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MARKET DEFINITION STUDY OF PHOTOVOLTAIC POWER FOR REMOTE VILLAGES IN DEVELOPING COUNTRIES

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Prepared for
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16. Abstract

THE POTENTIAL MARKET FOR PHOTOVOLTAIC SYSTEMS IN REMOTE VILLAGE APPLICATIONS IN DEVELOPING COUNTRIES IS SIZEABLE, ABOUT 20,000 mwp, AND IS READY TO BE DEVELOPED.

PHOTOVOLTAICS, EVEN AT TODAY'S COST, IS COST-COMPETITIVE WITH DIESEL GENERATORS IN MANY REMOTE VILLAGE APPLICATIONS. THE MAJOR BARRIERS TO DEVELOPMENT OF THIS MARKET ARE THE LIMITED FINANCIAL RESOURCES ON THE PART OF DEVELOPING COUNTRIES, AND LACK OF AWARENESS OF PHOTOVOLTAICS AS A VIABLE OPTION IN RURAL ELECTRIFICATION.

A COMPREHENSIVE INFORMATION, EDUCATION AND DEMONSTRATION PROGRAM SHOULD BE ESTABLISHED AS SOON AS POSSIBLE TO CONVINCE THE POTENTIAL CUSTOMER COUNTRIES AND THE VARIOUS FINANCIAL INSTITUTIONS OF THE VIABILITY OF PHOTOVOLTAICS AS AN ELECTRICITY OPTION FOR DEVELOPING COUNTRIES.

SUCCESSFUL IMPLEMENTATION OF SUCH A PROGRAM COULD RESULT IN A CUMULATIVE MARKET PENETRATION OF 1000 MWp IN THE NEXT TEN YEARS.

AN OPPORTUNITY OF THIS MAGNITUDE WILL INDEED ENCOURAGE INDUSTRY TO GEAR UP PRODUCTION OF PV MODULES AND SYSTEMS, AND SHOULD RESULT IN ACCELERATING THE COST REDUCTIONS NECESSARY TO ALLOW PV TO CONTRIBUTE TO SOLVING THE ENERGY NEEDS OF THE FUTURE.

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EXECUTIVE SUMMARY

The objective of this market definition study is to assess the market potential for the use of photovoltaic power systems for remote villages in developing countries.

The approach used was to conduct an in-depth literature search followed by in-country surveys of selected developing countries in Africa, the Middle East, Southeast Asia, and Latin America. The purpose of these surveys was to determine the current energy situation in these countries, the level of rural electrification activity, their knowledge and interest in solar and specifically photovoltaics, their financial resource capability, and the probability of development of a market for photovoltaics based on these and other factors.

Following this executive summary are matrices giving a thumbnail sketch of this information for each of the countries surveyed. A more detailed summary of each of the regions and countries surveyed is included in the body of the report.

All of the countries visited have serious concerns about future energy supply, since energy and particularly electricity is the key to their future economic development. Currently they are all quite dependent on oil to fuel their growth, and are obviously concerned about its future availability and cost, and the impact it can have on their rate of development.

As a result, many of them are investigating alternate sources of energy. Many are blessed with undeveloped natural resources which can provide part of the answer to their problem. Such sources as hydro, geothermal, and biomass are being seriously explored in addition to the continuing search for coal and oil.

In these countries there was a general lack of awareness about photovoltaics. In those cases where some knowledge did exist, it was thought that photovoltaics (PV) is a laboratory technology which might someday emerge to provide some useful function. In no case was photovoltaics being seriously considered as a viable source of power for rural electrification or for applications other than remote small power uses, such as communications.

After having been exposed to the advantages of photovoltaics, its commercial availability today and its dramatic future cost reduction potential, most of the people contacted became quite interested and enthusiastic about its viability for some applications today and its potential as a significant source of power in the future.

Most of the countries visited have limited financial resources of their own to carry out their development programs. They are dependent on donor countries such as the U.S., France, Germany, the U.K., Canada, and the OPEC countries. They are also widely supported by international financial institutions such as the World Bank and area development banks as well as the U.N. Given a high enough level of interest and priority, funds would be available to finance development of a PV remote village market, providing the financial institutions are convinced of its economic and social viability. PV is economically viable today in small remote village power applications. As PV costs go down and oil costs go up, PV will become increasingly more attractive.

The conclusion reached by the survey is that there is a significant market potential for photovoltaics in village power applications in developing countries. Extrapolation of the number of unelectrified villages results in an estimated potential of as much as 20,000 MWp, a potential similar in magnitude to previous U.N. and World Bank estimates.

In most cases the market will not start out as a village power application but will initially satisfy a basic need of the villagers, such as potable water pumping, or medical refrigeration, or grain grinding, or emergency communications. As the villagers gain confidence in PV and become aware of the other benefits to be derived from electricity, they will want to expand the system to meet new needs.

Without external stimulation this market will develop slowly. However, if it developed more rapidly, it would accelerate the cost reduction of PV and build up the industry capacity, thus making it possible for photovoltaics to begin to be cost effective in the U.S. and developed country residential and utility applications. Since it is in the U.S. national interest to have PV contributing to the national energy supply as quickly as possible, it follows that the U.S. should act to stimulate the development of this market, while continuing the technology development currently underway.

The major thrust of this market development program should be to develop confidence in photovoltaics as a viable energy source. This effort should consist of an information, education, and demonstration program, stressing the benefits of photovoltaics, its capabilities, current and future cost effectiveness, ease of maintenance, high reliability, and commercial availability today. This should be directed not only to the ultimate users and local governments, but also to the international financial community.

Demonstrations of highly visible functional PV systems should be installed in all of the countries representing significant market potential. These demonstrations would be tangible proof of the effective operation of PV systems.

Successful implementation of this program would plant the seeds necessary to grow into a cumulative market penetration of over 1000 MWp in the next 10 years. An opportunity of this magnitude will encourage industry to build a volume manufacturing capability and should result in accelerating the cost reductions necessary to enable photovoltaics to contribute to the energy needs of the future.

AFRICA

COUNTRY	ENERGY SITUATION	POPULATION TOTAL	RURAL W/O ELECTRICITY	RURAL ELECTRIFICATION ACTIVITY	SOLAR ACTIVITY	SUGGESTED PV PROJECTS	FINANCIAL RESOURCES
SENEGAL	Major energy source, wood, rapidly depleting. Heavily dependent on imported oil. Some oil and gas reserves being explored. Electric grid powered by thermal plants using fuel oil; secondary plants on diesel. Residential electricity price is 24 cents/Kwh.	4.5M	3.6M	Rural electrification so far has followed the pattern of establishing satellite power plants which serve as mini-grids. Some of these diesel generators are being considered for replacement by solar thermal-electric systems.	Solar energy programs have been active here for over 20 years, primarily sponsored by France. Majority of installations have been for water pumping and have solar thermal-electric systems, mostly SOFRETES installations. Government authorized $27 million to be spent on solar (1977-1981). Projects include combined wind/PV water pumping, solar distillation, solar refrigeration, and air conditioning, development of two rural energy centers.	Several village power installations have been considered. A joint Senegal/U.S. program for a village power demonstration near Dakar would pay dividends, since Senegal is regarded as the solar pioneer in West Africa.	While not one of the richer countries in Africa, because of the serious need for energy, primarily to produce water, Senegal has shown a willingness to invest in solar. In view of past French contributions, a U.S. cost-shared demonstration project would be appropriate.
IVORY COAST	Heavily dependent on foreign oil. Will begin to produce off-shore oil by late 1980, but will only cover 25% of present need. Although hydroelectric power currently only represents 17% of current electricity generated, plans are to increase this to 50% by year 2000. Balance of electric power is from oil-fired plants.	7.3M	5M	Plan to electrify all villages through an all interconnected network. Estimated cost of $115 million, to be financed by Germany, Canada, and World Bank at end 1977 366 villages electrified, 600 by end 1980, total of 1000 by 1985.	Primary interest in PV is for communications. Government has had an off and on again plan for a major educational TV program. Original plan was to install over 14,000 systems; however, budget problems have delayed the program.	No government programs are recommended here since the major opportunity, when it takes off, educational TV will be a commercial procurement. Module manufacturers should monitor the development of the program.	No major problem, but concern over growing foreign debt has caused curtailment of several planned projects, such as the educational TV program.
CAMEROON	Becoming energy independent. Considerable hydropower currently in place, supplying 95% of electric power, with more potential available to be developed. Just beginning oil production. Reserves in excess of their own needs.	8M	6.4M	Currently more concerned with increasing electrification of the larger towns. Looking seriously at mini-hydro for generation of power at locations remote from the grid. Some use of diesel generators in the north.	Mostly in planning stage - solar thermal-electric and PV water pumping, PV for communications and railway signals, possibly some educational TV.	A high visibility demonstration project featuring water pumping, grain grinding and possibly crop drying would be instrumental in stimulating government interest in PV. The government of Cameroon would also be interested in assistance in carrying out insolation data measurements.	Although Cameroon can afford to finance the programs, the early demonstrations will probably have to be cost shared to stimulate interest.
GABON	Rich in oil and other mineral resources. Fifty percent of electricity generated by hydro, the rest by decentralized diesel generators.	1M	700K	Dense jungles will prevent extension of existing grid, so rural electrification will require decentralized secondary generating plants.	As a direct result of this market study visit, Gabon is quite interested in a PV village power demonstration. Currently NASA LERC and government of Gabon are planning to install 4 villages. Considerable interest in PV for communication.	Village power projects already underway in planning stage.	No problem. Gabon is one of the richest countries in Africa.

AFRICA (continued)

COUNTRY	ENERGY SITUATION	POPULATION TOTAL	POPULATION RURAL W/O ELECTRICITY	RURAL ELECTRIFICATION ACTIVITY	SOLAR ACTIVITY	SUGGESTED PV PROJECTS	FINANCIAL RESOURCES
NIGERIA	One of the world's largest exporters of oil. Significant coal and natural gas reserves. Large hydro potential. Electricity demand increasing rapidly (25% per year). Planning several large hydro and gas turbine plants.	81M	55M	Planning an integrated grid system covering the entire country.	Very little activity except in universities and research centers. Some PV water pumps in the north.	Early activity in PV will probably be in communications and remote medical centers. Probably best developed by commercial contacts rather than government projects.	No problem, but sometimes difficult to get remittance out of the country.
MALI	No oil, gas, or coal reserves. Limited hydro. Lots of sunlight. Imported oil and gas represent over 30% of total imports.	6.5M	5.6M	No major program identified.	Lots of water pumping activity both PV and solar thermal-electric sponsored by France, U.S. AID, U.N., and Mali Acqua Viva. Over 25 PV water pumping systems totalling over 45 KWp.	A village power demonstration possibly cost shared by the U.S. and another donor agency is recommended.	Totally dependent on foreign aid, but availability of solar powered water supplies can provide tangible financial results by improving the agriculture potential.
TOGO	Heavily dependent on noncommercial sources (wood and charcoal). No oil or gas resources. Some hydro potential. Imported oil fires local electric generating plants, while 40% of electricity demand is bought from neighboring Ghana.	2.5M	2M	Proposals being put together to include solar energy systems for rural electrification in next 5 Year Plan (1981-1985).	A natural potential for solar due to lack of other alternatives. PV water pumping systems to be installed sponsored by European Development Fund. Some commercial solar activity already started.	A village power demonstration would provide the experience necessary to ensure inclusion of PV in the next 5 year rural electrification program.	Dependent on foreign aid for development programs.
KENYA	No known oil. gas, or coal deposits. Large untapped hydroelectric potential. Exploring geothermal capability. Considering nuclear generation.	14.3M	10M	Currently looking to hydro- and geothermal to provide rural electrification.	No known activity except a few installations of solar water heating. Little government interest shown in solar to date. Major village effort directed at simple technologies, capable of being locally produced.	A totally donated village power project might stimulate government interest otherwise potential market will be for low power applications in communications, water pumping, and medical centers.	Capable of financing its own programs, but lack of government interest suggests that any programs will probably have to be externally funded.
TANZANIA	Eighty percent of energy used is from secondary noncommercial sources (wood and charcoal). Some untapped hydro potential. Exploring oil, gas, and coal potential.	16M	13M		As a result of the solar seminar in Dar-es-Salaam in 1977, there has been a great deal of interest and activity. PV systems are to be used for all communication load requirements of 250 W or less. First installation in 1978 at Mt. Kilimanjaro, 16 other sites being installed. Seriously investigating village power.	A village power demonstration would be well received and would undoubtedly result in demand stimulation.	Early programs would most likely have to be externally financed but increased productivity, particularly in agriculture could eventually begin to pay back the investment.

ARAB AND MIDEAST

COUNTRY	ENERGY SITUATION	POPULATION TOTAL	POPULATION RURAL W/O ELECTRICITY	RURAL ELECTRIFICATION ACTIVITY	SOLAR ACTIVITY	SUGGESTED PV PROJECTS	FINANCIAL RESOURCES
JORDAN	Totally dependent on imported oil today. Oil imports equivalent to more than half the governments domestic revenues. Diesel fuel heavily subsidized. Exploring oil shale and geothermal energy resources.	3M	640K	All villages to be electrified by 1990. 150 villages now electrified, 400 villages being electrified, 400 remaining to be electrified by 1990. Plan to extend electric lines to all villages over 500 people.	Active program with W. Germany on desalination. Working iwth EEC for support for solar thermal collector facility. Other programs sponsored by W. Germany are 200 PV powered emergency telephone systems, 9 wind/PV powered water pumping projects - 5.5M D marks. U.S. AID discussing 100 KWp water pumping/desalination program.	Seminomadic transition villages security checkpoint villages drip irrigation and water pumping.	Would probably require outside aid from donor countries or international agencies.
EGYPT	Practically energy independent. Fuel and electricity costs heavily subsidized. Net exporter of oil. Sizeable installed and expandable hydroelectric capacity. Significant reserves of natural gas. Coal potential in Sinai. Growth in population and energy demand may require energy importing by year 2000.	40M	12.3M	Plan to extend electricity to all rural communities by 1982. Establishing "new towns" in the Western Desert to relieve population expansion pressure on Cairo and Alexandria. Main priority: connect all villages of 500 or more to national grid.	Solar thermal joint venture projects with U.S. National Science Foundation, New Mexico State University, and the W. German and Canadian governments. National Research Center doing PV lab research on a grant from W. Germany. Applications projects for PV in water pumping, desalination, communications, refrigeration, and lighting supported by W. Germany. PV TV sets for rural village sponsored by France American University in Cairo working on renewable energy technologies in the Desert Development project.	Powering the smaller, more remote of the new towns. Participation in the American University Desert Development project.	Capable of, and willing to cost-share development programs.
SUDAN	Ninety-six percent of energy supplied by imported oil. Hydro represents 2% of energy sypply but has greater potential. Some oil and gas discovered. Short supply and high cost of oil is seriously limiting agricultureal growth. Diesel fuel costs $7 per gallon in remote areas. Cost of electricity subsidized. Energy consumption will double over next five years. Energy supply/demand gap will widen.	17.5M	15M	No strategy - little effort.	Limited activity in solar thermal, wind, and solar water distillation. Solar thermal-electric system for water pumping sponsored by France - failed, replaced by diesel. UNDP PV water pumping program in planning stage. U.S. AID program for renewable energy also in planning stage.	Solar water pumping systems for irrigation to develop agricultural potential would later result in village power usage.	Mostly dependent on foreign aid. Kuwait based Arab Fund for Economic and Social Development estimated that by the end of the century Sudan could be meeting most of the Arab world's food requirements if adequate water was supplied. Envisaged spending $6.6 billion in first stage to irrigate 1.5 million acres.

ARAB AND MIDEAST (continued)

COUNTRY	ENERGY SITUATION	POPULATION TOTAL	POPULATION RURAL W/O ELECTRICITY	RURAL ELECTRIFICATION ACTIVITY	SOLAR ACTIVITY	SUGGESTED PV PROJECTS	FINANCIAL RESOURCES
YEMEN	One hundred percent dependent on imported oil. Eighty percent of foreign exchange for oil purchases. Exploring oil, oil shale, geothermal potential. Oil product prices heavily subsidized. Oil product demand expected to grow 35%. Deforestation and desertification resulting from excessive wood use.	5.5M	500K	Primarily accomplished on local initiative. Using Japanese made diesel generators. Financed by remittances from families working in Saudi Arabia. Maintenance, repairs, and spare parts a major problem. U.S. NRECA developing an electrification plan.	PV systems being used in remote microwave repeater sites. Rural cooperative organization has requested a PV demonstration. One PV pumping system installed (1350 Wp). European and Japanese firms are promoting PV by way of government sponsored missions.	Most purchases will be commercial, rather than government sponsored, so commercial companies need to associate with a local Yemini company.	Unlike most developing countries, Yemen has both the requirement for alternative energy and the ability to pay for it.
UNITED ARAB EMIRATES	Have adequate oil reserves to be energy independent, but currently import 80% of petroleum product demand. Natural gas a significant contributor to energy demand (21%).	775K	130K	No national grid exists today. Each emirate has its own power authority. Forty five villages to be powered in 1980, 100 villages additional without electricity.	An integrated food, water, power completely installed and supervised by the University of Arizona in the 1960's, a 1Kw water pump installed by the French government. Energy committee to be established June 1980.	A government to government cost-shared village power demonstration project would likely result in development of a commercial market.	No problem.
PAKISTAN	Dependence on petroleum reduced from 75% in 1949 to 40% in 1980. Natural gas increased from 23% in 1964 to 49% in 1978. Thirty six percent of oil usage is imported oil, increased 10% per year over the past five years, but cost has increased a total of 600%. Also has some coal, hydro, and nuclear. Energy prices, particularly for electricity, are heavily subsidized. Energy demand growing faster than they can develop production. Significant foreign exchange burden will continue.	75M	44M	Consolidation of grid, in and around urban areas. Trend from diesel powered systems to hydro. 20,000 villages too remote to extend grid.	Canada sponsoring hydrogeneration. Switzerland supporting afforestation. UNDP sponsoring a rural energy center. U.S. supporting a nonconventional energy project. Established Energy Research Cell.	Village to be electrified near Islamabad looking for a sponsor. U.S. AID program currently in limbo. World Bank and UNDP may sponsor. Interested in PV for communications, but need to be convinced of reliability, especially under lengthy cloudy conditions.	Limited capability. Reliance on Arab or other donor funds.

SOUTHEAST ASIA

COUNTRY		POPULATION TOTAL	POPULATION RURAL W/O ELECTRICITY	RURAL ELECTRIFICATION ACTIVITY	SOLAR ACTIVITY	SUGGESTED PV PROJECTS	FINANCIAL RESOURCES
PHILIPPINES	Ninety-five percent dependent on imported energy sources (oil). Plan to reduce dependence to 46% by 1988. Planned domestic sources: oil 25%, hydro 12%, coal 10%, balance by geothermal and nonconventional energy sources. Will require capital investment over $13.6 billion. Sixty-five percent externally financed.	42.5M	30M	Plan total electrification of country by 1990. Program patterned after U.S. program of 1930's, including extensive participation by cooperatives. Rural electrification expenditures will total $1.3 billion. Program heavily supported.	Well organized nonconventional energy program including solar heating and cooling, drying, biomass, wind, but little on PV so far. German grant of $2 million will feature PV. UNDP will test PV water pumping.	A village power demonstration could result in inclusion of PV in rural electrification program. An existing planned program IVES (Integrated Village Renewable Energy Systems) would be a good vehicle to initiate village PV work.	In addition to substantial internal resources, the Philippines has many sources of international finance.
THAILAND	Very little oil, some oil shale. Recent gas discoveries could provide up to 20% of energy needs. Imported oil supplies 90% of energy needs. Significant undeveloped hydro potential. Electricity demand doubling every 5 years.	45M	31M	Aggressive rural electrification plan. Electrify all 47,000 villages by 1991. Special agency established, PEA (Provincial Electrification Agency)	Some activity in solar thermal electric. Experimenting with solar air conditioning. Have used PV for remote communication sites. At least one PV water pumping site. Ready to try PV remote village.	Cost share a PV village power project as a pilot program for their village electrification plan.	Typically supplies 50% or more of development funds internally. Also supported by World Bank, OPEC, Saudi Fund, Japan, Germany, Canada, and U.S. AID.
MALAYSIA	Energy independent. Net exporter of oil. Large natural gas reserves. Large hydro potential. Energy exchange agreements with Singapore and Thailand. Electric energy grows at 12 - 13% per year.	13M	8M	Rural electrification plan under development. Anticipate use of minihydro and gas or diesel generators.	Active PV research program sponsored by France. Seriously investigating PV power for microwave repeaters and remote radio telephones.	Most interest in the near term for specialized rather than village power applications. At this stage commercial rather than government activities are more appropriate.	Quite self sufficient.
INDONESIA	Energy independent. Significant exporter of oil. Natural gas playing increasingly important role. Extensive coal deposits. Developing hydro and minihydro capability. Researching geothermal and solar.	140M	110M	U.S. AID and NRECA (National Electric Cooperative Association) assisting in development of rural electrification plan. Encouraging private investment and cooperatives. Program must be largely decentralized due to widespread dispersion of users (3000 islands).	Solar research being conducted at Universities. A German grant has resulted in a 5.5 KWp village power installation. Primary purpose is to pump water to double the rice growing season. Agency for the development and application of technology quite optimistic about PV	A cost-shared program for electrifying an island fishing villages, complete with walk-in cooler for storing fish, would have a potential for replication many times among Indonesia's 3000 or more islands.	Quite adequate, but initial demonstrations need to be need to be cost shared to stimulate interest.

LATIN AMERICA

COUNTRY	ENERGY SITUATION	POPULATION TOTAL	POPULATION RURAL W/O ELECTRICITY	RURAL ELECTRIFICATION ACTIVITY	SOLAR ACTIVITY	SUGGESTED PV PROJECTS	FINANCIAL RESOURCES
MEXICO	Becoming energy independent due to oil and gas discoveries. Considerable coal reserves. Abundant sun light.	63M	40M	Out of 100,000 villages, 80,000 have no electricity. Major program for rural telephone and rural electrification in the planning stage.	Active interest in PV for communications, instrumentation, water pumping, non-aids, and village power. Numerous French and German PV installations donated.	A PV village power project is currently under discussion between U.S. DOE and the Mexican government.	Becoming increasingly self-sufficient as oil exports increase.
BRAZIL	Heavily dependent on foreign oil (oil imports equal 11% of GNP). Major effort underway to produce alcohol for fuel. Also expanding hydroelectric capacity. Working to develop coal gasification and shale oil capability.	117M	54M	Spending about $100 million per year on rural electrification. Primarily extension of existing grid. Importing over 10,000 small gasoline generators per year for rural use.	Not much activity other than solar thermal. Will probably not develop rapidly until PV systems are manufactured locally.	Because of import restrictions and desire for local manufacture, the best approach is for PV companies to license or set up manufacturing facilities in Brazil. Government activity not recommended, if motivated solely on export potential.	No problem.
COLOMBIA	Net importer of oil, but exploring for more sizeable coal reserves. Continuing expansion of hydroelectric capability; currently produces 65% of electricity.	25M	14.2M	Mountainous terrain makes grid extension difficult and costly. National Rural Electrification Plan projected to supply electricity to 228K family at a cost of $110 million.	Quite active in use of PV for communications, particularly rural telephone. Interested in joint PV village power project.	Continue discussions already initiated by NASA for a joint PV village project.	No problem.
PERU	Self sufficient in terms of oil demand. Unable to meet energy demands in spite of having great hydroelectric potential.	20M	15.2M	Serious problems of having adequate electricity for the cities and industry have overshadowed the need for electricity for rural areas.	Some research work on solar hot water, drying, distillation and wind. Little or no activity in PV.	Until basic electricity supply problems are solved, it will be difficult to get much interest generated in PV.	Foreign exchange problems.

INTRODUCTION

In order to ensure that photovoltaics is given the proper opportunity to contribute to the long-term energy demand of the United States, the U.S. Congress passed Public Law 95-590, known as "The Solar Photovoltaic Energy Research, Development and Demonstration Act of 1978." This law authorizes a 10 year, $1.5 billion federal program intended to encourage the development of a large volume manufacturing capability of photovoltaic modules and systems, and to accelerate the cost reduction of these systems to ensure that photovoltaics produces electricity cost competitive with utility-generated electricity from conventional sources.

The cost reduction effort must have two components. One component relates to the necessity to develop new manufacturing processes capable of producing low cost modules. The other cost component requires the automation and large scale production of these processes to achieve the economies of scale which will contribute to lower costs.

The technology development program is progressing well, and it is likely that one or more new low cost processes will be ready to put into production in the next 3 to 5 years. However, for these processes to achieve their low cost potential they must be put into large scale production. At these low costs huge markets will open up. We have, therefore, a classical "chicken-and-egg" situation: large markets when you have low prices, and low costs when you have large volumes.

The question is, "Is there a sizeable market between today's small remote application market and tomorrow's huge residential/utility market?" One market that has been thought to have great potential for photovoltaics is that of supplying the electricity needs of remote villages in developing countries. It is <u>that</u> market which this study addresses.

FORMAL REPORT

I. DEFINITION

REMOTE VILLAGE: A grouping of up to 2000 people living in a remote area, but in close enough proximity to interact with each other on a daily basis.

Remote implies that the village is located such that it cannot be supplied economically with central station utility power.

II. OBJECTIVES

A. GENERAL

To assess the international market potential for photovoltaics in remote village applications from the point of view of a company engaged in the manufacturing and marketing of photovoltaic modules and systems.

B. SPECIFIC

1. To identify the specific types of villages most likely to represent the greatest potential for use of photovoltaic power.
2. To compile a list of potential near-term applications.
3. To quantify the future market potential by type of application.
4. To identify the barriers and obstacles which might inhibit the growth of the market.
5. To recommend action necessary to enhance the development of the market.

III. METHODOLOGY

A. LITERATURE SEARCH

A review of the existing literature on subjects pertinent to the study was conducted by Motorola at the outset of the program and on specific subjects of interest as the program progressed. Examples of the types of subjects researched are as follows

1. Energy problems in the developing countries
2. Rural electrification programs
3. Village power applications
4. Refrigeration
5. Lighting
6. Water pumping
7. DC equipment
8. Utility rates and cost of power line extension
9. Performance and cost data of alternate forms of generation of electricity, i.e., diesel generators
10. Photovoltaic and other solar market studies
11. International financial institutions.

This literature search served the following basic purposes:

1. To identify data already available
2. To identify key areas and countries for further study and on-site investigation
3. To confirm or deny previous preconceived notions
4. To determine the appropriate approach to be used for the in-depth, in-country surveys.

B. IN-COUNTRY SURVEYS

As a result of the literature search, a list of key countries in Africa, the Middle East, Latin America, and Southeast Asia were picked as candidates for in-country visits.

The countries were selected to provide a representative cross-section of the spectrum of developing countries. Primary selection criteria were:

1. Located in or near the sun belt
2. Possible sizeable market potential
3. Accessible market for U.S. companies
4. Representative wealthy and poor countries
5. Oil importing and oil exporting countries.

In addition to the above, an attempt was made to not duplicate other surveys or studies already conducted. Even so, we frequently encountered other organizations doing similar, but broader surveys on energy needs and alternate energy sources.

The purposes of these in-country visits were as follows:

1. To gather new data and validate data acquired in the literature search
2. To acquaint the local officials with the present status and the future plans of the PV industry and technology
3. To determine potential obstacles or barriers to PV market development in these countries
4. To assess the degree of possible penetration of the potential market and determine steps necessary to make it happen.

The general approach used was as follows:

1. The purpose of each visit was communicated to the commercial attache and local A.I.D. representative in the country to be visited at least 1-1/2 months prior to the visit. In the communication we suggested various local government agencies and activities who would be appropriate contacts for our survey. We requested the assistance of the local U.S. Embassy personnel in contacting these people and in setting up meetings with them. In general, the support we received from them was very good.
2. Our first contact on arrival in the country was with the U.S. Embassy personnel. We generally found it most productive to give our presentation to them as early as possible because the presentation tended to generate a high level of enthusiasm which resulted in many suggestions of programs, contacts, and other valuable information being offered. Most of these people had not been well informed about the current status of the PV industry and the export opportunity it represents.
3. Meetings were then set up with the appropriate local government agencies and officials. Again, it was found that starting off with the presentation was the best method of stimulating interest, often resulting in subsequent lengthy discussions. Generally, with a few exceptions, the people contacted were not aware of the present state of development of the PV industry and technology. Most had felt that PV was still a laboratory curiosity that might some day emerge as a useful technology.

In the Appendix are lists of the countries visited, organizations contacted, and the number of people attending the presentations. In total, over 800 key people in 23 developing countries were surveyed and exposed to the current status of the PV industry and the technological and economic outlook for the future. Judging from the reception to the presentation, this exposure to PV made the trips worthwhile.

AFRICA

MOROCCO
TUNISIA
WESTERN
SAHARA
ALGERIA
LIBYA
EGYPT
MAURITANIA
MALI
SENEGAL
NIGER
CHAD
SUDAN
SOMALIA
GUINEA
SIERRA
LEONE
NIGERIA
ETHIOPIA
LIBERIA
CAMEROON
TOGO
IVORY
COAST
GABON
CONGO
UGANDA
KENYA
GHANA
ZAIRE
TANZANIA
ANGOLA
ZAMBIA
NAMIBIA
BOTSWANA
MADAGASCAR
MOZAMBIQUE
SOUTH AFRICA

IV. REGION AND COUNTRY SUMMARIES

A. INTRODUCTION

Due to the fact that the in-country surveys were performed at different times and by different groups, the format of the Region and Country summaries vary slightly.

Common to all of them is the content of the key information required to evaluate the market potential for photovoltaics in remote villages. Opening each country summary is a capsule summary of the PV potential outlook. Following this is a brief description and general information about the country. The subject of the current and future energy supply and demand is covered next, followed by a discussion of rural or village electrification activities in the country. The final section covers the alternate energy activities and organizations in the country, with specific coverage of photovoltaics.

B. AFRICA

1. Region Overview

The African in-country surveys were conducted during June and July of 1979. Four of the countries were visited in conjunction with an Electrical Energy Equipment Trade Mission, co-sponsored by the Departments of Energy and Commerce. These countries were Ivory Coast, Nigeria, Cameroon, and Gabon. Senegal was also visited, due primarily to the relatively high level of solar interest and activity there, due in large part to the efforts of the French government and industry. Togo and Mali were also included due to their expressed interest in renewable energy. Kenya and Tanzania were included due to the large potential they represent and to round out the African sun belt countries by inclusion of East Africa.

This report covers African countries located south of the Sahara desert but excludes the Republic of South Africa and its protectorates and the Republic of Sudan. This region is made up of 35 countries with an estimated population of over 350 million of which 85 percent live in rural areas. The African rural population live in villages which vary widely in population according to local culture and conditions, from a few tens to a few thousands of people.

The chief sources of energy in these rural areas are human and animal power, fuelwood and charcoal, animal dung, and agricultural wastes - noncommercial sources, and sunshine, wind and hydro - renewable energy sources. In most of these countries, fuelwood and charcoal account for over 60 percent of energy source in the rural areas, while electricity accounts for only 5 percent. The possibility of making electricity available to the rural population in Africa is very remote, due to the fact that most of the African countries are still unable to satisfy the demand for electricity in urban areas and the power requirements of industrial and commercial enterprises whose growth is essential to the economic survival of these countries. It is common to find a central power grid with 75 percent of power generated absorbed by one or two industrial plants. Sometimes these power stations are built principally to serve a particular industrial concern with the surplus power made available for other commercial or urban use. Even countries such as Nigeria, Ivory Coast, and Ghana which have committed to total integrated grid system in their rural electrification plans have found it necessary to install secondary decentralized power plants in some rural areas to meet the immediate energy demand of these areas while waiting for the grid extention which might take from 20 to 30 years in some cases.

Even though the commercial energy demand in the rural areas of Africa is very low, the need for non-human energy is very high indeed. They need it to provide water for themselves and their livestock, to grow crops, and to satisfy basic sanitation needs. From 60 to 80 percent of rural energy demand in Africa is currently being satisfied by fuelwood and charcoal and animal/human power. The first is producing rapid depletion in forestation and creating environmental problems, while the second is limiting the extent to which the villagers can improve the quality of their life. The development of renewable sources of energy appears to be the best if not the only immediate and near-term solution to the energy problems of the rural population of Africa.

Solar energy sources are particularly suitable for these countries since most of them are blessed with abundant sunshine - insolation as high as 8 KWh per square meter and duration of sunshine as long as 3000 hours per year are common in this region of the world - but very little is being done to take advantage of this "free" and renewable source of energy. With the exception of the very few oil producing countries, oil imports account for 16 to 30 percent of total imports of these countries, and the situation is getting worse as the price of oil increases. Hence the use of fossil fuel to generate electricity or other forms of energy to serve the rural population requirements in Africa will not result in a cost effective approach to the problem. On the other hand, the high initial cost of hydroelectric plants requires that the demand for electricity be high enough to justify its construction which is not the case in most of the rural areas in Africa.

Solar energy systems represent one of the most viable sources of energy for these villages, and solar photovoltaic systems in particular have the potential to provide the optimum energy source to satisfy the basic needs of the villagers. The following characteristics of solar photovoltaic systems make them a very attractive and viable solution to village power applications:

No fuel cost
No fuel delivery or storage problems
Minimal maintenance required
Modularity
Nonpolluting.

The development of solar photovoltaic systems in African villages will have a higher probability of success if it is directed towards the basic needs of the villagers first. One of these basic needs is adequate water supply for both human consumption and livestock as well as for crop irrigation. PV systems directed towards this need will eventually develop into a PV village power system which provides other needs such as lighting, health needs, and entertainment.

Some countries like Senegal and Niger have long since realized the need for developing solar energy as a viable source of energy and have invested in this area. Most of the current systems involved are solar thermal based, but these countries are also looking seriously into solar photovoltaic type of applications. Others like Ivory Coast are planning to install solar photovoltaic systems to power educational TV's and radios. This type of application is expected to spread to other African countries in the near future. Still other countries like Gabon and Tanzania are putting together plans for remote communication systems using solar photovoltaic generators as the power source.

One of the main factors limiting the development of solar photovoltaic power systems is its high initial cost. The fact that these systems are new and little known need not constitute a major problem. People can be made aware of these products through education and local demonstration projects. Most African countries have no capital and capital formation is a slow process so far as these countries are concerned. Availability of capital is therefore essential to the success of solar photovoltaic projects in these countries. This capital is usually made available in different forms by donor countries and international financial institutions. Any effort to market photovoltaics for village power applications in Africa must identify capital availability in order to be successful.

2. Senegal

2.1 Summary

Senegal offers a very good potential for the PV market for several reasons. The biggest problem facing Senegal today is the need for adequate water supply both for human and livestock consumption and for irrigation purposes. The depth at which water can be found in Senegal is relatively low and there is a lot of potential for surface water pumping systems for irrigation. This is an area of application where the combination of need, source, and technology greatly favors PV systems.

Due to the dispersed nature of Senegal's rural population, it is uneconomical to extend the main electric grid to supply electric power to the rural areas. A recent study on this subject has recommended to the government to pursue the decentralized power station system of electrical energy supply to the rural areas. SENELEC, Senegal's major electric utility company, now runs 21 decentralized power stations across the country, all using diesel generators.

Senegal's oil resources are insignificant and oil importation accounts for a substantial percentage of the country's total imports. With the price of oil in continuous uptrend, Senegal will have to find ways to depend more and more on its renewable energy sources. In fact, SENELEC is planning to replace 13 of its 21 present diesel power stations with solar thermodynamic plants. Solar PV plants also have the potential of replacing these diesel plants in the future. SENELEC is planning to start looking at the possibility of putting up PV power plants and will start studies in this regard in 1981/1982.

Senegal has a very high average daily insolation, 6 kilowatt hours per square meter, with certain areas reaching 8.12 kilowatt hours per square meter. There are solar energy programs coordinating all solar energy projects and activities in the country. The major activity of the newly created Ministry of Scientific Research and Technology Development is in the solar energy area. The government has committed funds in its present fifth four-year development plan for the development of renewable energy source and systems, especially solar energy systems.

There are quite a number of private and public funding sources for solar energy projects, which predominantly represent French interests. Judging from the amount of financial institutions present on the Senegalese solar energy market today, it is fair to conclude that solar energy market development in Senegal will not be hampered by lack of funds.

PV market development in Senegal will have to start in the water pumping application area, where it will have to compete with thermodynamic systems. These systems have a definite advantage over PV systems for three reasons:

1. Senegal has invested 20 years of human and material resources in solar thermal and thermodynamic systems and won't do away with them for PV systems.

