Syrian Arab Republic has been carried out by the Ministry of Industry, and eight private firms are taking active interest in the rapidly growing solar heating business.

Table 6.2 shows the manufacturers of solar water heater systems in Egypt and Jordan.

6.5 Skilled manpower requirements

It is realized that many renewable energy technologies are particularly appropriate for small-scale and decentralized systems, and that the energy resources on which these technologies rely are abundantly available in rural areas. The rather low rate of progress achieved in the dissemination of renewable energy technologies in rural and remote areas tends to confirm that a rural energy development programme, to be successful, will depend on efforts to build and strengthen the self-reliance of local communities to devise, implement, manage, maintain and make the most productive use of decentralized, non-conventional energy systems. Therefore, the assessment of manpower and skill needs in the renewable energy industry is a vital component of energy planning.

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* Mention of firm names and commercial products does not imply the endorsement of the United Nations.

Table 6.2. Manufacturers of solar water heater systems

Country	Manufacturer	Capacity sq.m collectors	Status
Egypt	- Solar Energy Corporation (SEC)	20,000	Producing, 1980
	- Renewable Energy French Egyptian Co. (REEFCO)	20,000	Producing, 1984
	- Arabic Organization for Industrialization	10,000	Starting 1985
	- Misr America for Solar	10,000	Producing, 1982
	- Helwan Co. for Metalic Work	10,000	Producing, 1980
	- El-Ahmady	N.A.	Not regular assemly
	- GESEC	N.A.	Producing, 1983
	- Kim Electric Co.	10,000	Producing, 1984
	- No. of importing agencies	variable	
Jordan	- Hanania	20,000	Producing, 1973
	- Rum	10,000	Producing, 1981
	20 small workshops	variable	

There is also general agreement that surveys of any manpower assessment may have to differ from country to country of the region. Decisions regarding surveys will have to be based on several factors which, inter alia, include: the importance and priority given to different energy subsectors within the entire energy development plan; energy resources and technologies which will have a bearing on the calibre of manpower required, and the gestation period required for their development and the substitution of old skills for new; and the level of training institutions and training programmes.

Currently, it is difficult to obtain detailed information on skilled manpower in renewable energy fields. Sometimes the information available is very general, referring simply to engineers, technicians, skilled, semi-skilled or unskilled workers, which are generally employed by the concerned ministries or by research institutions. As stated earlier, renewable energy systems are being developed mostly in rural and remote areas. The related promotion activities, carried out by state or para-statal development authorities or private voluntary organizations, conform more closely to rural development activities. The phases of programme development and relevant activities, such as a project for installation of a plant using renewable energy technologies on a farmer's premises, are shown below:

(a) Survey, study and extension/promotion phase;

(b) Processing of requests for assistance phase;

(c) Construction to trial run phase;

(d) Operation phase.

Unfortunately, very little has been documented on the manpower requirements of the activities listed above. More serious is the lack of substantiated information on manpower with respect to the renewable energy installations in the region.

6.6 Local manufacturing capability

The development of solar and wind energy in the ESCWA region demands that countries be able to design and manufacture equipment to transform such sources into thermal, mechanical or electrical energy. The industrial capacity to produce such equipment exists in most of the countries in the region, albeit in varying degrees. Obviously, it will require much greater effort to increase quality as well as reduce costs. In reality, this means increasing the capacity of local engineering to improve the design of solar and wind energy equipment.

On the basis of all industrialization data collected, the capacity for instalment of solar and wind energy equipment was estimated for the various branches of industry that might eventually produce such equipment. The industries considered were heavy machinery, electricity, electronics, chemical and construction.

The following procedure has been used to obtain information on the region's potential for manufacturing such equipment:

(a) Equipment of great potential use was studied and broken down into its component parts or subsystems;

(b) After obtaining information on equipment components, an analysis was made of the industrial processes that are required both for the manufacture of components and for the production of equipment from the components;

(c) Once information was obtained on manufacturing requirements, it was possible to determine whether or not such industrial processes are potentially available within the current industrial capacity of each of the countries of the region.

Table 6.3 lists the equipment components utilised in converting solar and wind energy and their related manufacturing processes.

It is well known that the level of sophistication of equipment or processes requires a long lead time of research and development, since the industrial processes known in some countries of the region are nonexistent in others. For example, technologies associated with the use of wind energy are usually of intermediate sophistication, and although industrial infrastructure exists in all countries, problems of the design and materials technology may still be encountered. On the other hand, technologies associated with the use of direct solar energy for heating, distillation, drying and greenhouses are at low levels of sophistication. However, this does not mean that little remains to be accomplished with regard to design and study of materials. Solar refrigeration and solar electricity, either by solar thermal conversion or photovoltaic conversion, are relatively sophisticated technologies in which technical and design problems continue to occur even on a worldwide level.