2. Most of the solar thermal and thermodynamic subsystems components can be manufactured locally and Senegal has been experimenting on these components for several years.

3. PV systems are presently very expensive and require the importation of the modules, a drain on the country's scarce foreign exchange resources.

Senegal is also very actively engaged in the development of wind energy power systems and biomass systems, which are directly in competition with solar systems. Senegal's wind resources are not very encouraging (about 7 meters per second maximum speed) and it is more difficult to match need, resource, and technology.

Village power systems and rural electrification in Senegal will develop as a natural consequence of water supply and irrigation systems. Villagers will migrate to the water pumping areas where they can get water for themselves and their livestock and probably do some farming too. The need for lighting some areas and some kind of machinery to process food will develop. As the villages grow, need for communication systems and some form of medical service centers will become necessary. Other village power applications such as battery charging and power for workshop tools will eventually become necessary.

2.2 General Information

The Republic of Senegal is located on the westernmost tip of the African continent. It is predominantly flat and sandy extending for 75,000 square miles (about the size of South Dakota) and laced by four rivers. The northwest is semidesert, the center and south are mostly open savanna, and the southeast is mountainous. Nearly 30 percent of the land is presently unexploited forest.

Senegal has a population of about 5.5 million people, of which nearly 25 percent live in the urban areas. The capital, Dakar, has a population of between 800,000 to 900,000 people. Other principal cities are:

Thies	: 120,000	people
Saint-Louis	: 90,000	"
Zuguinchor	: 58,000	"
Rufisque	: 54,000	"
Kaolack	: 53,000	"

Dakar and its suburbs, generally referred to as the Cap Vert area, account for over 50 percent of the urban population, with a population density of nearly 34,000 people per square mile, against 11 people per square mile in the eastern less populated sector of the country. As in most developing nations, the urban population is growing at a much faster rate than the rural population (in this case 12 percent against 5 percent total population growth).

The primary economic sector in Senegal is the agriculture and livestock raising sector which accounts for nearly 25 percent of total GDP and employs more than 80 percent of the active workforce.

The industrial or the secondary economic sector is mainly engaged in the production of peanut oil, phosphate and textiles, and contributes nearly 20 percent of total GNP.

By far the largest and the fastest growing economic sector is the tertiary sector, that is to say, transportation (state owned), commerce, tourism, and other services. This sector accounts for nearly 40 percent GDP.

The major foreign exchange earners for Senegal are peanuts, phosphates, tourism, and fish in that order of importance. The principal export market is France, which absorbs over 50 percent of Senegalese products (10 times more than any other Senegalese trade partner). As to be expected, the principal Senegalese supplier is France (43 percent of total imports into Senegal), followed by the U.S. (7 percent), and West Germany (6 percent). The main products of importation are foodstuffs (rice and sugar), machinery, and metals.

Senegal is an associate member of EEC (European Economic Community) and signatory of the Economic Community of West African States - ECOWAS.

Senegal is a member of the West African monetary union with a common currency, the franc CFA, issued by a common central bank, BCEAO (Banque Centrale des Etats de l'Afrique de l'Ouest) with headquarters in Dakar. The franc CFA's unlimited convertibility into French francs is guaranteed by France and is maintained at 50 CFA to 1 French franc.

Commercial banks provide 75 percent of the short-term credit, while the national development bank, BNDS (Banque Nationale de Developpement du Senegal), and the recetnly established Senegalese-Kuwaiti investment bank are the two major banks in Senegal offering medium- and long-term credit.

External financial sources are the World Bank (IBRD and African Development bank) on one hand and bilateral funding agreements with France, Germany, Canada, Saudi Arabia, and the U.S. on the other hand.

The government of Senegal has established the National Amortization Fund, CNA (Caisse Nationale d'Amortissement), to guarantee foreign loans and to provide greater security to current and potential foreign creditors.

The U.S. EXIM bank and the foreign credit insurance association offer a full range of loan and credit insurance for export of U.S. products to Senegal.

In 1974 the government of Senegal established a free trade zone area located at M'bao (a suburb 13 km east of Dakar) to attract foreign companies to set up labor intensive industries or low cost facilities for the manufacture of products intended for exportation.

Senegal's economic, financial, and cultural ties with France result in its heavy dependence on France for its development. The government relies greatly on French technical advisors and consultants in practically all sectors of activity and many industrial and commercial concerns are directly controlled by the French.

Under the fifth four-year development plan (1977 - 1981), agriculture and livestock raising was declared "priority of priorities" by the president of the Republic. Two hundred and fifty million dollars is expected to be invested in this sector during the life span of the plan and will be directed towards the diversification into other crop areas in order to reduce the country's dependence on peanuts and the development of irrigation systems. In fact, one of the three largest priority projects of Senegal today is the development of irrigation and hydroelectric systems along the Senegal, the Casamance, and the Gambia rivers to help minimize the effect of droughts on the country's economy.

Senegal's current economic development is largely dependent on climatic conditions, specifically on rainfall. The 1972/1973 drought caused a 20 percent decline in real total GNP of the country, affecting mainly agriculture and livestock raising. In 1977 the late arrival of the rains resulted in a 45 percent reduction in peanut output (the country's No. 1 export item). Other crops whose production suffered significant loss in output as a result of the delay in rainfall were: rice - 45 percent, millet - 40 percent, and cotton - 27 percent. The food grain deficit alone was estimated at 180,000 metric tons.

The need to obtain adequate and regular supply of water for human and animal consumption as well as for crop irrigation purposes is the primary concern of the Senegalese government.

Water supply from service connections cover only 30 percent of the Cap Vert area (Dakar and suburbs). The remainder of this area (70 percent) gets its water supply from public wells. All rural areas get their water supply through wells built by the ministry of rural development. The average water rate in service connected areas is 115 CFA per cubic meter (52 cents per cubic meter).

2.3 Energy Situation

Sixty percent of Senegal's energy source is in fuelwood which is in rapid depletion and may soon be creating environmental problems if no alternate sources of energy are tapped. Senegal depends largely on imported oil as a commercial source of energy. In 1976 nearly 16 percent of all imports was for oil. Senegal has a reserve of 100 metric tons of heavy oil off the coast of Casamance. Prospects for larger offshore reserves are promising. There are also natural gas deposits in Senegal, some of which are presently being tapped.

Senegal's consumption of petroleum products in 1977 is estimated between 600 and 700 metric tons with fuel oil accounting for 50 percent of the total consumption, diesel fuel 25 percent, and gasoline 20 percent, kerosene 4 percent, and gas 1 percent. Price of gasoline is 120 CFA per litre ($2.07 per gallon) and that of diesel fuel is 75 CFA per litre ($1.29 per gallon).

Installed electrical energy capacity in Senegal is between 110 - 150 MW (all thermal plants). Consumption of electrical energy is expected to reach 550 GWh in

1980, 770 GWh in 1985, and 1160 GWh in 1990, representing a 7 percent annual rate of increase from 1980 through 1990. Nearly 75 percent of the electrical energy is consumed by industry, 20 percent in household appliances, and the remaining 5 percent in lighting. The distribution network is 110 and 220 V, 1/3 phases, 2/3/4 wires and 50 cycles. Distribution costs are: 110 V = 58 CFA per KW (26 cents per KW), 220 V = 31 CFA per KW 914 cents per KW). Price of residential electric power in Senegal is 50 CFA per KWh (24 cents per KWh).

Senegal's electricity is supplied through a main grid whose network is mainly concentrated in the west-central portion of the country with the main focus on Dakar and through 21 decentralized or secondary power stations located in various parts of the country. The main grid runs on thermal plants using fuel oil and the secondary plants run on diesel fuel with the exceptin of the Ziguinchor plant which is run on peanut shells and fuel oil.

2.4 Solar Irradiation Status

The average daily insolation in Senegal is over 6 Kwh per square meter per day with the total insolation values for certain regions being;

North Central :	700 cal/square cm/day	=	8.12 kwh/square m/day
Middle Central:	625 cal/square cm/day	=	7.25 kwh/square m/day
South Central :	550 cal/square cm/day	=	6.38 kwh/square m/day

The responsibility for collecting solar energy irradiation is assigned to the IPM (Institut Physique Meteorologique) which has been engaged in this kind of activity for the past 20 years in collaboration with the World Meteorological Organization and other world meteorological centers.

IPM has installed a number of pilot stations for the collection of meteorological data in various parts of Senegal. One of their main requirements is for simple PV powered stations for weather and environmental data collection and monitoring.

IPM is also engaged in projects for the standardization of solar radiometric instruments and in developing more economic and efficient collectors for solar irradiation measurement purposes.

2.5 Solar Energy Activity in Senegal

As mentioned earlier, research work in solar energy in Senegal is 20 years old, the first works being concentrated at the IPM, a department of the faculty of science of the University of Dakar.

Research and experiments on solar energy for water pumping applications carried out under the supervision of Professor Henri Masson some years ago resulted in the construction of the first practical solar motor pump in Senegal. This water pumping system, baptised SEGAL, used flat plate solar collectors of 88 square meters and was of the low temperature thermodynamic cycle type. It operated for 5 to 6 hours a day and pumped 25 cubic meters of water from a manometric depth of 30 meters. Further work on solar energy water pumping systems was directed towards taking the solar energy systems out of the laboratory to the production line. The French company MENGIN first and SOFRETES afterwards were the most active in this respect.

Due to particular climatic conditions of Senegal, by far the major activity of solar energy is in the area of water pumping systems for human and animal consumption and for crop irrigation.

There is no significant known activity taking place in solar energy for educational radios or televisions. Reliable data on the number of ETV systems operating in Senegal today is not available.

The Senegalese government has allocated more than 6 BCFA ($27 million) in it s current fifth four-year development plan (1977 - 1981) for the funding of solar energy projects whose feasibility has already been ascertained, the major ones being:

- Replacement of a number of diesel generators - decentralized power stations with solar energy powered stations (seven such stations are under consideration).

- Construction of a solar tower in bricks of 1500 kg per day and capable of attaining a temperature level 1000 degrees C.

- Water pumping system with wind energy and photovoltaics combined; estimated cost = 35 MCFA ($160K).

- Power supply for the center for rural training of Mboro (in the Niayes region) for water pumping, refrigeration, and lighting.

Of the 6 BCFA ($27 million) allocated for solar energy projects, 130 MCFA ($590K) is to be assigned exclusively for financing solar energy research and development work, the major ones being:

- Storage elements for concentrator systems.

- Solar fish dryers for Mbour fishing village.

- Design of solar distillator of multiple purpose.

- Solar refrigeration and air conditioning (absorption type).

- Experimentation on new types of collectors.

- Creation of two rural energy centers at Ndigourey (in the Louga region) and at Niagawolof (in the Niayes region) for demonstration purposes.

- Development of mix PV/wind systems; 26 MCFA ($118K) allocated for this purpose.

The Institute of Technology of the University of Dakar (IUT) is organizing a symposium on solar energy systems and applications in Dakar in November. Different solar systems under development in Senegal will be exposed to the participants of the symposium and to the public at large.

The government has recently created a new ministry to coordinate all research and technology development activities in Senegal - the SERST (Secretariat d'Etat pour les Recherches Scientifiques et Techniques). SERST now coordinates all solar energy activities in Senegal and has established a new center for scientific research on renewable energy sources whose responsibility is to coordinate the activities of the various agencies and institutions presently involved in renewable energy sources development in Senegal.

2.6 Various Groups Involved in Solar Energy Activity in Senegal

IPM

Apart from its role as the official coordination of weather and environmental data collecting and monitoring, IPM is also involved in solar energy research and development functions such as:

- Performance improvement of low temperature solar thermodynamic systems.

- Comparative test on solar motor-pump fluids.

- Experimentation on forced ventilation and solar drying chambers.

- Improvement of efficiency levels of solar distillation processes.

- Solar thermosyphon and irradiation systems for hot water systems.

IPM is not involved in solar PV systems development, but is doing some work on wind and biomass subsystems.

SINAES (Societe Industrielle d'Applications de l'Energie Solaire)

SINAEA was created in 1976 with a capital of 100 MCFA ($450K) to carry out the industrial production and commercialization of solar energy systems. SINAES is also involved in solar system design and installation. It plays the role of prime contractor for most of the major solar energy projects in Senegal. SINAES is best described as a technico-commercial group. The biggest shareholder of the group is SOFRETES, which together with Briau and Renault put the French participation in the group at 70 percent leaving 30 percent in the hands of the Senegalese, practically shared equally between the government, Electricite du Senegal, and other Senegalese interests.

Briau (the French pump group) seems to be assigned the design and installation of solar pumps below the 10 kw capacity level, while any water pumping system above 10 kw is reserved to SOFRETES.

A solar thermodynamic water pumping system of 50 kw installed by SINAES in the north of Senegal is presently under test.

All major current solar energy contracts being handled by SINAES are solar thermal and solar thermodynamic systems, areas in which Senegal has been involved for the past 20 years and in which SOFRETES (major stockholder of SINAES) has contributed in developing into systems from successful pilot or experimental laboratory subsystems.

No major projects in PV systems are envisaged by SINAES before the 1982/1984 period.

SINAES has installed a 1 kw village power system at Bakel, the power source being solar thermodynamic supplying power for lighting and for water pumping for irrigation purposes. The cost of the project is between 15 and 20 MCFA ($68 - 91K).

As part of the first phase of the DIEURIGNOU project, SINAES has installed four water pumping systems of 1 kw each (all thermodynamic) located respectively at Merina Dakhar, Niakhene Meouane (Thies), and at Diagle (River region). The systems were financed by FAC (Fond Aide et Cooperation) of France.

Other SINAES projects are expected to be funded by U.S. AID, UNIDO, and then directly by the French government.

Semiconductor Laboratory of the
Faculty of Science of Dakar University

The laboratory's activity in solar energy is mainly devoted to the development of solar cells for direct conversion of sunlight into electricity. They are also involved in the design and testing of pilot PV subsystems, such as PV water pumping subsystems with RTC and Solarex panels.

Their involvement in the solar cell development is in the area of chemical vapor deposition and electron beam deposition processes using CdS-Cu S, Si-SiO (CdTe-HgTe) as solar cell materials.

The S/C lab is very much interested in technology transfer and already have some form of R & D collaboration worked out with some universities in France in the solar cell development area. They are also engaged in some work on amorphous silicon, GaAs as well as in battery storage systems and voltage control circuits.

Dakar Institute of Technology
(University of Dakar - IUT)

The institute has taken the responsibility of training engineers and technicians in the solar energy subsystems and total systems area and of the design and construction of feasible prototypes of solar systems in Senegal.

Solar energy activity at the institute is carried out through its recently established renewable energy applications department. The solar "charter" of the institute includes:

- Optimization of energy balance solar irradiation/thermal of a 100 square meter flat plate collector.
- Optimization of civil structures to take advantage of solar flat plate collectors and feasibility of producing these collectors in Senegal with locally available material.
- Study of the pasteurization of foodstuffs with solar energy and the study of high temperature (over 200 degrees C) solar thermodynamic cycles with concentrator systems.

The institute is presently carrying on experiments on small PV water pumping and refrigerator systems, particularly in the design and testing of more efficient inverters, battery storage systems, voltage regulators, and DC/DC converters for PV systems. They are presently using Solarex and RTC panels in donation.

One major area of future activity of the institute in solar energy will be the design and testing of combined wind and PV systems.

SENELEC (Societe National d'Electricite)

This is Senegal's major electric utility company. SENELEC controls the main electricity grid and 21 decentralized power stations in Senegal. The avergge capacity of the decentralized stations is around 40 kw per station. The cost of generating electricity from these stations varies between 20 CFA to 174 CFA per KWh (9 - 32 cents per KWh). According to studies conducted by SENELEC and other foreign consultants, at least five of these stations whose cost per KWh is between 47 - 82 cents can be replaced with cost benefits by solar thermodynamic systems by 1981. The same studies show that solar thermodynamic systems are more cost effective than PV's (cost per Wp of PV modules used is between $30 - 35). PV systems are being considered for 1985 projects when SENELEC believes they might be cost effective assuming present price trends continue in the future.

The most ambitious solar project planned so far for Senegal is the conversion of 13 decentralized power stations from diesel generators to solar energy electricity. Diakhao, a village 22 kilometers south of Diourbel, has been selected as the first village to be converted to solar electricity. The planned capacity for Diakhao is expected to be 50 kw while the present project is for a first phase of 23 kw capacity. The generator will be of the thermodynamic type with flat plate collectors of 2040 square meters and is expected to cost 290 MCFA ($1.3 million). BOAD (Banque Ouest Africain pour le Development), the West African Development Bank, the CC (Cisse Centrale of France loan top SENELEC) and the FAC will provide funds for the project. FAC is believed to have already advanced 40 MCFA ($180K) which will enable work to be started on the project. SINAES is to produce the collectors locally.

SENELEC has recently established a department of renewable energy electric systems with one full-time young engineer working on solar energy systems and plans to increase this number to three by year end. No studies are being conducted right now on PV's, but SENELEC expectes to start something on PV's in 1982 for systems to be installed in the 1984/1985 time period.

UN Agencies - UNEP (United Nations Environmental Protection)

After a meeting in May 1979 between the Senegalese authorities and UNEP to define the proposed renewable energy demonstration center in Senegal, Niagawolof (located 40 kilometers east of Dakar) was selected as the site for this experimental rural energy project. The project is to be financed by the UN Center of Natural Resources, Energy, and Transport and will feature:

- Pyrolytic converter fed by peanut hulls.

- Biomass converter of animal dung from 200 head of cattle.

- PV system for water pumping from a well to a tank.

- Windmill.

CARITAS - Catholic Relief Organization

Caritas-Senegal requested funding for the installation of 30 Guinard PV pumps over a three year period (10 per year) from FED (European Development Fund) through Central Agency for Joint Financial Development Programmes, a Catholic bishop's organization in the Netherlands. The funding requested was 75 percent FED, and 25 percent Caritas. To date, FED has agreed to fund nine installations, i.e., three per year.

Thirteen potential sites (between M'bour and Thiadiaye) have been identified as potential sites for these installations.

Caritas has decided to use two pump sizes: 1800 W and 2600 W, the former for tubewells of 13 to 20 meter manometric head and the latter for 20 to 28 meter manometric head tubewells. Estimated output from these PV powered wells will be 90 - 120 cubic meters per day (normal requirements estimated at 300 cubic meters per day). Emergency needs at night or on no-sun days will be supplied through hand pumps installed in wells connected to and filled from the tubewells.

SOFRETES/THERMODYNAMIC/SINAES

A 30 - 60 kw thermodynamic water pumping system at Bakel will be constructed through the joint efforts of SINAES (Senegal), SOFRETES (France), and THERMODYNAMIC (U.S.).

The project, estimated to cost 300 MCFA ($1.4 million) will irrigate about 200 hectares of farmland. Funding will be provided by US-AID and FAC jointly. SAED (Societe d'Amenagement du Delta), the Senegal river authorities, will be responsible for management and operation when the project is completed.

Other Solar Energy Projects

We have learned that there is a 1 BCFA ($5 million) project under study for the installation of several 5 kw solar energy water pumping systems in Senegal. Right now the study tends to favor solar thermodynamic over PV's having discarded PV's as not cost effective (cost per Wp is $30 - 35). We, however, believe that by the time this project goes into implementation (1981/1982) PV's will be cost effective compared to solar thermodynamic for 5 kw systems.

Solar thermodynamic water pumping system of 10 kw capacity to be installed at Dahra whose purpose will be to compare the behavior of the solar system to a diesel generator system of the same capacity. The system will be used for pumping water from wells to irrigate fodder plants in the neighborhood of the zoological research center of Dahra.

A 7 to 10 kw water pumping station is to be installed at Bondie Samba (40 kilometers north of Kaffrine) and will be financed by France. The original 10 kw project was estimated to cost $324K.

A PV pump (with RTC panels) is to be installed at the Bombey center for agronomic research - CNRA. Prototype of this system was developed at IUT and has been operational since February 1978. The pump will draw surface water into a 10 meter water tower for drip irrigation.

Two PV water pumping systems, one of 1300 Wp (installed at Babak) and the other of 900 Wp (installed at Toki in the Diourbel region), are being used to draw water from wells for human and livestock consumption. The pump at Babak operates 10 hours per day (8 a.m. to 6 p.m.) with Solarex panels. That at Toki, which has just begun operation, supplies 80 cubic meters of water every day.

The second phase of the DIOURIGNOU project provides for the installation of a solar motor pump of 2 kw capacity located at Kanel (in the river region) the cost of which is expected to be partly borne by the villagers themselves.

2.7 General Comments

U.S. policy and funding of solar energy programs in Senegal leaves a lot to be desired. We see no real positive actions taking place except the diversion of some US-AID funds towards solar energy systems in the agricultural development area.

The French government is very active in Senegal and funding all areas of renewable energy systems development, especially solar energy projects. French solar energy companies are enjoying the benefits of their government's direct and indirect intervention on the Senegalese marketplace. There are high incentive programs for French companies wishing to export energy products to Senegal.

France is also acting through the EEC to channel funds to finance solar energy projects in Senegal. FED, the European Development Fund, is allocating from 10 to 20 percent of all its energy funds to renewable energy development projects (over $10 million). In fact, some of the most ambitious solar energy projects in Senegal are receiving FED funds.

COMES, the French solar energy agency, is planning on financing some solar projects in Senegal. The agency is planning to install nearly 100 kw PV systems in developing countries in 1980.

France's strong ties with Senegal and lack of experience on the part of the U.S. to do business in Senegal dictate a more aggressive approach to the market by the U.S. government. Incentives for U.S. companies and U.S. government firm programs and commitment are required to combat the French influence rather than the "timid" US-AID actions and the rush to "unworkable" joint ventures U.S. companies are getting themselves into. Direct U.S. intervention on the market, probably through European, African, or local talents familiar with American style of business will be highly recommended.

There is urgent need to set up effective training programs to train Senegalese people in PV systems and applications. In this case, the U.S. can send its technical experts to Senegal for a period of time to train technical assistance personnel and set up a well-equipped PV system training center. We advise that this effort be coordinated with IUT, the Technical Institute of St. Louis, and other institutions already involved in this kind of activity.

To acquaint people more on solar PV system capabilities, it is recommended that the U.S. design and install a PV demonstration center in Dakar or a few miles away where it can be visited by prospective users or technicians.

The U.S. should also set up a number of pilot PV systems in specific areas in Senegal. In doing this, we should try to:

- Closely match need, source, and technology requirement.

- Design PV systems with power levels equal or nearly equal to competitive systems power levels for performance or behavior comparisons under similar loads.

It is recommended that the U.S. invest some money in developing simple instruments for in-loco solar irradiation measurements. Most present PV systems are overdesigned (therefore costly) because of lack of reliable irradiation data. Senegal does not have the means to acquire such instruments, hence, solar irradiation data for most locations is either unreliable or does not exist at all.

To reduce the present excessive overhead cost of PV systems, pilot PV systems should have standard design concepts easily adaptable to a series of applications rather than the custom or quasi-custom design approach prevailing today, which is far too time-consuming and costly for Senegal. We also suggest providing simple and reasonably accurate module sizing processes as well as simple and fewer PV system design parameters at the user's reach. Senegalese technicians are uncomfortable with the use of computers to size their systems and they are not happy having to depend on U.S. technicians to do all their sizing and design work for them.

Prototypes of subsystems should be first operational in the U.S. before attempting to export them to Senegal; but total systems are best tested installed locally.

Senegal villages are organized into very workable and convenient administrative groups, making PV village power installation, operation and management quite straightforward.

PV village power systems in Senegal will develop as a natural consequence of potable water supply and irrigation projects. This will include area lighting, rural dispensaries, educational radios, and TV's and cottage industry.

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3. Ivory Coast

3.1 Summary

Near and intermediate-term markets for solar PV systems in the Ivory Coast will be heavily centered around the communications market segment. This segment is, in fact, one of the sectors receiving major emphasis in the country's current five-year (1976 - 1980) development plan.

Village power systems with solar PV's, in the context of rural electrification projects, have not much potential in Ivory Coast because of the government's already heavily committed plans towards the interconnection of the entire national grid from coast to coast and from one extreme of the country to the other. The plans do not really allow for the construction of decentralized power stations except on temporary basis.

Ivory Coast's energy requirements are estimated to increase from the 1210 GWH in 1977 to 3000 GWH in 1982 and to 7000 GWH in 1990. There is, therefore, urgent need for the country to start looking at some form of renewable energy sources. To date, solar energy does not constitute one of the renewable energy sources Ivory Coast is looking at to satisfy its future energy needs. Biomass, agricultural produce transformation, and ocean thermal are the type of renewable energy sources being considered.

Due to the low level power requirements for communication equipment, it is very unlikely that educational television centers, for example, will develop into solar PV village power centers in the near or intermediate future. Some form of area lighting might, however, develop around the ETV centers for night classes and for community center activities of some kind.

On a long-term basis, we see some water pumping applications coming up in some areas of the country. PV systems will be very competitive in this case for water pumping systems below the 10 KW capacity level, if the price of PV modules goes below the dollar mark. These water pumping sites are more likely to develop into village power requirements than communication sites.

3.2 General Information

The Republic of Ivory Coast is located on the west coast of Africa on the Atlantic Ocean. It has a rain forest extending from the coast to over half the country, the rest being mainly wooded and grassy savanna with mountainous regions in the northwest. Ivory Coast has a surface area of nearly 125K square miles (about the size of New Mexico).

Ivory Coast's population is about 7.3 million of which 25 percent is urban. The latest estimate is that more than 40 percent of the population in the year 1980 will be living in the urban areas. Abidjan, the capital, has a population of just over a million people; the other major city, Bouake, having over 250,000 people. Over a million of Ivory Coast's population are foreigners with more than 60,000 French nationals.

Agriculture constitutes the main economic sector in Ivory Coast. Together with forestry, animal husbandry, and fishing this sector accounts for 28 percent of the country's GDP and 80 percent of the country's total exports. Agricultural products form the basis of Ivory Coast's main processing and manufacturing industries.

Major export earners of Ivory Coast are all in the agricultural sector; in fact, Ivory Coast is among the world's leading suppliers in coffee, timber, and cocoa. Other foreign exchange earners for Ivory Coast are palm oil, sugar, and rice.

The industrial sector, which is mainly centered around the transformation of agricultural produce, accounts for about 15 percent of the country's GDP.

The Ivory Coast is an associate member of the EEC (European Economic Community) and signatory (in May 1975) of the Economic Community of West African States (15 states) - ECOWAS. Ivory Coast is also a member of the four-country Council of Entente with Niger, Benin, and Upper Volta. This council and ECOWAS are working towards the elimination of trade barriers between member countries.

Ivory Coast is a member of the six West African monetary unions with a common currency - the franc CFA, issued by a common central bank (BCEAO). The CFA has an unlimited convertibility with the French franc. The CFA franc partners of Ivory Coast are: Senegal, Benin, Togo, Upper Volta, and Niger.

Five major commercial banks and five major specialized public credit institutions service the financial market in Ivory Coast. Other credit institutions of national importance are: Caisse Automne d'Amortissement (CAA), the National Treasury, the Post Office Bank, and the National Savings Bank.

The US-EXIM bank and the foreign credit insurance association intervene on the Ivory Coast market with full range loans and credit insurance converting products exported from the U.S. to Ivory Coast.

France's close ties with Ivory Coast extends to all areas of activity - economic, financial, and cultural (French is the official language and the French education system is transplanted over there), and renders rather difficult the country's trade with other developed nations. The French population in Ivory Coast is estimated at 60,000.

Great concerns over growing foreign debt have cause the government to reduce significantly the country's 1979 investment and administrative budgets, resulting in the curtailment of several key industrial projects. These budgets have been trimmed by 7 percent in real terms (equivalent to 20 percent in current dollar values). The investment program has been reworked to give priority to export-oriented investments.

France has by far the largest share of the foreign investment in Ivory Coast and is also its largest supplier and market. France has played and continued to play a major role in the development fo Ivory Coast.

The percentage distribution of Ivory Coast's import and export by major trade partners is:

Total Exports to:	France 28% EEC (less France) 39% Other france zone 11% U.S.A. 10%
Total Imports from:	France 39% EEC (less France) 20% Other franc zone 5% U.S.A. 8%

3.3 Energy Situation

Ivory Coast's energy resources profile and projections have been estimated in thousands of petroleum equivalent as follows:

RESOURCES	1975	1980	1985
Wood & charcoal	438	500	580
Electricity	287	857	1400
Petroleum prod.	591	859	1218

Ivory Coast is to begin producing off-shore oil by late 1980. Preliminary estimate of 70 million barrels plus 11 million reserves will cover about 25 percent of the country's present annual crude consumption at maximum exploitation rate. Several oil companies, meanwhile, continue to search for oil reserves both on land and off-shore.

The price of some petroleum products are:

Gasoline	100 CFA/litre	($1.72/gal.)
Kerosine	68 CFA/litre	($1.18/gal.)
Diesel oil	65 CFA/litre	($1.13/gal.)
Fuel oil (1500)	26,670 CFA/ton	($121/ton)
Fuel oil (3500)	17,468 CFA/ton	($79/ton)

The production of electricity in Ivory Coast in 1977 was around 1200 GWH of which 17 percent are from hydro sources. Production is estimated to reach almost 2000 GWH in 1980 and 3000 GWH in 1982. There are some estimates putting production of electricity at 3500 GWH in 1985 and 7000 GWH by the end of 1990.

There is a $30 million project of electricity sharing between Ivory Coast and Ghana. The project is being funded by the African Development Bank and the respective governments as the first phase of a giant project of the integration of West African Electricity network.

Ivory Coast depends heavily upon fossil fuel for the generation of its electricity. Nearly 85 percent of total production is thermal, the rest being hydroelectric. Current development plans are putting more emphasis on hydropower sources with the view of bringing the percentage of hydroelectricity production in the country from 17 percent to 30 percent in ten years' time and 50 percent in 20 years' time.

Price of domestic electricity in KWH in Ivory Coast varies from about 20 CFA per KWH to about 40 CFA per KWH depending on the amount of electricity consumed.

Up to 90 KWh	38.20 CFA/KWH (17¢/KWH)
From 91 - 180 KWH	29.40 CFA/KWH (13¢/KWH)
Over 180 KWH	19.70 CFA/KWH (9¢/KWH)

As regards rural electrification, Ivory Coast has embarked on a giant project to electrify its villages through an all interconnected network. The estimated cost of the project is about $115 million and will be financed jointly by Germany, Canada, and the World Bank. At the end of 1977, 366 villages were electrified. By 1980, an estimated 600 villages are to be electrified, bringing the number to about 1000 villages by 1985. Plans are afoot to set up five large "spider" power plants at Odienne, Man, Korhogo-Ferke, Boundiali, and Seguela, which will service surrounding areas. These plants will be run on fossil fuel pending their connection to the national grid.

3.4 Solar Irradiation Status

No serious and reliable solar insolation data is readily available in Ivory Coast. CATEL, the educational TV supplier in the country, claims to have conducted a thorough study on solar irradiation measurements in North, Central, and South Ivory Coast. Copies of this report can only be obtained directly from the Ministry of Education on special application.

3.5 Solar Energy Activity in Ivory Coast

The only known solar energy activity going on in Ivory Coast is in the communications area, especially in the educational TV sector. This ETV sector is entirely controlled by one company - CATEL (Compagnie Africaine de Television).

CATEL

CATEL is an independent profit-making concern with share jointly owned by the Ivory Coast government, private Ivorian inventors, and private French investors. They supply the entire ETV system to Ivory Coast and some other West African francophone countries. The entire ETV system includes the television receiver, the antenna, and the power supply device. CATEL has been involved in the solar PV for ETV's for over five years now and has installed pilot PV powered stations in Ivory Coast, Niger, and some other francophone West African countries.

CATEL has developed new low power ETV sets of 40 W, 24 V or 12 V versions which they intend introducing on the market. To power these sets, they are looking for 25 W, 12 V PV modules. They will be using zinc/potassium (in water solution) storage batteries (SIBEL products) with the PV modules as power supp;ly source. These batteries are supposed to have a capacity of 2000 A-hours and are constructed with 1 volt elements.

Due to the unfavorable economic conditions presently existing in Ivory Coast, the government has decided to cut back on several projects, including that of PV powered ETV's. Plans in this area have been pushed back for at least 12 months.

A recent CATEL study on PV powered ETV's concluded that seven years (minimum) of operation of PV (ETV) is equivalent to three years of primary battery (ETV) under the same conditions.

EECI (The Ivory Coast Electric Utility Company)

EECI has no plans for solar energy electric generation in the Ivory Coast, but they are interested in looking at PV village power applications for water pumping and telecommunications. They require some recent literature on PV price trends and system design and specifications, to enable them to set their own study group to work on PV electric power systems.

As in many other African countries, the current problems facing the electric utility companies (in the area of power generation) power outages, distribution networks, and very high rate of demand, make it almost impossible for these companies to consider power sources such as solar electric with capacities in the kilowatt range. Moreover, it is Ivory Coast's goal to electrify all cities, towns, and villages under one national interconnected grid.

The African development bank is highly interested in financing development projects for rural areas of Africa, especially for small towns and villages. Any cost-effective alternative projects of supplying electrical power to African villages will receive priority treatment from the bank. They would like to be kept informed about progress in the PV technology and price trends to enable them to evaluate future plans for solar PV systems for village power supply. The bank is headquartered in Abidjan, Ivory Coast.

Due to the unfavorable economic situation now prevailing in the Ivory Coast, the government has decided to cut back on several projects including that of solar ETV's. The highly publicized $12 million ETV project (of which $4 million are for solar panels) will not take off this year as planned. The guess is that it might not take off until towards the end of 1980.

A series of meetings is now taking place between CATEL and the government to obtain funds to install from 500 to 1000 solar PV, ETV stations beginning this year. CATEL believes a substantial dollar savings will result from the PV installations.

CATEL is presently installing pilot solar PV, ETV stations all over Ivory Coast using solar panels from Solar Power Corporation, Motorola, RTC, and Solarex. They are also engaged in solar PV ETV's in Niger, Senegal, and the Cameroon. Their goal is to cover all the west African francophone countries. They believe Senegal will introduce ETV's in 1983 and might opt for solar PV generators. Cameroon is believed to have called for offers on both commercial and educational TV's. (Cameroon has no TV network at present.)

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4. Nigeria

4.1 Summary

Nigeria is one of the world's largest exporters of oil; 40 percent of its GDP is derived from oil. The country is presently faced with huge problems in the energy supply area due to rapid increase in demand of electrical energy to sustain the high growth rate brought about by income from oil exports. Much of the country's attention is turned towards producing more power to satisfy present needs and near-term future requirements. Futhermore, Nigeria intends to develop an integral all-interconnected electric grid system to take care of consumption in the country including the rural areas. It is looking mainly at the development of its hydroelectric potential and using its abundant natural gas to generate electricity.

The development of renewable sources of energy such as solar energy is not yet being considered by Nigeria. The water table in some parts of the country (where water pumping might be needed) is too deep for the application of solar PV water pumping systems. Village solar PV power applications in Nigeria might develop around educational or community or television stations and village health center or dispensary applications. Nigeria has the capability of funding its own projects and might be inclined to prefer solar PV technology transfer to the importation of solar panel and solar power systems.

4.2 General Information

Nigeria is located on the west coast of Africa on the Atlantic Ocean. It covers a surface area of about 357,000 square miles (a little larger than Texas and Utah put together). It has a population of 81 million people (unofficially estimated at 100 million people) with the capital city, Lagos, having close to 2 million people. Other major cities are Ibadan with 1.5 million people and Kano with half a million people. The non-African population is estimated at 50,000 people. Over 75 percent of the population live in rural areas.

Nigeria can be divided into four main zones, the southern swampy coastal belt, intersected by deltas of the Niger and other rivers, the northern Sahel type zone, the tropical rain forest, and the central plateau.

4.3 Energy Situtation

Nigeria is the eighth largest exporter of oil in the world. It also possesses natural gas and coal reserves. Oil accounts for over 85 percent of government revenues which also accounts for 40 percent of GDP. Nigeria is also blessed with a large hydroelectric potential which is, however, unreliable due to the effect of draught.

NEPA (the government controlled electric utility company) generates almost the enture electric power required (98 percent). Nigerian Electric Supply Company (a private enterprise) generates the remaining two percent, mainly concentrated in the norther area (JOS). Grid-connected electricity plant supply accounts for 95 percent of the total electric power distribution in the country.