Table 6.3. System components and manufacturing processes of solar and wind energy equipment

Type of energy	Components	Manufacturing processes
Direct solar energy		
Hot air drying	Collector, drier trays	Sheet metal work, basic chemistry, mechanical engineer/glass/plastic
Distillation	Tray with polluted/brackish/ saline water, condensing glass reservoir	Sheet metal work, basic chemistry, mechanical engineering
Water heating	Collector, water circuit, hot and cold water tanks	Sheet metal work, mechanical engineering, electrical chemistry
Solar cooling/refrigeration	Collector, heat exchanger, refrigeration chamber	Sheet metal work, mechanical engineering, chemistry, boilermaking
Solar electricity	Photovoltaic arrays or gas expanders, turbine, generator, pump	High purity chemistry, precision mechanics
Wind energy		
Windmills for pumping water	Rotor, transmission, pump, supporters, towers	Mechanical engineering, casting, machining, ball bearing, laminating, stamping
Aerogenerators	Blades, generator, batteries, supporters, towers	Stamping, fiberglass, electrical

Local commercial involvement in solar and wind energy is as yet very limited, although a few small companies in the area manufacture solar water heaters of local design (mainly in Egypt, Jordan, and the Syrian Arab Republic). There are also some companies which import water heaters and simple collectors under licence (mainly in Egypt and Jordan). In Saudi Arabia and the Gulf States, foreign companies, with local partners to promote their products, have established factories for manufacturing solar heaters. Table 6.4 shows the involvement of private companies from developed countries in the region's solar energy development.

Table 6.4. Involvement of foreign oil company[a/] in the field of solar and wind energy in the ESCWA region.

Company*	Links with other firms	Area of interest
Exxon	Solar Power Corporation (USA)	Photovoltaics
	Solar Thermal Systems (USA)	Collectors
	(Seeking wind energy company)	Photovoltaics
Shell	Solar Energy Systems (USA)	Photovoltaics
	Solahart (Australia)	Hot water systems
Atlantic Richfield	Arco Solar (USA) Electronic Conversion Devices (USA)	Photovoltaics
Mobil	Mobil Tyco (USA)	Photovoltaics
Sohio (Standard Oil-Ohio)		Various
Amoco (Standard Oil-Indiana)	Solarex (USA)	Various
Chevron (Standard Oil California)	(seeking company)	Various
Philips	Accurex Solar Collectors Corporation (USA)	
Eni	Solaris (Italy)	Photovoltaics
Agip	Jacorossi (Italy)	Collectors
	Solaron (USA)	
CFP	Total (Australia)	Air conditioning
	Sofretes (France)	Various
	Photon Power (USA)	Photovoltaics

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* Mention of firm names and commercial products does not imply the endorsement of the United Nations.

In the production of photovoltaic conversion systems, four distinct types of product are manufactured. They are the following:

(a) <u>The raw material from which the cells are fabricated</u> are cheap and abundant. The cells may be produced by firms specializing in silicon production for the semi-conductor industry or other industries, by firms producing only the raw material for solar cells, or by firms which also fabricate the photovoltaic cell itself.

(b) <u>The cells themselves</u> may be manufactured either by firms which also produce the raw material or by firms which purchase this material and fabricate the cells and modules.

(c) <u>Other components of a conversion system</u> include batteries, power conditioning units, support structures, as well as the design and installation of systems. These products may come from the cell producers or from independent companies.

(d) <u>Other devices needed for a conversion system</u> include pumps, engines, and other equipment.

These components cannot be manufactured in ESCWA countries, since the existing industrial capabilities relevant to the photovoltaic industry are very limited. However, Iraq and Saudi Arabia manufacture modules of single-crystal silicon, while NRC of Egypt pursues the research and development of silicon ribbon (see table 6.5).

Table 6.5. <u>Photovoltaic system components</u>

PV System Component		Existing Industry	
Component	Type	Status	Country
	Flat-plate concentrators		
Modules	Single-crystal silicon	Producing	Iraq, Saudi Arabia
	Polycrystalline silicon		
	Amorphous silicon		
	Silicon ribbon	R & D	Egypt (NRC)
Supporting structure	Pole mount Fixed Tracking	Installed	Egypt
Batteries	Lead Acid Lead-calcium Nickel-cadmium	Producing	Egypt
Regulators and Controllers	Shunt regulation Series regulation Maximum power	Imported	
Power Conditioning	- Inverter - Frequency converter - DC/DC converter - AC/DC converter - AC regulator	Imported	
End Use	As required		

It is clear that the application of solar and wind energy is seen as an area of market expansion in which many major solar and wind companies are involved. Companies in France, Italy, Japan, the Federal Republic of Germany and the United States of America participate in the renewable energy market, exporting their products to the developing countries.