Electricity consumption in Nigeria is increasing at an annual rate of 25 percent, due in part to the rapid growth in the country's oil income and in part to the low rate of electricity unchanged since 1973. Nigeria's electric power grid capacity is estimated at 987 MW of which 560 MW are derived from hydroplants, 407 MW from gas turbine plants, 20 MW from diesel plants, and 10 MW is exported to Niger.

Nigeria is seeking long-term financing to expand its electricity generating capacity. Several large hydroelectric plants and gas turbine plants are being planned. By 1986 Nigeria expects to bring its total electricity generating capacity to about 5 GW, of hwich 3.5 GW from hydroplants and 1.5 GW from gas turbine plants.

In terms of power consumption (KWH), 42 percent of current capacity is absorbed in residential uses, 36 percent in industrial plants, and 22 percent by the commercial sector.

There are about 25 diesel generators installed all over Nigeria for secondary power generating stations. The total capacity is estimated at 36 MW. Nigeria, however, plans to discontinue these diesel stations and is planning an all integrated grid system covering the entire country.

4.4 Solar Energy Activity

There are no serious programs in solar energy in Nigeria. The few things happening are all concentrated in the universities and research centers. The National Science and Technology Development Agency was established in 1977 to coordinate research and development in new sources of energy. This agency is more interested in technology transfer and the building of their own solar energy equipment capability.

The Federal Ministry of Water Resource and Irrigations does not think solar PV systems are suitable for water pumping applications in Nigeria, since where they are needed water is available at very deep levels.

There are some solar PV pumps operating in the north of Nigeria and donated by ELF oil company. No other information is available on these pumps.

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5. Cameroon

5.1 Summary

Solar energy systems have a good potential in Cameroon, even though there is no direct government involvement yet in the development of this energy source. Many individuals and some government institutions are doing something in solar energy development on their own.

The very wide variation in population density across the country and the absence of any plans to interconnect the entire national grid, suggest that Cameroon will be inclined to develop decentralized energy sources to satisfy the electric power needs of its rural population. Solar energy systems could represent a big potential for decentralized power systems, especially in the sunny Sahelian northern sector of the country, with large solar resources and with little fuelwood availability.

Unlike Senegal, Cameroon has not acquired any experience in solar thermal of solar thermodynamic systems and hence is more disposed to consider solar PV power systems for village power applications. Wind energy systems are not likely to be adopted on any appreciable scale in Cameroon because mean wind speeds around the country don't exceed the 10 miles per hour threshold value suggested for efficient wind power systems development.

Cameroon is laced by many rivers and therefore derives more than 90 percent of its electric power from hydrosystems. The main sources of electrical energy system likely to be considered for rural electrification purposes are minihydro plants. These plants have been installed in certain parts of the country and have failed to generate the power required for several different reasons. Cameroon might, in these circumstances, want to consider solar energy systems this time.

Solar PV systems have a great potential in micro-irrigation in Cameroon, with its numerous rivers and fertile river beds. In these areas, subsurface water is availlable at depths less than six meters; hence, micro-rigation systems adapt perfectly to their water needs. It is estimated that with a solar PV system of 400 Wp, it is possible to micro-irrigate one hectare of rice field (or two hectare of other crops) where the water table is close to the surface. Irrigation along some of Cameroon's river beds is being accomplished through chadoufs, gasoline, and diesel pumpsets. these pumpsets are acquired by farmers through soft loans. The cost of running these pumpsets (delivered cost of fuel, spare parts, repairs, etc.), their average life, and their first cost altogether go to make solar PV systems very cost effective in this application area.

There is a great interest in Cameroon for solar crop drying systems, especially for cocoa drying by means of simple solar collectors as the heat source and moving air through and over the cocoa beans to accelerate the drying process. In this case, solar PV powered vent fans can be adopted to accomplish the air moving function. A lot of other crops produced in Cameroon need to be dried to prevent decay and this kind of drying system, if successful, is bound to have widespread application across the entire country.

Refrigerators run on kerosene generators are not widely used in Cameroon. These refrigerators are widely used in some developing countries for drug and vaccine preservation in rural medical centers. Solar PV powered refrigerators as a replacement market for kerosene types do not present any big potential in the immediate future in Cameroon. This market will develop only where there are trained medical personnel capable of handling the drugs and vaccines available at the rural medical centers of dispensaries.

5.2 General Information

The United Republic of Cameroon is located at the crossroads between the western and central African countries on the gulf of Guinea. It covers a surface area of about 184,000 square miles (about the size of California). The northern region is mainly low savanna gradually sloping to a marshland around Lake Chad while the southern region is a coastal plan with equatorial rain forests. The western region is made up of mountainous forests including Mount Cameroon while the central portion of the country has the form of a transitional plateau.

The population of Cameroon is around eight million people, the capital, Yaounde, having about 300,000 people. Duala, the nation's commercial and industrial center, has a population of 400,000 people. English and French are the official languages spoken in Cameroon. The population density varies from nearly three people per square kilometer in the eastern less populated area to 75 people per square kilometer in the western more populated region.

With its enormous forestry potential and very high agriculture possibilities, Cameroon's economy is presently almost entirely build around the agricultural sector, where 80 percent of the country's total workforce is concentrated and which accounts for over 70 percent of total exports. Major foreign exchange earners are coffee, cocoa, and timber.

The industrial sector, in expansion, represents about 14 percent of total GDP and is mainly made up of a large aluminum manufacturing complex at Edea (joint France-Cameroon enterprise) and about 200 small manufacturing, processing, and assembly plants mainly for the production of consumer goods.

Cameroon is an associate member of the EEC (European Economic Community) and signatory of the ECOWAS (Economic Community of West African States). Cameroon is also a member of the central African monetary union with a common currency - CFA franc - which bears an unlimited convertibility rapport with the French franc and floats with it. Other trade and financial organizations in which Cameroon participates are: UDEAC, Customs and Economic Union of Central Africa, and LCBC (Lake Chad Basin Commission).

The government encourages foreign investments with a very favorable investment code, coupled with a well-conceived development plan. In 1967 the government concluded an investment guarantee agreement with the United States as further inducement to potential U.S. investors.

Over 64 percent of Cameroon's total trade is with the EEC countries. France, being the major aid donor, also absorbs 28 percent of Cameroon's exports and supplies 47 percent of its import needs. Cameroon's main trading partners are: France, Netherlands, West Germany, and Italy in that order.

Cameroon maintains major treaty relationships with France in the areas of economic, cultural, and military assistance and cooperation.

5.3 Energy Situation

Cameroon's numerous rivers greatly favors hydropower development over all the other means of generating electrical power. Right now, a single hydroelectric plant generates about 95 percent of the electric power in Cameroon. Two new hydropower plants are presently under construction and a third one is being planned. Present installed capacity is in the neighborhood of 263 MW. The aluminum comlex, ALUCAM, absorbs 65 percent of the total power generated and is located in the same area as the hydropower plant. Total consumption in 1978 is estimated at 1276 GWH. The other five percent is provided through diesel generators installed mostly in the north of the country.

The greater part of the population is still not served by electricity. It is estimated that only 20 percent of the population (mostly concentrated on the western portion of the country) is served with electricity. The demand for electricity is growing at approximately 15 percent per annum, the largest demand coming from the country's manufacturing sector, in rapid expansion.

The cost of electricity to industries is around 14 mills per KWH except ALUCAM, the major consumer (65 percent of the total), which pays 7.6 mills per KWH for its electrical power consumption. Domestic charges range from 20 cents per KWH to 26 cents per KWH.

Cameroon is now an oil-producing country after ELF-Serepca in collaboration with Shell-Camrex discovered offshore oil reserves in commercial quantities at Rio-Del Rey. An oil refinery is being constructed at Limboh point near Victoria with initial capacity of 1.5 metric tons per year. This quantity will more than satisfy Cameroon's oil requirements and therefore will make it one of the oil exporting countries in the future.

Funds for all major energy development projects are provided by France through its Caisse Centrale de Cooperation Economique (CCCE). There is a very close relationship between Societe d'Electricite de France and SONEL, the Cameroon electric utility company (which supplies all the country's electric power requirements).

Retail cost for gasoline is about $1.85 per gallon and that of diesel fuel is about $1.65 per gallon.

5.4 Solar Irradiation Status

So far, Cameroon has not yet embarked on any serious activity in the area of solar insolation measurements. The only such measurements ever carried out were those of professor Guy Lacaze of the faculty of science at the University of Yaounde. These were measurements of the intensity of solar radiation in Yaounde, covering approximately a four-year period from 1969 to 1973. The department of meteorology pulishes data on the duration of sunshine hours per day for a number of stations all over Cameroon. It is, however, believed that the government is now seriously looking for aid to start a program for the measurement of solar insolation, wind speed, and rainfall in at least six different locations across the country.

5.5 Solar Energy Activity in Cameroon

There is no significant activity going on in the solar energy development sector in Cameroon. There are no plans or projects being conceived by the government, in solar energy systems, in the immediate future. The very little activity going on is concentrated in one or two groups under ONAREST (Office Nationale de la Recherche Scientifique et Technique), Cameroon's research and technology development center. It is believed that attempts are being made by the government to set up a renewable energy development program under the supervision of ONAREST. One of the groups under ONAREST is working on solar thermodynamic systems for village power application purposes in the north of the country. The choice to go thermodynamic was dictated by the fact that some of the components of these systems can be manufactured locally with material available in Cameroon.

There are plans to install three solar PV pumps in the northern part of the country. These are to be financed by EEC, the UN, and France. A SOFRETES solar thermodynamic water pump is operating at Makari. More solar thermodynamic water pumping systems are expected to be installed next year (1980). It is believed that AID is planning to use solar PV panels to power their communication systems. They are not interested in adopting solar PV's for their rural electrification projects in the near future. In the distant future, if solar energy should become one of the viable means of generating electricity in Cameroon, the thermodynamic type of solar electricity appeals more to them than PV systems.

The railway authorities are considering using solar PV systems to power railway signals and telephone relays between stations on the Douala-Yaounde line. Six hundred panels are supposed to have been ordered from RTC, France, and experimental units are already installed at Belabo.

According to CATEL, the Abidjan-based educational television company, Cameroon intends to introduce educational televisions and is considering using solar PV panels as the power source for these televisions.

Various Groups Involved in
Solar Energy Activity in Cameroon

In the absence of government programs or projects in solar energy development, some isolated private and public groups have engaged themselves in different forms of solar energy activity.

ERU (Energy Research Unit) a department of ONAREST

ERU is presently training two full-time technicians in the solar energy development field. Even though the training program is only in the solar thermodynamic area, it is believed that it will be expanded to make room for some solar PV training too. ERU is also oriented towards solar insolation data measurement and monitoring.

IRTISS (Institut de Recherche sur les Techniques, l'Industrie et le Sous-Sols) Yaounde, a department of ONAREST

The ground and subsurface research center of this group is planning to install water pumping systems (in the north) for human and animal consumption as well as for crop irrigation. They are interested only in turnkey PV water pumping systems and will soon be installing some solar thermodynamic water pumping systems.

IRTISS as a gorup is highly interested in some kind of technology transfer or an opportunity to participate, to a certain degree, in the system development of solar PV's.

Ecole Polytechnique Yaounde (School of Technology)

The research group on electrical energy and electronics at this school is putting together a program to perform a series of experiments on the current produced by solar PV cells, such as: inverter systems, voltage regulation, and storage systems. They require some solar PV panels (1 KWp) to carry out the experiments.

5.6 General Comments and Recommendations

Again, the strong ties between Cameroon and France require that the U.S. approaches the Cameroon solar PV market with well proven and coordinated programs.

The major funding institution in the energy development and production (excluding oil) is the Caisse Centrale de Cooperation Economic of France. Other energy funding bodies in France and the EEC are not yet operating on the Cameroon market. It is advisable that the U.S. encourages some of its funding institutions to enter the market now. The French solar energy commission is planning on installing 100 KWp of solar PV power in developing countries in 1980. The European development fund-(EEC) has allocated over half a million dollars for the installation of 5 KW solar energy water pumping systems (thermodynamic) in two areas of Cameroon (Logene and Chari) for crop irrigation purposes. The U.S. ambassador in Cameroon is very much interested in solar energy development and may be consulted on what type of U.S. programs will best suit Cameroon energy needs.

It is recommended that the U.S. put up a solar PV demonstration center in Cameroon (somewhere near Yaounde) to stimulate the government's interest in solar PV systems and applications. The applications recommended will be water pumping and grain grinding.

It is believed that some agencies of the government are looking for financial assistance and expertise help to carry out solar insolation data measurements in different parts of the country. NASA may want to help.

In the absence of direct government involvement in solar energy programs, such institutions like IRTISS (ONAREST) and the polytechnic are devoting some effort and resources to solar energy development. We recommend NASA to assist these institutions establish firm programs and ship them some PV panels in donation and probably help to train technical personnel in solar PV systems development and applications.

In some areas constituting the river beds in Cameroon, farmers are using hand pumps (Briau) and foot pumps (Vergnet) to draw water from subsurface depths to irrigate their crops. Even though the cost of equivalent solar PV pumps will be about ten times the cost of these pumps, it is highly recommended that NASA installs pilot solar PV pumps in these same areas to compare cost. It has been estimated that the operation cost (maintenance and spare parts), breakdown, and repair costs and replacement cost of these pumps within a year or two are equivalent to the cost of a solar PV pump. Many of these areas also use gasoline and diesel pumpsets. Solar PV systems have been estimated cost-effective compared to these pumpsets at present PV module prices. A solar PV water pumping system of 200 to 300 Wp is all that is required to raise water from these subsurface depths.

Crop drying as a means of preservation is increasingly being adopted in Cameroon. Solar PV systems can be of advantage where the drying process involves air being blown across the crops. PV vent fans will do the job. It is recommended that NASA look into this kind of application, especially for drying onions in the northern region of Cameroon.

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6. Gabon

6.1 Summary

Solar PV power development has some potential in Gabon. Even though there are no specific government sponsored development programs in solar energy as such, still there is a lot of interest on the part of the authorities and on the part of the electric utility company. A symposium on solar energy products is being organized by the U.S. cultural center in Libreville to inform the Gabonese authorities on the latest developments in solar energy power systems and applications.

About 50 percent of the country's electricity is generated through hydro-sources, the rest by thermal sources most of which are made up of decentralized diesel generator systems. Due to the thick rain forests covering nearly 90 percent of its territory, it is highly unlikely that Gabon will plan for an all grid interconnected system. Even though there are other hydroelectric systems planned, it is most likely that the less populated rural areas will have to get their electricity through secondary decentralized systems. Solar PV power systems have a good potential as power sources to villages for surface or subsurface irrigation systems and for cottage industry requirements. The government is giving a high priority to agriculture and rural development in its current five year development plan (1976 - 1980). Furthermore, since more than half of Gabon's population live in the cities, it is the government's desire to develop certain rural or provincial centers in view of reducing the present urban growth rate with all its problems.

Gabon is rich in oil and other mineral resources and can fund its own solar projects. On an intermediate term basis, we expect the development of solar PV village power systems as a natural consequence of the country's growth and development. This is because there are presently certain areas in which solar PV power systems are being requested in Gabon, viz, the telecommunications sector and the railway signaling area. Acceptance of solar PV power systems in these sectors will accelerate their application in village power systems.

6.2 General Information

The Republic of Gabon is located in the central portion of the African continent on the Atlantic Ocean. About 85 percent of the territory is made up of dense rain forest with plateaus and mountains in the northern and eastern parts of the country and extending for 103 thousand square miles - about the size of Colorado. Gabon's population is just over one million people; the capital, Libreville, having a population of about 150,000 people. Over 50 percent of the population is urban.

Petroleum accounts for nearly 75 percent of Gabon's export revenue. Oil drilling at present levels is estimated to last from 10 to 15 years if no new discoveries are found in commercial quantities. Apart from petroleum, Gabon possesses about 25 percent of the world's known manganese deposits and is the leading supplier of manganese to the U.S. Managanese accounts for eight percent of the total exports of the country. Gabon has also large uranium reserves. Timber and other forest products also constitute foreign exchange earners for Gabon.

The industrial sector, which represents 7 percent of the GDP, is mainly centered around timber processing, mineral refining, and power generation areas. Under the present development plan, 10 percent of the profit of petroleum companies are to be plowed back into the development of the industrial sector.

Agricultural production accounts for a very small proportion of the GNP and covers only 10 percent of the country's needs. The remaining 90 percent is imported from France and from neighboring African countries. Agricultural development is being given the highest priority in the current five year development plan (1976 - 1980).

The transGabon railway construction project remains the major development project on which the country's economic growth depends. This is a railway network intended to connect all major centers where the country's main resources are being tapped, a very ambitious project directly linked to all other development projects.

France is Gabon's major trading partner absorbing 37 percent of its total exports and supplying 54 percent of its total imports. Other trading partners worth mentioning are West Germany and the U.S. Gabon's major imports are electrical equipment, iron, steel, and transport equipment.

Gabon, as most francophone African countries, is an associate member of the EEC and of OPEC (Organization of Petroleum Exporters). Gabon is also a member of UDEAC, the Central African Customs and Economic Union with Cameroon, Central African Republic, and the Congo.

Gabon shares the same common currency, the franc CFA, with the Central African Republic, Chad, the Congo, and Cameroon, issued by a common central bank, BEAC.

Seven major commercial banks and five financial institutions constitute the financial services bodies in Gabon. Credit facilities are also offered through the U.S. EXIM bank and through the U.S. foreign credit insurance association which makes available a full range of loans and credit insurance for export of U.S. products to Gabon.

6.3 Energy Situation

Production and distribution of electricity and water in Gabon are under the responsibility of SEEG (Societe d'Energie et d'Eau de Gabon), which is a semipublic company (42 percent government shares). Production of electricity is about 330K GWH, while the total installed capacity is around 133 GVA. Nearly 50 percent of electric power is produced through hydropower, the rest through thermal sources.

6.4 Solar Energy Activity in Gabon

There is practically no solar energy activity going on in Gabon at the moment, but there is a grreat interest in solar energy products. ELF, the French oil company, has donated a couple of solar PV pumps to the government. These pumps are believed to be installed in the Port Gentil area (oil drilling sector). ELF intends to donate more PV pumps in the future if the present ones prove operational.

SEEG, the electric utility company, is interested in solar PV village power systems similar to that of Schuchuli and possibly a more sophisticated type. They may start designing some PV systems if they have the necessary information on PV system development. They will also take up the responsibility of solar irradiation measurement in collaboration with the meteorological department.

The railways and the port authorities are already considering the use of solar PV power supplies in their signalization and communication systems on one hand in marine applications on the other hand. In fact, ELF-Gabon has received some solar PV power supply systems from ELF-France for marine applications in Port Gentil.

Gabon is planning to establish community television network across the country in 1980. The current television network covered only three or four cities. Solar PV powered community televisions are likely to be considered as one of the possibilities of implementing the above plan.

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7. Togo

7.1 Summary

Even though there are no government projects in the solar energy development area, Togo represents one of the biggest potentials for solar energy products and systems. Togo has a population of just over 2 million people, of which 90 percent live in the rural areas. It imports its oil requirements and buys about 40 percentof its total electricity consumption from neighboring Ghana. Togo's electric generating capacity is currently estimated at 20 MW total, all of which is thermal. Although there are plans to step up the development of the country's hydroelectric potential, the need for solar energy development in Togo is very real and needs some stimulation.

The PV village power installation in Tangaye, Upper Volta, where power is being supplied by a PV power system to power a water pumping system and a grain grinding machine, has stirred a lot of interest in Togolese authorities. In fact, the minister of agriculture and rural development will be visiting Upper Volta very soon and will make it a point to visit the solar PV system in Tangaye.

The Department of Hydraulics and Energy of the Ministry of Public Works is currently putting together plans for the installation of solar energy water pumping systems in some parts of the country.

The U.S. Ambassador to Togo is very much interested in promoting solar energy rural systems and is prepared to help get funds to put up demonstration stations in Lome. She would use the embassy premises or the residence for this purpose if necessary.

7.2 General Information

The Republic of Togo is located on the west coast of Africa. It is one of the smallest countries in Africa - 22,000 square miles (about the size of West Virginia) - with a population of 2.5 million people. The capital, Lome, has the population of 130,000 people. Ninety percent of the Togolese population lives in the rural sectors of the country.

- Togo has an equatorial hot and humid climate and it extends among plateaux, hills, savannas, and valleys.

- Seventy-five percent of the active population is engaged in agriculture which accounts for nearly 25 percent of GDP and 20 percent of total exports of the country. Principal agricultural products are cocoa, coffee, cotton, and palm kernels.

- The major foreign exchange earners for the country are high grade phosphate, cocoa, and coffee. Major trading partner being France, which absorbs 40 percent of Togo's exports and supplies over 30 percent of its import requirements. Major foreign aid contributors to Togo are France and

West Germany, with the U.S., Canada, other EEC, World Bank, and UNDP also quite active.

- More than 66 percent of the country's manufactured products are produced by four companies: a brewery company, a textile company, a soda factory, and a cement factory.

- Togo is a member of the six West African monetary union with a common currency - the franc CFA - issued by a common central bank (BCEAO) and which has an unlimited convertibility with the French franc.

- Togo is an associate member of the EEC (European Economic Community) and signatory of the Economic Community of West African States (ECOWAS). Other members of ECOWAS are: Benin, Gambia, Ghana, Guinea, Guinea Bissau, Ivory Coast, Liberia, Mali, Mauritania, Niger, Senegal, Sierra Leone, and Upper Volta. ECOWAS is the largest and the most important single economic grouping in Africa.

- Togo is also a member of the council of ENTENTE with Benin, Ivory Coast, Niger, and Upper Volta. The objectives of this council is to coordinate member countries' economic and commercial policies.

- Five commercial banks and the National Development Bank, the Agriculture Credit Fund, the Post Office Bank, the National Savings Bank, and the Caisse Centrale de Cooperation Economique, constitute the country's financial market.

7.3 Energy Situation

- Togo depends heavily on non-commercial sources of energy to satisfy over 35 percent of its energy requirements. Wood and charcoal are the main sources of energy in the country. Togo has no oil resources, and therefore, imports all its petroleum products.

- Electrical power capacity of the country is estimated at 20 MW, all thermal. More than 40 percent of Togo's consumption of electricity is supplied by its neighbor - Ghana.

7.4 Solar Energy Activity

- No specific government projects are being pursued in Togo so far as solar energy systems development is concerned. There is no provision in the current five-year development plans (1976 - 1980) for renewable energy sources development; but according to the Ministry of Planning and Development, the government intends to include renewable energy sources development for rural development projects in the next five-year development plan. Some private foreign companies are, however, collaborating with government agencies to promote the application of some form of solar energy systems and the government is encouraging this action.

7.5 Various Groups Involved in Solar Energy Activity in Togo

Direction de Hydraulique et de l'Energy: of the Ministry of Public Works

- This department is already putting together solar PV water pumping systems to be installed both in the north of Togo (Mango or Dapango) and in the south (near Lome, the capital). FED, the European Development Fund, will finance these installations. Presently they are considering a water pumping system from a maximum depth of 40 meters and a pump capacity of 10 cubic meters per hour. The pumping is to be done into reservoirs while the sun is shining.

- There are also proposals being put together to be inserted in the next five year plan (1981 - 1985) for rural electrification projects using solar energy systems. This, as a result of a recent government engineer conference in Niger, where all francophone African nations were represented. At this conference it was agreed to follow Niger's example in solar energy development for telecommunications (especially radio telephones), educational TV's for rural areas and water pumping in the arid areas of the participating African nations. Niger has agreed to make available its experience in the field of solar energy products to other African nations.

Department of Solid State Chemistry - University of Benin, Lome

- The solid state chemistry department is involved in the study of solar cells in collaboration with some French universities. They sent a representative to attend the recent solar energy conference in Atlanta.

- They have one full-time research engineer working on solar energy systems development and plan to increase the staff of engineers in the future.

- They are interested in collaborating with some U.S. universities engaged in solar energy system development and application.

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8. Mali

8.1 Summary

Solar PV village power systems have a very good potential in Mali. The question is not whether solar PV power systems will find use in Mali, but when? This timing will depend on the rate at which fuel costs rise in the future and the rate at which PV panel costs and other associated costs decline in the future.

Mali is a relatively poor country without any commercial energy resources (oil, gas, coal, etc.). it is very limited in hydropower capability because of high evaporation rates and is affected by drought. The development of minihydro plants for rural applications are not feasible because most of the small rivers dry up during the year. Wind velocities both in the southern and northers parts of the country run below the required threshold of 10 miles per hour, necessary for any kind of efficient wind-power systems. Solar irradiation, on the other hand, is good in the south and excellent in the north. Under the sponsorship of the World Meteorological Organization and the UNDP, Mali is setting up systems to measure solar irradiation parameters in different parts of the country. Solar irradiation measurement stations are said to be installed in Bamako, Timbuktu, San, and Kayes.

Mali's economic survival is mainly based on its agricultural products, which are subject to cyclical climatic conditions, especially rainfall. The need to develop efficient systems for adequate and regular supply of water for human and livestock consumption as well as for crop irrigation is primary to Mali's economic welfare.

We believe solar PV power systems will contribute appreciably to Mali's economic development. Village energy needs such as: lighting, cereal grinding, water pumping, small scale refrigeration, and battery charging, can easily and effectively be provided by solar PV systems.

Mali being a poor nation, has to depend largely on outside donors to finance its projects. Quite a number of such donors including the US-AID and the Mali-Acqua Viva, a religious organization, are already actively engaged in solar energy systems development in Mali.

8.2 General Information

Mali is located in the interior of West Africa with the most part of the country lying in the savanna region, between the coastal rain forest and the desert, while the northern portion lies in the Sahara Desert. Mali covers a surface area of 465,000 square miles, the equivalent of Texas and California put together.

The current population of Mali is estimated at 6.5 million people of which 90 percent live in the rural areas. The capital, Bamako, has approximately 400,000 people. Other major cities are Mopti, 33,000 people; Kayes, 29,000 people; and Sagou, 28,000 people.

Mali is considered one of the poorest countries in the developing world, the fourth poorest in fact.

Agriculture and livestock raising account for nearly 45 percent of total GDP of the country. More than 50 percent of Mali's total exports is in agricultural products, which are affected by drought of cyclical climatic conditions. Main exports are meat, livestock, baskets, cotton, fish, and peanuts. France, EEC, the Communist countries, Japan, and Upper Volta mainly absorb Mali's products. Food, machinery, vehicles, and oil are the major import items in Mali, while its main supplies come from France, EEC, the Communist countries, and Ivory Coast.

Manufacturing accounts for 14 percent of the country's GDP, textiles and food processing being the major areas of activity.

Mali is a member of the Senegal River Valley Development Organization (with Senegal and Mauritania) and of the Liptako Gourma Authority (with Niger and Upper Volta). It is also a member of ECOWAS and of the Niger River Commission, all of them being economic organizations aimed at reducing trade barriers between member countries.

Mali is a member of the (French) franc monetary zone and an associate member of the EEC.

8.3 Energy Situation

As in almost all developing countries, Mali derives its main energy requirements from noncommercial sources such as firewood, charcoal, animal dung, agricultural wastes, animal and human power. Mali imports its petroleum products needs; oil and natural gas requirements in 1977 represented over 30 percent of total imports.

Total installed electric power is estimated at 33 MW of which 26 MW are generated from thermal sources while the remaining 7 MW is from hydroelectric plants. Hydroelectric plants are going to play a major role in providing electric power to Mali by 1982, with the completion of the Souligne Dam.

8.4 Institutions Involved in Solar Energy in Mali

Solar Energy Lab

This lab was created in 1964 as a division of the Direction Generale de l'Hydraulique et de l'Energie, of the Ministry of Industrial Development and Tourism. Other divisions in the "Direction" are Hydrogeology, Hydrology, Thermal and Hydroelectric Energy, Rural Hydraulic, Urban Water Supply, and Well operations. The lab was actively involved in development work for flat plate solar water heaters and solar still. The activities of the lab have reduced during the years, due to lack of adequate financial support and appropriate measuring instruments and equipment. The current activity of the lab is mainly in the area of applied research.

It is believed that US-AID is putting together new programs to help the lab become effective again in the field of solar energy systems development. Some of the new programs being considered are:

- Testing and improvement of solar water heaters for urban and rural institutions.

- Testing and improvement of crop/fish dryers.

- Development of efficient wood burning stoves.

- Development of efficient PV battery charging systems, emphasizing reliability and ease of operation.

Ecole Normale Superieure - Technical Institute

The physics department of this technical institute is believed to be engaged in some of the highest quality work going on in solar energy in Mali. The only valid insolation measurements on Mali today are from the works of the head of this department. Current programs being pursued in this department in the solar energy area are solar refrigeration by the absorption cycle method and solar concentrators applied to PV systems.

National School of Engineering

The electro-mechanical department of the National School of Engineering is expanding its current solar energy courses to include a full course in solar PV systems and applications. This school is the major supplier of engineers to the Solar Energy Lab.

Solar Energy Activity in Mali

In September 1976 representatives of the solar energy organizations in Mali, Niger, and Senegal met together with delegates from Chad, Ivory Coast, Mauritania, and Upper Volta to discuss the promotion of solar energy in African countries. The meeting was organized under the auspices of the West African Economic Community (made up of francophone countries) and the Interstate Committee for Drought Control in the Sahel. The meeting took place in Bamako and ended with the recommendation of the establishment of national research centers and of a regional center for research and promotion of solar energy in Africa.

In 1977, the Genie Rural requested US-AID to help finance the installation of solar PV pumps for irrigation in three locations of Mali, with the purpose of comparing their overall performance with that of diesel pumps and a SOFRETES solar thermal pump. The locations selected are Kayes, Dilly, and Mopti.

The price of a 1300 Wp solar PV water pumping system for Mopti, for example, was estimated at $31K ($14 per Wp panels and $1.8 per Wp BOS components). Genier Rural further estimated other costs as $9.8 for fencing and storage tank (160 cubic meters), $6.5 for well, and $850 for solar PV expert, bringing the total to $48.15K, that is to say, installed. This pumping system is expected to draw enough water from a well to irrigate 1.6 hectares of farmland.

The European Development Fund (EEC) is planning to finance the installation of several solar PV water pumping systems in Mali. Under the current agreement the fund will provide financing up to 75 percent of the total cost of installation, the normal level of funding being 50 percent of the total cost of installation. According to Mali Acqua Viva, the religious organization coordinating the project, a total of 18 solar PV water pumping systems are expected to be installed in various locations in Mali by the end of 1979. The locations being considered are Timbuktu, Gao, Kayes, and Mopti, while system capacity being considered are 2, 3, and 5K Wp, suitable to draw water from depths of 50 - 60 meters.

There are five solar pumps currently installed in Mali; two are of the flat plate collector type (developed by SOFRETES) and three of the solar PV type with Guinard pumps. The solar PV panels were supplied by Solarex and Solar Power Corporation. Presently under construction at Dire, on the bend of the Niger near Timbuktu, is a 50 KW solar power plant (thermodynamic system) designed by SOFRETES, to provide power for water pumping, refrigeration, and lighting.

The first solar thermal pump (SOFRETES) was installed at Dioila. It cost $134K ($39K solar pumping system) and was financed by CIMADE, a French ecumenical aid agency. The pump is now dismantled due to a series of problems.

The second solar thermal pump (SOFRETES) was installed at Katibougou in the garden of the Rural Polythenical Institute. The pump is in disuse due to lack of maintenance and other types of inefficiencies.

The first solar PV water pumping system was installed in Koni in July 1977. It is a 900 Wp (six solar power panel) PV system with a six inch Alta-x Guinard pump, drawing water from a 18 meter deep well at 35 - 40 cubic meters per day and pumped into a 120 cubic meter reservoir. The installation was funded through Mali Acqua Viva, partly with external contributions and partly from FED, the European Development Fund. The cost was $54K. Problem: delamination of some of the panels soon after installation.

In October 1977, Mali Acqua Viva funded the installation of another solar PV water pump at Nabasso, a village of nearly 3,000 inhabitants. The panels were supplied by Solar Power Corporation, while the pump was a four inch Guinard type. The system pumped water from a well for human and livestock consumption.

The third solar PV water pump in Mali was installed in Tominian. As in the two other cases, the funding was through Mali Acqua Viva. The panels were supplied by Solarex, while the pump was a six inch Alta-x Guinard type. This system was installed in February 1978 and capable of drawing 60 cubic meters of water every day.

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9. Tanzania

9.1 Summary

Tanzania represents a "fertile ground" for the development of solar energy, especially for solar PV systems. These systems are already being designed and installed in the country to power its radio communication systems. There are already plans being put together to step up the use of renewable energy sources in the country.

Since Tanzania depends heavily on agriculture for its economic development and since it is affected by drought, the pressing problem for Tanzania is to develop efficient and regular water supply channels to fight the drought situation. The development of efficient water pumping systems should be one of the priorities the country should be looking at, and solar PV water pumping systems should be taken into consideration. In fact, the Ministry of Water, Energy, and Minerals is in the process of installing an experimental solar PV water pumping system near Morogoro, with PV system and subsystem donated by Philips.

Tanzania is relatively poor so far as energy resources are concerned (both commercial and noncommercial forms of energy), but is rich in solar insolation and must take advantage of that to develop solar energy systems. In August 1977 the Tanzanian National Scientific Research Council, in collaboration with the U.S. National Academy of Science, organized a seminar/workshop in Dar-es-Salaam to discuss the use of solar energy systems for the villages of Tanzania. The seminar/workshop was financed by US-AID.

There is a great interest in Tanzania today to try and improve the life style of their villagers through the use of solar energy systems. We see solar PV systems, playing the important role of supplying electrical power to run motors for small-scale refrigerators, for water pumping systems, for cereal grinding, for spinning machines, and for powering educational television sets. Due to the economic conditions prevailing in the country, it is our opinion that the development of solar PV systems in Tanzania will depend largely on donor countries or international funding bodies. Tanzania does not have the potential for funding its own solar energy projects. Furthermore, due to the policy of selfsufficiency prevailing in the country, solar PV systems being high technology products, would have to be imported into the country, which once again puts Tanzania at dependence on foreign know-how.

9.2 General Information

Tanzania is located on the east coast of Africa on the Indian Ocean and covering an area of 931,000 square kilometers. The northern region (on the border with Kenya) is very mountainous (the highest peaks in Africa), the west central being of the high plateau type. The eastern coast is made up of low land.

The population of Tanzania is estimated at 16 million people, the capital, Dar-es-Salaam, having about 500,000 people. As in most African countries, about 80 percent of the people live in rural sectors of the country. Tanzania is believed to have 13 million of its population living in about 8000 villages all over the country.

Tanzania is essentially a poor country affected by drought and relies very heavily on foreign-aid donors to finance its development projects.

Agricultural products account for about 38 percent of the total GDP and 66 percent of total export earnings. The major foreign exchange earners are coffee, cotton, sisal, and tobacco.

Industrial production represents 10 percent of GDP.

Tanzania is a member of the commonwealth and has joint commission of cooperation with Zambia and Mozambique.

The financial market in Tanzani is made up of one state-owned commercial bank, The Tanzanian Investment Bank, the Tanzanian Post Office Bank, and the National Insurance Company.

9.3 Energy Situation

As in most developing countries, 80 percent of energy used in Tanzania is from secondary nocommercial energy sources such as wood and charcoal. The rural areas depend 100 percent on noncommercial sources of energy.

The coastal grid system is the only integrated system in the country and is supplied 90 percent by TANESCO, Tanganyika Electric Supply Company (government owned). Current hydrocapacity is 13 MW, but there are plans under way for a 260 MW hydroelectric plant in the near future. Power demand is increasing at 10 percent per annum with the 1980 estimated demand at 161 MW and that of 1985 at 295MW.

The average cost of grid electricity in Dar-es-Salaam is about 11 cents per KWH.

9.4 Solar Energy Activity in Tanzania

On August 1,1977 35 Tanzanian and U.S. experts met in Dar-es-Salaam for a nine-day workshop on solar energy for the villages of Tanzania. this was a results of a joint effort on the part of the Tanzania National Scientific Research Council and the United States National Academy of Science. The seminar/workshop was fully supported by the government, and US-AID provided the funds for the occasion. Other interested government bodies which took part in the seminar/workshop were the Ministry of Water, Energy, and Minerals, the Prime Minister's Office of Regional and District Authorities, the University of Dar-es-Salaam, the Small Industries Development Organization, the Tanzania Electric Supply Company, and the Capital Development Authority. At the end of the seminar/workshop a Provisional Solar Energy Promotion Committee was formed under the direction of the Tanzanian National Scientific Research Council to coordinate future solar energy activities in the country. The Prime Minister's office has the special role of coordinating development efforts and of following up the implementation of national development policies. The Capital Development Authority has the function of coordinating all activities leading to the transfer of the current capital city, Dar-es-Salaam, to a new location, i.e., a new capital city, Dodoma. This new capital city is expected to grow from the present 60,000 people to 350,000 people in the next 10 years.

Tanzania has relatively high solar insolation levels and long hours of duration of sunshine. The number of hours of sunshine varies from 1500 per year in the southern highlands to 3000 per year o the coastal zone. The Electric Power Laboratory of the faculty of engineering of the Univeristy of Dar-es-Salaam is well equipped to carry out solar irradiation measurements in the country.

The first solar PV system was installed in Tanzania in April 1978, after the Post and Telecommunications Corporation decided to use solar PV systems for all load requirements below the 250 MW level, in their VHF, UHF, and microwave radio repeater stations. These solar PV systems were to be used in place of disposable primary cells and small diesel generators being previously used. The first solar PV system thus installed was used to power a VHF radio telephone system on the slope of Mount Kilimanjaro, with a 21 AH per day load (12 volts), which required three 31 Wp panels connected in parallel. On the successful results of this first installation four other installations were converted into solar PV systems in February 1979 and 12 new installations with solar PV systems are in advance planning stage.

Tanzania is now looking into extending the use of solar PV systems to the rural areas for village power development. The Electric Power Laboratory of the faculty of engineering is expected to play a major role in this area. In fact, they are the best equipped and motivated to handle solar PV systems. They have installed the solar PV VHF radio repeater system on Mount Kilimanjaro and have also tested most of the solar panels currently in Tanzania.

Village power application for solar PV systems in Tanzania will include water pumping (human and livestock consumption) lighting, small-scale refrigeration, grain grinding, cottage industry, and battery charging.

The Ministry of Water, Energy, and Minerals is in the process of installing an experimental solar PV water pump near Morogoro. The solar PV panels were donated to the Tanzania government by Philips. In fact, the solar PV system was designed by Philips with 48 panels of 11 Wp each connected 16 in series and 3 in parallel to obtain a 528 Wp at 248 volts and 2.1 amps at full sun. The system also includes an inverter and a standard 220 volt AC motor.

Based on the cost of electricity delivered to a consumer in Dar-es-Salaam, it has been estimated that solar PV systems will become cost-effective compared to grid electricity at 64 cents per Wp, i.e., assuming the electric utility company sells its electricity to the consumer at cost. Furthermore, solar PV electricity can become cost effective at $1.30 per Wp compared to grid electricity in Tanzania, if there is "no demand" capability required of the solar PV system, i.e., if power is utilized exclusively as it is being generated; in this case as the sun is shining.

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10. Kenya

10.1 Summary

There is practically no known activity going on in Kenya so far as solar energy systems development is concerned. There is a large potential for solar PV village power application in Kenya, but the country's present rural development projects are directed towards the utilization of other sources of energy such as geothermal and hydropower. Water pumping for human consumption and for irrigation purposes in the arid desert of the north may eventually be the area where solar PV power systems will find their applicaton in Kenya. Village power applications will then develop around these water pumping stations to include cottage industry, small scale refrigerators, emergency communications, and lighting. Right now, the government's emphasis is on educating the villagers to use locally available materials and talent to improve their life style.

This idea led to the creating of the village technology center at Karen, just outside Nairobi. The center is being sponsored by UNICEF. The objective is to train villagers in the application of simple technology appropriate to their needs and capabilities. The simple technologies include solar crop dryers, water heaters, agricultural processes, mechanical water pumps, etc. The center is visited by over 500 people every month from all over the African continent.

While solar PV systems do not fit into the village technology center concept, it might be equally useful to acquaint the villagers and the authorities of the capabilities of a high technology village power source with the sun as "feedstock."

10.2 General Information

Kenya is located on the east coast of the African continent, straddling the equator and on the Indian Ocean. The Great Rift Valley, in the central and western regions, is girded by plateaux and mountains including Mount Kenya (5200 meters), the second highest peak in Africa, while the northern portion of the country is made up of large arid desert.

The population of Kenya is estimated around 14 million people, of which 85 percent live in the rural areas. Nairobi, the capital, has a population of 600,000 people. The other major cities are Mombasa with 250,000 people and Nakuru with 50,000 people.

Kenya is mainly an agricultural country with 30 percent of total GDP being produced through this sector. Its principle exports are coffee, tea, sisal, beef, and Pyrethum. In its current five year development plan, Kenya is putting a lot of emphasis on rural and agricultural development.

The manufacturing sector accounts for about 14 percent of GDP, while the commercial sector represents about 10 percent of the same gross domestic product. Main foreign exchange earner for the country is tourism.

Kenya's principal imports are crude oil, machinery iron, steel, and vehicles, the major suppliers being the U.S. (21 percent), EEC (20 percent), the U.S. (10 percent), and Iran (15 percent). The U.K., West Germany, the U.S., and Zambia absorb most of Kenya's exports.

Major sources of development funds are World Bank, EEC, United Nations, and special Arab funds.

10.3 Energy Situation

Kenya is blessed with a large untapped hydroelectric potential. Hydroelectricity account for 50 percent of Kenya's current source of electrical power. A twenty-year (1966 - 1986) National Power Development Plan calls for the production of 853 MW of electricity by 1986, which entails the construction of 760 MW of new generating capacity, 640 MW of which will be in new hydroelectric capacity being planned for the Tana River.

Three companies supply electricity in Kenya: The East African Power and Lighting Company, Ltd., The Kenya Power Company, and The Tana River Development Company, Ltd. Electricity production by source is as follows:

Hydroelectricity	=	130 MW
Thermal (steam)	=	65 MW
Thermal (diesel)	=	29 MW
Thermal (gas)	=	20 MW

30 MW is obtained from Uganda bringing the total installed capacity to 284 MW.

There are no known deposits of oil or coal in Kenya. The country imports all of its commercial fuel which accounts for 75 percent of the energy consumed. More than 80 percent of the total crude oil required in Kenya is imported from two countries, Iran and Saudi Arabia. Coal and coke is also imported.

Kenya is believed to be considering the use of nuclear plants to generate electricity in the future. It is also interested in developing cheap geothermal power systems for application in the rural electrification sector. The cost of gasoline is 33 cents per litre and that of diesel is 22 cents per litre.

10.4 Solar Energy Activity in Kenya

There is very little interest in solar energy development in Kenya, even though there is a lot going on in the way of finding new energy resources to improve the life of villagers in Kenya. There might be some form of interest in solar energy systems in the future, if the discussion bears mainly on the technology transfer aspects. Kenya is a member of INTELSAT, the international communications network via satellite, and is actively engaged in the development of its telecommunications systems. The experience being gained in the use of the solar PV systems for communication equipment in Tanzania might influence solar PV systems adoption in Kenya too.

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ARAB & MIDDLE EAST

C. ARAB AND MIDDLE EAST

1. Introduction and Overview

This survey was performed by the Near East Development Group under subcontract to Motorola. The criteria for selection of the countries was as outlined in Section III, also taking into consideration the special knowledge and relationships which the Near East Development Group has with some of the countries covered.

This energy survey of selected countries in the Near East is based on data accessed in the United States over a six-week period and in each of the six countries over a three-week period in visits averaging three days per country in January-February 1980. The U.S. based data were obtained mainly from documents furnished by the World Bank, United Nations, US-AID, local embassies, and professional institutes as well as interviews with leading development specialists at universities and private firms with energy expertise in the region. In-country data were based on visits wih either/or the Minister, Deputy-Minister, and appropriate Communications, Electricity, and Economy, as well as interviews with leading academics, businessmen, members of the local international development community, and locally-available documentation. It should be borne in mind that the development of an adequate data-gathering and analysis process in these countries is generally accorded low budgetary priority with the result that data are often incomplete and incorrect; hence, in analyzing what data are available, including that presented here, the reader should seek to identify broad relationships and trend as well as focus on individual facts.

The data are selected with a view to assisting the photovoltaic industry in shaping a marketing strategy for their products in this region in a manner consistent with the best interests of the development of the technology as a whole.

Most of the two hundred million people of this region live in small rural villages in pockets of rich cultivation and river valleys within a vast infertile desert area, and have been introduced to or are aware of village electrification. Camel and goat-herding nomads, often thought as the region's principal inhabitants, make up less than 10 percent of the total population and are rapidly being integrated into agricultural settlements. These villages vary in affluence and outlook from those in the mountains near Beirut, Lebanon whose inhabitants commute in 747's to business in Saudi Arabia and Europe to those in the Nile Valley whose inhabitants have never seen an airplane.

For purposes of this study, a "Near Eastern Village" may be pictured as a cluster of stone, adobe, or thatch dwellings surrounding a mosque or church with a public building and bazaar with a grocer/general store, fresh vegetable market, baker, blacksmith, and cafe. The streets are designed to be wide enough for donkeys with sidebaskets on their backs to pass and are filled with sidewalk vendors, bicycles, motorbikes, and other vehicles. In their homes, most of the village inhabitants sit on the floor rather than on chairs and divans and eat with their fingers rather than with utensils; consequently, the layout of a house is remarkably simple and uncluttered. Reed mats cover the floor and the family's few belongings include a large chest for valuables, a pile of bedding to be rolled out at night, several cups, a transistor radio, kerosene lamp, and gas burner in the kitchen. The family goats or cow may be kept in an adjacent room and share their quarters with the children at night.

The sources of energy in this village are, in order of importance, human labor, beasts of burden, wood, crop residues and animal dung, and are used mainly for household cooking and crop cultivation.

The question, "Should sources of non-human energy be introduced to this village?" has already been answered by the villagers who are becoming aware of the disparity between their subsistence way of life and that of the larger towns, a disparity often referred to by economists as the "dual economy." Those in the village who have not already voted with their feet to leave will explain that life can "become better" if the villagers could keep medicines cool, preserve perishable food, provide lights for their children to read at night and watch television, things which would also give them the psychological satisfaction that they are part of the modern world.

Villagers will point out that more than half of village energy is consumed in the gathering of wood and the hauling of water, which if performed by non-human means would release more energy for the planting and harvesting of crops, raising more livestock, etc. More time could also be devoted to non-food agricultural pursuits such as blacksmith work, women's handicraft and other activities potentially income-producing for the village.

Once it is accepted that a village should have additional energy sources, the question then arises, "Should it be provided from within or without the village?" Energy planners in the capital act on the assumption that the energy-use pattern of the city must be duplicated in the village. This approach has proved valid in many cases but interim and long-term energy strategy must be based on the often overlooked potential of the village or group of villages in question. In Pakistan, for example, mini-hydel facilities are providing electric power satisfactorily to many villages at a fracton of the cost of the grid or diesel alternatives and are being constructed and maintained by the villagers themselves. Central government energy planners often overlook the actual cost of obtaining energy whether from within the village or from external sources.

If the perspective of the village itself is taken as the point of departure for any village energy strategy, solar energy, in all its forms, seems likely to assume an ever-increasing role because of: (1) modularity of hardware, (2) the improbability of the grid reaching most villages even in the long-term and (3) the inability of non-OPEC economies to bear the foreign exchange burden of fossil fuels and to rely on its continued availability.

Solar electric systems have an immediate potential to promote the social and economic development of these villages in two broad aspects: (1) increasing productive capacity by, for example, replacing hand-drawn water systems and the mortar and pestle with solar powered water pumping and grain grinding devices, and (2) improve the "quality of life" by providing electric lights and cooling for medicine and perishable foods.

It is not clear whether the installation of such a "life support" system will "stem the rural exodus," but it will undoubtedly reduce or stabilize the rate of rural emigration and could give the already overcrowded cities a chance to begin absorbing the large number of rural migrants already there.

The first stop towards a village power system is usually taken with the introduction of a diesel electric pump, bought by the village council or government water authority. When the pump is installed, the villagers will often tap the generator for power to run a light, a television in square and then run other wires to individual houses for more lights and perhaps a refrigerator. Another generator may be bought and soon a rudimentary village power system takes shape.

The diesel generator has become widespread in the region, especially with the appearance of inexpensive Japanese units in the past ten years, but in this study we will observe several specifics which favor a transition from this technology to solar electrification over the long term:

- The low social status often assigned to mechanical/electrical service occupations, making it difficult to recruit and keep reliable operation and maintenance personnel;

- An inhibition towards building and equipment maintenance based on a cultural view that anticipating the future in the form of stocking spare parts and laying out maintenance programs may be contrary to divine will;

- An increasing desire to reduce dependence on foreign suppliers for critical spare parts which, for diesel generators, can take six months to deliver.

Three successive steps must be taken to introduce new technology such as solar electric power systems: prove technical feasibility, determine economic viability and test social acceptance. Mideast energy planners appear to agree that solar power is a feasible technology, at least for spacecraft, and want to take steps to evaluate the true cost and acceptability of the technology at the village level. As will be noted below, nearly all Mideast governments now have a "renewable resources" working group or energy official to coordinate these efforts and, accordingly, it is suggested that the U.S. solar industry and government establish cooperative agreements with them to make solar electric systems a part of village electrification strategy.

2. Jordan

2.1 Summary

The early markets for solar photovoltaic village power in Jordan will likely be related to government resettlement projects. These projects include establishment of new villages for people transitioning from a semi-nomadic way of life and development of new agricultural areas by providing desalinated water for irrigation of farmland. Many of these projects would be remote from commercial power sources and would be a natural for photovoltaics. This is particularly true since Jordan is totally dependent on imported oil, making use of diesel generators increasingly expensive.

Photovoltaics could also play a role in the rural electrificaton program which is intended to electrify all 251 villages with populations of 500 and above. It could also be used to electrify those 237 villages of less than 500 people for which there is no electrification planned.

2.2 General Information

The Hashemite Kingdom of Jordan came into being after the First World War when Imperial Britain conferred on Amir Abdullah, grandfather of the present King, lands east of the Jordan that had been only nominally administered by the Ottoman Turkish Government. About the size of Maine, the landscape falls into two broad categories: the desert zone and the cultivated areas along river valleys. The former encompasses the majority of the three million population and the latter includes most of the occupied West Bank. As part of the condition for accepting British help in setting up a modern government, the Amir Abdullah received financial aid, and throughout its existence, Jordan has depended on such external aid, first from Imperial Britain, then the United States, and after the 1967 War from her Arab oil-producing neighbors, along with remittances from Jordanians in the Gulf oil-producing countries.

An attempt to achieve economic self-sufficiency, manifested in the five year plan of 1974, emphasized development of agriculture, industry and tourism and was about to succeed had not the 1967 War interrupted the process, notably by halting the important tourist income in the captured West Bank and Jerusalem and imposing on the fragile economy yet another flood of refugees from Palestine. Growth has since resumed, but at a much lower pace, with fewer resources and more uncertainty about the role of Jordan in an overall settlement of the Palestine Conflict.

2.3 Energy Situation

Jordan must import all of its primary commercial energy requirements. These imports are, for the most part, crude oil, but some products are also imported. Table 1 provides an overall picture of Jordan's production, trade and consumption of primary commercial energy for the years 1975 to 1978. In addition to the absence of any indigenous primary energy production, the table shows the absence of any product exports in the last two years from the Jordan refinery and a steady increase in per capita consumption. While the quantitative increase has been gradual over the last three years, the cost of maintaining those levels of consumption and rates of increase has risen considerably.

Table 1

PRODUCTION, TRADE AND CONSUMPTION OF PRIMARY ENERGY
(in million metric tons oil and kilograms per capita)

Year	Production: Total Primary Energy	Trade: Imports	Trade: Exports	Bunkers	Consumption: Aggregate	Consumption: Liquid Fuels	Consumption: Per Capita
1975	--	0.860	0.009	0.081	0.716	0.716	265
1976	--	1.169	0.033	0.116	0.902	0.902	324
1977	--	1.253	--	0.118	0.984	0.984	342
1978	--	1.273	--	0.119	1.082	1.082	364

Source: United Nations

Jordan currently has no known indigenous petroleum resources, but does have an estimated 10 billion tons of proven oil shale reserves. In addition, quantities of uranium are known to be mixed in with Jordan's phosphate reserves (2000 million tons, 1979). A concession for oil prospection, granted to a Canadian firm in 1972, was withdrawn nine months later with no positive results having been reached. Spurred by the January 1975 announcement by Israeli geologists of the possibility of a big oil strike near Ramallah on the Israeli-occupied West Bank, the Jordanian government awarded a 30-year 8400 square kilometer concession to the American Filon Corporation in April 1975. In 1977 the Companie Francaise des Petroles (CFP) and Fuyo Petroleum Company of Japan each bought a 37.5 percent interest in the Filon exploration contract. CFP under a separate agreement with the Jordanian government, and under the auspices of its Natural Resources Authority has also been conducting nationwide photogeological, geochemical and seismic surveys, the results of which were due to be compiled in the Spring of 1980.

All of this activity is an attempt to discover and develop indigenous sources of petroleum, but as yet no reserves have been discovered. The contribution of domestically produced crude petroleum to Jordan's commercial energy requirements is likely to be minimal or continue to be nonexistent over the next five years.

a. Consumption by Sector

Industry: Jordan's industrial sector, principally the production of phosphate, is of recent origin. It accounted for 15.6 percent of the gross domestic product in 1975 and 18 percent in 1976, 1977, and 1978. Approximately 65 percent of Jordanian factories produce food products or clothing, but the major industrial income comes from three heavier industries: phosphate extraction, cement manufacture and petroleum refining. Jordan experienced a 22.7 percent rate of growth in its industrial sector from 1977 to 1978.

The production and export of phosphates are Jordan's principle industry and souirce of foreign exchange. Production has increased from 1.5 million tons in 1975 to 2.32 million tons in 1978. On an aggregate basis, as was previously noted, Jordanian industries only accounted for approximately 15 percent of total energy consumption in 1978.

Transportation: Roads, Rail, and Air

The lack of adequate transportation network has in the past inhibited the growth of the Jordanian economy. In recent years the Jordanian government has placed increased emphasis on the improvement and expansion of both road and rail transportation. Under the previous five year economic development plan, JD 119.9 million was to be spent on the transportation sector. Of this total, JD 37 million was designated for road construction and improvement and JD 14 million was to be used to improve the Aqaba to Al-Hasa railway line.

Agriculture: Agriculture productivity contributed to 10.3 percent of the gross domestic product in 1975, and the Jordanian National Planning Council estimates that percentage will fall to 8.3 percent in 1980. Cereals, fruits and vegetables are the principal crops of Jordan's agriculture. Increases in production can be expected as irrigation systems are expanded, new seed hybrids, such as the Mexican dwarf wheat, are introduced and mechanization spreads. The King Talal Dam, on the Zarka River, has increased the arable land and expanded irrigation. The Magarin Dam (designed by the American firm Harza of Chicago), on the Az Zarka River, is to be completed by 1986.

The East Ghor Canal, running parallel to the Jordan River for some 48 miles, it being extended further south, its water carrying capacity doubled and its irrigation tributaries expanded.

Mechanization in the form of tractors has increased rapidly, from 2000 in the whole of Jordan (East and West Banks) in 1966, to 2856 on the East Bank alone in 1971.

Agricultural workers comprise the largest single component of the Jordanian labor force, or about 23 percent.

Jordan, currently a net importer of foodstuffs, hopes to become self-sufficient in the near future. Expansion of irrigation systems, increased usage of chemical fertilizers and increased mechanization are among the means chosen to achieve this goal. All of these measures tend to make Jordanian agriculture a more energy intensive sector.

b. Energy Costs

Jordan pays the full OPEC price for its petroleum imports. In August 1979, Jordan raised oil prices to its own consumers by 20 percent, making the cost of gasoline $1.58 a gallon. Recent increases in the international per barrel price of crude oil have had an even more devastating impact on the Jordanian government's ability to meet expenditures and continue its development plans. Prime Minister Abdul Hamid Sharaf announced in February of this year that Jordan expects to pay JD 112 million ($392 million) for oil imports in 1980, a sum he said is equivalent to more than half the government's domestic revenues.

Domestic prices for petroleum products, however, are unrelated to international prices. The government pays heavy subsidies to keep kerosene, gasoil and fuel oil prices well below world market prices and maintains gasoline and jet fuel prices above world market prices.

c. Electrical Power

Jordan's electricity is presently generated by thermal, petroleum-powered plants. The more than 700 million kilowatt hours (KWH) produced in 1978 flowed from numerous grids, comprised of both private and public producers (see Table 2 below). The per capita consumption of approximately 215 KWH in 1978 placed Jordan well above the lowest category of developing countries.

Table 2

JORDAN'S PRODUCTION AND CONSUMPTION OF ELECTRICITY, 1978
(in '000 KWH)

Producer	Amount Produced	Percent of Total Production	Amount Consumed	Percent of Total Consumption
Manufacturing Industries	114,183.4	16.2	115,625.8	18.9
Electricity Authorities & Companies	569,051.1	80.8	473,552.6	77.6
Municipalities	21,153.2	3.0	21,190.1	3.5
Totals	704,387.7	100.0	610,368.5	100.0

Source: Jordan Electric Authority

A partial breakdown of the sectorial consumption of electricity shows the "domestic" sector responsible for 36 percent of consumption; "industry" 27 percent, "commercial" 12 percent, and "water and sewage pumping" 8.8 percent.

Total costs of electricity consumed in 1978 amounted to $19.7 million. This figure yields an overall cost of $.03 per kilowatt hour, although sectorial costs are certain to vary. The Jordanian government is committed to a policy of subsidizing electrical tariffs. In 1979, it maintained electricity tariff rates constant while allowing fuel oil and petroleum prices to rise (see above on petroleum costs). These direct governmental subsidies of electrical consumption are partly responsible for the increasing demand for electricity in the country. Nationwide, demand grew at an annual rate of 17 percent in the period 1975 - 1978. In selected urban areas the rate of increase in demand has been much larger. In the northern city of Irbid, electrical consumption doubled between 1977 and 1979 and is projected to double again by 1985.

Projects are currently underway to expand Jordan's electrical generating capacity. The Hussein Thermal Power Station at Az-Zarka will be capable of producing 330 megawatts by late 1981 with the addition of three steam turbine generators of 66 megawatts each. This project is being completed under a $90 million contract with three Japanese companies. Upon completion, the station will supply electrical power to northern and central Jordan including Irbid, Amman, and Karak as well as potash projects in Ghor-al-Safi and al-Hasa and the cement factory at Rashidiyah.

A new power station with an ultimate generating capacity of 1200 megawatts, the largest in Jordan, will be built in Aqaba. The initial phase of the project calls for the installation of three steam-powered turbine generators of 38 megawatts each at a cost of $70 million. A British firm, Preece, Cardew and Rider, is the consultant on the initial phase.

d. Energy Production and Consumption Forecast

The prospects for the discovery of currently economically recoverable petroleum in Jordan do not appear favorable. At the same time, current international oil prices wil undoubtedly slow the rate of increase in demand for petroleum products. Current governmental subsidies and pricing practices with regard to petroleum may have to be eliminated or changed to ease the burden of increased consumption on the national budget.

Oil Shale: The Natural Resource Authority (NRA), responsible for all geological surveys, describes oil shale as the most promising indigenous energy resource in Jordan, nearly one billion tons in the region of El-Lajjun. A feasibility study is planned, reportedly with Russian assistance, to determine whether to produce the ore or oil in Jordan; if ore, whether to burn it directly for low-grade power generation in specially constructed boilers. The NRA cites the successful use of shale in neighboring Turkey but is apprehensive about ash disposal, which constitutes fully 80 percent of the volume of raw shale. The NRA estimates 10 years at a minimum to put any oil shale facility on stream, during which time substantial capital injections would be required from international donors (the most likely of whom are increasingly questioning the long-term viability of this technology).

Geothermal Energy: The NRA describes several promising sites for geothermal development near the Dead Sea. A group of hot springs with a surface termperature of 88 - 64 degrees C and flow rate of 2000 cubic meters per hour discharge into the Dead Sea in this area. A geological investigation and electrical resistivity survey have been completed which recommended a drilling phase (now in progress) to locate a hotter source. NRA hopes to develop this into a geothermal electrical generator facility which, they note, can be developed in phases as demand increases. The confidence of the NRA in this option is not currently shared by other energy officials in the government, making its future doubtful.

2.4 Village Survey

Demographic Base: In 1975, the Jordanian capital of Amman had a population of a little over one million, or 38 percent of the entire population. As a result of the slow but steady rural to urban migration, especially to Amman, and the political, social, and economic dynamics of this migration, the Jordanian Ministry of the Interior carried out a rural social services survey in 1975.

The survey revealed the number of Jordanian villages of less than 1000 population to be 588 and 206 villages with populations over 1000. these villages are concentrated in the provinces of Amman and Irbid (546 villages), with Karak, Ma'an, and Balka having 110, 73, and 65 villages respectively.

Currently 85 percent of the Jordanian rural population is without electricity. The National Rural Electrification Plan of 1977 seeks to extend electrical lines to all villages with populations of 500 and above (251 villages), of which 239 were near existing electrical networks and 12 of which were remote sites. Planned improvements called for the installation of 880 kilometers (JD 10,000 per kilometer) of 33 kilovolt lines and 29 diesel units to reach an estimated 39,000 village dwellers). The total cost of the six component projects was to be $45.1 million. The Jordan Electricity Authority also announced electrification of 23 villages in Karak province. All Jordanian villages are currently intended to be electrified by 1990.

2.5 Solar Energy Activity and Potential

Current Solar and Photovoltaic Activity: Jordan is the main center of solar energy activity in the Arab world, coordinated by the Royal Scientific Society (RSS) in Amman. In the solar area, the RSS assigns highest priority to desalination. To date, the most significant solar energy project in Jordan is the RSS-West German (Dornier) desalination plant of Aqaba. The Deutsche Mark 1.3 million project has been operational since 1977; its objective is to enable development of fully automated desalination systems, which operate at remote sites with little maintenance. Maintenance problems with the project have arisen and will be systematically addressed after data on durability and weatherability characteristics have been analyzed.

The Royal Scientific Society also cooperates with other solar energy institutions in Europe and the Middle East. Discussions are underway with the EEC for support for a solar collector facility. A research grant from the Kuwait Institute for Scientific Research led to plans for a 100-square meter solar house in Amman where research will be conducted on air and fluid based solar heating and cooling. In addition, the RSS conducted a very successful experiment in solar water heaters made from local materials, which has since been transferred to Kuwait with encouraging results.

Other RSS solar activity includes coordination with the German government in:

- Installation of 200 single pole emergency telephone systems "using an American design" 20 kilometers apart for medical/police and fire use. Each system consists of a VHF FM transceiver powered by 24 volt Spectrolab photovoltaic panels.

- Five and one-half million DM energy program including 9 water pumping projects, 3 in north Jordan, 3 in mid-Jordan, and 3 in south Jordan. At each site, one pump is to be photovoltaic powered, another wind powered, and the third a combination of wind and photovoltaics.

US-AID is discussing with the RSS, through the Ministry of Planning, a 100 kilowatt photovoltaic water pumping unit. Several sites have been suggested, including Wadi Arabi, 30 kilometers south of the Dead Sea, in an agricultural area to which the government hopes to attract settlers. Preliminary proposals suggest 30 kilowatts of the PV power source for the pumping unit, 40 kilowatts for the reverse osmosis desalination unit, and the balance, 30 kilowatts, for other uses, including lighting.

Suggested Solar Project Areas: Two categories of settlements offer an early potential for solar electrification in Jordan: semi-nomadic desert settlements and road security checkpoints.

The desert settlements are located mainly near the Iraqi and Saudi Arabian border and consist of goat and camel-herding nomad who are in the transition from the mobile goat-hair tents to a concrete block dwelling. The government supports this process and would prefer settlement in the tribal turf rather than have them drift towards Amman to live in a kerosene can slum. Electricity is demanded as a minimum condition for permanent settlement for lighting, waterpumping, and refrigeration, but even minimal mechanical skills demanded for diesel systems are non-existent among the Bedouins and solar electric systems would appear to be an attractive option. There are approximately 200 such settlements, with some 400 at each settlement.

Security checkpoints are established not only at designated border crossings but also along main roads, e.g., the Amman-Tabuk/Saudi Arabia road via Ma'an and the Amman-Aqaba/Red Sea road. There are approximately 50 such posts with 6 to 20 people in several houses with a diesel system providing power. Jordanian officials complain of the difficulty of operating and maintaining these posts and inquire how solar systems may be used as an alternative.

FIGURE 3
COMPARATIVE ANALYSIS OF ENERGY RESOURCES IN JORDAN

Planning Department, Jordan Electricity Authority,
Energy in Jordan, April 1979--from the original Arabic

The most recent and authoritative energy
study by the Jordanian government

Resource	Availability	Potential for Exploitation	Estimated Time Required for Exploitation (Years)	Relative Share In Meeting the Energy Crisis	Economics	Technology	Priority
Petroleum	under exploration	--	--	0 percent currently	increasingly costly	relatively complicated but known	?
Oil Shale	abundant	possible	10	30 percent to year 2000	equivalent to petroleum in 1990	limited familiarity	1
Waterfalls	limited	possible	6	5 percent to year 2000	very cost-effective	known	6
Nuclear Energy	--	--	10	from 0 to 50 percent in year 2000	costs equivalent to petroleum in 2000	complicated	2
Coal	none	--	--	--	--	--	--
Geothermal	under exploration	limited	15 to 20	0	unknown	available	7
Solar Energy	abundant	limited to year 2000	20	5 percent to year 2000	economical within severe limits	complicated to generate electricity otherwise simple	5
Wind Energy	limited	limited	--	1 percent to year 2000	economical within severe limits	simple	7
Regional Cooperation	abundant	possible	4 years or more	10 to 15 percent	acceptable	--	3
Energy Conservation	--	possible	2	10 percent	excellent	simple	4

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3. Egypt

3.1 Summary

Egypt is practically energy independent and is a net exporter of oil. Hydro, natural gas, and coal represent significant sources of energy for future demand. Even so the population growth and even greater growth in energy demand indicate that Egypt may have to import energy by 2000.

Part of this projected increase in demand is to electrify some 25,000 villages without existing power. In addition, power will be needed to electrify the "new cities" which are being created to prevent continued overcrowding of Cairo and Alexandria. Photovoltaics could be used to power the smaller, more remote villages initially, and as a supplementary power source for the larger villages later.

3.2 General Information

Egypt is geographically part of Africa, occupying the northest corner of the African continent, but historically and culturally part of Asia. The modern history of Egypt begins in the early 19th century when her strategic positin along the road to British India attracted British and French military invasions and competing political and economic influences. This culminated in the British Occupation of 1882 which continued, in the opinion of Egyptian nationalists, until the Republican Revolution of 1952. The American presence in Egypt began, as in much of the Near East, with the establishment of Christian missions, one of the most prominent being the school which became the American University of Cairo.

The "accident of geography" has historically compelled successive Egyptian governments to emphasize defense spending. These rose, after the Fall of Palestine in 1948, to such levels that even essential maintenance of health, agriculture, and other sectors stagnated, and in some cases, regressed. Much of the impetus for the recent peace process can be attributed to a feeling that social and economic matters could no longer be postponed until the Palestine Conflict was resolved on Egyptian terms.

3.3 Energy Situation

The following comments illustrate the complex and contradictory nature of the energy picture in Egypt.

Positive Aspects

- Egypt, compared to most developing countries, has a sizeable installed and expandable hydroelectric generating capacity.
- Natural gas development seems to face no constraints as far as reserves are concerned.
- Egypt possesses significant human resources for most types of energy production.

Negative Aspects

- Egypt's population of 40+ million people is growing at an annual rate of 2.2 percent (1970 - 1977).

- Consumption of petroleum products increased at an annual rate of 9.2 percent.

- Politically sensitive, heavy governmental subsidies on certain petroleum products impede conservation and a switch to renewable energy sources.

- The development of arable land and expansion of eater supplies for the production of foodstuffs is heavily energy dependent.

The kinds of developmental choices the Egyptian government makes in energy in the next couple of years, assisted perhaps by US-AID and other experts, will, to a great extent, determine whether the corner is turned away from defense and towards orderly social and economic development.

a. Energy Production

Egypt is a net exporter of petroleum. Production of 600,000 barrels a day (b/d) at the end of 1979 provided Egypt with foreign currency earnings on some 160,000 b/d of exports. Because of the lack of certain types of refining capacity, Egypt still imports quantities of lubricants, distillates and bitumen. Egyptian refining capacity has expanded from 99,000 b/d in 1973 to an estimated 251,000 b/d in 1979. Continued expansion of crude oil production and refining capacity will be needed in the next decade if Egypt is to contine present levels and rates of increase in consumption of oil as an energy source.

The future of Egyptian oil production is uncertain, with proven reserves estimated to be only between 2 and 5 billion barrels.

Egyptian crude oil output for 1982 was forecast to reach 870,000 b/d. The scope of oil exploration by foreign oil companies has narrowed considerably in the past three years. During that time foreign companies spent an estimated $500 million on signature bonuses, geological surveys, and wildcat drilling without success. The most promising areas for future exploration appear to be in the Gulf of Suez, the Egyptian Red Sea coast, and off the Sinai peninsula. The intensity and scope of oil exploration will undoubtedly depend much on international and regional political developments (e.g., the future course of Israeli-Egyptian peace negotiations, the resolution of the Iranian domestic/international crisis) as on the economics of the international petroleum industry.

In 1978, oil accounted for 93 percent of commercial energy production and 79 percent of consumption. Natural gas production has increased more than twenty-two fold from 1975-1978, rising from 0.3 percent to 4.0 percent of total commercial energy production. Proven reserves of non-associated natural gas are estimated to be 71-113 billion cubic meters.

Hydroelectricity's share of commercial energy production, however, has declined from 4.8 percent in 1975 to 3.3 percent in 1978. The present hydroelectric production of the Aswan High Dam is below capacity, but if Egyptian industrialization and economic expansion plans are realized, its capacity must and can be expanded.

Table 1 below provides an overview of Egyptian energy production and consumption by energy source for the period 1975 - 1978. As can be seen from the table, Egypt had no commercial production of coal and lignite during this period. Commercial quantities of coal exist in the Sinai peninsula and could, at least partially, offset the need for future coal imports in the industrial sector. Its production potential, however, is yet to be determined.

Overall, the future of Egypt's indigenous sources of primary commercial energy is quite uncertain. Expansion of oil production, both to meet increases in consumption at home and as a major source of badly needed foreign exchange earnings, awaits significant new discoveries which, in turn, are dependent on the economics of world oil as well as regional and international political considerations. A major thrust of current Egyptian policy is to expand domestic natural gas production and consumption to enable future oil production increases to be used for exports and foreign exchange revenues. This expansion is dependent on the development of an infrastructure (e.g., pipelines and related facilities) to utilize both associated gas, currently flared, and non-associated gas.

Expansion of hydroelectric generating capacity, as mentioned above, is possible both at the Aswan High Dam and other barrages on the Nile River. Studies are also underway to determine the economic feasibility of the Qattara Depression as a source of hydroelectric power. With the depression about 500 feet below sea level, an 80 kilometer canal would be constructed from the Mediterranean to the depression. The flow of salt water from the Mediterranean would be harnessed to develop hydroelectric power. The enormous cost and construction time, one estimate is 40 years, makes its contribution to Egyptian energy production a very remote consideration. The development of the Qattara Depression project is also significantly dependent on the expansion of oil production for export and significant economic growth rates. Recent environmental problems, generated by the Aswan High Dam, have also raised questions, yet to be answered, about the effect a large body of salt water in the western desert would have on Egypt's climate.

b. Consumption by Sector

Egypt is the least dependent on energy imports of the 6 countries included in this survey. In 1978, Egypt imported the equivalent of 9 percent of its commercial energy needs. Coal for industrial uses accounted for 76 percent of total energy imports, but only 6.9 percent of total energy consumption.

Aggregate commercial energy consumption in Egypt grew at the annual rate of 9.2 percent between 1975 and 1978. Consumption by energy source in 1978 displayed the following pattern: solid fuels (imported coal), 6.9 percent; liquid fuels, 79.2 percent; natural gas, 7.6 percent; and hydro-generated electricity, 6.2 percent.

Table 1

Year	Production					Trade	
	Total Primary Energy	Coal and Lignite	Crude Petroleum and Natural Gas Liquids	Natural Gas	Hydro-Electricity	Imports	Exports
1975	12.395		11.785	0.042	0.569	3.528	6.144
1976	17.906		16.886	0.345	0.675	1.663	8.274
1977	22.986		21.386	0.881	0.736	1.069	11.033
1978	23.229		23.508	0.951	0.770	1.129	11.025

Source: United Nations

A breakdown of energy consumption by economic sector for 1975 is shown in Table 2 below.