6.7 Economic viability

There is a considerable interest in the manufacture of renewable energy equipment in the ESCWA region. The area is already seen by the developed countries as a major potential market where both governments and private companies are deeply involved in research programmes and joint ventures. Developed countries seem to view the region as a vast experimental laboratory where they can test new equipment, and some of the richer countries seem to be willing to co-operate.

Following are the factors that contribute towards increasing the economic viability of solar and wind energy equipment(47).

(a) Production cost. The determining factor here appears to be the production cost of equipment. If mass consumption is desired, the equipment must be produced at the lowest possible price, without any subsidies or any other kind of incentives given by the government.

(b) Economy of scale. It is important to bear in mind that a kind of vicious circle exists with regard to cost, since one of the important variables determining the cost of a specific piece of equipment is the volume of production, which in turn is determined by the degree of market penetration of the technology, further influenced by the production cost of equipment that uses the technology. In order to overcome this vicious circle, clear-cut policies are required to support the development of the energy sector.

(c) Operation cost. The economic viability of equipment and consequently the market penetration of a technology, are strongly influenced by the operational cost of alternative equipment. This is principally determined by the cost of conventional energy. The price of energy for users is a political variable that depends essentially on the rate policies of the government concerned. If the price of electricity is subsidized by the government, it is highly unlikely that equipment such as a solar water heater will be competitive in urban areas.

(d) Cost of transfer of technology. The cost of equipment using renewable energy manufactured under license, requiring the payment of royalties or patents, may be higher in accordance with the arrangements made for the transfer of the technology in question.

(e) Intensity of use of equipment. The economic viability of renewable energy equipment also depends upon its use for long periods; otherwise, an extraordinary amount of time is required to amortize such cost.

(f) Marketing network. Another factor having an influence on the promotion of such equipment is the need for an adequate marketing network that will make it possible to inform rural inhabitants of the possibilities offered by the use of non-conventional sources of energy and that will enable them to observe how much equipment will function without the need to travel to urban centres. An adequate marketing network would also make it possible to provide appropriate technical servicing to the users of such equipment. Audio-visual aids such as video cassettes recording the different stages of development, performance and maintenance of renewable energy equipment are the best tools for this purpose.

6.8 Policies directed towards increasing the economic viability of solar and wind energy equipment

In analyzing the above factors which influence the economic viability of solar and wind energy equipment, there are several tactics that may be adopted as a means of achieving, *inter alia*, the following objectives:

(a) Diminishing the cost of production of equipment: this may be achieved either by means of offering technical and economic support to producers or by assisting them in acquiring inputs or by co-operating in their efforts to increase productivity;

(b) Expanding the market: a few measures that may contribute to achieving this objective are:

- purchase of equipment by the public sector;
- financial support to users to assist them in making the initial investment;

(c) Increasing the intensity of use of the equipment: this will make it possible to reduce the amortization period;

(d) Co-operating in the organization of a marketing network;

(e) Increasing the competitiveness of equipment using renewable energy.

6.9 Social and environmental acceptability.

Solar and wind energy are clearly the renewable sources of energy that offer the greatest possibilities for the future and that have achieved the greatest degree of development. However, the penetration process of technologies using NRSE is also determined by diversive factors: technological, economic, political, social and environmental. Table 6.6 will illustrate the degree of social and environmental acceptability of solar and wind technology in the ESCWA region.

6.10 Opportunities for regional and international co-operation.

In view of the inevitable depletion of oil and natural gas sources in the long run and the need for ESCWA countries to preserve their resources for future generations, one policy option would be the acceleration of the utilization of NRSE.

Table 6.6. Social and environmental acceptability of solar and wind technologies

	Solar Collectors: Passive	Low-Temperature Active	Solar Collectors: Intermediate and High Temperature	Photovoltaics	Wind
Degree of Social Acceptability Scale: Poor Good Very Good Excellent	Excellent With appropriate designs system components can be integrated aesthetically into a building.	Excellent Most systems can be aesthetically integrated into building structures.	Good Rural land areas covered by a large collector filed ar expected to be acceptable in selected arid areas. Areas adjacent to urban and scenic areas are expected to be very limited	Excellent Systems produce electricity which is well under stood and widely accepted by consumers. There is little noise in home installation, and system reliability is well established.	Very Good Locating wind machines away from urban areas will mitigate problems of noise and television interference.
Environmental Acceptability Scale: Poor Good Very Good Excellent	Excellent There are some potential concerns with indoor air pollution arising from close control of building air exchange.	Excellent There are minor problems in handling some waste products.	Good Some minor concerns exist regarding potential harm to desert environment.	Excellent Some minor concerns in manufacture. Generally, a very clean approach to power generation.	Excellent Minimal impact on air and water quality and wildlife.