Table 2

EGYPTIAN COMMERCIAL ENERGY CONSUMPTION BY SECTOR

Economic Sector	Percent of Total Commercial Energy Consumption (%)
Industry	36.4
Residential	18.4
Transportation	19.4
Agriculture	5.2
Commercial	20.0
"Public Activities - Electricity"	0.6
TOTAL	100.0

Source: U.S. Department of Energy

Industry: The Egyptian industrial sector consumed 36.4 percent of total commercial energy and produced 20 percent of gross domestic product (GDP) in 1978. While heavy industries, such as the Helwan Steel Plant and the Nag Hammadi Aluminum Plant, accounted for a large portion of industrial energy consumption, food processing and textiles contributed 55 to 60 percent of the total value of industrial output. Textiles alone accounted for 33 percent of total industrial output. Employment figures show that the industrial sector employed approximately 19 percent of the employed labor force.

Major industrial expansion projects include: an increase in the capacity of the Helwan Steel Plant from the present 900,000 tons per year (t/y) to 2,000,000 t/y by 1982; an increase in the capacity of the Nag Hammadi Aluminum Plant (opened 1975) from its initial 40,000 t/y to 100,000 t/y; construction of a fertilizer plant at Talkha (cost: $130 million); establishment of a domestic auto industry in cooperation with the Ford Motor Company, American Motors Corporation, and Volkswagen; a tire plant in cooperation with Michelin near Alexandria ($81 million); and plans to extend electric power to all Egyptian rural communities by 1982. This industrial expansion is geared to increases in oil production and exports to acquire the necessary capital to pay for the international loans and credits needed to initiate and complete these projects.

Agriculture: Agriculture's contribution of 30 percent of gross domestic product has remained fairly constant over the past several years. Forty-three percent of Egypt's employed labor force works in the agricultural sector, which produced roughly 60 percent of the country's total export earnings in 1978. Export earnings from agricultural products, unlike petroleum exports or Suez Canal revenues, are, for the most part, soft currency revenues; they are direct payments for long-term barter deals and loans from the USSR and eastern European countries. While agricultural production has risen at the rate of 2 to 3 percent in recent years, this increase has not been sufficient to cancel out population increases, making Egypt a substantial importer of foodstuffs (e.g., wheat and meat).

Of Egypt's six million feddans (1 feddan = 1.038 acres) of arable land, only a little over one-third are serviced by main or secondary irrigation drains. Land reclamation, a costly enterprise due to soil types and the necessity of irrigation, is a high priority of Egyptian economic planning. From 1952 to 1976, some 912,000 feddans were reclaimed, but nearly an equal amount of arable land was lost to residential and industrial construction in Egypt's narrow ribbon of existence - the Nile Valley.

The principal crops of Egyptian agriculture are: long-staple cotton (one-third of total world production), fruit, rice, sugar cane, vegetables, wheat, barley, millet, and maize. The agricultural sector used 5.2 percent of total commercial energy consumption in 1975. Further increases in agricultural productivity and production through further mechanization, wider use of commercial fertilizers and more extensive irrigation will, undoubtedly, be directly related to increases in commercial energy consumption.

c. Energy Costs

Egyptian energy pricing practices present the government with a real dilemma. Fuels for domestic use, largely cooking, are heavily subsidized. Should these subsidies be reduced or eliminated, as the World Bank and US-AID have been urging, in order to reflect true costs and bring about structural economic development? Or should these subsidies be continued in order to preserve the potential income redistributive effects of economic expansion? In January 1977, President Sadat chose the first option, and the ensuing riots were seen as the most serious challenge to his authority since he succeeded Gamal Abdul Nasser in 1970. After the Egyptian military quelled the riots, the subsidies were quickly reinstated. Table 3 below shows the current levels of fuel subsidization for commonly used cooking fuels.

Table 3

CURRENT LEVEL OF SUBSIDY FOR COOKING FUELS

Fuel	Local Price in LE/GS	Local Price as Percent of World Price	Local Price Expressed in U.S. $/Unit
Buttagas	1.10	11.95	$1.30/Mcf
Kerosene	0.48	12.30	$ .10/Gal
Mazout (Residual fuel oil)	0.17	5.76	$ .03/Gal

In addition to direct fuel costs, the prices charged to consumers for electricity are, in many instances, significantly below generating costs. Industrial users, medium and low-voltage users outside of Cairo and Alexandria and foreign investors in the newly created "free trade zones" all have received underpriced electrical service for one "economic" purpose or another.

d. Electrical Power

In 1970, the previously independent power systems of Cairo, Upper Egypt, the mid-Nile Valley, Alexandria, and the Delta were integrated into a unified power system. The capacity of this system is 3847 MWe, of which 2445 MWe is hydro capacity (2100 or 54 percent from the High Dam) and 1402 MWe thermal capacity (1265 MWe petroleum-thermal and 137 MW gas turbine). Maintenance problems have limited power transfer capability at the High Dam to under 1975 MW, and insulation problems with transmission lines have caused over 15 power interruptions between 1971 and 1975. In one instance the Upper and Lower Egypt systems became separated. Authorities note fewer system failures in the past few years.

Consumption demand has grown rapidly in recent years, from 12 percent in 1973 to 19 percent in 1977. Per capita consumption, including industrial/commercial and domestic components, is about 300 Kwh while domestic consumption per capita alone is 60 Kwh.

According to U.S. and local estimates, electricity production for 1978 by hydro and thermal generation, and industrial and public producers was as follows in Table 4 below.

Table 4

PERCENTAGES OF EGYPT'S ELECTRICITY PRODUCTION

PRODUCED FROM INDUSTRIAL AND PUBLIC SOURCES, 1978
(in percents)

Type	Industrial Production	Public Production	Total
Thermal	4	28	32
Hydro	--	68	68
TOTAL	4	96	100

Source: United Nations

Construction of numerous new electric power generating facilities and additional transmission lines is expected to be completed by 1985. The planned generating stations are themal-powered: four fossil-fuel steam plants and two gas turbine plants. In total, 18 units are to be installed, adding 1420 MWe of generating capacity in the near vicinity of Cairo, Suez, and Alexandria. Financing of this construction will be shared by the U.S., West Germany, and the Egyptian government.

Since the above plans were drawn up, in 1977 to 1978, an additional 600 MWe thermal project has been approved. The estimated completion date is 1984.

Two other developments are planned in the electricity sector. In 1980 - 1981, the National Energy Control Center is scheduled for completion. This control system will be computer-assisted, and will use microwave communications to control and protect power facilities in Cairo, Alexandria, and the Nile Delta. The United States has provided financing for this $48 million project. There are also plans for expanding hydroelectric capacity in Upper Egypt. These plans have not been finalized, but options include a second power house at the High Dam, and additional power houses at three existing barrages downstream from Aswan. A possible total of 19 units would add 350 MWe of hydro capacity. Other schemes, e.g., the proposed Qattara Depression project, are a step further removed from realization.

e. Energy Prospects 1980 - 1985

Egypt's energy demand will continue to increase at rapid rates between now and the end of the century. The following percentage increases in energy demand, by economic sector and energy resource are projected for the period 1975 - 1985 in Table 5 below.

Key aggregate energy projections for the 1975 - 1985 period are:

- Overall demand will increase 97.1 percent
- Industry's share in total demand will increase to nearly 50 percent, with industrial level of demand growing one-and-a-half times;
- Natural gas consumption (and production) will almost quadruple, to where it will provide one-tenth of all energy needs
- Electricity growth will be extremely rapid, with over 50 percent of increased production going to industry
- Petroleum products, although expanding more slowly than natural gas and electricity, will still provide over 65 percent of total energy needs.

Table 5

SECTORAL AND ENERGY RESOURCE DEMAND GROWTH, 1975 - 1985

Economic Sector/ Energy Source	Percent of Total Demand in 1975	Percent of Total Demand in 1985	Expected Demand Increase in 1985 Over 1975 (Percent)
Industry	36.4	46.9	146.0
Residential	18.4	18.5	93.0
Commercial	20.0	10.8	3.0
Transportation	19.4	17.4	71.0
Agriculture	5.2	5.5	100.0
Electricity	8.8	15.4	218.0
Petroleum Products	78.2	66.1	61.0
Natural Gas	4.0	10.0	370.0
Coal	8.9	8.5	83.0

Noncommercial Energy: Egypt's noncommercial energy sector was estimated to have produced about one-third of all the energy used in Egypt in 1975. According to a U.S. team, crop residue, animal dung, and firewood consumption estimates for 1975 were 172 QJ (quadrillion joules = 1 X 10 15 joules), 43 Qj and 1.5 QJ. These fuels provide the primary energy in rural areas for cooking and baking, and occasionally, space heating.

The projected production levels for these fuels are not exactly known, except that fuelwood production is not expected to expand. As for consumption, it is assumed that demand for these traditional fuels will gross at a slower rate than overall energy demand, implying that commercial fuels are expected to figure more importantly in rural consumption patterns (see below). Table 6 summarizes a World Bank estimate of Egypt's noncommercial energy sector.

Table 6

TRADITIONAL FUELS USE AND AVAILABILITY: ESTIMATES AND PROJECTIONS

Year	Fuelwood and Charcoal Use		Available Live-Stock Residue		Available Cereal Residue		Bagasse	
	Total (million GJ)	Per Cap (GJ)	Total (million GJ)	Per Cap (GJ)	Total (million GJ)	Per Cap (GJ)	Total (million GJ)	Per Cap (GJ)
1976/ 1977	1.22	0.03	61.53	1.56	220.47	5.59	38.26	.96
1980	1.35	—	—	—	—	—	—	—
1985	1.50	—	—	—	—	—	—	—
1990	1.62	0.03	74.84	1.47	304.95	5.59	n.a.	n.a.

Rural Uses of Commercial Energy: In areas not connected with Egypt's main power grid, diesel engines are frequently used for irrigation and electric power. Available estimates of installed diesel capacity used for irrigation totals roughly 280 MW, of which 255 MW is made up of some 40,000 small privately owned units. Diesel electric generating capacity is substantial outside the Nile Valley, though even less is known about its size. Five MW of installed capacity is found in the public systems of the towns along the Mediteranean coast. As of 1978, about 17 percent of rural homes had electricity.

Commercial household fuels used in rural Egypt are kerosene and butane. Annual consumption of these fuels, measured in 1978, was:

Kerosene	796,000 metric tons
Butane	14,000 metric tons

Expected consumption growth rates for these fuels are one percent (kerosene) and 7 percent (butane), as they continue to displace traditional fuels for washing, cooking and, and government subsidization level remain high.

3.4 Village Survey

Demographic Base: Of Egypt's total population of 40+ million people, some 15 million people reside in rural areas. Of this 15 million, roughly 12,300,000 or 82 percent are without electricity. Egypt has approximately 30,000 villages, with an average population of 1500 people. Of these, approximately 25,000 villages are currently without electricity. A government objective is to extend electricity to all rural communities by 1982, replacing diesel with electric motors.

A major task of the Egyptian economic planners is to halt the rural to urban migration and simultaneously create new urban centers near Cairo and elsewhere for a rapidly expanding population. (Egypt added one million people to its population in the first 9 months of 1979.)

A partial solution to this problem has been found with the reconstruction of the cities along the Suez Canal which were totally destroyed and abandoned during the Egyptian-Israeli War of Attrition 1969 - 1970. An estimated one million Egyptians have returned to those cities since 1974. New cities, such as Sadat City, Sixth of October, and Al Uber, are being created in desert areas to further disperse the population. Egyptian planners emphasize that Cairo and Alexandria are already disintegrating under pressure of rural migration and consequently, the concept of "new towns" and the "new valley" in the western desert must somehow catch the public imagination for economic development to "take off."

3.5 Solar Electric Potential

Current Solar and Photovoltaic Activity: A large number of Egyptian personnel and institutions are involved in solar energy development. Some of the better known research institutions, personnel and areas of research are listed in Appendix 1. The major solar energy research laboratory is that of the National Research Center (NRC), Dokki, Cairo, which began its program in 1957. From 1957 to 1968, NRC concentrated on preparing personnel to do solar energy research. In 1970 NRC began work on solar thermal applications, and in 1973 they began to cooperate with international bodies. They have undertaken joint venture projects with the U.S. National Science Foundation, New Mexico State University, and the West German and Canadian governments.

Qattara Depression Authority has recently been assigned major coordinating responsibility in the government for renewable resource development, an assignment coincident with the temporary suspension of their mandate to manage the Qattara Depression Project until technical and environmental problems are resolved. The Qattara Authority has order 1000 solar energy water heaters for projects under its control. These are being provided by Canadian, French, and Cypriot companies.

Solar water heating has been the principal solar energy application to date. There is one noteworthy solar manufacturing capability, the Arab Company for the Utilization of Solar Energy. Current production capacity of this manufacturer is a maximum of 5000 units (100, 150, and 200 liters/day) per year. Lack of quality control in the company's manufacture and installation of these units is said to reduce collection efficiency by 20 to 30 percent. Six other commercial enterprises to produce solar water heaters, some beginning in 1980, are in the start-up stage. If all six reach their planned maximum production capacity, they should at least produce 7000 units per year.

The Mitre Corporation study previously cited estimates that there is a market for 100,000 solar water heater units per year in the new construction market in and around existing urban areas. If one adds to this current construction plans for new cities and satellite towns (4000 residential units/year to 1985 and 17,000 units/year after 1985), and the two million new rural dwellings by the year 2000, the potential market for solar water heating is enormous.

Concerning photovoltaics, the National Research Center has been doing laboratory research on a unit granted by the German government but has not as yet produced any hardware. Two other current activities in photovoltaics are one by the Federal Republic of Germany involving eight different applications (viz, drinking and irrigation water pumping; water desalination; powering a loud speaker; refrigeration and lighting), and another by France for two TV sets in a rural village. In 1978, Egyptian energy authorities announced plans to use solar energy to operate 35 waterwells in villages along the northern coast of the Sinai, but have taken no steps toward implementation as yet.

<u>Suggested Solar Projects</u>: Although official government plans call for electrification of all villages by 1982, the Rural Electrification Authority's main priority is to connect villages with 500 or more people to the national grid. As costs for petroleum-based, thermal electrical generation rise and the per kilometer cost of installation of transmission lines increases (currently L.E. 4500/kilometer for 11 Kv line), it is safe to assume that most, if not all, rural villages with 500 or less population will never be connected to the grid. The main photovoltaic applications in these small villages would include: electricity for some 200 - 300 health clinics for refrigeration of drugs, remote communications, lighting and educational TV applications, water pumping for domestic use and irrigation (perhaps as high as 2000 MW in 400,000 units), and water desalination using water vapor compression or reverse osmosis.

Egyptian government personnel concerned with Egypt's future energy resources are very interested in solar energy. Indeed, Egyptian budget allocations for R & D in direct solar energy applications were projected to climb from L.E. 2.7 million in 1979 to L.E. 8.28 million in 1982. Like most governmental efforts, including that of the U.S. in the solar energy field, the Egyptian government's efforts lack a central authority or planned coordination. The recent estalishment of the Supreme Council for Renewable Energy chaired by the Minister of Electricity, within the framework of the Qattara Depression Authority, is an attempt to give direction and purpose to Egypt's diverse institutional efforts in solar applications. The success of the Supreme Council will, undoubtedly, depend on its ability to commit the government as a whole to a renewable energy future and in the short term to plan specific projects for specific solar energy applications for demonstrative effect. Perhaps the most innovative institution in solar R & D is the desert development demonstration and training project sponsored by the American University of Cairo. This project may be regarded as a series of solar energy workshops aimed at developing cost-effective options for the resettlement programs alluded to earlier.

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Dr. Sherif K. Arif USAID American Embassy 5 Sharia Latin America Garden City/Cairo twl: 28129, ext. 374	Works with Neury-Furmen Renewable Energy Development Authority
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4. Sudan

4.1 Summary

Ths use of photovoltaics to power water pumps for irrigation will be the forerunner of PV village power applications in the Sudan.

Vast fertile areas lacking only water to turn them into a productive agricultural resource has caused agricultural experts to claim that Sudan could be the "breadbasket of the Arab World." As a result, Arab petrodollars are being channeled into ambitious projects. Continuation and expansion of these programs could provide the basis for a PV market in Sudan, where the availability and cost of oil is already a serious problem.

4.2 General Information

The Sudan is the largest country in Africa, about the size of the U.S. west of the Rockies, made up of an Arab, Muslim, and desert northern region and a black, African animist and Christian tropical southern region, through which flows the River Nile. External influences in the Sudan entered via the Ottoman Turks who sent raiding parties into the country's interior for slaves (the word Sudan is Arabic for black) and the British who established their colonnial presence in the mid-19th century, as a backstop to their position in Egypt. Through the "Anglo-Egyptian Condominium," the British administered Sudanese affairs until 1956 when an independent government was formed.

Modern agricultural experts claim that vast underpopulated fertile areas of the country make Sudan "the breadbasket of the Arab World." To that end, Arab petrodollars are being channelled into ambitious projects which constitute the thrust of socio-economic development.

4.3 Energy Situation

As of early 1979, Sudan depended almost entirely on imported crude oil and products to meet its primary energy demand. Installed hydroelectric generating capacity (105 MW) existed at two sites (El Roseires and Bennar) and accounted for slightly more than 2 percent of total primary energy consumption.

Commercial quantities of oil were discovered by Chevron Oil (subsidiary of Standard Oil of California) in July 1979 and in February 1980. Product production from these indigenous sources awaits the construction of pipelines pumping stations and a second oil refinery at Khartoum (projected completion date of 1985). Two natural gas fields have been discovered with confirmed estimated reserves of around 2.6 billion cubic meters.

Current oil refining capacity of the one refinery at Port Sudan is 26,000 barrels a day or 1.3 million tons a year. The capacity of this refinery is to be raised by 50 percent over the Six-Year Plan period (1976/77 - 1982/83), and a second refinery of twice the capacity is to be completed by 1985.

The Nile and its tributaries offers a technically feasible potential of 2700 megawatts of hydroelectric power distributed over the entire length of the river system. Energy economist in the Sudan estimate the capital costs of one megawatt at $2.5 million, a considerable expense for a country with serious current balance of payment problems.

Consumption of fuelwood and charcoal raises Sudan's per capita energy consumption to a level second only to that of the United Arab Emirates for the six countries included in this study. The ecological effects (deforestation and desertification) of continued or expanded consumption levels of these products warrant careful scrutiny, and cast doubts on optimistic assertions that biomass industries will ever become a significant factor in lessening Sudan's dependence on imported energy.

a. Energy Resources and Uses

Raw Materials: As noted above, oil has been discovered, but it is too early to predict how much of this is commercially recoverable and, if so, what interim and long-term effects this will have on import levels of crude and refined products.

Sudan does have 105 MW of installed hydro-generating capacity. Consumption of hydro-generated electricity accounts for a little over 2 percent of total primary energy consumption. Development plans call for expansion of the hydro-generating capacity at the two existing sites, El Roseires, and Bennar, but even these expansions will not significantly raise hydro-generated electricity's share of total primary energy production.

Petroleum Production: Tables 1 and 2 below give an overall picture of Sudan's recent energy production and consumption. Sudan's heavy dependence on imported petroleum is quite apparent. As can be seen from Table 2, Sudan's oil requirements, based upon present patterns of demand, will rise by more than 10 percent per annum over the next decade.

Consumption by Sector: Annual consumption of petroleum products for fiscal year 1978 - 1979 (July 1 to June 30) was 1.25 million metric tons, equal to 81 percent of foreign exchange. Transportation used 55 percent of those products, mostly diesel fuel; pumping for irrigation consumed 18 percent.

In 1977 a breakdown of the consumption of petroleum fuels (imported and domestically produced) consisted of: transportation - 50 percent; tractors, pumping, and construction plants - 19 percent; industrial direct heat - 12 percent; domestic direct heat and light - 10 percent; and thermal electricity generation - 8 percent. At the time, increased use of petroleum, in the transportation and electricity sectors was expected. However, Sudan since that time has had serious difficulty in maintaining a constant supply of petroleum and economic life in many parts of the country has been severely disrupted by a lack of these energy resources.

Total energy consumption for Sudan, commercial and noncommercial energy combined, was approximately 3 million tons of oil equivalent. Sectorial use of this energy was as follows:

Table 1

SUDAN'S PRODUCTION, TRADE AND CONSUMPTION OF PRIMARY ENERGY
(in million metric tons oil equivalent and kilograms per capita)

Year	Total Primary Energy	Hydro-Electricity	Trade			Consumption			
			Imports	Exports	Bunkers	Total Commercial Energy Aggregate	Total Commercial Energy Per Cap	Liquid Fuels	Hydro-Electricity
1975	0.027	0.027	1.789	—	0.017	1.795	114	1.768	0.027
1976	0.033	0.033	1.759	—	0.017	1.777	110	1.744	0.033
1977	0.037	0.037	1.865	—	0.021	1.852	112	1.815	0.037
1978	0.041	0.041	2.024	—	0.023	1.975	117	1.934	0.041

Source: United Nations

Table 2

SUDAN'S PRODUCTION, TRADE AND APPARENT CONSUMPTION OF ENERGY PETROLEUM PRODUCTS
(in million metric tons and kilograms per capita of petroleum products)

					Apparent Consumption	
Year	Production	Imports	Exports	Bunkers	Total	Per Capita
1975	1.110	0.613	n.a.*	0.016	1.707	109
1976	1.115	0.584	n.a.*	0.016	1.683	104
1977	1.171	0.599	n.a.*	0.019	1.751	106
1978	1.227	0.660	n.a.*	0.021	1.866	110

* = not available

Source: United Nations

Table 3

SUDAN'S PRODUCTION OF ELECTRICITY BY TYPE AND CONSUMPTION OF ELECTRICITY
(in thousand million kilowatt hours)

	Production				Consumption	
		Public				
Year	Total Industrial and Public	Total	Thermal	Hydro	Total	Per Cap (in kilowatt hours)
1975	0.640*	0.640*	0.320*	0.320*	0.640	41
1976	0.720*	0.720*	0.330*	0.390*	0.720	45
1977	0.810*	0.810*	0.370*	0.440*	0.810	49
1978	0.911*	0.911*	0.417*	0.494*	0.911	54

* = Statistical Office estimate; official figures unavailable or inconsistent.

Source: United Nations

and several diesel and gas stations which add up to 65 MW. The remainder of the grid, 70 MW, is made up of a small number of thermla power-generating stations.

Table 3 gives the best available estimates of electrical output in Sudan from 1975 to 1978. Their most recent assessment hs hydro-electricity making up 54 percent of total electrical production. Furthermore, the 54 Kwh per capita consumption figure places Sudan below that of most LDC's.

As noted, the Blue Nile Grid is Sudan's major electric power system, providing approximately 85 percent of total electricity production in 1978. (Another system is the large Eastern Grid, 100 kilometer transmission distance as compared with 500 kilometers for the Blue Nile Grid.)

Noncommercial Energy: The overall energy picture in the Sudan is changed considerably when the noncommercial sector dimension is added. Total energy consumption per capita, including traditional fuel consumption, is more than four times as high as per capita commercial energy consumption. The addition of firewood and charcoal to commercial energy consumption raises the level of Sudan's per capita energy consumption to a position second only to the United Arab Emirates among the countries under consideration in this survey.

Sudan has vast amounts of available livestock and agricultural residue which could be used with firewood and charcoal for energy purposes. However, the future of the traditional fuel sector in Sudan will depend on rising prices and scarcity of supply of petroleum products (especially kerosene) in rural Sudan (which have increased demand on already endangered fuelwood resources). The result has been a serious degradation of the environment and prospects for further degradation if current demand patterns continue.

b. Energy Prospects for 1980 - 1985

Aggregate energy consumption in the Sudan is expected to double between 1980 and 1985, with the largest increase being in consumption of petroleum. Table 4 below details the expected growth in demand for different products, with the largest increase (in absolute and relative terms) expected for gas oil. The average annual growth in demand for petroleum products overall is 8.4 percent.

TABLE 4

SUDAN'S REQUIREMENTS OF PETROLEUM PRODUCTS UNTIL 1985
(thousands of metric tons)

Product	1978	1979	1980	1981	1982	1983	1984	1985
Gasoline	142	149	157	165	173	182	191	200
Kerosene	102	109	116	124	132	141	150	160
Gas Oil	468	514	564	619	680	747	820	900
Diesel	25.58	26.16	27.17	27.38	28.01	28.66	29.32	29.99
Furnace Fuel	210	221	233	245	258	271	285	300
Airplane Fuel	4.8	4.49	4.21	3.94	3.69	3.45	3.23	3.02
Jet Fuel	58	64	70	76	84	92	101	110

By 1985, a second refinery will be built to raise national capacity to 1.6 to 2.5 million tons per annum, necessary to meet the projected national consumption of 1.9 million tons of petroleum products per year. In addition, both port and pipeline capacity will have to be expanded.

Electricity consumption is expected to continue to rise at 15 percent per annum until near the end of the century. At that rate demand will more than double between 1980 and 1985.

Petroleum Production: As a result of the crisis in rural energy supplies and the pressure of international oil price increases, much emphasis is being placed on the domestic petroleum sector to produce solutions to Sudan's growing energy needs. To date petroleum industry activity has been limited to the Port Sudan refinery (capacity 26,000 barrels per day at the end of 1979) and the piping of oil products to Khartoum. Chevron, which owns the largest concession in Sudan, announced a discovery of oil in commercial quantity at Abu Gabra in 1979. In February of this year (1980), Chevron announced the further discovery of a second well (2900 barrels per day of heavy gravity oil) 14 kilometers south of its initial find. This has led to official optimism that indigenous oil supplies can be counted on to ease the foreign exchange burden of oil imports in the near future. To date, twelve agreements have been concluded with foreign companies and governments for exploration of Sudan's petroleum and other mineral resources. In addition, the president of the Sudan, Jaafar Numayri, recently designated 1980 as "the year of petroleum" in Sudan.

Electrical Power: The six-year economic plan, 1976/1977 - 1982/1983, called for pursuing eight principal expansion projects in the electric power sector, incurring costs of LS 70 million. These project areas and their costs are outlined below.

Table 5

ELECTRICAL POWER PROJECTS UNDER THE SIX-YEAR PLAN

Project	Cost
Hydro-electric power stations	LS 6 million
Thermal power stations	LS 11.5 million
Rural electrification	LS 6 million
Stations and transmission lines	LS 6.2 million
Services	LS 6 million
Port Sudan	LS 3.5 million
El Roseirers power station	LS 5 million
Distribution network and substations	LS 20 million

In 1979, a fourth water turbine was to be added at el-Roseires, and a 16 MW diesel generator completed at Burri. Great Britain, the World Bank, and West Germnay agreed to finance foreign exchange costs of a large development scheme in Blue Nile Province to supply power needs there through 1986 (the so-called "Third Power Project"), all of which represent scheduled improvements on the Blue Nile Grid.

As for expansion of rural electrification, a new station (power source unspecified) was scheduled for completion by Spring 1980 to provide power to rural development projects at Kinana and Asalaya in Blue Nile Province. Similarly, planned establishment of a station at Juba, in the extreme south, was announced in late 1979, funded by an LS 2 million loan from Denmark.

Interim Energy Prospects: A senior energy official, in appraising the overall energy prospects of the Sudan remarked:

> "Unless the Chevron oil exploration in Darfur succeeds, the Sudan will go under."

As noted above, even if the more optimistic goals are met with respect to domestic petroleum production, refining and distribution, as well as the doubling of hydroelectric capacity in the Nile Valley to 560 MW by 1985, the gap between total energy availability and demand will continue to widen.

Sudanese energy officials are highly critical of what they regard as the callous indifference to their plight by their Arab oil-producing "brothers" who offer few concessions on price and supply. They have, however, received some concessionary financial aid from the Arabs, notably Saudi Development Funds, and for the indefinite future are looking forward to further emergency budgetary support from these sources, as well as concessionary aid and loans from international organizations.

c. Village Survey

Demographic Base: About 15,750,000 people or 90 percent of Sudan's 17.5 million population live outside the principal cities of Khartoum, Port Sudan, Wad, Medani, El Obeid, Atbara, and Juba. Of this 90 percent, approximately 85 percent or 13, 387,500 people are without electricity. About 10 percent of the population is either nomadic or seminomadic.

The settled rural population includes some 12,000 villages with an average population of 1200 people. Approximately 10,000 of these villages have no source of electrical power.

At the village level, water, or the lack of it, appears to be the primary need. In a typical village, wells are drilled to depths of 100 meters or less by five well-drilling companies (two public and three private). Diesel power pumps are used and fuel has to be brought in every other day. Either the village pays for the fuel or it pays for the water, all wells being government property. Diesel fuel costs $7 - 8 per gallon at remote sites due to country-wide fuel shortages, black market operations and the lack of transportation. In addition to fuel costs, village market pumping operational costs include: LS 40 ($80) per month for the guard; LS 30 ($60) per month for the operator; and LS 35 ($70) per month for the clerk for each pump. Some of these monthly operating costs could be eliminated with the installation of photovoltaics

Village Electrification: The Central Electricity Administration in Khartoum mainly occupies itself with successfully maintaining the existing grid in Khartoum and the main towns and has little time to devote to the electrification of villages which are being left to fend for themselves. Qualified engineers and technicians are constantly beseiged with offers of triple or quadruple salary from the neighboring oil-rich Gulf states, making it very difficult to retain even a minimum level of technical and administrative competence. A popular magazine recently ran a picture of a shop floor in a power plant gradually abandoned by employees who went to Saudi Arabia.

The General Director of the Electricity Administration remarked: "The Sudan and more specifically my department, has assumed the status of a technical school and training ground for the Gulf States."

d. Solar Energy Potential

Current Solar Activity: Solar research and development work is coordinated by the Energy Research Institute directed by Dr. Yahya Hamid, who is also head of the Mechanical Engineering Department at the University fo Khartoum. Established in 1973, the Institute has three departments: solar thermal with nine specialists, and wind and biomass with one each. Using the University for technical support, the Institute is currently:

- Building and testing several solar thermal designs to determine optimum specifications for eventual manufacture of the units in the Sudan; these projects are often undertaken by individual students as part of advanced degree programs;

- Testing single effect distillation systems, producing about 10 gallons of water per day for eventual manufacture and use in remote villages;

- Monitoring a solar refrigeration unit granted by the Technical University of Denmark;

- Testing several types of solar dryers for fruits and vegetables to improve storage and marketing efficiences in remote agricultural areas;

- Cooperating with the General Directorate of Meteorology to collect solar insulation data at 18 stations, covering half of the country;

- Overseeing the operation of a SOFRETES solar thermal dynamic pumping unit at Hillat Hamad, south of Khartoum, and part of an "Energy Protocol" with the French government. The system recently failed and the villagers have reinstalled a diesel electric system;

- Cooperating with the University of Reading in the U.K. on wind energy development in remote areas, a program including training of ERI staff.

The Energy Research Institute is one of several research bodies in the National Council for Research, headed by Dr. Wadie Habashi, who is planning the following projects for ERI:

1. A UNDP photovoltaic pumping project developed by J.D. Walton of the Georgia Institute of Technology and awarded by the World Bank to a British firm for implementation, due in Fall 1980. This is one of four World Bank funded photovoltaic pumping projects, the others being in Mali, the Philippines, and India (the latter recently withdrew from the program).

2. A US-AID $1 million program to develop renewable, including solar energy, resources awaiting final design by a U.S. consulting firm and due for start-up in Fall 1980. Local US-AID officials indicate their intention to fund many small projects having an immediate impact on the rural poor rather than focus on a few large ones.

Suggest Solar Projects: The severity of the energy crunch in the Sudan has, as noted above, meant that fuel is often unavailable for irrigation pumps at critical points in the crop production cycle with the result that fields are being abandoned. Sudanese planning "would overcome the major obstacle towards solving all other energy and developmental problems in the Sudan."

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Installing water pumps in Wadi Halfa area

5. Yemen Arab Republic

5.1 Summary

Paradoxically, the Yemen Arab Republic, in the heart of the oil rich Persian Gulf area, represents one of the best potentials for photovoltaics among the developing countries surveyed. Though they provide much of the labor for the Saudi Arabian oil fields to the north, they have no oil of their own.

Flow of over $1.5 billion in remittances from workers in the oil field back to their families in their home vililages provides a financial base to build village electrification programs. These electrification programs are being conducted at the local level by village cooperatives. Since many of the villages are quite remote and inaccessible, they represent a natural potential for photovoltaics.

5.2 General Information

Yemen is located in the southwest corner of the Arabian Peninsula, on the Red Sea, bordered by Saudi Arabia and the Marxist Democratic Republic of (south) Yemen with whom it is often confused. About the size of Missouri, the Yemen is about equally divided into three regions, a flat lowland along the Red Sea inhabited by tribes of mixed Arab and African origin, a densely populated central mountain region of villages amongst terraced cultivation, and a desert region near Saudi Arabia with a nomadic population. Yemenis often remark that their country has more people and arable land than the rest of the Arabian Peninsula combined. For this reason, the ancients called the region "Arabis Felix," or Arabia the Prosperous.

Under the rule of a feudal monarchy, Western travel was restricted and economic development discouraged. Many Yemenis emigrated to the U.S. (mainly Detroit), and the country became known as the "Tibet of the Red Sea." In 1962 a Republican government replaced the Monarchy and, after a period of civil war and consolidation, began in the early 1970's to undertake programs of social and economic development. At the same time, almost eight out of ten adult males flocked to the Gulf oil fields and sent back remittances that have grown from $350 million in 1972 to over $1.5 billion in 1979. Much of these funds are mobilized by Local Development Associations (LDA's), the Yemeni equivalent of cooperatives which, without central government help, have built roads, clinics, and schools. These cooperatives give a local and entrepreneurial dimension to the social and economic development process which the government supports as it consolidates its authority and seeks to provide a national perspective.

5.3 Energy Situation

The Yemen Arab Republic (YAR) produces no primary commercial energy. Exploration for oil began in the Salif-Luhayya area as early as 1952, but to date, no commercially exploitable fields have been discovered. Some oil shale deposits have been found, but they too, as yet have not proven to be economically exploitable. Known coal deposits exist but the extent is yet undetermined. Geothermal resources exist in the area southeast of Damar (southern YAR), whose economic potential is being evaluated.

The uncertainty surrounding indigenous primary commercial energy in the YAR can be, in the main, attributed to three inhibitive factors:

- Heavy governmental subsidization of oil products has encouraged ever increasing demand and dependence on oil products as the principal energy source;

- Occasional Saudi Arabian willingness to provide free oil products to the YAR on an emergency basis;

- The lack of a strong central governmental apparatus to establish energy policy for the YAR.

Commercial Energy: Commercial energy needs in the Yemen Arab Republic (hereafter, YAR or Yemen) are met entirely from imported petroleum products. The country has no refinery capacity, and thus must obtain these products through purchase contracts negotiated for three-year periods. The 1976 - 1978 contract wth the Kuwait National Petroleum Company allowed for import of over 450,000 metric tons per year, at specified prices. Table 1 below outlines the dimensions of Yemen's petroleum imports and their use.

Table 1

YEMEN ARAB REPUBLIC'S
PRODUCTION, TRADE AND APPARENT CONSUMPTION OF ENERGY PETROLEUM PRODUCTS
(in million metric tons and kilograms per capita)

					Apparent Consumption	
Year	Production	Imports	Exports	Bunkers	Total	Per Capita
1975		0.209		0.021	0.188	28
1976		01234		0.006	0.228	33
1977		01248		0.010	0.238	34
1978		01265		0.015	0.250	34

Source: United Nations

These products are imported by the Yemen Petroleum Company (YPC) through the mainport of Hrdeida, where YPC maintains storage facilities of some 40,000 tons. Distribution to the main consumption centers of Sana'a, Taiz, Ibib, Dhaman, and Sa'adah is by a fleet of 100 rad tankers of which the YDC owns a third and rents the rest.

Petroleum Consumption: The following Table 2 indicates the relative demand for different petroleum products in 1975.

Table 2

1975 SALES OF PETROLEUM PRODUCTS IN YEMEN

Type of Product	Amount Sold (in long tons)	Percent of Total Sales
Motor gasoline	47,863	24.4
Aviation gasoline	1,082	0.6
Kerosene	38,535	19.6
Jet fuel	5,268	2.7
Diesel oil	93,135	47.5
Residual fuel oil	10,228	5.2
TOTAL	196,111	100.0

Source: Yemen Petroleum Company

Table 3 below reveals the use of motor pumps for agriculture more than tripled between 1969 and 1976 mainly due to the proliferation of inexpensive Japanese units in all but the most remote villages. The 1980 figures are expected to be more than double those of 1975/1976.