Total energy supplies from solar and wind energy are not expected to have any tangible effect on the energy balances of this region by the year 2000. However, it is important to recognize the significance of advancing endogenous research, development and demonstration in these new technologies, including the adaptation of progress made in the industrialized countries. In this context, regional and international co-operation in the application of NRSE is of paramount importance in grouping the scattered research pursued simultaneously by several countries of the ESCWA region. The objective of reformulating such research into co-operative programmes is to provide the benefit of specialization and to solve the particular needs of the rural and remote areas. It is in these areas that NRSE can make a contribution to the enhancement of economic and social progress.

Another important aspect for the development and utilization of NRSE is its suitability as a source of energy for decentralized, scattered rural and remote areas. The provision of available energy for these areas is, in itself, an assurance for socio-economic development.

In areas of research and development co-operation among regional institutions involved in NRSE could be further enhanced for manufacturing the components of solar, wind, energy and biogas systems. The stage of industrial development of the countries of the ESCWA region allows for the production of such components. This, in itself, could lead to co-operative arrangements for standardizing components, exchanging expertise, etc.., suitable for the region.

Three main potentially fruitful fields of co-operation are:

(a) Policy issues

From the available information, it seems that falling oil prices and the resulting availablilty of relatively cheap oil have led the majority of institutions active in NRSE research to abandon ongoing research in large-scale utilization of solar and wind energy. This situation may encourage rich oil-producing ESCWA countries to take advantage of the financial constraints faced by the technically advanced countries and to propose joint research, development and demonstration programmes. This would ensure the funding and continuity of solar and wind energy projects and the transfer of such research to the ESCWA region. Needless to say, such an approach, in addition to enhancing international co-operation enabling regional experts to share the advanced knowledge so far gained by the industrialized countries, will perhaps also result in practical contributions to regional and specific research and the development and manufacture of the new technologies.

(b) Technological issues

The exchange of information, data and experience could be useful for ESCWA countries in the following areas:

(a) New technologies and problems related to their manufacture and commercialization;

(b) Institutional and regulatory policies related to standardization and quality control;

(c) Exchange of design, development and testing engineers to work in joint teams on national projects.

(c) <u>Action-oriented co-operation</u>:

In this field, some ESCWA countries have developed a very good bilateral and multilateral co-operation with developed countries, as shown in tables 6.7 and 6.8. ESCWA can play a positive role in the action-oriented co-operation programmes, identified below:

(i) Establishment of regional prototype testing facilities for new technologies, especially in the field of NRSE;

(ii) Setting-up of demonstration projects in high-priority areas for new technologies for NRSE. (In fact, ESCWA is already formulating nine NRSE project proposals, which will be submitted for implementation to various funding agencies for financial assistance);

(iii) Establishing a Regional Information Network on NRSE (already operating since 1986);

(iv) Establishment of a regional training programme on NRSE;

(v) Establishment of a regional technology support programme in the field of NRSE, with micro-computer and software systems which can be used by all member countries.

Table 6.7 Federal Republic of Germany's involvement in the renewable energy programmes of some ESCWA countries

Country	Local institution	Project	Company
Egypt	National Research Centre	Cooling Desalination	Dornier GTZ
		Power generation	Dornier
	Ministry of Electricity	Qattara depression feasibility Co-operative agreement	
Jordan	Royal Scientific Society	Desalination plant	Dornier
Kuwait	Government Kuwait Institute for scientific Research (KISR)	5 year co-operation Thermal conversion Unit (US$1.7mn)	MBB
Saudi Arabia	King Abdel Aziz University	Co-operation	
UAE	General Enterprises Company	Marketing	Dornier

Table 6.7 France's involvement in the renewable energy programmes of some ESCWA countries (Cont'd)

Country	Local institution	Project	Company
Egypt	National Research Centre	Photovoltaics	
	Ministry of Electricity	Reverse osmosis Solar Refrigeration	
		Co-operation agreement (FF 7 mn) testing stations	Sofretes
Qatar	Government	Research Centre (US$ 5.5 mn)	
Saudi Arabia	Government	Environmental data collection station	Photowatt
	Ministry of Industry & Electricity Riyadh University	US$ 5 mn co-operation agreement; power plant; pump	Solfrance Sofretes
	King Abdel-Aziz University	Pump	
UAE	Trade & Industry Ministry	1 kW pump	CFP

Table 6.7 United States of America's involvement in the renewable energy programmes of some ESCWA countries (Con't)

Country	Local Institution	Project	University	Company
Egypt	Al-Mansoura University	Various	Florida University	Solar Industries
	National Research Centre	Power generation		
	Solar Energy Commission	Feasibility study		
	Ministry of Electricity	Renewable Energy Technology Project		
Jordan	Telecommunications Corps	Solar telephones		Telecom
Kuwait	Kuwait Institute for Scientific Research (KISR)	Heating & cooling buildings		CIT
		Thermal conversion	Delaware University	
Oman	Petroleum Development Oman (PDO)	Telecommunications		Solarex Solar Power Corps Arco Solar Solenergy
Qatar	Sigma Enterprises	Marketing		Alpha Solarco
	Industrial Development Technical Centre (IDTC)	Desalination plant		Alpha Solarco
Saudi Arabia	KACST	Soleras (US$100mn)		
	Petroleum & Minerals University (Dhahran)	Terraset School (Virginia, USA) US$ 600,000		
	Riyadh University	Air conditioning unit	Georgia Institute of Technology	
	Government	Tabuk Air School water heating (US$ 4.5 mn)		Sverdrup & Parcel
	Jeddah	Photovoltaic desalination plant (US$ 1 mn)		Mobil Tyco
UAE	General Enterprises Company	Marketing		Solarex

Table 6.8 Other European countries' involvement in the renewable energy programmes of some ESCWA countries

Country	Local institution	Project	University	Company
EEC				
Egypt	Renewable Energy Development Organization (EREDO)	Studies for research center		
Jordan	Royal Scientific Society (RSS)	3kW photovoltaic power plant		
Austria				
Egypt	Solar Energy Commission	Collectors		MEA
Denmark				
Kuwait	Kuwait Institute for Scientific Research (KISR)	Co-operation		
Italy				
Egypt	EREDO	Research centre feasibility		Cesan (Ansaldo)
Switzerland				
Saudi Arabia	King Abdel-Aziz University Arab Development Technology National Research Centre (NRC)	Desalination plant Collectors		Liebi Polisolar (SOTEC) Liebi
UK				
Saudi Arabia	Government Dallah Enterprises Abana Enterprises	Environmental data stations (Pds 2.7 mn) Marketing		Plessey Spencer Solaris
Oman	Government Petroleum Development Oman (PDO)	Wind pumps Telecommunications (Pds 8 mn)	Durham University	InternationalTechnology Development Group (ITDG) Cable & Wireless
Qatar	General Petroleum Company	Photovoltaic catholic protection		Lucas services

Table 6.9 Other countries' involvement in the renewable energy programmes of some ESCWA countries

Country	Local institution	Project	University	Company
Japan				
Saudi Arabia	King Abdul Aziz University	Desalination plant		Oriental Metal
Kuwait	Government	Co-operation (housing)		
	Institute for Scientific Research (KISR)	Absorption chiller; collectors		Yasaki
Qatar	Industrial Development Technical Centre (IDTC)	Desalination plant		Kobe Steel
UAE	Trade & Industry Ministry	Desalination plant (US$ 7 mn)		T. Ito Trading Nihon Kihatsu
Australia				
Saudi Arabia	Saudi Technology & Research Consulting Council	Aid of $5 mn	Sydney University	
	King Abdel-Aziz University	Hot water system	Sydney University	
UAE	General Enterprises Company	Marketing		Solahart
Canada				
Egypt	National Research Council (NRC)	Solar Drying		
	Electricity & Power Ministry	700 water heaters (CN$900,000)		Petro Sun
India				
Egypt	Ministry of Power &	Co-operation agreement		
Kuwait	KISR	Co-operation		
Jordan	Royal Scientific Society	Co-operation		

VII. INSTITUTIONAL SETTING FOR THE APPLICATION OF SOLAR AND WIND ENERGY

7.1 Energy planning and policy co-ordination

In some ESCWA countries, the lack of government and popular support for the promotion of the utilization of renewable energy has been closely linked to institutional weakness in this subsector. Institutional weakness in the energy subsector has contributed to the lack of coherent policies for the pricing, taxation and marketing of renewable energy equipment. In addition, at the sectoral level, there is a need to strengthen policy co-ordination and energy planning to evaluate future energy demand and options for management. There is also a need to establish realistic priorities among subsectors and to reconcile energy development objectives with sectoral and macro-economic constraints. In attempting to improve policy co-ordination and energy planning, the resources that are available to the government are unlikely to increase significantly. Therefore, pragmatic solutions will be needed to use scarce resources more efficiently, and these can be achieved by strengthening existing institutions rather than creating new ones.

7.2 Institutional co-ordination

Bearing in mind that renewable energy can make a relatively limited contribution to meeting future energy requirements and that there is potential for private sector activity in this field, governments should have become an effective lead institution for renewable energy development. This institution should be part of the formal government structure and should be responsible for:

- setting priorities based on economically viable options;
- monitoring the operating agencies;
- co-ordinating external assistance for renewable energy projects;
- directing efforts in data collection.

Figure 7.1 shows the basic hierarchy of a regionally integrated energy plan which could be applied(11).

7.3 Manpower development and training

(a) Manpower development

The skilled manpower most concerned with the design, manufacturing, installation, etc., of renewable energy systems includes various branches of engineering and basic sciences--mechanical, chemical, civil, electrical and industrial engineering, and chemistry, physics and biology. Also relevant is the participation of specialists in the applied sciences related to environment, architecture, rural development and agricultural production, as well as that of specialists in the social sciences and economics.