TABLE 3

MOTOR PUMPS AND FUEL CONSUMPTION

Year	Pumps	Fuel consumed (1,000 liters)	Price (YRLs/Liter)	Total Cost of Fuel (YRLs)
1969/70	1,264	12,640	0.380	4,803,200
1970/71	1,614	16,140	0.380	6,133,200
1971/72	2,014	20,140	0.430	8,660,200
1972/73	2,384	23,840	0.460	10,966,400
1973/74	2,900	29,000	0.630	18,270,000
1974/75	2,451	34,510	0.720	24,847,200
1975/76	3,951	39,510	0.810	32,003,100

Source; CPO and ECWA, National Accounts of YAR, 1969/70-1975/76. Cited in World Bank, Yemen and Arab Republic (Washington, D.C., 1979), p. 259.

The consumption patterns noted above occur in an economy installed from the full impact of the rise in world petroleum prices, by occasional gifts from Saudi Arabia, e.g., 50,000 tons of petroleum products in 1974/1975 and by a policy of government subsidy, especially of diesel and fuel oil. Table 4 illustrates this pattern.

Table 4

COST OF PETROLEUM PRODUCTS: 1975

Type of Products	C.I.F. Value	Cost, excluding taxes and duties	Cost, excluding taxes and Duties	Selling Price
Motor gasoline	53.39	64.67	96.5	93.0
Aviation gasoline	73.60	84.94	117.5	122.5
Kerosene	53.48	64.04	74.5	61.5
Jet Fuel	54.48	63.69	78.0	89.5
Diesel Oil	51.75	61.65	78.5	47.5
Residual Fuel Oil	39.06	44.56	52.5	56.0

(Figures on file per liter)

Source: 1976 Yemen Petroleum Company

Energy Prospects 1980 - 1985: Demand growth estimates of 35 percent per annum for petroleum products are anticipated through 1981, as shown in the OAPEC data below, reprinted in Table 5.

Table 5

DEVELOPMENT AND PROJECTED CONSUMPTION OF PETROLEUM PRODUCTS IN YEMEN

Year	Total Consumption a Year Earlier	Projected Increase in tons (35%)	Total Consumption (tons)
1977	257,000	90,000	347,000
1978	347,000	121,000	468,000
1979	468,000	263,000	631,000
1980	631,000	220,000	851,000
1981	851,000	298,000	1,149,000

Source: OAPEC Bulletin, November 1979

Yemeni energy officials envision an increase of 35 percent between 1980 and 1985 in the consumption of all petroleum products which they predict will not adversely affect the foreign exchange burden of imported energy. Indeed, they do not anticipate any problem of product availability until 1990. The only option being discussed to reduce the impact of this possible product shortfall is a projected "oil refinery" to be built around 1985.

Yemenis commonly believe that large oil deposits exist in the country and in the 1973 established the Yemen Minerals Resources Corporation (YEMONCO) to promote the exploration of hydrocarbons. Exploration activities had included that of a German team in 1952, near Salif in the Tihama, drilling by the U.S. firm John Mecom near Hodeida in 1961/1962, and an Algerian-Yemeni joint venture seismic survey in the Tihana in 1971. In 1974, the Yemen Shell Exploration Company G.M.B.H. was formed as a subsidiary of Deutsch Shell (Hamburg) and granted an off-shore concession (extendable 30 years if oil or gas was found) of 7330 square miles, from the Saudi border to Ras Zabid in the south. YEMONCO reports the following results of initial geological surveys:

- Indications of oil shale deposits in the central highlands;
- Potential for commercial oil deposits in the Red Sea, whose identification and development is impeded by high cost;
- A "good chance" for crude oil deposits in the Tihama, warranting further exploration;

Prices are below YPC's costs for motor gasoline, kerosene, and diesel oil, which amount to over 90 percent of sales volume. In the case of diesel oil, the selling price is below C.I.F. price. The aggregate difference between actual and selling prices amounted in 1976 to over YR 43m ($10 million) for which the government had to reimburse YPC. The Council of Ministers has recently reaffirmed the policy of not allowing the price of diesel to rise above the 1973 level because of its importance to agricultural and to pass on other increases, principally gasoline, on a gradual basis.

Electrical Power: Upon the recommendation of consultants, the Yemen General Electric Corporation (YGEC) was created in July 1975 to develop a unified system of electricity generation in the Yemen. It absorbed the assets of the then electrical utilities of Sana'a, Taiz, and Hodeida.

Initial electrification efforts focused on extending the grid to the urban populations of the above noted principal towns, nearly half of whose inhabitants use kerosene for lighting in their homes, by the end of the current five-year plan in 1981. YR 585 million will be spent during this period, and already about two-thirds of the present urban population now have electricity. The cost of electricity is higher than in most developing countries, nearly 18 cents per Kwh and unreliable with the result that most industrial enterprises generate their own power. In fact, one-half of total sales in the main towns are to private, mostly residential consumers.

A major step towards establishing a national grid and rural electrification strategy was taken in 1979 with retention of the U.S. National Rural Electrical Cooperative Association to present, by the end of 1980, an electrification plan encompassing all the main towns and contiguous rural areas. The YGEC notes that the remote and inaccessible nature of Yemen will limit its ability, even under this new approach, to electrification of no more than 40 percent of Yemen's rural villages before the Year 2000.

Noncommercial Energy: Wood, charcoal, bagasse (stalks and roots of the main cereal crops) and dung are, in order of importance, the principal forms of noncommercial energy. Wood is the main cooking and heating fuel for both urban and rural households and as late as 1972, the average household in Sana'a spent more to purchase firewood than for all nontraditional fuels (i.e., kerosene, liquid petroleum, gas, and electricity) combined, although the trend is towards the latter. Village women spend up to half their working day gathering fuelwood within the framework of elaborate customs spelling out rights of collection and method of payment (which is principally barter rather than cash payment).

Deforestation of the mountain slopes and desertification of the arid and semi-arid lowlands near the Red Sea have been increasing with demand increases. As a direct result more and more time is being expended to gather fuelwood, leaving less time for other chores. Soil fertility is also declining as dung is used for fuel rather than fertilizer. The Yemeni government recognizes the long-term danger these trends pose to the environment, and has approached the FAO for advice. The FAO has recommended a fuelwood planting program concentrated in rural areas, which will have to depend on wood and charcoal for the foreseeable future.

- Commercial quantities of coal;
- No uranium deposits;
- Promise of lignite deposits.

Promising geothermal sites were also surveyed by the German group and are now the object of evaluation by a geothermal section of YEMONCO, aided by a US-AID expert. Three sites have been identified, the towns of Lysee and Sabil near Dhamar, and near Ibb, all in the central highlands. It is hoped that further drilling will yield data supporting a project to establish a geothermal electricity plant for the provincial city of Dhamar (population 20,000) and nearby villages.

5.4 Village Survey

Demographic Base: Roughly 90 percent of the total population of 5.5 million live in rural areas. There are approximately 52,600 villages in Yemen, 63 percent with populations with less than 50, 25 percent with populations between 50 to 100, and 22 percent with populations between 100 to 1000. Most of the population is concentrated in the south around the provincial city of Taiz and in the western escarpment of the mountains facing the Red Sea.

In the fishing villages along the coast, the predominant house form is the square reed hut, about 3.5 meters in size. Further east into the Tihama Lowland, African-like circular huts with conical roofs are common, about 4 meters in diameter. These huts have one or two doors but rarely any windows, and are often found in family groups of 4 or 5 in enclosed compounds (see Appendix 1). In the mountains are found the tower-like "skyscraper" houses of four to six stories constructed of boulders, coral, or hewn stone, many of them thousands of years old. Nearer the river valleys the houses are also tower-like, made of compact layers of clay.

The departure of most Yemeni skilled labor for the Gulf oil fields and consequent high cost of local labor is forcing potential homebuilders toward prefabricated housing, or the use of unskilled labor and less expensive materials such as clay and sun-dried brick.

Village Electrification: The introduction of electric power into Yemeni villages is almost synonymous with the establishment of distributorships for several Japanese-made diesel generators, notably Yanmar and Hitachi. One of the most popular units is a 10 KVA generator selling for $5000 and now available from prominent merchant houses in Sana'a, Hodeida, and Taiz. Some units are bought in Saudi Arabia and smuggled across the border. Once in the village, they operate water pumps full time, and in the evening lights and an occasional T.V. set.

Villagers have little faith in the willingness or ability of the central government to assume responsibility in the near future for their power needs and have taken the initiative, through Local Development Associations, the Yemeni equivalent of cooperatives, to set up village power schemes either owned by the LDA or a group of prominent townspeople in a private power company. Financing is facilitated by the remittances flowing into the villages from heads of families working in Saudi Arabia.

5.5 Solar Energy Activity

Current Solar and Photovoltaic Activity: Several international groups have visited the Yemen to promote the use of solar thermal and solar electric systems. A Cypriot firm has been successful in marketing a simple solar water heater costing about $200, several of which have been installed on some houses in Sana'a. Following discussions with the Near East Development Group, the Minister of Communications has installed solar electric power systems for remote microwave repeater sites and in the process has been converted from a skeptic to active proponent of solar technology, within the government. The Confederation of Yemen Development Associations, a rural cooperative organization, coordinating the activities of 190 members throughout the country, has asked Near East Development Group to install a solar electric demonstration system on their headquarters building as a step towards introducing the solar electric option into their membership's ongoing development programs.

One of the first solar electric pumps in the Yemen is to be installed by the FAO at a small underground reservoir northwest of Taiz and features a 1350 watt (peak) array pumping 25 to 40 cubic meters per day with a head of 40 meters.

A first step towards establishing a systematic research and development program in solar energy is being taken by Dr. A. G. Shayeb of the University of Sana'a who, with probable US-AID financial and institutional support, will set up a series of solar workshop projects beginning with solar thermal and eventually solar electric systems at a site outside of Sana'a. This will undoubtedly become a principal focus of renewable resource development in the country.

Suggested Solar Project Areas: Aside from the Ministry of Communications and the Confederation of Development Associations, who have already purchased photovoltaic systems, several prominent merchants and government bodies have expressed an interest in using solar electric systems for remote power use, including village lighting, water pumping, and refrigeration. European and Japanese firms are responding to this interest in the form of government-sponsored missions which promise to capture a major share of this market.

Yemenis at all levels, in both the public and private sectors, stress that theirs is a private economy in which initiative is taken by private firms working closely with a foreign supplier. U.S. manufacturers wishing to market PV systems should, as a first step, establish a working relationship wtih a local firm, bring solar hardware to the country, and jointly work to approach the government organizations, some of whom are listed below, to propose the solar alternative in remote power programs. Unlike most developing countries, Yemen has both the requirement for alternative energy and the ability to pay for it.

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6. United Arab Emirates

6.1 Summary

The use of photovoltaic systems to provide village power has a limited near-term potential in the United Arab Emirates. This is true due to two major factors: even though current per capita oil consumption is quite high and expected to continue to grow, the oil reserves are more than adequate to meet these demands and still allow considerable oil for export. Secondly, it is likely, based on current plans, that the majority of the villages will be eventually hooked up to an extensive electricity grid.

This plan should cover all but about 100 villages in the member states of the Emirates. These villages could be candidates for photovoltaic power, since there is a significant interest in alternate energy, even in spite of the previous commentary.

6.2 General Information

Located along the Arabian shore of the Persian Gulf, opposite Iran, the Emirates fit the stereotype Western image of the Arab oil producer, going from camel to Cadillac in less than a generation. In 1961, the ruler of Abu Dhabi, Sheikh Zayed, sat in a two-story mud hut in Al-Ain Oasis with a bare floor, kerosene lantern, and several camels for transportation in the surrounding desert. Sheikh Zayed's personal income this year will be $7 million per day, the highest in the world. Abu Dhabi, Dubai, and the other smaller emirates that comprise the federation had lived under British suzerainty since the late 19th century when their pirate ancestors were subdued by gunboats from British India. When in 1968 the Imperial budget could no longer support an East of Suez defense presence, the British announced their intention to withdraw from the region, which decision gave the impetus for the creation of a United Arab Emirates in 1971.

6.3 Energy Situation

Member states of the Emirates are Abu Dhabi, Dubai, Sharjah, Ras Al-Khaimah, Ajman, Umm, All-Qaiwain, and Fujairah. It is difficult to speak of "the UAE economy" or "an overall UAE energy picture" since these are areas where federalization has made little progress. In general, one can say that the oil producers (Abu Dhabi, Dubai, and Sharjah) pursue independent policies on petroleum issues (viz, level of production, exploration contracts, degree of nationalization) while Abu Dhabi, with 80 - 85 percent of total UAE production and by far the largest proven reserves, is the key emirate in the UAE's energy future. How AbuDhabi views its petroleum resources in relation to maintenance of the Federation, the need to develop alternative, renewable sources of energy, and the need to diversify the economic base are the key factors in determining the UAE's energy policies.

Currently, the UAE's oil production of 1.8 million barrels a day is a function of three factors: declining production in Sharjah's Mubarek field (30,000 b/d in 1977 to 13,000 b/d in 1979)l Abu Dhabi's decision to slow down its rate of production (1.68 million b/d in 1977 to 1.45 million b/d in 1979); and Dubai's decision to continue to expand production at optimum capacity (315,000 b/d in 1977 to 363,000 b/d in 1979). The table below showing 1979 production levels in thousands of barrels per day and millions of tons per year clearly demonstrates Abu Dhabi's dominance of the UAE oil picture.

Table 1

UAE OIL PRODUCTION, 1979

Emirate	Production--,000b/d (million tons/year)	Percentage of UAE Total
Abu Dhabi	1,456,000 (72.5)	79.5
Dubai	363,000 (18.0)	19.8
Sharjah	13,000 (0.7)	0.7
TOTALS	1,832,000 (91.2)	100.0%

Current refining capacity of 15,000 b/d at the one refinery in Abu Dhabi represents total refining capacity in the UAE. Each emirate takes care of its own product consumption. Dubai's imports of oil products amounted to $250 million in 1977. Refining capacity is being expanded with new refineries being built at Umm Al-Nar (750,000 t/y) and Ruweis (6000 t/y) in Abu Dhabi, and at Jebel Ali (150,000 b/d) in Dubai.

Natural gas production and utilization for industrial and electrical generating projects is being emphasized. Associated gas from the Fateh and Southwest Fateh fields in Dubai, for example, is piped to the industrial area at Jebel Ali where propane, butane, and condensate are extracted for export and some 80 million cubic feet a day are used to power the aluminum plant, a power plant (525 MW) and a 25 million gallon desalination plant.

Aside from crude oil and natural gas, the UAE has no domestic sources of primary energy. There exists no hydroelectric generating capacity, no coal, and few noncommercial sources (fuelwood, crop residue, etc.). Petroleum is the key to the UAE economy.

Petroleum Production and Consumption: Table 2 presents primary energy production and consumption in the UAE as a whole for the period 1975 to 1978. Total production of 92.7 million metric tons of oil equivalent was some 300 percent higher than that of Egypt, the next highest country in this survey. With a very small population (estimates for 1980 range from 600,000 to 900,000), the UAE per capita energy consumption level put even more distance it and the second highest country in this survey. UAE's per capita consumption of 12,617 kg of oil equivalent in 1978 was 34 times that of Jordan. Natural gas consumption represented 21.5 percent of total commercial energy consumed.

Table 2

UNITED ARAB EMIRATES' PRODUCTION, TRADE AND CONSUMPTION OF PRIMARY ENERGY
(in million metric tons oil equivalent and kilograms per capita)

	PRODUCTION			TRADE			CONSUMPTION			
							Total Commercial Energy			
Year	Total Primary Energy	Crude Petrol., Natural Gas Liquids	Natural Gas	Imports	Exports	Bunkers	Aggregate	Per Cap	Liquid Fuels	Natural Gas
1975	82.776	82.058	0.718	1.086	82.103	0.008	1.796	8,091	1.078	0.718
1976	96.060	95.265	0.795	1.304	95.447	0.097	2.315	10,110	1.520	0.795
1977	98.916	97.648	1.269	1.881	97.521	0.095	2.969	12,581	2.295	0.674
1978	92.769	90.114	2.654	1.923	91.505	0.102	3.079	12,617	2.415	0.663

Source: Abu Dhabi National Oil Company (ADNOC), United Nations

As of January 1979, Abu Dhabi had 31 billion barrels of proven reserves, with high likelihood of more discoveries; Dubai, 1.4 billion barrels; and Sharjah, 16 million barrels. Abu Dhabi's reserves are equal to more than 50 years of production at current levels.

Only Abu Dhabi and Dubai have active natural gas poroduction. Both essentially began production in 1977. Table 3 shows gas production to date.

Table 3

UAE PRODUCTION OF NATURAL GAS
(in billions of cubic feet per year)

	1977	1978
Abu Dhabi	136.8	93.4
Dubai	31.0	30.6
TOTALS	167.8	124.0

The decline in production in 1978 from the level of 1977 was mainly due to mechanical problems and a decision to move more slowly after the explosion at the LNG plant in Doha, Qatar. Proven gas reserves as of January 1979 were 20 trillion cubic feet for Abu Dhabi and 1.6 trillion cubic feet for Dubai.

Ras Al-Khaimah has recently made some oil and gas discoveries. Reserves are thought to be sufficient to give production levels within four years of 70,000 to 140,000 b/d.

Sharjah's oil production, while of extremely high quality, has declined rapidly in the last two years in spite of the addition of an enhanced recovery project in 1978. Sharjah's one field, Mubarek off the island of Abu Musa, is the deepest field (13,000 to 14,000 feet deep) in the Persian Gulf. Production is shared 50/50 with Iran while Sharjah in turn shares its 50 percent of production with Umm al Qaiwain (30 percent) and Ajman (5 percent).

Table 4 indicates that to meet demand for petroleum products, the UAE must import between 79 - 80 percent of domestic product consumption. The apparent total of 2.3 million metric tons in 1978 was more than double the amount of products consumed in 1975. From 1972 to 1977, consumption grew at an annual rate of 25.8 percent. One projection suggestes that in 1985 the UAE will consume over 10 times its level of consumption in 1977. Refining capacity is being expanded in Abu Dhabi as was mentioned above.

Electrical Power: The electric power sector in the UAE produced 3279 Kwh for each consumer in 1978 (see Table 5). This level of consumption was nearly 10 times the amount used by a consumer in Egypt. As seen in Table 5, demand of electricity grew at an annual average rate of 13 percent between 1975 and 1978. Power was generated at publicly-owned thermal generators.

Table 4

UNITED ARAB EMIRATES' PRODUCTION, TRADE AND APPARENT CONSUMPTION OF ENERGY PETROLEUM PRODUCTS
(in million metric tons and kilograms per capita)

Year	Production	Imports	Exports	Bunkers	Total	Per Capita
1975	—	1.037	—	0.008	1.029	4635
1976	0.303	1.249		0.095	1.456	6358
1977	0.578	1.806	0.080	0.093	2.202	9331
1978	0.680	1.845	0.100	0.100	2.315	9488

Source: United Nations; Abu Dhabi National Oil Company (ADNOC).

Table 5

UNITED ARAB EMIRATES' PRODUCTION OF ELECTRICITY BY TYPE AND CONSUMPTION OF ELECTRICITY
(in thousand million kilowatt hours)

Year	Total Industrial and Public	Public		Consumption	
		Total	Thermal	Total	Per Capita (in kilowatt hours)
1975	0.500*	0.500*	0.500*	0.500	2252
1976	0.600*	0.600*	0.600*	0.600	2620
1977	0.600*	0.600*	0.600*	0.700	2966
1978	0.700*	0.700*	0.700*	0.800	3279

Source: United Nations; Abu Dhabi Statistical Office/Ministry of Electricity and Water.

Electricity rates in Sharjah and Abu Dhabi are as follows:

domestic rate: $.07 per kwh

commercial rate: $.12 per kwh

These are expected to rise 10-15 percent by 1981.

No national grid exists in the UAE. A decision to establish one was made in 1978, at which time a Swiss firm was contracted to study electricity needs. Until then the development of electrical generating capacity and extension of the grid mirrored the oil production capabilities and development priorities of the individual emirates. As federal revenues grew, the government extended its concern for providing adequate electricity to the northern emirates. Local leaders were, however, reluctant to relinquish jurisdiction to the central authorities. Hence, equipment was installed as needs sprang up; coordination was nonexistent.

Energy Prospects: Domestic energy demand conditions for the 1980 - 1985 period are expected to be based on current patterns. Local consumption of petroleum is expected to rise from 3.2 million tons in 1980 to 7 million tons in 1985. Between 1985 - 1990 average annual growth of 5 percent will lead to a consumption level of 10 million tons of petroleum per year, which will be more than covered by growth in petroleum per year, which will be more than covered by growth in petroleum liquids production, expected to rise to 100 million tons per annum in 1990.

In addition to these general demand and production conditions, a number of other measures are anticipated to form the broader context of UAE energy perspectives.

1. New oil discoveries outside OPEC will relieve pressure to produce oil at above local market needs.

2. Arab oil countries will participate in international efforts to develop alternative energy sources, particularly solar. Solar powered space cooling is pointed to as a crucial necessity.

3. Preserving low cost oil and gas for use as feedstock in the petrochemical industry.

4. Coordination among Arab countries in energy studies and planning.

Plans were announced in late 1979 to establish a committee to plan and implement a national strategy in the area of "UAE energy and power requirements, 1980 - 2000." This Committee is to consist of the Ministers of Finance, Planning, Water and Electricity, and Communications. (See Current Solar Activity below.)

6.4 Village Survey

Demographic Base: The population distribution of the Emirates is skewed, both in concentration and ethinic makeup. At the end of 1979, the population totaled 775,000, distributed among the seven emirates as follows:

Emirates	Urban	Rural	Total
Abu Dhabi	200,000	80,000	280,000
Dubai	210,000	40,000	250,000
Sharjah	—	—	80,000
Ras al Khaimah	—	—	65,000
Fujairah	—	—	35,000
Ajman	—	—	30,000
Umm al Qaiwain	—	—	22,000

Development-induced immigration has swollen annual population growth to an average of 19 percent with the result that indigenous Arab inhabitants are a minority in their own land, not more than 40 percent of the total population; some are third-country Arabs (Egyptians, Palestinians), but most are Pakistanis and Indians.

Eighty-four percent of the total population or 650,000 people are classified as rural. The total number of villages is about 500 with an average population of 750, a third of which live in the emirates of Abu Dhabi and Dubai. Less than 3 percent are engaged in agriculture, 40 percent in construction, 7 percent in manufacturing, and about 30 percent in community and personal services. The predominant age group is 25 to 34 years old while in most Arab countries it is the 6 to 14 age group.

Village Electrification: As of March 1979, responsibility for electricity in most, if not all, of the emirates belonged to the federal government, i.e., the Ministry of Electricity and Water, in Dubai. The Ministry was allocated $47.7 million from the UAE budget in 1979 for projects including construction of new stations and extension of existing power networks. Umm Al-Qaiwain is also in the process of developing its own electricity service.

A contract has been given for construction of a 33 MW power plant in Ajman. A british firm will spend $4.5 million to supply electricity to 20 villages in the Emirates, denoting first-time provision of electricity for some 15,000 rural inhabitants. Mitsubishi Electric is involved in two rural electrification projects in the UAE. The first will provide power for seven villages in Ras al-Khaimah; the second, to be completed in July 1980, involves distribution of power to 18 additional villages. There are still some 100 villages with an average population of 750 people without electricity. The recent federalization of electricity in the UAE may become a "test case" of the federal authority, and all villages, no matter what the cost, may be eventually hooked up to the "National Grid."

6.5 Solar Energy and Photovoltaic Activity

Current Solar Activity: The climate of the UAE is hot and arid with daytime temperatures frequently reaching 120 degrees F during the months of June to September on the coastal plain. Temperatures are lower and vegetation is relatively more abundant at higher elevations. During the late summer months, humid winds (called shargi) make the coastal plain especially unpleasant. This hot, humid, corrosive environment has caused problems at some industrial sites and might affect solar electric handpumps.

Average annual rainfall in the coastal region is less than five inches. When it occurs, it does so in cloudbursts causing flooding and runoff problems. In the mountains, rainfall often reaches 15 inches a year. As a whole, the UAE has very limited supplies of groundwater.

As far as sunshine is concerned, the UAE has an ideal environment for all solar applications, but the effect of high temperatures and high humidity on solar hardware should be taken into account.

In March 1979, the UAE hosted the first Arab Energy Conference. This convention was an expression of the need to expand cooperation on energy issues, and paved the way for addressing the question of alternative energy sources in the Arab world.

Shortly thereafter it was announced that studies were in progress to set up a solar research unit at the university at al-Ain. Collaboration was planned with the Colorado Institute for Energy and Development. Further definition of the UAE solar energy program is being carried out at the Ministry of Petroleum and Minerals, Abu Dhabi.

Other solar energy activity in the UAE includes:

- An ongoing, integrated food/water/power complex on al-Saiyat Island, Abu Dhabi, supervised and installed by the University of Arizona in the 1960's.

- A one kilowatt solar water pump recently set up at al-Ain, on a government experimental farm, by the French government.

An energy committee will be established by June 1980 to coordinate energy strategy in the UAE consisting of a representative from:

The Foreign Office
Ministry of Petroleum
Ministry of Finance
Ministry of Electricity and Water
Department of Electricity/Abu Dhabi
Ministry of Planning
Ministry of Communications

The chairman will probably be Ambassador Najm Addin Hamoudi of the Foreign Office and the Secretary, Khamis Suheil, also of the Foreign Office.

Suggested Solar Projects: As noted above several projects are underway to incorporate rural villages into a utility grid. There remain, however, about one hundred villages with an average population of 750 without electricity. Many of these will obtain some electric service by asking their respective rulers for a generator and thereafter call on his technical administration to furnish operators, maintenance, and occasionally fuel. This has become a familiar process in tribally-strong areas wherein providing electricity has become an aspect of the ruler's paternal largesse. One result is that energy in rural areas of the Emirates has no cost associated with it.

The problems of operating and maintaining a diesel generator, referred to elsewhere in this survey, are exaggerated in this environment due to an incompatibility of mechanical devices wiht bedouin inclinations. Some Bedouins believe that handling any mechanical device is degrading and lifting even more so; as a result, expatriate technicians are employed who spend hours rushing across the desert on a maintenance call only to find a switch turned off or a wire loose.

The reliability and maintenance-free aspects of photovoltaic systems appeal to local energy officials, but implementation of any PV system awaits a demonstration project. The Energy Committee referred to above has suggested a commercial-funded demonstration or preferably a government-to-government agreement, similar to the U.S.-Saudi Arabian Joint Commission as the framework for such a project.

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7. Pakistan

7.1 Summary

The outlook for the potential market for photovoltaics in village power applications in Pakistan is good.

While possessing a diverse mixture of indigenous sources of energy including oil, coal, natural gas, hydro, and nuclear, the outlook is that these sources will not be able to keep up with the projected rapid increase in demand. As a result, photovoltaics and other alternate energy sources may be called upon to fulfill part of this future demand.

There has been a significant amount of work carried on in solar energy, including photovoltaics; so its potential is being recognized. Some concern exists relative to PV reliability and performance, especially during long periods of cloud cover. When these concerns have been resolved, Pakistan will probably attempt to manufacture solar cells locally.

7.2 General Information

Pakistan is an Islamic but non-Arab country that came into being in 1947 when Muslim nationalists of British India chose to live in a separate state. With this as its original "reason for being," it is not surprising that a sense of Islamic mission provides the main undertow to the conduct of both domestic and foreign policy.

Most of the country's social and economic development is concentrated in the densely-populated and fertile provinces of the Punjab and Sind in the south and west which produce over 90 percent of the country's rice, wheat, and cotton. The other provinces, the Northwest Frontier Province and Baluchistan in the mountainous north and desert west respectively, are ethnically and culturally set apart from the rest of the country and have historically received less attention from the central goverment.

7.3 Energy Situation

In 1978, Pakistan's total commercial energy consumption was equivalent to 13.2 million metric tons of coal equivalent. This level of consumption was equivalent to 172 kilograms coal equivalent per capita, making Pakistan, tied with Sudan, the second lowest per capita consumer of commercial energy in this six-country survey. Commercial energy consumption was derived from the following fuel sources: natural gas (48.7 percent), liquid fuels (39.9 percent), solid fuels (6.3 percent), and hydro-generated power (5.1 percent).

The following general, over-time observations can be noted concerning these sources:

- Since its discovery in 1952 at Sui, natural gas has played an increasingly important role in Pakistan's commercial energy consumption, rising from 23 percent in 1964, to 33 percent in 1972, to nearly 49 percent in 1978. Pakistan has a surplus of gas production and several undeveloped fields and senior energy officials focus on this indigenous resource as key to energy independence.

- Oil's share of commercial energy consumption has declined from 54 percent in 1964, to 43 percent in 1972, to around 40 percent in 1980. Pakistan's imports of crude oil have increased at the rate of 10 percent per annum over the past five years, but the cost of those imports has increased fro $67 million to $400 million, a 600 percent increase.

- Indigenous crude oil production in 1976 to 1977 of about 3.7 million barrels met only 12 percent of total oil consumption. With estimated proven reserves of 385 million barrels as of June 1979, Pakistan hopes to double its present 10,000 barrels a day production rate by 1982/1983. Exploration operations are presently being conducted by Amoco International (Standard Oil of Indiana), Marathon, Gulf, Union, and others in cooperation with the government-owned Oil and Gas Development Corporation.

- Hydroelectricity's share of total commercial energy consumption increased from 8.5 percent in 1964 to 15.5 percent in 1972. From 1972 to 1978, hydro-generated electricity's share has decreased to 5.1 percent of the total.

- Pakistan has some coal reserves, estimated at 477 million metric tons in 1978. Coal usage, mainly for power generation, has declined from 15 percent of commercial energy consumption in 1964 to about 6 percent in 1978. This decline is mainly due to increased usage of natural gas. The quality of coal found in Pakistan is poor; consequently Pakistan's better quality coal/coke requirements are met through imports.

- Pakistan is the only country in this survey with installed nuclear capacity. This nuclear power accounts for 4 percent of electrical generating capacity and less than one-half of one percent of total commercial energy consumption. (Precise data on this energy source are difficult to obtain due to the sensitivity of local officials to western interest in their nuclear policy.)

- Imports, mainly crude oil, represented 45 percent of total commercial energy consumption in 1978. While import volume has increased at the rate of 10 percent per annum over the past five years, import costs, as indicated above have increased 600 percent over the same period.

Pakistan is quite aware of its need to increase production of oil and natural gas to lessen its dependence on costly imported oil. It is also aware of the need to emphasize renewable energy usage in its rural development efforts for the same reason.

Energy Resources: Production and Consumption Patterns

Petroleum: Table 1 shows the energy production by fuel source and average annual growth rate by source over the period 1976/1977 to 1978/1979. As is clearly shown, oil and natural gas were the predominant sources of energy produced in 1978/1979, accounting for 76.5 percent of all energy supplies. Furthermore, Pakistan's dependence on oil as an energy source has declined from almost 60 percent in 1960, to 43 percent in 1972, to approximately 40 percent today. This decline in dependence on oil as an energy source is quite the opposite of the world trend, where growing dependence on oil is the norm.

Table 1

PAKISTAN ENERGY SUPPLIES
(in KJ x 10^9)

Product	1976-77	1977-78	1978-79
Oil (excluding exports and overseas)	156,628	177,590	192,510
Percent	(39.0)	(38.9)	(39.2)
Gas (Excluding feed stock)	160,714	171,282	181,510
Percent	(40.0)	(37.6)	(37.0)
Coal	24,398	25,197	27,417
Percent	(6.1)	(5.5)	(5.6)
Hydel (Excluding auxiliary consumption)	54,592	78,356	86,674
Percent	(13.6)	(17.2)	(17.7)
Nuclear (Excluding auxiliary consumption)	3,998	2,193	1,006
Percent	(1.0)	(0.5)	(0.2)
L. P. G.	1,084	1,412	1,627
Percent	(0.3)	(0.3)	(0.3)
TOTAL	401,414	456,030	490,744
Percent	(100)	(100)	(100)

Source: Directorate General of Energy Resources (D.G.E.R.) analysis, cited in *Energy Year Book 1979*.

Table 2

PAKISTAN: DISTRIBUTION OF ENERGY DEMAND AMONG ENERGY RESOURCES
(in KJ x 10^9)

Product	1976-77	1977-78	1978-79
Oil	145,241	160,741	174,885
Natural Gas (Excluding feed-stock)	90,854	101,487	109,237
Coal	23,373	24,675	26,855
L.P.G.	1,084	1,412	1,627
TOTAL	260,552	288,315	312,604
Thermal Electric Generation:			
Oil	7,105	1,539	700
Gas	62,348	62,373	62,115
Coal	1,019	522	562
Hydro*	36,467	52,342	57,898
Nuclear*	3,358	1,842	845
TOTAL	110,297	118,618	122,120
TOTAL COMMERCIAL DEMAND	370,849	406,933	434,724

Source: DGER Analysis, cited in Energy Year Book 1979.

Pakistan's proven oil reserves, as of June 1979, are estimated to be 485 million barrels. Crude oil production 1978 of a little less than 10,00 barrels a day was sufficient to meet 12 percent of local demand for petroleum products. Pakistan exports significant quantities of kerosene and aviation fuel because of its excess refining capacity in these fuel types at the three existing refineries.

Natural gas has, since its discovery in 1952, played an increasingly important role as an energy source. Proven gas reserves are estimated to be 22.6 trillion cubic feet. Recent studies have indicated total recoverable reserves to be in the neighborhood of 140 trillion cubic feet.

Pakistan is the only country in this survey known to have an installed nuclear capacity. Nevertheless, nuclear energy's role in the production of commercial energy in Pakistan is declining.

Table 2 shows the distribution of demand for energy by fuel source. It also indicates contributions to electrical generation by fuel source. According to this table, electrical generation accounted for 28.1 percent of total demand for energy in 1978 - 1979. Overall, oil and natural gas account for 80 percent of energy consumed in 1978 - 1979. Outside the electrical generation sector, oil is plainly dominant. Since 1976 - 1977, each resource's share in energy consumption has remained relatively stable, except for the increase in hydroelectric's share and the decline of nuclear power in the production of electricity.

Pakistan is much less dependent on external sources for oil products than it is on crude oil imports. Three refineries are in operation, with an aggregate capacity of 5.51 million metric tons or 110,000 b/d.

Product Imports: At the same time, imports of certain petroleum products were necessary. Table 3 gives the dimensions of these imports in 1978-1979, and the rate of increase over 1977-1978, and accounted for almost 60 percent of product imports.

TABLE 3

PAKISTAN: IMPORTS OF PETROLEUM PRODUCTS

1978 - 1979

Product	Amount Imported (metric tons)	Percent of Total Imports	Percent Increase Over 1977-1978
Aviation Fuel	5,565	0.3	-24.1
Motor Spirits	36,515	2.6	7.1
SK	535,498	38.1	22.4
Diesel Oil	826,368	58.9	35.0
TOTAL	1,403,946	99.9	28.7

Source: Oil Companies Advisory Committee, cited in Energy Year Book 1979.

Consumption by Sector and Fuel Source: Table 4 gives a sectorial breakdown of energy consumption for the most recent year, 1978-1979. Industry remained the largest consumer of commercial energy, using 50 percent more fuel than transportation. Since 1971, residential energy usage has increased at the fastest rate, becoming the third largest sectorial consumer in 1978-1979. The commercial sector, despite having the second highest growth rate from 1971 to 1979, remains the smallest consumer of commercial energy.

Table 4

PAKISTAN: DISTRIBUTION OF ENERGY DEMAND AMONG ECONOMIC SECTORS, 1978-1979

Sector	Consumption of Energy (in KJ x 10^9)	Percent of Total Consumption	Annual Compound Growth Rate 1971-1979
Residential	71,017	14.9	14.7
Commercial	13,391	2.8	12.1
Industrial	149,195	31.4	4.2
Agriculture	29,704	6.2	3.4
Transport	100,870	21.2	10.4
Power	63,377	13.3	3.9
Fertilizer (Excluding feedstock)	15,456	3.3	9.6
Others	32,256	6.8	(-) 0.2

Source: D.G.E.R. Analysis, cited in Energy Year Book 1979.

With supply of products coming from a combination of production and imports, consumption was distributed across a range of products and economic sectors. Overall, the volume of oil product consumption increased 8 percent over 1977-1978. As Table 5 shows, transportation is by far the largest user of products, with domestic uses a distant second. These are also the fastest growing sectors. The rapid decline in products use by the power sector is due in large part, to the rapid growth in hydroelectric production.

TABLE 5

SECTORIAL DISTRIBUTION OF PETROLEUM CONSUMPTION IN PAKISTAN

Sector	Petroleum Products Consumption (metric tons)	Percent of Total Consumption	Annual Average Compound Growth Rate, 1971-1979
Domestic	680,974	17.5	8.7
Industry	202,752	5.2	- 3.9
Agriculture	234,563	6.0	- 2.9
Transportation	2,223,596	57.2	10.4
Power	15,521	0.4	-23.7
"Other Government"	533,333	13.7	- 2.7
TOTAL	3,890,739	100.0	5.0

Source: Oil Companies Advisory Committee, cited in Energy Year Book 1979.

Natural gas ranks just behind petroleum as the main source of commercial energy for Pakistan. As a purely domestic resource, the expanding place of natural gas is the key to any significant degree of energy independence for the country. Gas production between 1971 and 1979 grew at an annual compound rate of 8.5 percent. The bulk of gas produced is "field" gas, although production of "associated" gas has a slightly higher growth rate.

In the preceding Table 4 industry was shown to be the largest consumer of commercial energy overall, though it consumes only a small fraction of oil. Industry's main source of energy is natural gas. Table 6 gives the sectorial breakdown of gas consumption. Industry's portion of around 60 percent of consumption has roughly remained the same since 1971, although volume of consumption has jumped by over 70 percent. As for other sectors, the volume of gas used in the power sector has been constant since 1976, while residential and commercial consumption have grown rapidly.

TABLE 6

NATURAL GAS CONSUMPTION BY SECTOR IN PAKISTAN 1978-1979

Sector	Gas Consumption (MMCFT)	Percent of Consumption	Annual Compound Growth Rate, 1971-1979
Residential	12,110	6.3	27.0
Commercial	6,063	3.1	17.0
Cement	24,256	12.6	5.7
Fertilizer	39,749	20.6	8.6
Power	60,758	31.6	5.6
G. Industries	49,632	25.8	8.7
TOTAL	192,568	100.0	8.1

Source: Gas Distribution Companies, cited in Energy Year Book 1979.

Table 1 reports coal as providing over 5 pecent of Pakistan's commercial energy supplies in 1978-1979. This proportion has fallen steadily from 8.3 percent in 1971-1972, with actual volume of coal production increasing only slightly during that period.

Pakistan's coal reserves are not large, estimated at 480 million tons, but they represent an as yet undeveloped source of commercial energy for the country. In 1978-1979, 94 percent of energy produced from coal was consumed by the brick-kiln industry. Other uses were in the domestic sector, power generation and "others."

Electrical Power Consumption: Pakistan's installed electrical generating capacity is 3353 MW in 1979-1980. Hydrocapacity is 47 percent (1567 MW) of the total; thermal capacity is 49 percent, and nuclear capacity is 4 percent.

Overall, electricity makes up 30 percent of Pakistan's total energy supply, of which 18 percent is hydro-generated electricity. In 1978-1979, electricity generation reached 14,174 GWH. Hydroelectricity produced 58 percent of this total. This denotes a higher percentage use of hydro capacity than thermal, inasmuch as thermal installed capacity, being larger, produced just 41 percent of total Kwh. The main fuel used in thermal generation in 1978-1979 remained natural gas (98 percent).

Electricity consumption grew at 7.7 percent annually in 1971-1979. Table 7 gives the sectoral distribution of energy consumption in 1971-1972 and 1978-1979, as well as each sector's consumption growth in that interval.

TABLE 7

SECTORAL ELECTRICITY CONSUMPTION IN PAKISTAN

Sector	Percent of Total Electricity Consumption, 1971-72	Percent of Total Electricity Consumption, 1978-79	Percent of Annual Compound Growth Rate
Residential	12.0	23.0	18.6
Commercial	7.0	7.5	8.6
Industry	54.0	40.0	3.3
Agriculture	18.6	20.0	8.8
Street Light	0.6	1.1	18.6

Source: Energy Year Book 1979.

The decrease in industry's share of electricity consumption due to a slow annual growth rate, is indicative of the low utilization of industrial capacity during a period of high inflation.

Energy Prices: Commercial energy prices are set by the government, as the cost of delivering the product in question at Karachi, rather than by the marketplace.

Crude oil prices are determined by law and by consideration of Persian Gulf prices of similar quality crudes. Product prices are set so that the margins of refineries, distributors, and freight concerns, as well as the consumer price, give allowance for needed rates of return and consideration of the consumer. As transportation costs increase, taxes are reduced accordingly to keep costs constant. No preference is shown to rural consumers. The most significant subsidy, however, is the low price of kerosene, "a common man's fuel." As of May 1979, kerosene was priced at 1.00 Rupee per liter, gasoline at 3.20 Rupees per liter, and furnace oil at 800 Rupees per ton.

Natural gas prices, claimed to be the lowest in the world, reflect government policy to allow mining companies to recoup exploration and development costs, reap a fair profit, and include purification, transmission and distribution charges for gas companies. Prices as of May 1979 were:

Government Industries	9.32/8.82 Rupees for first MCFT
Commercial	17.20 Rupees for first MCFT
Domestic	9.60 Rupees for first MCFT
	12.00 Rupees for over first MCFT

Electricity prices in Pakistan are believed to be heavily subsidized by the government. Certain rates, effective in mid-1979 are:

Domestic and General:	.26 Rupees/kwh for 1 - 20 units .29 Rupees/kwh for balance
Office and Commercial:	.66 Rupees/kwh for 1 - 100 units .74 Rupees/kwh for balance
Agricultural, e.g., Tubewells, Life Pumps in Quetta (Baluchistan), and NWFP	6.00 Rupees/kw/month + 0.10 Rupees/kwh

Energy Prospects: Pakistan has a diverse energy resource base and seems, at least temporarily to lessen its dependence on imported oil. However, the latter still accounts for 36 percent of all commercial energy requirements which will cost $925 million in fiscal year 1979/1980.

Energy strategy seems focused on the development of nuclear energy to reduce oil imports further, thus at least partially offsetting price increases, and increased domestic production.

Since 1973, oil concessions have been granted to 11 international companies, who now participate in the exploration and development of Pakistan's oil and natural gas resources. The projected impact of these resources on Pakistan's present energy situation by 1985 is subject to disagreement. A World Bank assessment, made in early 1978, anticipates that Pakistan could increase its oil production to approximately 45,000 barrels per day by 1985, which would meet more than half of domestic needs. The same report cited Pakistani plans to increase natural gas production to 900 million cubic feet per day by 1985. However, Pakistani officials point out that the rate of new oil/gas finds is slowing down while demand is increasing, making it increasingly difficult to achieve "self-reliance" in petroleum products. Other assessments, local and foreign, question the ability of Pakistan to attract the large financial capital required to exploit these resources in a degree commensurate with expected energy demand. Recent events in Afghanistan have not helped Pakistan's ability to obtain such capital. In addition, some potential fuel reserves are said to be in the Baluchistan province, near Iran, where local tribesmen, complaining of central government indifference, are seek autonomy.

Pakistan faces serious energy supply problems in the face of expanding energy demands between now and 1985. Domestic resources are not likely to be developed in the oil and natural gas sectors to enable any substantial reduction in the oil imports situation by that time. Pakistan will be far from energy independence. Energy and/or financial shortfalls could slow down or stop economic activity in a number of sectors.

Electric Power Strategy: A variety of organizations and governments have assisted in development of Pakistan's electric power sector. These include the World Bank, the Asian Development Bank, West Germany, Japan, France, Canada, Great Britain, China, Arab countries, and the United States. Almost without exception, assistance has been for the generation and distribution of electricity in urban areas.

Bids were opened in 1979 for the Pipri Thermal Power Station, Karachi. This project is scheduled to be a 200 MW thermal generating station, capable of ultimate expansion to 1000 MW. Total foreign exchange costs are to be covered jointly by the Asian Development Bank, the Saudi Development Fund, and French government aid. Project completion date is set for 1982.

Feasibility studies were outlined in 1979 for a coal-powered station at Sind. Size of the station is expected to be 250 MW and the estimated completion date is 1985. The Japanese government is likely to be the funding source for this project on a collaborative basis.

In 1979, two 50 MW units at the Kotri Gas Turbine station were commissioned. At Korangi town, a gas turbine power station of 90/100 MW was also put into operation. Sources of funding for these projects were not specified.

1979 was also to have seen the initial implementation stages of a U.S. funded rural electrification project. However, the proposed $39 million project was cancelled due to political conditions. The degree to which other projects undertaken in Pakistan have been affected by these same circumstances is uncertain. However, it has been acknowledged that aid inflow to Pakistan was reduced during 1979.

7.4 Village Survey

Demographic Base: Of Pakistan's population of approximately 74 million people, some 74 percent, or 55 million, live in rural areas in some 43,000 villages. Only 6000 of these villages are electrified, leaving perhaps as many as 47 million Pakistanis without electrical power. Of the remaining 37,000 villages without electricity, 20,000 are so located that it is impractical, given current costs for running transmission lines or natural gas pipelines, to bring conventional electrification or natural gas to them. Currently, the government is electrifying villages at the rate of less than 1000 per year.

Noncommercial energy sources for these villages include fuelwood, animal dung, crop residue, etc. All are consumed at considerable cost to the environment and/or health of rural communities. Nearly half of the growth in energy demand of the rural areas is met from these noncommercial sources. This growth in demand has produced extreme soil erosion, in some cases, depletion of the limited forest resources of the country and reduction in the cash crop value of fruit trees in northern areas.

Village Electrification: Between 1964 and early 1978, Pakistan electrified 3594 villages. Much of this rural electrification occurred in a haphazard fashion and at the expense of technical and economic efficiency. Over the five-year period, 1972-1972 to 1977-1978, rural electrification programs received $99.1 million million, or 9.6 percent, of total power sector budget allocations. This total went for the electrification of some 2900 villages.

As was previously stated, 20,000 of Pakistan's villages are located in areas to which the running of transmission lines is increasingly cost prohibitive. If these villages are to be electrified without reliance on fossil fuels or extremely costly large-scale hydroelectric generating schemes, renewable, nonconventional energy sources will have to be considered.

7.5 Solar Electric Potential

Current Solar Activity: A number of governmental agencies have been sporadically involved in solar energy development. The Pakistan Atomic Energy Commission, the University of Peshawar, and the Engineering University at Lahore are conducting activities related to solar energy. A recent survey of renewable energy-related foreign assistance programs showed Pakistan to be receiving assistance in a number of areas. Canada was funding a $500,000 study on hydrogeneration; Switzerland was supporting an afforestation project (amount unspecified); the United States had a $500,000 nonconventional energy project; and the UNDP had provided $47,000 for development of a rural energy center. The degree to which these non-U.S. programs are still functioning in Pakistan is unknown, but the U.S. program is for the moment suspended. These programs indicate an interest in exploring renewable energy alternatives on the part of the government of Pakistan.

Solar enegy has for some time been cited for consideration in Pakistan. A 1976 description of the country's program stated that research and development of solar energy began with the Pakistan Atomic Energy Commission early in the 1960's and dealt with: water heaters, solar water pumping, photovoltaic conversion, and solar desalination. The program was subsequently taken over by the Pakistan Council of Scientific and Industrial Research (PCSIR). This effort was expected to develop into a national solar energy institute. Other evidence suggests PCSIR has expanded its program to include radiation measurement, air heaters, solar cooling, and an 8000 gallons per day solar still. In 1977, the Energy Resources Cell (ERC) of the Ministry of Petroleum and Natural Resources began a small solar cooking/water heating project with rural applications. Experimental work in biogas had also begun, and consideration was being given to studies of wind-powered water pumps and to initiating drilling for geothermal resources. For all such projects, the ERC now acts as the principal coordinator of solar energy development.

Suggested Solar Projects: The manner in which the Energy Resources Cell addresses the role of solar energy in Pakistan could be considered a model for developing countries. A competent local staff of engineers, economists, and technicans has been assembled to address systematically the requirements of energy in urban and rural development programs, and on its own initiative is undertaking R & D programs in renewable resources. In the field of photovoltaics, several projects are being considered. The most notable of these is the electrification of a village near Islamabad, Tara Garh, beginning with street lighting and later including domestic power and water pumping. The major uncertainty appears to be the source of funding. With the US-AID program temporarily in limbo until U.S./Pakistan relations are regularized, the ERC is looking towards other sources, including the World Bank and UNDP, who are interested in participation.

After photovoltaics have been proven successful in a series of demonstration projects, the ERC intends to take steps to manufacture solar cells in Pakistan.

In the interim, several government ministeries in Islamabad involved with remote communication have expressed an interest in solar power systems for remote inaccessible sites, e.g., in the northwest mountains and in desert areas of Baluchistan. They remain to be convinced of the reliability of photovoltaics, and especially performance during long periods of cloud cover.

List of Principal Contacts

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Asif Ali Sheikh Vice-Chairman Appropriate Technology Development Organization Ministry of Science and Technology Government of Pakistan Islamabad, Pakistan tel: 24483	Focuses on mini-hydel power systems and other locally-constructed energy and agricultural production facilities
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Wasiq Mahmood Divisional Engineer HF Construction Telephone House islamabad tel: 22833	Designing power systems for remote communication facilities
Zeirllah Khan Survey Engineer T & T Directorate Islamabad, Pakistan	
Mohammad Javed Director, Microwave Development Region/Islamabad	
J. F. Hanks Rural Development Officer USAID c/o American Embassy Islamabad, Pakistan	Principal USAID energy specialist
Jamil Nishtar, Chairman Agricultural Development Bank Islamabad, Pakistan tel: 26746	Interested in financial solar electric projects

SOUTHEAST ASIA

D. SOUTHEAST ASIA

1. Introduction and Overview

The in-country surveys of Southeast Asia were conducted in March of 1980. The four countries selected, the Philippines, Thailand, Malaysia, and Indonesia, were chosen because they were thought to represent the greatest potential market for village power due to their location near or on the equator, a not well developed electricity grid, active rural development programs, and relatively stable governments, currently operating in a peacetime economy.

Two of the countries have distinctly different conditions than the other countries included in this study, due to the fact that their land area consists of a large number (over 20,000) of islands. This situation naturally results in a large number of isolated remote villages, not likely to be connected to a national electricity grid, making them ideal candidates for distributed power generation, such as photovoltaic power systems. In Southeast Asia, over 90 percent of the population live in villages and their livelihood depends on agriculture. Their diet consists mainly of rice, with a small amount of fish and vegetable. Although in many countries improved roads have opened villages to the 20th century, traditional customs dictate the life of people in most rural areas.

In general, the people in the rural areas are not sharing in rising prosperity in these countries, and so the gap between the rich and the poor is widening even further. As a result, while the cities are modernizing and the city dwellers have more and more of the advantages economic development can provide, the villages and the villagers remain tied to agriculture and to a way of life that has existed basically unchanged for centuries.

This situation creates a problem in Southeast Asia as well as in the developing countries in Africa. The people who want to improve their way of life migrate to the cities. The result is a two-edged problem: the cities become overcrowded and crime-ridden, and the country loses some of its agricultural potential. It is primarily for this reason that the government planners are so concerned with rural development and rural electrification. Availability of electricity in the villages will not only provide better living conditions, but can also provide the tools to allow improved agricultural techniques as well as the possibility for development of cottage industries.

It is important that the government planners are made aware of the viability of photovoltaics as another energy option for their use in rural electrification. In several of the countries visited this awareness is just beginning to develop, but it needs more stimulation.

2. Philippines

2.1 General Information

The Republic of the Philippines is composed of an archipelago 1100 miles long and consisting of over 7000 islands. The majority of the over 40 million people live on the 11 largest islands. The entire archipelago lies within the sunbelt (0 degree to 20 degrees NLAT). The larger islands are mountainous and although the climate is tropical, the rainfall varies by location due to wind directions and the shielding effect of the mountains. An average of 15 typhoons strike the islands each year.

The Philippines is blessed with extensive mineral and forest resources, generally adequate rainfall, and is located in a fertile fishing belt. As a result, agriculture, forestry, and fishing are the most important sectors of the economy with mining and industrial production growing rapidly.

The Philippine trade balance has been negative since 1974 due primarily to imports of oil. Their oil bill in 1978 was over $1 billion and represented over 80 percent of the trade deficit in that year. It is expected to exceed $2 billion in 1980.

2.2 Energy Situtation

In the mid-sixties, the Filipino population of 36 million was consuming an average of 1.1 barrels of oil equivalent energy per capita. By the late seventies the increased population of 45 million was consuming an average of 1.8 barrels per capita per year. This resulted in 81 million barrels of oil-equivalent-energy, approximately doubling the country's aggregate consumption. Oil has consistently represented 93 to 95 percent of these totals and until this year was 100 percent imported.

Forecasts of future demand show that by 1988 the total demand will be 192 million barrels, or an average of 3.4 barrels per capita, based on a projected population of 57 million.

It is concern over these factors that has resulted in the "Ten Year Energy Program: 1979 - 1988" under the responsibility of the Ministry of Energy. The areas of particular interest are the development of energy resources and the electrification program.

A primary goal of this plan is to reduce the dependence on energy imports from 95 percent in 1978 to 46 percent by 1988. The major thrust to accomplish this is by development of indigenous oil and coal reserves and by utilization of hydro, geothermal, nuclear, and nonconventional energy resources. The proposed mix is as described below:

National Energy Source Mix (In Million Barrels-of-oil Equivalent, MMB)

	1979		1983		1988	
	Volume	*%*	*Volume*	*%*	*Volume*	*%*
Power						
Hydro	5.558	5.96	11.285	8.75	22.317	11.62
Geothermal	0.975	1.05	5.778	4.48	9.723	5.06
Nuclear	–	–	–	–	6.518	3.39
Coal	0.257	0.28	3.053	2.37	13.535	7.05
Oil	21.195	22.74	26.864	20.83	23.659	12.31
Nonconventional	–	–	0.015	0.01	0.170	0.09
Subtotal	27.985	30.03	46.995	36.44	75.922	39.52
Nonpower						
Oil	63.669	68.32	75.488	58.53	107.134	55.76
Coal	1.538	1.65	5.569	4.32	6.340	3.30
Nonconventional	0.006	–	0.913	0.71	2.721	1.42
Subtotal	65.213	69.97	81.970	63.56	116.195	60.48
Total Commercial Energy	93.198	100.00	128.965	100.00	192.117	100.00
Oil Share (%)		91.06		79.36		68.07
Per Capita Consumption	2.0 bbls.		2.5 bbls.		3.4 bbls.	
Non-commercial Energy*	9.365		10.541		12.219	
Non-energy Consumption**	3.235		8.278		13.577	
Memo Total***	105.798		147.784		217.913	

*Includes agro-industrial wastes and charcoal only.
**Non-energy consumption refer to petroleum only.
***Memo total is the sum of total commercial energy, non-commercial energy and non-energy consumption.

The total Ten Year Program will require capital investments over $13.6 billion and a foreign exchange component of 66 percent. It will result in gross dollar savings for oil import displacements of up to $1.5 billion annually.

The planned role of nonconventional energy sources is best described by the following page taken from the Ten Year Energy Program. Note that currently solar is projected to play a relatively small role, in spite of its suitability for the widely dispersed nature of the towns and barrios and the favorable climatic conditions. As was seen elsewhere, this minimal planned use of solar is largely due to unfamiliarity by energy planners with the viability of photovoltaics as a future energy source.

The near-term thrust of the nonconventional energy program is to bring widespread utilization of these readily available energy forms to the rural areas. The program places emphasis on adapting simple and available technologies to practical applications for rural conditions. Hand-in-hand with the introduction of these low capacity but numerous utilization ends, is a simultaneous effort to develop and demonstrate higher level technologies that have potential for large-scale displacement of conventional fuels.

The program envisions to utilize direct solar radiation, wind energy, biomass including fuel alcohol, integrated rural energy systems, hot springs, and surface gas emanations. Supportive projects to back-up the proliferation of these technologies are also programmed to include public information and promotions strategies, energy surveys, and technical cooperative efforts with relevant international organizations.

Present estimates of the nonconventional energy contribution on the country's total energy mix reveals significant and far-reaching impacts especially to rural areas isolated from a grid. Alongside these benefits also, are potential urban-based applications such as commercial and industrial heating.

Among the nonconventional energy sources presently under serious consideration are managed-energy crops like *ipil-ipil* for power generation and sugar cane for power alcohol. These renewable resources offer the highest potential for contribution to the national-commercial energy mix. Consisting of power alcohol blended with gasoline in technically viable proportions, alcogas could displace as much as 15 percent of total premium gasoline consumption by the time the program shall have come to full swing.

In terms of barrel-of-oil equivalent (BOE) from these resources, the program envisions a significant rise in contribution from only 0.006 MMBOE in 1979 to 2.9 MMBOE by 1988 or a total of 12.93 MMBOE over the ten-year period. The nonconventional sector, however, provides the country with noncommercial energy at quantities easily greater than ten percent of commercial consumption.

Energy Contribution of Nonconventional Energy Systems
(In Thousand Barrels-of-Oil Equivalent, MBOE)

	1979	*1980*	*1981*	*1982*	*1983*	*1984*	*1985*	*1986*	*1987*	*1988*
New Products										
Producer Gas	0.4	1.4	3.4	3.4	3.4	8.4	8.4	13.4	13.4	15.4
Alcohol	–	–	–	451.3	902.6	1,353.9	1,805.2	1,156.4	2,707.4	2,707.4
Biogas	0.3	0.7	1.0	1.5	2.0	2.7	3.4	4.3	5.2	6.1
Direct Solar	2.2	3.7	4.9	6.5	8.3	10.9	15.3	21.1	29.4	41.2
Dendro-Thermal	–	6.1	6.2	6.1	6.1	30.5	30.5	30.5	29.3	79.3
Marsh Gas	0.1	0.2	0.3	0.3	0.4	0.4	0.5	0.6	0.6	0.7
Wind Energy	2.4	2.9	3.5	4.3	5.1	6.2	7.4	8.9	10.8	13.2
Hot Spring	0.3	0.3	0.8	1.3	1.7	4.2	8.2	16.3	24.4	32.3
Total	5.7	15.3	20.1	474.7	929.6	1,417.2	1,878.9	1,251.5	2,820.5	2,895.6
Current Uses										
Agro-Industrial Wastes	7,004	7,214	7,430	7,653	7,883	8,120	8,363	8,614	8,872	9,139
Charcoal/Wood	2,361	2,432	2,505	2,580	2,658	2,736	2,819	2,904	2,991	3,080
Total	9,365	9,646	9,935	10,233	10,541	10,856	11,182	11,518	11,863	12,219
Grand Total	9,371	9,661	9,955	10,708	11,471	12,273	13,061	12,770	14,683	15,115

NOTES:
1. The targets are based on the assumption that the viability of all R&D systems are established.
2. Assumes positive government decision on national alcogas program by 1979.
3. Contribution by 1980 represents actual R&D installation. Figures beyond 1980 assumes establishment of viability.
4. Agro-industrial wastes includes only bagasse, wood wastes and coconut wastes partially surveyed.

2.3 Rural Electrification

The rural electrification program is under the responsibility of the National Electrification Administration (NEA). The NEA has a mandate to provide electric service to the rural population on an "area coverage" basis through rural electric coperatives. They have been supported in the planning of this concept by US-AID and the U.S. NRECA (National Rural Electric Cooperative Association).

Under this concept electric service is to be extended to remote and distant areas, supported by the dense loads and revenues from more densely populated central areas. The NEA has been assisted in this task by generous budget allocations from the Filipino National Treasury and by substantial foreign loan assistance. For example, in 1979 the total foreign loan commitments for electrification were over $218 million. Examples of loans and grants in the 1978 - 1979 timeframe are:

US-AID	$86 million	:	Rural electrification
World Bank	$60 million	:	Backbone systems
OEF (Japan)	$52 million	:	Electrification of Cagayan Valley
Germany	$21.3 million	:	Electrification of 7 islands
France	$18 million	:	Mini-hydro and dendro-thermal plants
Norway		:	Mini-hydro

In addition, discussions were going on for loans from the U.K. for $30 million for mini-hydro, and with the People's Republic of China regarding manufacturing mini-hydro power plant equipment.

Current status and plan for energization in the rural areas are as follows:

	As of Dec. '78	1979	As of Dec. '79	By 1988
Co-ops energized	88	12	100	124
Towns energized	651	178	829	1433
Barrios energized	6,995	1,823	8,818	34,000
House connections	845,137	272,858	1,117,995	5,549,000

From this it can be seen that the rural electrification program in the Philippines has been quite effective, is continuing to show results, and has established aggressive future goals. Recognition of this program is exemplified by the following letter from President Carter.

2.3 Solar Activity

As previously described, the Republic of the Philippines has already planned and is implementing programs expanding the use of hydro and geothermal to help solve their energy problems. They also have a program entitled "The National Nonconventional Energy Resources Development Program" sponsored and administered by the Bureau of Energy Development (BED) in the Ministry of Energy.

This program was initiated in January of 1977 in recognition of the necessity to develop new sources of energy to meet the increasing needs of the future. The efforts were intended to concentrate primarily but not exclusively on solar energy.

THE WHITE HOUSE

WASHINGTON

June 23, 1979

Dear President Marcos:

On the occasion of the connection of the one millionth electric meter in the rural areas of your country, I congratulate you on your outstanding accomplishment. Appropriately, the observance falls on the birthday of Mrs. Marcos, who together with you has provided inspired leadership for your program of rural electrification.

I know from personal experience the tremendous benefits which we in this country have enjoyed as a result of our own program of rural electrification, and I know that the people of the Philippines are finding as we did that rural electrification brings many blessings to the people and to the rural areas it reaches.

We are very pleased that the National Rural Electrification Cooperative Association, through the U.S. Agency for International Development, has been able to assist in your great accomplishment. I wish you continuing success as you move toward completing extension of service to all the citizens in your rural areas.

Sincerely,

His Excellency
Ferdinand E. Marcos
President of the Philippines
Manila

It was further recognized that the program should not duplicate R & D efforts being carried on in the more developed countries.

A total of 28 projects were initiated in 1978 with a funding level of over $1 million. These projects included solar water heating, solar drying, solar cooling, biomass, biogas, wind, hot springs, marsh gas, and dendro-thermal power. This last technology, dendro-thermal, consists of cultivating fast-growing trees for use as fuel in wood-fired power plants. One tree, locally called ipil-ipil, grows to adequate size for such use in 3 to 5 years. It also grows profusely in other areas of southeast Asia, and, called by other names, such as Leucaena, is being considered elsewhere for the same purpose. Recent new programs have been added, such as industrial and commercial solar water heating, village energy systems, and mini-hydro.

They have also recently received several offers of bilateral assistance from a number of foreign governments and agencies. One of these is a grant of approximately $1 million by the German government to install a 10 KW PV power plant.

US-AID has provided a loan/grant program of $8.65 million over a four year period for renewable energy development and application. Photovoltaics was originally included, and was to be jointly funded by US-AID and the Philippine government, but was reportedly dropped to prevent duplication with the German PV program. We have urged putting it back into the program.

US-AID and NRECA are apparently doing an excellent job here, and with their support early PV demonstrations can pay large future market dividends because the Philippines has the need for it and has one of the best climatic environments for solar.

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Dr. Ernesto Terrado
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3. Thailand

3.1 General Information

Thailand is located in the tropical monsoon zone of Southeast Asia. It has a population of over 45 million and an area of 200,000 square miles, extending in latitude from 6 degrees to 21 degrees north and in longitude from 97 degrees to 106 degrees east. The mainland lies within the central interior of the Indo-China peninsula. It is bounded on the west by Burma, on the north by Burma and Laos, on the east by Laos and Cambodia, and on the south by the Gulf of Thailand, Malaysia, and the Andaman Sea.

Thailand is well endowed with land, water, and labor resources for agricultural production. Agriculture is the major economic activity, contributing about 30 percent of the GDP and employing 76 percent of the labor force.

The Thai economy, like many others, is being adversely affected by the rising cost of energy, but is still growing at about a six percent real growth rate. The trade balance is unfavorable at about a $2 billion deficit. Most of this deficit can be attributed to imported oil, costing about $1.8 billion or almost a quarter of its total import bill.

3.2 Energy Situation

Thailand's energy consumption is growing at the rate of 10 percent per year. Eighty percent of this energy is supplied by imported oil. The country has very little in the way of domestic oil resources, but has begun to develop its natural gas potential in the Gulf of Thailand. First gas should begin flowing by the end of 1981 and could supplant 15 to 20 percent of Thailand's projected imported fuel costs by 1984.

There is a significant hydro-power potential in Thailand, but so far only about five percent of the potential has been developed. As a result, hydro-power meets less than seven percent of the total energy requirements. Thailand also has reserves of oil shale and lignite but doesn't have the technology to convert them.

Thailand and Indonesia have concluded a government-to-government crude oil sale which will provide about 5000 barrels of crude per month to Thailand in 1980. However, intermittent shortages of highly critical diesel fuels are expected to hamper the Thai economy.

Generation and transmission of electricity in Thailand is the responsibility of the Electricity Generating Authority of Thailand (EGAT). As of the end of 1978, EGAT had a total installed capacity of 2,806,000 KW made up of the following:

Type	Installed Capacity	% of Total
Thermal	1,702,500	61
Hydro	909,200	32
Gas Turbine	165,000	6
Diesel	29,000	1

Over half the electricity usage is in Bangkok where electricity distribution is the responsibility of the Metropolitan Electricity Authority (MEA). Electricity distribution and local generation outside Bangkok is the responsibility of the Provincial Electricity Authority (PEA). PEA employs over 300 diesel generators for local generation ranging in size from 50 to 6000 KVA with a cost of generation from 10 cents to 20 cents per Kwh.

3.3 Rural Electrification

Rural electrification is a major priority in Thailand. There are some 47,000 villages in the country, of which some 12,000 are electrified. The goal is to electrify 90 to 95 percent of the population in the next 15 years. The responsibility for this program lies with the Provincial Electricity Authority (PEA). Within PEA the program called Accelerated Rural Electrification (ARE), is the responsibility of the Office of Rural Electrification.

The planning for the program has been conducted by several consultants supported by the Royal Thai Government and US-AID. The plan consists basically of four phases. The first phase, which concludes in about a year, calls for electrification of 5000 villages. This phase was funded to a level of $125 million of which the Thai government contributed $75 million and the balance came from loans from Japan, Germany, OECD, World Bank, Canada, Kuwait, and OPEC.

Phase Two is under negotiation now and will call for electrification of 10,000 villages. This phase will be funded at a level of $250 million of which the Thai government will contribute $150 million and the balance will come from the World Bank and the Saudi fund.

Under Phase Three, 15,000 additional villages will be electrified. Another 17,000 villages are planned to be electrified by what they call contribution projects. In these projects the villages contributed 30 percent of the required funding.

For Phase Two they are looking at potential use of nonconventional energy sources. They are seriously investigating micry-hydro (1 MW and less) and have identified around 1000 potential sites. They are also considering photovoltaics as an option.

3.4 Solar Activity

Although there is no formal policy directed toward utilization of solar energy, there is a fair amount of solar activity going on. Several universities have active R & D programs. Several companies are locally manufacturing and selling solar hot water heaters. Some work is being done on solar stills, solar drying, and solar cooking. A solar air conditioner, donated by the Yazaki Corporation, is being tested by the National Energy Administration (NEA).

Both solar-thermal-electric and photovoltaics are being investigated by the Electricity Generating Authority (EGAT) as a possible source of electricity for areas remote from the utility grid. With a little encouragement, photovoltaics could very well be included as a viable option in Thailand's rural electrification program.

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Office of Rural Electrification

4. Malaysia

4.1 General Information

Malaysia is located in the sunbelt between the equator and 10 degrees north latitude. The country is divided in two parts. West Malaysia is the southern half of the Malay peninsula bordered on the north by Thailand and on the south by Singapore. The other half of the country, East Malaysia, is the northern quarter of the island of Borneo. The area of the two combined is approximately 130 square miles, with a total population of about 13 million people.

The climate is tropical with high temperatures and high humidity. It has two monsoon seasons, with as much as 160 inches of rain per year. This rainfall supports the agricultural industry, with rubber and palm oil representing two of the larger export contributors.

Malaysia has the third strongest economy in Asia, surpassed only by Japan and Singapore. It has a real GNP growth of about 8 percent and a quite favorable trade balance of about +$2 billion. This trade surplus is due to exports of rubber, palm oil, tin, and timber. It also results from exports of petroleum greater than it imports.

4.2 Energy Situation

Energy usage is growing at a 12 to 13 percent rate per year. In the power area, almost 90 percent is generated by oil-fired generators with the balance being supplied by hydro. There is significant additional hydro potential yet to be developed.

Malaysia is a net exporter of petroleum and is exploring for additional reserves. Some estimates indicate that at the present usage rate the current oil reserves could be depleted in 5 to 10 years. The country also has significant reserves of natural gas.

Malaysia has signed two bilateral energy exchange agreements with Singapore and Thailand. The objective is to allow the countries to supplement and complement each other's electricity needs.

Generation of electricity on Peninsular Malaysia is the responsibility of the National Electricity Board (NEB). NEB currently operates six main thermal plants, three principal hydroelectric stations, and numerous minor hydro and diesel installations throughout Peninsular Malaysia. The installed capacity is 1778 MW composed of 55 percent thermal, 34 percent hydro, 6 percent gas turbine, and 6 percent diesel. Over the next six years the capacity will be increased by about 2000 MW, mostly thermal. The transmission network is being expanded and will soon span the entire west coast of Peninsular Malaysia and a large part of the east coast.

Electricity in Sarawak, the largest state in Eastern Malaysia, is the responsibility of the Sarawak Electricity Supply Corporation. The current small demand here of 86 MW is supplied by diesel generators. If two industrialization projects come to pass, an aluminum smelting plant and an iron fabricating plant, the expanded demand of over 1000 MW would be likely to be fueled by natural gas which has recently been discovered in the area.

4.3 Rural Electrification

A comprehensive rural electrification program is under development. The primary effort will be to spread the nationwide grid across the country, with mini-hydro and gas or diesel generators serving areas too remote to be connected to the grid. Through 1978 a total of 4600 villages had been electrified.

4.4 Solar Activity

Several agencies of the Malaysian government are already using photovoltaic systems. The usage is not great at this point, but the potential is significant and will undoubtedly develop after the current experimentation and demonstration phase. The telecommunication agency is planning to use PV for microwave repeaters and remote radio telephones. The Draining and Irrigation Department are using PV to power flood monitoring equipment. The Marine Department and the Malayan Railway are also using solar energy for certain operations. NEB is also co-sponsoring a PV research program with CNRS of France.

Due to the well-developed national grid and the availability of other energy sources such as mini-hydro, it is not likely that PV will find wide application in village power in Malaysia, except for the rural areas of the east coast of Peninsular Malaysia, where their remoteness from the electricity grid makes it uneconomical to extend power lines. PV will, however, find widespread usage in other remote applications, such as communications.

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Chi Yok Lin
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Twenty-ninth Annual Report
National Electricity Board

5. Republic of Indonesia

5.1 General Information

The Republic of Indonesia is an archipelago nation of more than 13,500 islands extending for 3,000 miles along the equator from the mainland of Southeast Asia to Australia. A population of 135 million people makes Indonesia the fifth most populous nation in the world.

Indonesia is very rich in untapped natural resources. In addition to vast timber resources it has rich deposits of petroleum, coal, gas, tin bauxite, nickel, copper, and iron ore. Rich volcanic soil and abundant rainfall contribute to an outstanding agricultural potential.

The gross national product is among the lowest in the world but has recently been growing steadily at about 7 percent per year. Agriculture, forestry, and fisheries account for 37 percent of GNP. Exports of oil, timber, rubber, and tin contribute to about a $2 billion positive trade balance.

The vast majority of Indonesians are dependent on one acre or less of rice land and 40% are below acknowledged world poverty levels. 64% of the population live on the intensively cultivated rice growing "inner islands" of Java, Bali, and Madura. Even with a large proportion of Indonesian land dedicated to rice production, and with improved methods and productivity, Indonesia is still the worlds largest importer of rice, importing over 2 million tons in 1979.

In order to encourage greater production of other foodstuffs, the government has established a transmigration program, resettling people from Java and Bali to the outer islands. This program, with assistance from the World Bank and Asian Development Bank, will cost in excess of $500M over the next several years.

5.2 Energy Situation

Indonesia is endowed with an abundance of energy resources. Its coal reserves are estimated at 11 billion metric tons, its natural gas at 30 trillion cubic feet, its oil at 50 billion barrels. It has a geothermal potential of 1460 MW and a hydro-power potential of 31,000 MW. In spite of all this energy potential, Indonesia's energy consumption is quite low, about 30 million tons of coal equivalent. This demand is expected to grow to 237 million tons of coal equivalent by the year 2000. It is this 7 times growth that has Indonesia's planners concerned about future energy supply. Even though energy rich they want to conserve energy for future use and as a medium for foreign exchange. For this reason they are quite interested in alternate energy, including solar.