It has been found that research studies on renewable energy have been dealt with in many of the universities and institutes of the ESCWA region.

Figure 7.1

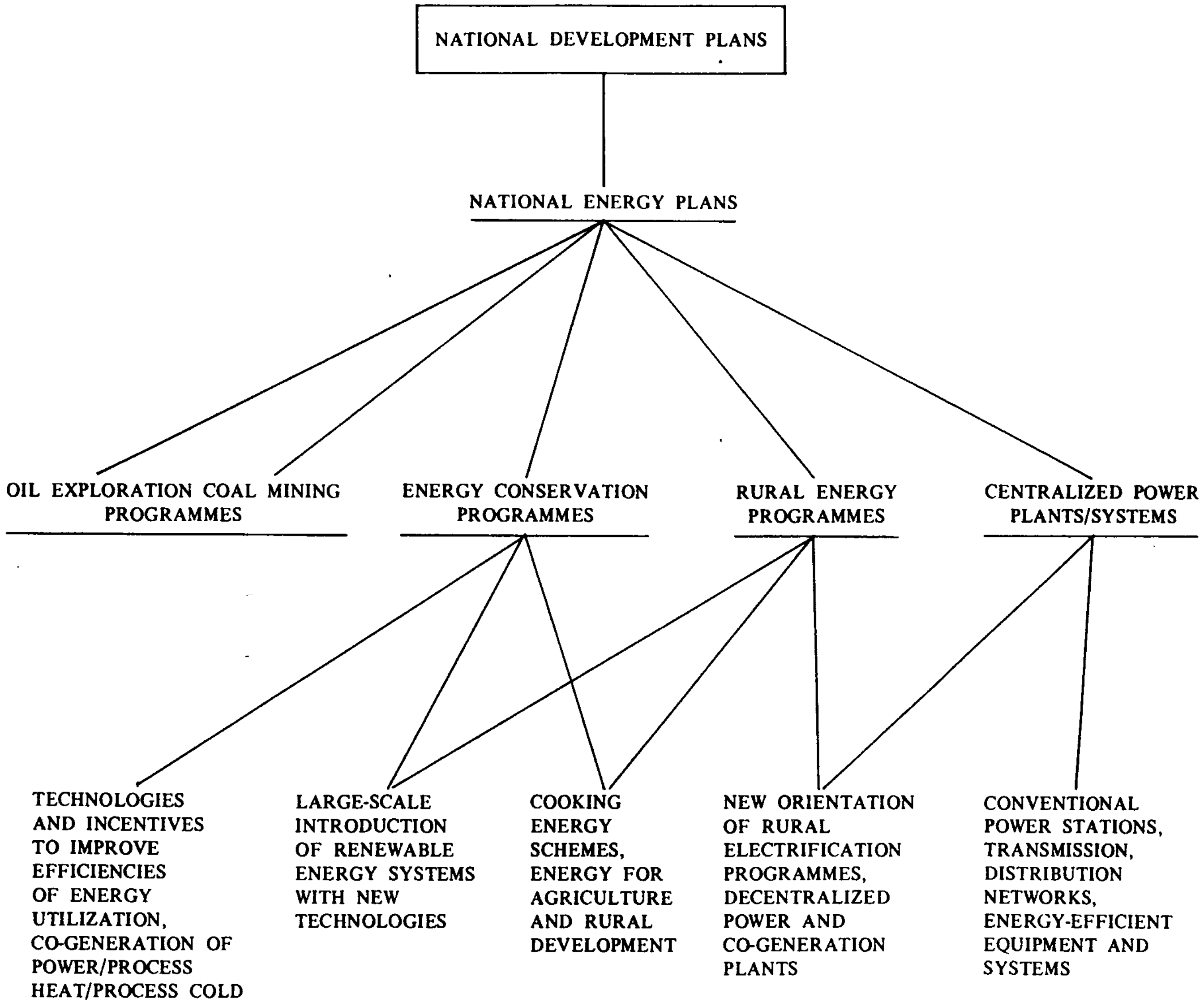

Figure Integrated energy planning

However, the lack of financial support often seriously limits the scope of these studies.

The following are major problems affecting renewable energy programmes in most ESCWA countries: lack of funds; the lack of instrumentation, equipment and laboratories; a shortage of personnel, both scientific and technical; and the lack of specialized information. Apparently, these problems could be solved locally, within each country. However, on examining the problem in the regional context, one learns that in almost every case the technology under consideration already exists in other developed countries and is generally adapted, even though only a few regional institutions pursue an exchange of experience, technology and personnel with their foreign counterparts. Moreover, in the majority of cases, no marketing studies exist on the technologies that individual countries of the region intend to adopt. The ESCWA region does have a sufficient number of qualified personnel to deal with and solve problems involving less sophisticated technologies for the use of renewable energy; however, such personnel in each invividual country cannot hope in the near future to undertake research involving high levels of sophistication.

The generation of solar electricity, the production of photovoltaic cells, the production and use of hydrogen, the design of special motors that can consume renewable energy, the study of powerful wind energy conversion systems, etc., are examples of technologies to be developed in the future. They will require the co-operation of personnel with high-level, specialized scientific and technical training in more than one ESCWA country. It is also true that many countries, particularly the smallest or least developed countries in the region, cannot take up the energy challenge individually, nor would it make sense for them to attempt to do so.

These facts lead to the conclusion that conditions for possible and fruitful co-operation should be created in the ESCWA region, both with regard to technology and the training of personnel. It appears necessary to set up advanced institutes, specialized in particular areas in which professionals from all countries may receive sound and thorough training.

At present, most developed and industrial countries are working actively to solve the energy problem with sophisticated and modern approaches. This might create in the future a new dependence on the part of ESCWA countries similar to their dependence on energy technology up to the present. The only way that is most appropriate in avoiding this problem is to initiate immediately the systematic training of scientists and professionals who will be required to carry out adequate research on the region's true energy requirements.

(b) <u>Education</u>

It is extremely important for the educational subsystem to create awareness among primary and secondary school and university students of the energy problem that the world will soon face, and of the importance of making economical use of depletable fossil fuels and promoting the utilization of renewable energy. A generation of young people educated to be aware of the energy problem is certainly a great asset to a country in search of competent manpower.

(c) Training

The training requirements of energy institutions should be systematically identified concurrently with manpower requirements. Each institution should be requested to prepare a training plan covering professional and technical staff development for incorporation into the energy and education sector plans. Candidates for training should be carefully selected by the affiliated institutions. Training should be specific and on-the-job, which could resolve any problems otherwise caused by releasing suitable staff for any length of time. Overseas training should be limited to higher level staff who require specific skills for which training is not available locally. The energy institutions should also plan for adequate training provisions, including updating the knowledge of technical and professional staff.

VIII. SUMMARY AND CONCLUSION

The present document has highlighted the regional scene in energy: the role which renewable sources of energy can play in the national energy balances, with particular emphasis on NRSE systems in remote and rural areas. Solar and wind energy are the two renewable sources of energy considered among the most important and appropriate alternative energy sources in the present, short- and long-term planning of the region's rural energy development. An overview of such renewable sources of energy and technologies has been made. Global scientific achievements and prospects of utilizing solar and wind energy have been examined, and the evaluation of their present and possible applications to the region has been elaborated upon, with due regard to their social and environmental acceptability. To promote and accelerate the utilization of mature solar and wind technologies in rural and remote areas of the ESCWA region, this document has analyzed the NRSE development infrastructure and its institutional setting. It has also covered the role of government and such other relevant aspects as local capability to manufacture energy equipment and to make available materials for the introduction of an endogenous renewable energy industry in the region.

It has been found that there are numerous activities for research, development and demonstration of solar and wind technologies in most of the ESCWA countries. Especially, attention must be given to the utilization of these technologies in rural and remote areas to meet the basic energy needs of scattered communities and to contribute to the development of an agricultural sector often hampered by an inadequate power supply. In some countries, the private sector has been active in promoting solar and wind applications. However, in spite of the successful accomplishment of some commercialized energy equipment and some demonstration/pilot projects, in many countries of the region the windspread utilization of renewable energy technologies is quite limited. Especially lacking is a clear perception of the various technical, economic, social and environmental implications of their applications in most rural and remote areas. These must be investigated before such technologies are implemented(10). In the long run, the ESCWA countries face numerous difficulties in promoting the utilization and development of solar and wind technologies. Some may be identified as follows:

(a) Inadequacy of information and data resource assessment and on renewable energy technology;

(b) Lack of know-how and limited technical capabilities;

(c) Lack of appropriate national policies regarding renewable sources of energy in long-term energy planning and the necessity of establishing adequate institutional infrastructures for the management and operation of solar and wind systems;

(d) Lack of financial resources for research, development and demonstration.

It is well known that for use for experimental purposes, some ESCWA countries are particularly attracted to the sophisticatred renewable energy equipment developed in the industrialized countries. However, the adaptation of this kind of equipment in any given country is dependent on that country's climatic conditions, suitability of natural resources, and skilled manpower for operating, maintaining and repairing. Therefore, a close co-ordination of research, development and demonstration programmes is needed to promote the development of indigenous renewable energy industries already in place in a number of ESCWA countries.

From the above observations, it seems that the main problems facing ESCWA countries in the development of solar and wind energy fall into the following three categories:

(a) Lack of skilled personnel and appropriate technology;

(b) Difficulty in raising the funds required for support activities (resource evaluation, education and training, research, development and demonstration) and investment;

(c) The need for co-ordination and planning of the action to be taken.

Solutions to each of these problems could be found within the context of the aspirations of ESCWA countries which have shown great interest in utilizing locally available materials and labour for the manufacture of renewable energy equipment. Funding agencies and donor countries in the region should continue, at the bilateral or multilateral levels, their role in promoting investment for the development of renewable energy sources. Due to the decline of oil prices, some industrialized countries find difficulties in carrying out research and development of the renewable sources of energy within their territory. Other countries of the region could offer them opportunities to do research by transferring the technology of NRSE to leading regional research institutions. This would result in their provision of technical assistance to build up regional technological capabilities and in the continuation of their own research and development objectives in the field of NRSE for future use.

Regional or bilateral co-operation among countries of the region is another step in the right direction to develop and promote the utilization of NRSE. Its establishment would eliminate duplication and pool financial resources and skilled manpower, which are scarcely available in most of the relevant countries.

Although some solar and wind energy equipment is costly and site specific at the present time, still its development will help increasingly to meet the needs of rural and remote areas of the region. By developing the locally available renewable sources of energy, countries of the region will be able to improve the standard and quality of life of their people.

ANNEX 1

Gross domestic product per capita at current prices for the ESCWA region

(US Dollar)

Country	1977	1978	1979	1980	1981	1982	1983	1984
Bahrain	6 585.9	7 639.7	8 400.0	11 027.3	12 239.3	12 584.3	12 619.5	12 473.0
Democratic Yemen	221.0	256.6	290.5	351.2	389.2	449.5	498.6	518.0
Egypt	541.2	629.5	453.2	609.4	681.2	721.5	761.2	801.0
Iraq	1 706.8	1 974.3	3 011.7	4 052.2	2 731.0	2 875.1	2 982.6	3 097.0
Jordan	827.8	1 048.5	1 188.9	1 431.2	1 479.0	1 558.6	1 537.0	1 415.0
Kuwait	12 743.1	12 944.8	19 122.1	20 014.9	16 356.0	13 260.9	13 928.2	12 934.0
Lebanon	929.0	972.1	1 107.9	1 214.8	1 218.5	1 225.5	744.2	413.0
Oman	1 738.0	1 690.0	2 232.1	3 467.3	4 062.4	4 139.7	4 213.1	4 544.0
Qatar	18 935.6	20 363.2	27 997.1	35 753.2	35 453.2	29 559.1	24 043.1	28 928.0
Saudi Arabia	8 372.4	9 557.6	14 140.7	18 757.4	15 632.4	11 547.8	9 938.4	8 688.0
Syrian Arab Republic	881.2	1 022.4	1 189.1	1 516.2	1 883.1	1 932.5	1 936.4	1 895.0
United Arab Emirates	18 874.2	18 024.56	23 464.4	28 713.1	29 375.2	25 824.1	22 118.8	20 276.0
Yemen Arab Republic	265.4	322.0	362.2	384.7	397.6	461.9	477.5	390.0

Source UN ESCWA, National Accounts Studies. Bulletin No. 8: Gross Domestic Product, National Disposable Income in the ESCWA Countries (Baghdad, October 1986).

ANNEX II

Area, Population, Gross Domestic Product (GDP), of the ESCWA Countries in 1984

Country	Area km2	Population 10 6	Per cent Urban (0/0)	GDP per capita US $	GDP real growth (0/0) 1983-1984
Bahrain	677.9	0.442	79	12 473.9	1.15
Democratic Yemen	332 968.0	2.239	39	518.1	3.90
Egypt	1 000 000.0	47.517	48	801.7	5.30
Iraq	438 500.0	16.110	66	3 097.0	3.80
Jordan	97 741.0	2.814	72	1 415.8	7.80
Kuwait	17 818.0	1.776	86	12 934.0	7.10
Lebanon	10 400.0	2.759	77	413.4	44.40
Oman	300 000.0	1.259	22	4 544.7	7.80
Qatar	11 437.0	0.313	87	28 928.8	20.30
Saudi Arabia	2 150 000.0	11.793	70	8 688.5	12.50
Syrian Arab Republic	185 180.00	10.873	49	1 985.3	2.10
United Arab Emirates	84 000.0	1.450	78	20 276.3	8.30
Yemen Arab Republic	195 000.0	7.318	15	390.1	18.30

Source: UN ESCWA, Survey of Economic and Social Development in the ESCWA Region 1985 (Baghdad, 1986). See also M. Al-Emady, Investment requirements in electricity sectors of the Arab Countries for 1985-2000. Proceedings of the Third Arab Energy Conference, Vol. 5, p. 67 (OAPEC, 1985).

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