The following estimate of energy resources was prepared by the Indonesian Institute of Engineers:

Geothermal: The total geothermal potential for Indonesia is estimated at 1460 MW spread across the country as follows:

Java	890 MW
Bali	120 MW
Sulawesi	180 MW
Sumatera	270 MW
	——
TOTAL	1460 MW

In addition, there are other isolated smaller reserves which might be of significance in rural electrification programs.

Coal: Coal of varying quality is abundant in Indonesia, with estimated deposits in excess of 10 billion tons, mostly located in South Sumatera. A coal fired electricity generating plant capable of producing 3000 MW of electricity by 1994 is in the planning stages in West Java. Other smaller plants are also being planned.

Oil: Since oil was discovered in 1885 approximately 7 billion barrels have been produced, with current production runnng about 1.7 million barrels per day. Total estimated reserves are about 50 billion barrels.

Natural gas: The estimate of proven reserves is about 34 trillion cubic feet, with a large part of todays production being used to produce LNG and LPG for export.

Uranium: Several possible reserves of uranium have been discovered, and discussions of joint ventures with France to explore and develop these reserves are in progress.

Hydroelectric: The hydro power potential of Indonesia is estimated at 31,000 MW. Although the potential for development of hydro is great, its growth is somewhat constrained by the not always favorable location of potential sites and by the long lead times required for construction. The hydropower potential is scattered through the islands as follows:

Sumatera	6750 MW
Java	2500 MW
Kalimantan	7000 MW
Sulawesi	5600 MW
Irian	9000 MW
Nusa Tengarra	150 MW

In addition, mini- and micro-hydro are being encouraged to meet some of the rural electrification needs.

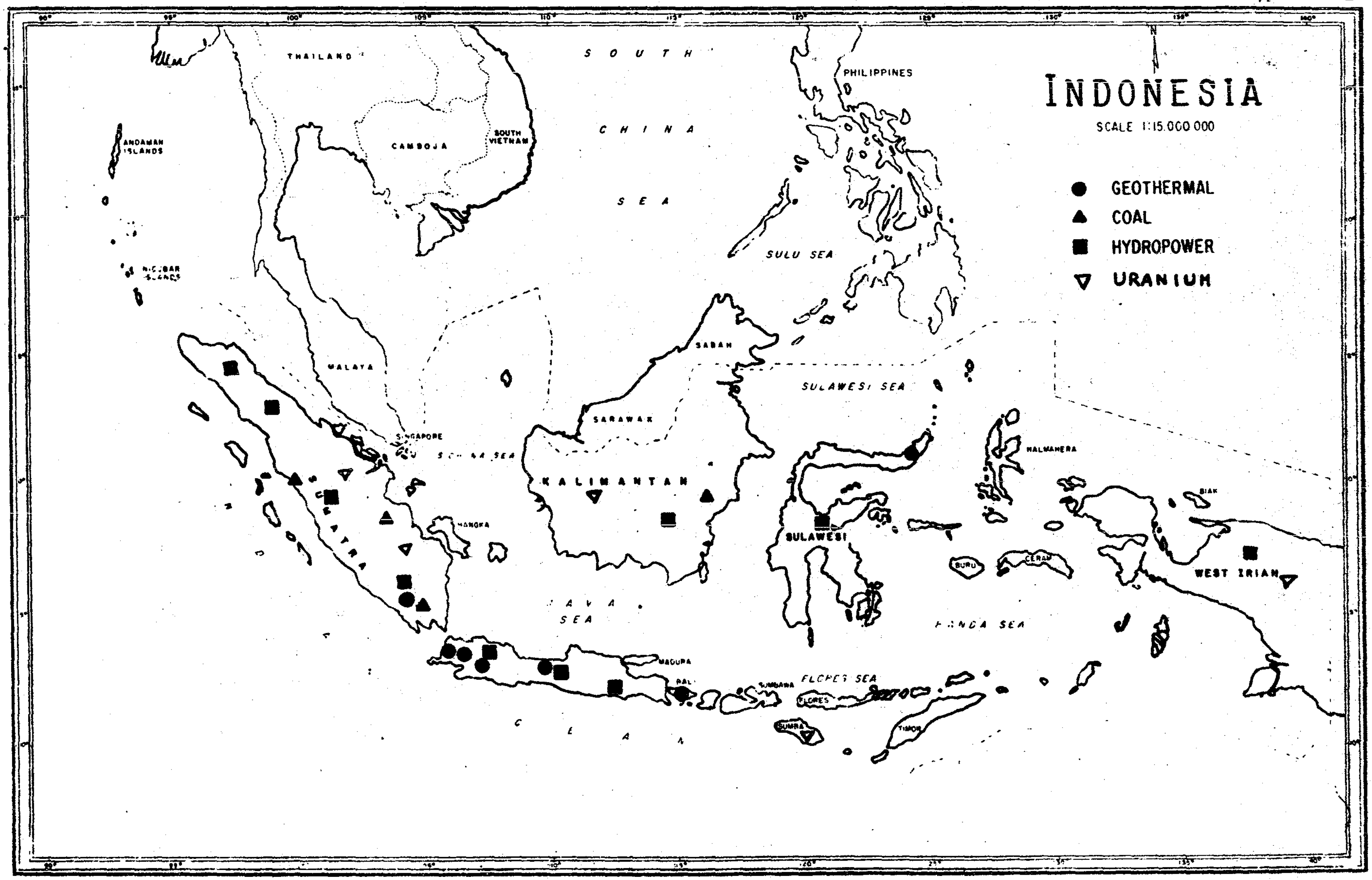
5.3 Rural Electrification

The Government of Indonesia has determined that electric service shall be an integral prt of its development program for all its people. Rural electrification is to be a key element in implementation of this policy.

U.S. AID and the National Rural Electric Cooperative Association (NRECA) are making a study and recommendations as to how this program should be carried out.

MAP OF ENERGY RESOURCES OF INDONESIA

Appendix 1



Their findings indicate that the natural wealth of forests and agricultural land, mineral, and water resources is largely still untouched. The people have not benefitted from this wealth of resources. Rural electrification is essential in opening the country's wealth to development, and benefitting the large percentage of the population which is impoverished.

In the near term, sources of energy for generation of electricity is not the problem. The problem is more associated with distribution of electricity. The modularity of PV and the ability to locate the source of energy where the demand is makes PV an extremely attractive option.

Availability of electricity will encourage the development of cottage industry, which will increase jobs and income, which will result in greater demand for household electricity. In the early stages of development, demand for electricity feeds on itself and multiplies rapidly.

U.S. AID and NRECA are recommending a system of rural cooperatives, patterned after the successful rural electrification program in the U.S. in the 1930's and the more recent program now underway in the Philippines. A successful program such as this can result in Indonesia becoming a major economic factor in the world.

5.4 Solar Activity

A fairly active solar program is underway in Indonesia. In addition to R & D work being done in the universities, a number of governmental agencies have active programs in solar.

One of the more active agencies is the "Agency for the Development and Application of Technology." They are in the process of developing the "Center for Research, Science, and Technology." This center will have numerous laboratories with capabilities in materials testing, aeronautics, energy, thermodynamics, etc.

One program currently under their responsibility is a PV powered village. This village has a PV array of 5.5 KWp which was installed under a grant by the Federal Republic of Germany. The primary purpose of the array is to power an irrigation pump. It will pump water from the nearby river into the rice fields which the villagers depend on for their livelihood. Irrigation during the dry season is planned to increase the rice output from the current one crop per year to two.

The PV system, manufactured by AEG-Telefunken, consists of 9 arrays of 72 modules each of cast-polycrystalline silicon wafers. The modules are 8" X 24" and contain 36 1-1/2" cells, encapsulated in a sandwich of glass, silicone, cell, silicone, and glass. It is a 60 volt array and has 420 AH of battery storage using VARDA lead acid batteries. The system originally used an inverter and a 2.2 KW AC motor and pump. At the time of the visit the system was down due to problems with the inverter. They are now planning to connect the system to a 1.5 KW DC motor to drive the pump.

Other activities involving Solar are as follows:

- Indonesian Institute of Sciences is doing research on PV applications.

- Bandung Institute of Technology is working on pyrolitic conversion, biogas, and solar water heating.

- GAJAH MADA University is working on solar dryers and ammonia systems.

- Bogor Institute of Agriculture is doing research of solar refrigeration.

- University of Indonesia is working on solar water heaters and meterological data for solar energy.

With the Republic of Indonesia emphasizing conservation of petroleum and the need for rural electriciation, coupled with the widely dispersed nature of the country, photovoltaics should be a highly desireable alternative for village power.

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Elizabeth Bollman

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NRECA

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LATIN AMERICA

E. LATIN AMERICA

1. Region Overview

The countries included in this section are Mexico, Brazil, Peru, and Colombia. Mexico and Brazil were selected because of their probable large potential. Peru and Colombia were selected as being representative of the other South American countries in the sunbelt.

This overview section will concentrate on South America, since the countries in this geographical region have many similarities, whereas Mexico's situation is different enough to warrant separate consideration.

South America is the fourth largest of the continents, having an approximate area of 6,879,000 square miles and a population of approximately 186,000,000 people. Two countries, Brazil and Argentina, make up over 60 percent of the total land area. The population is concentrated in densely populated urban areas, with large scarcely populated rural areas. The migration to the cities is on the increase and is largely uncontrolled.

The climate varies from the tropics of the Amazon basin to the Atacama Desert along the west coast which is one of the driest areas in the world. Although some areas may receive up to 150 inches of rainfall a year, most of the continent has abundant sunshine.

South America is well endowed with petroleum. Venezuela has the greatest wealth of petroleum reserves, estimated at over 18 billion barrels, which makes it among the largest in the world. Argentina, Colombia, Peru, and Bolivia also have large proven reserves. In addition, South America has large undeveloped hydroelectric potential, as well as other renewable energy resources, such as agricultural wastes, biomass, geothermal, and solar. These renewable energy resources will undoubtedly begin to play an increasingly important role in the region, particularly in view of the growing interest in "self-sufficiency," in part brought on by the past oil crises and the uncertainty of oil supply in the future.

Unfortunately there is not a widespread awareness of solar as a viable energy source. Only in the area of communications are photovoltaic systems finding much usage. Village power requirements are being satisfied by diesel generators, with mini- and micro-hydro being considered for future use. The region does have a large potential for solar, but it will take a great deal of external stimulation to cause the market to develop.

2. Mexico

2.1 General Information

Mexico, with its fast growing population of about 65 million people, is a politically and economically stable country, having a broad agricultural base and a rapidly expanding industrial plant. It is in the enviable position of being the world's fifth largest oil producer. Oil fueled the Mexican economy to a growth rate of 8 percent in 1979. This was the highest growth rate in 10 years. Mexico should see similar growth in 1980, with foreign exchange earnings from oil and natural gas trebling from 1979 to 1980.

The U.S. is by far the major trading partner with Mexico. In 1979 the U.S. accounted for 63 percent of the imports into Mexico, and purchased 69 percent of Mexico's total exports. This trade relationship is due partly to the geographical proximity which permits fast delivery, lower transportation costs, and easily accessible servicing and technical assistance. This trading advantage is being countered by aggressive marketing offensives by Japan, Germany, France, Canada, and Brazil. These countries want to share in Mexico's oil wealth and economic boom.

2.2 Energy Situation

Even though Mexico's oil reserves may remove the urgency other countries feel to develop new sources of energy, the country has ambitious plans for decreasing reliance on hydro-carbon fueled energy, which now accounts for over 67 percent of the power generated. This is partially due to the rapid increase in demand for electricity, fueled by the economic boom. The Federal Electricity Commission (CFE) originally was working with a six year plan to increase installed electric generating capacity by 87 percent, to 19,800 MW by 1982. This was supposed to leave a reserve cushion of 20 percent. New projections indicate that this capacity will be barely adequate to meet the anticipated demand and must be increased to meet the 1982 goal and even greater anticipated demand for 1990.

Over the next three years CFE plans to spend $6 billion on projects to double its hydroelectric generating capacity (currently representing 31 percent of total generating capacity) to 826 million KWh. It will also bring Mexico's first coal and nuclear power plants on stream.

Mexico's estimated hydroelectric capacity is around 172,000 GWh per year. At present less than 20 percent of known potential is being harnessed by the 100 generating plants in operation. While much of the new capacity gained in the next few years will be hydroelectric, Mexico is not counting on it to play a very large role in the long term. This is due to the fact that much of the potential is concentrated in a few areas of the country, not always located economically close to the areas of greatest demand.

Proven coal reserves in Mexico amount to about 3.3 billion tons. About 480 million tons of it is high enough quality to be used for generation of electricity. The first major coal-fired plant will go on stream late in 1981 and will ultimately add 1200 MW to Mexico's power capacity. Other planned expansions would bring the capacity up to 8400 MW by the year 2000, satisfying about 12 percent of the estimated national demand at that time.

Current plans are for nuclear to provide as much as 25 percent of the power needs by the year 2000. Their first nuclear plant is due to come on stream by 1983. It will initially have a capacity of 654 MW but is planned to be doubled one or two years after operations begin. Mexico has proven uranium reserves of about 10,000 tons, but possible reserves could run as high as 500,000 tons.

Mexico is currently producing oil at the rate of 2 to 25 million barrels per day of which about 1 million barrels per day is exported. Proven reserves are estimated at 200 billion barrels. Natural gas reserves are estimated at 12 trillion cubic feet. Even though these reserves provide Mexico with a fairly secure near-term energy future, the stated policy of the government is to develop the electrical power system through the use of resources other than petroleum.

Currently geothermal plays only a minor role in Mexico's power requirements, but is planned to gain in importance in the future. The largest plant in operation today has the capacity of 150 MW which is to be increased to 400 MW in the future. Approximately 130 more areas have been identified which may have good geothermal potential. Exploration work is going on to try to prove their potential.

2.3 Rural Electrification

Over 60 percent of Mexico's population are living without the benefits of electricity. There are over 100,000 villages in Mexico, of which 80,000 are unelectrified. Most of them are also without telephone or emergency communications. Many of the villages are inhabited by less than 100 people.

In order to cope with and solve the problem, the Mexican government has developed a 10 year plan by state. One aspect of the plan is to try to consolidate the smaller villages of 100 or less people into larger villages with a goal of consolidation to 40,000 villages total.

Another part of the plan is to provide at least one rural telephone for each village. Initially telephones would be installed in 18,000 of the villages which already have electricity. Later stages of the program would extend the rural telephone system to the other villages. It is quite likely that the first use of photovoltaics in remote villages in Mexico will be to power these remote rural telephones.

2.4 Solar Activity

While solar is not currently planned to play a large role in the energy picture in Mexico, there is a lot of solar activity. In addition to basic research being done at several Mexican universities, photovoltaics is being seriously considered for communications and instrumentation applications. There are currently over 200 PV systems installed in NAVAID applications.

Several programs utilizing PV for village electrification are under consideration. The Mexican government agency responsible for solar energy "Direccion General de Aprovechamiento de Agua Salinas y Energia Solar" has been developing plans to use PV to provide power to a village of about 60 people. The system would provide water pumping, lighting, and refrigeration. In addition the Mexican government has been discussing an energy program with the U.S. Department of Energy which would also include a PV village power program. This program is currently undergoing revision to make it fit in with the National Development Plan which includes refurbishing existing villages. There is also rumored to be a joint Mexican/West German program to use solar to electrify villages in Baja California.

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Direccion General de Telecommunicaciones

Carlos Gonzalez Ochoa
Hector Arellano Moreno
Jose Niceford Sanchez Tejada
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Telefonos de Mexico

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3. <u>Brazil</u>

3.1 General Information

With a population of 117 million people, Brazil is the most populous country in Latin America and the seventh most populous in the world. Half of the population lives in the urban areas, with 12 million living in Sao Paulo, 9 million in Rio de Janiero, and 2.2 million in Belo Horizonte.

Brazil's area of 3,286,000 square miles makes it the fifth largest country in the world. It is made up of 4 topographic regions: densely forested lowlands in the north (undeveloped basin of the Amazon River), the semi-arid scrubland of the northeast, the rugged hills and mountains of the central west and south, and the 4500 mile long narrow coastal belt. Almost all of the country lies within the tropics with a warm humid climate with moderate to heavy rainfall.

This climate is quite favorable to agricultrue, which employs 38 percent of the total work force. Coffee, soybeans, and sugar are the main foreign exchange earners, representing over 40 percent of Brazil's total exports.

The industrial sector represents over 33 percent of the GDP and is heavily concentrated in the southeast, while the northeast is "poverty stricken" and underdeveloped, plagued with periodic droughts in its semi-arid backlands. There are two regional development agencies: SUDENE (Superintendencia de Desenvalvimento do Nordeste) and SUDAM (Superintendencia de Desenvalvimento do Amazonia). These agencies intend to attract both foreign and Brazilian investments in the northeast and Amazon regions through incentives and subsidizing financing through regional development banks.

Brazil's growth rate of nearly 9 percent per year has in the past represented a significant export opportunity for the U.S. Brazil buys about 22 percent of its total imports from the U.S. and sells about the same percent of its exports to the U.S. The escalating cost of oil has contributed to a balance of payments and inflation problem for Brazil. Where oil used to represent 10 to 15 percent of total imports, it now represents about half. This has resulted in imposition of import restrictions to attempt to rectify the balance of payments problem. It has also resulted in encouragement of joint ventures with foreign companies, particularly in high technology industries, designed to produce equipment locally rather than import.

3.2 Energy Situation

Oil currently supplies over 50 percent of Brazil's total energy needs. Consumption is down from past usage resulting in a decrease of imports from the 1 million barrels per day level of a year ago to 850,000 barrels per day. The majority of this oil has come from the Persian Gulf, mainly Saudi Arabia and Iraq. Recent problems in Iraq have resulted in Brazil replacing some of the shortfall with additional oil from Indonesia, Gabon, Russia, Ecuador, and Venezuela. The government's goal is to dramatically decrease the use of foreign oil by 1985. Late last year the Ministry of Mines and Energy (MME) announced a series of very ambitious targets by which Brazil would reach that goal. The assumption was that the country would be consuming 1.7 million barrels per day by 1985. The proposed mix would be:

Imports	500,000 BPD
Domestic oil	500,000
Conservation releases	140,000
Coal	170,000
Shale oil	25,000
Alcohol	170,000
Charcoal	120,000
Hydro-conversion	60,000
Other, including solar	15,000

This goal is believed to be quite optimistic, particularly the 500,000 BPD of domestic oil. A more realistic goal for domestic oil is thought to be 300,000 to 375,000 BPD.

An important contributor to the imported oil reduction program is the "Proalcohol" program, the National Alcohol program. Its goal is to be producing 10.7 billion liters of alcohol in 1985. Brazilian cars are already running on this alternative energy source. By 1987 they will be producing 14 to 15 billion liters, equivalent to what is being consumed in gasoline today. Already 57,000 cars are operating on ethanol with a 1982 goal of 900,000 cars manufactured to run exclusively on this fuel, and another 270,000 converted from gasoline operation. A side benefit of the program is the employment of 200,000 workers in the sugar cane fields and a forecast of another 150,000 jobs as the program expands. This aggressive program can result in alcohol providing 10 percent of Brazil's energy needs by 1985. The Brazilian government will invest $5 billion in alcohol production over the next five years.

"Procoal," the National Coal program, is expected to make a similar contribution by 1985. Planned production of 27.5 million tons in 1985 represents a 5-1/2 times increase over today's production.

Hydroelectricity is another important source of energy. Electrobras, the state electric energy holding company, estimates the country's hydroelectric potential at 200 million KW, of which only about 28 million KW has been harnessed. In addition to conventional large hydro projects, serious consideration is being given to low-head hydro and mini- and micro-hydro.

Since the major portion of Brazil's hydroelectric potential in the industrialized southeast region will have been harnessed by 1990, the government initiated a large scale nuclear power program in 1970. U.S. companies were selected to provide the nuclear technology and equipment, but opposition in the U.S. to export of nuclear technology caused the Brazilian government to look elsewhere for support. In 1975 Brazil signed a 15 year agreement with the West German government to develop the nuclear energy program.

By 1990 the Brazilian nuclear generating capacity will be over 10,000 MW. Over this time period a total of $8 - 10 billion will have been spent on the program.

3.3 Rural Electrification

Somewhat less than 8 percent of Brazil's 4.5 million rural properties are served with electricity. As a result, several rural electrification programs have been initiated. In the 1976 - 1978 program $230 million was spent increasing the number of farms electrified by 83,000 to a total of 350,000 farms. In 1979 $75 million was spent to serve an additional 22,500 homes. Almost all of this additional coverage was accomplished by extension of electric utility power lines.

Small gasoline generators are used by small farmers remote from the grid. It is estimated that approximately 10,000 of these generating sets of 5 KW or less capacity are imported into Brazil each year, most from Japan.

3. Solar Activity

Because of the intense interest and major effort in the alcohol, coal, and hydro programs, relatively little attention has been paid to solar. Some market exists for solar hot water heating and is being satisfied by local manufacturers. Some PV research is being done in the universities, after sponsored by West Germany and France.

Promotional activities in photovoltaics, particularly with an effective demonstration program, could stimulate the development of the market for PV in Brazil, initially for agricultural applications such as water pumping. Any marketing program here should include plans to assemble modules locally or license their manufacture.

4. Republic of Peru

4.1 General Information

Peru is located on the westernmost tip of the South American continent on the Pacific Ocean. It is the third largest country in South America (after Brazil and Argentina) and shares the same borders with Ecuador, Colombia, Brazil, Bolivia, and Chile. The coastal area is arid with mild temperatures throughout the year. Most of Peru's economic activity is concentrated in this region. In fact, 50 percent of the entire population lives there and produces nearly 70 percent of the country's GNP. Other regions are the Andes mountains which occupy about 30 percent of the country's land and the eastern lowlands which occupy more than 50 percent of Peru's total land area. Peru's population is just over 20 million, the capital, Lima, having a population of about 5 million people. About 50 percent of the population is urban.

Peru is known for its rich mineral resources, in fact 56 percent of its total exports are minerals: copper, silver, petroleum, zinc, lead, and iron. Other sectors of the country's economy are agriculture and construction. Services account for about 50 percent of Peru's GDP. Other export items are cotton, sugar, coffee, and wool. Imported goods are machinery, cereals, chemical and pharmaceutical products.

Peru is a member of the Andean Pact, a trade group formed with its neighbors Colombia, Ecuador, Bolivia, and with Venezuela. Peru is also a member of the OAS (Organization of American States), the LAFTA, and the INTELSAT - USA, EEC-Japan, and the Andean Pact are Peru's major trading partners. USA investment in Peru is concentrated in mining and petroleum products. The U.S. also grants economic assistance to Peru through AID (Agency for International Development) and through the Export-Import bank.

4.2 Energy Resources

In 1978, Peru became a net oil exporter. Oil exports in 1979 are estimated at $700 million, more than the then No. 1 export - copper. Peru has one of the greatest hydroelectric potentials in the world due to its so many rivers. Despite this there was practically no construction work on hydroelectric plants during the past decade and about 50 percent of currently installed electric power is generated through thermal means. Figures in 1977 show 1136 MW of capacity of thermal plants against 1406 MW of capacity of hydroelectric plants.

4.3 Solar Energy Activity in Peru

There is practially no major government supported activity going on in solar energy in Peru. The U.S. Department of Energy and the Peruvian government have just completed a joint study on energy assessment in Peru, which will give the Peruvian government some cost and feasibility data required to embark on such alternate sources of energy such as solar, geothermal, and mini/micro-hydro-systems, all of which are abundantly available in Peru. The Ministry of Mines and Power is putting together a rural electrification project to be operational across the entire country using a combination of mini/micro-hydro and solar systems. The Ministry has also established a committee, SENAMHI, to study the various viable ways of exploiting the country's vast energy resources. The committee is working with the West German government on hydro-systems, with the United Nations on energy balance, and with the U.S. Department of Energy on the development of renewable sources of energy.

The Government Institute of Research and Development, ITINTEC, is engaged in a series of solar energy projects - solar collectors, solar dehydration systems, solar cookers, solar distillation systems, and solar photovoltaic systems. The institute is also engaged in wind power systems. There is no major project in photovoltaics;

in fact, all photovoltaic activity is concentrated in the electronic laboratory where photovoltaic power systems are being developed for remote communication applications. The Ministry of Transport and Communications is seriously considering the use of solar photovoltaic generators to power its microwave stations across the country, especially in the mountainous regions. Even though the potential for photovoltaic power systems for village power requirements is very large in Peru, there are currently no serious plans to exploit this potential. The use of photovoltaic power systems to power remote communication equipment is likely to develop into some form of village power applications, either for water pumping in the arid zones or for lighting and educational TV's in the poor rural areas.

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5. Republic of Colombia

5.1 General Information

The Republic of Colombia, located at the northwest corner of South America, is the fourth most populous nation in Latin America, with a total population of 25 million people, spread over an area of 440,000 square miles. There has been a heavy migration from the rural to urban areas, resulting in an increase of the urban population from 40 percent of the total in 1951 to over 65 percent today.

Colombia has three main topographic regions: (1) the flat coastal areas (900 miles on the Pacific and 1100 miles on the Caribbean) interrupted by the Sierra Nevada de Santa Marta mountains, (2) the central highlands, and (3) the sparsely settled eastern plains, comprising 54 percent of the land area, but only 3 percent of the population.

The climate ranges from the tropical seacoast to the cool, relatively dry weather of the highlands. Sitting astride the equator there is a significant availability of sunlight in most areas.

Although the pace of the economy has slowed somewhat, it is still growing at an impressive 5 to 7 percent, but an inflation rate of approximately 30 percent in 1979 represents a problem being addressed by the government. Exports of $2.3 billion in 1979 were led by coffee ($1.3 billion) but were not high enough to offset imports of $2.9 billion consisting primarily of manufactured goods.

The government of Colombia has outlined its development priorities for the 1979 to 1982 period. The list of project priorities emphasize hydroelectric power, transportation, water supply, and communication.

A key part of the development strategy is solving Colombia's energy problem. After years of being a net exporter of oil they are now a net importer. This has spurred efforts in exploration for oil and development of other energy resources.

5.2 Energy Situation

Colombia's oil reserves of 903 million barrels represent the third largest reserves in Latin America. Current production of 123,000 barrels per day is down from the 1970 peak of 219,000 barrels per day. To counteract this declining production, Ecopetrol, the state owned oil company, will invest $1 billion in the 1979 - 1983 period for exploration, development, and distribution. Imports of crude will probably reach 50,000 barrels per day this year and could climb to 150,000 barrels per day if new oil discoveries do not materialize. Current exploration for natural gas reserves could relieve this problem somewhat, if successful.

Hydroelectric power represents a very large untapped potential in Colombia's energy future. An estimated 92,000 MW economically producible potential exists, of which only 2700 MW are currently operational, with another 5700 MW under construction or in the design stage. Hydropower could represent about 80 percent of the projected 23,600 MW total electrical production in 1990. The remaining 20 percent would be supplied by thermal units, either coal or gas fired.

Coal is the largest fossil fuel resource of Colombia, with reserves estimated at 11 billion metric tons. At the current extraction rate of 5 million metric tons per year, the coal reserves could last for 2200 years while the oil and gas presently known could last no more than 20 and 22 years respectively. Most of the coal is of high quality and is located near the major urban centers making its energy contribution economically feasible.

Other energy options for Colombia are being considered. There are no plans for nuclear in the coming decade, but it could contribute as much as 2 percent of Colombia's total generating capacity by the year 2000. Geothermal energy is being explored in cooperation with the Italian government. Colombia has a well developed sugar cane industry, which could be used to produce ethanol.

5.3 Rural Electrification

So far, Colombia's rural electrification plans and programs follow the classical approach of extension of the existing power grid into the isolated regions. We were unable to find any indication of plans to provide small diesel generating or mini/micro-hydro plants to serve the rural areas.

5.4 Solar Activity

As might be surmised, from the previous dissertation, solar does not currently play a role in the energy plans of Colombia. It is, however, one of the most advanced Latin American countries in using PV in communication systems. Because of the mountainous nature of much of the country, as much as 50 percent of the long distance service in Colombia is provided by microwave radio systems, providing a natural market for PV in the more inaccessible transmitter and repeater sites. Currently over 1500 rural telephone systems powered by photovoltaics are being purchased.

While village power applications may not currently represent a major PV market in Colombia, the dynamic government programs in telecommunications make it a very interesting near-term market for PV.

V. QUALITATIVE RESULTS

Before attempting to quantify the market for photovoltaics in remote village applications in developing countries, we must first identify and discuss those factors which will promote the development of the market, and those which will inhibit it. These factors will not only affect the size of the market, but also how quickly it will develop. This section of the report addresses those factors and attempts to assess the impact of them.

A. THE DEVELOPING COUNTRY DILEMMA

1. The Situation

The developing countries are faced with serious economic growth problems which are compounded by the rapidly escalating cost of energy. Energy, especially electricity, is the key to economic development. If it becomes too expensive, the relatively poor countries will be forced to delay or slow down their development program.

Major emphasis has to be placed on developing the agricultural and industrial base for these countries, but the social and economic needs of the people, both urban and rural, must not be neglected. A major problem for many of these countries is that there is an increasing migration of people from the rural areas to the cities. In most cases this migration is to satisfy the desire of the people to improve their standard of living and to share in the "good life" they believe awaits them in the cities and towns.

The result is not only overcrowding in the cities, with all the associated problems of unemployment, crime, creation of slums, etc., but also a reduction in the agricultural potential of the country.

For this reason, many of the countries realize that one way to reverse or at least slow down this migration is to improve the standard of living of the rural people and provide alternative employment for them by encouraging the decentralization of industry away from the cities. Electricity, and its many benefits, is a key element in improving the standard of living and is a prerequisite for the establishment of a productive industry.

Generally this rural electrification is accomplished by extending the existing utility grid. This may be prohibitively expensive for small loads or where necessary to traverse long distances, possibly across dense forests or jungles. This means that the smaller and more remote villages may never be reached by the grid.

Another option to electrifying these villages is to provide local generation by the use of oil fired generators. This is rapidly becoming a less desireable option due to the uncertain availability and escalating cost of oil. The cost is compounded because as oil cost increases the cost of delivery of oil to the site of use also increases. It is quite common to see diesel fuel costs, including delivery, of $2 per gallon, or more. In one country we found that diesel fuel was in such short supply that it could only be bought on the black market and cost up to $5 per gallon.

Another major drawback to the use of diesel generators in remote areas is their propensity to breakdown. Maintenance and repair capability and spare parts availability are a serious problem in developing countries and are practically non-existent in remote villages. In some situations we heard of generators that had been down 3 months waiting for a repairman. Everywhere you go in developing countries you see equipment idle and rusting due to lack of repair capability. This is a major problem which is difficult to measure in terms of cost impact.

Because most of these countries have limited sources for foreign exchange, they need and want energy sources which will allow them to reduce the requirement for foreign exchange by using as much local labor or materials as possible. This is further enhanced by their desire to be as energy independent as possible.

2. The Need

What the developing countries need, then, is a source of electricity which has the following characteristics:

Adequate availability of fuel
Reasonable cost of fuel
Fuel easy to deliver and store
Modular and scaleable in size
Equipment reliable and relatively maintenance free
Maximum local content
Minimum capital investment

3. The Solution

Unfortunately no energy source meets all these criteria, but there are a number of renewable energy sources which have many of these attributes for specific sites. Figure compares these attributes for various renewable energy sources.

ALTERNATE ENERGY COMPARISONS

	FUEL			MAINTENANCE	MODULARITY	LOCAL VALUE ADDED	CAPITAL INVESTMENT	
	Availability	Cost	Delivery				TODAY	TREND
Wind	Variable	Free	No problem	Some: moving parts	Good	Some	High	Same →
Hydro	Somewhat variable	Free	No problem	Some: moving parts	Fair	Some	High	Higher ↗
Biomass	Must be replaced	Cheap	Local labor	Some: burners, ash disposal, moving parts	Good	High	Low	Same →
Solar Thermal Electric	Variable	Free	No problem	Some: moving parts	Fair	Medium	High	Same →
Photovoltaics	Variable	Free	No problem	Minimum: no moving parts	Excellent	Some	High	Lower ↘

FIGURE 5

4. Conclusion

Renewable energy resources do provide a viable alternative for providing electricity for remote villages. The applicability of the various technologies varies dependent on the local environmental and economic conditions, and in fact combinations of these renewable energy sources may be the optimal approach for some locations.

While photovoltaics is not the panacea for the developing country dilemma, its modularity and low maintenance characteristics make it a quite appropriate alterntive for village power and will become increasingly attractive as costs continue to decrease.

B. BARRIERS AND OBSTACLES

Some of the barriers and obstacles to development of a PV remote village market have been touched on previously but will be amplified in this section.

1. Desire to electrify remote villages

Many developing countries have much higher priority problems than bringing electricity to the rural areas, but the rapidly growing consciousness of the rural poor of a better way of life being experienced by others in the same country is a factor that cannot be ignored for too long.

Some of these higher priority concerns can in fact be the forerunner of the development of village power systems. One example is the need for improved or expanded agricultural output. Oftentimes the limiting factor is availability of water. PV powered pumping systems can often be the answer, and can later be expanded to perform other village functions.

Another example is in countries where health problems represent the higher priority. Remote medical centers with refrigerators, lights, and sanitary water supplies powered by PV can be the seed which grows into a village system.

Other areas where communication or education are higher priorities could also very effectively use PV, then expand into other uses.

It follows, then, that many PV remote villages will not start out as village systems but will expand to that end as the users become more conscious of what electricity from the sun can do for them.

2. Resources to electrify remote villages

Some developing countries have the financial resources to fund these programs internally. Unfortunately, most of the countries needing electricity the most can afford it the least. There are, however, many sources of funds available to developing countries. In addition to donor groups such as the U.S., the European countries, Japan, the OPEC nations, there are many financial institutions who have and are providing development funds for rural electrification and other programs.

The World Bank is a prime example. They estimate that up to 1971 about $10 billion had been spent on rural electrification in developing countries and expected that another $10 to $15 billion would be spent in the following 10 years. The World Bank is currently planning a massive 5 year $25 billion program to help poor countries develop additional energy resources of their own. Currently, photovoltaics is planned to play a relatively insignificant role.

In addition to the World Bank there are the Regional Development banks and the commercial banks. The sources of funds are well covered in the Strategies Unlimited report to SERI, "Impact of International Financial Institutions on Markets for Solar Energy Systems" (SERI/RR-8228-1). According to this report over $64 Billion was funneled into developing countries in 1977 by these sources.

Availability of financial resources is a limiting factor, but if rural electrification has a high enough priority for a developing country, there are funding possibilities available. Before these funds can be made available, however, the lending and donor agencies have to be convinced of the viability of PV power systems as a reliable and worthwhile investment. More about this later.

3. Economic viability

Assuming that there is a desire to electrify villages, and that funds can be made available to finance the projects, are photovoltaic power systems cost effective options?

To answer this question we must first estimate the electricity needs of some typical villages. We will then compare the cost of supplying this electricity by a photovoltaic power system at various prices per watt with the other power options. These other options are extension of the utility grid and local generation by use of diesel electric generators.

3.1 Village needs

The range of electricity needs for remote villages varies widely from village to village and region to region. At one extreme are the villages who need and can afford only the bare minimum, including potable water, some lighting and a grain grinder or other food processor, possibly a medical refrigerator, and an emergency radio and an educational TV set. At the other extreme are the villages in the more developed countries which may have considerably increased electricity usage, approaching that of the rural U.S. and European towns.

Realizing that there is no such thing as a "typical" village, we have estimated the requirements of two villages which might be representative of most of the remote villages scattered around the world.

We assumed that an average village population would consist of about 500 people living in 100 homes. We then assumed two degrees of electrification: minimal and intermediate. We did not estimate the requirements for the more developed villages since they represent a small percent of the total potential. Figure 6 shows the assumptions made for these two levels of electrification.

VILLAGE POWER

TYPICAL LOAD REQUIREMENTS

Village size: 500 people, 100 homes

FUNCTION	DEGREE OF ELECTRIFICATION Minimal	Intermediate
Water		
Liters/person/day	25	50
Total usage	12.5K L/day	25K L/day
Well depth	30M	30M
Wh/day (pumping 5 hrs.)	3000 (1/3 hp)	4700 (1/2 hp)
Lighting - Indoor		
Lights/home	1	2
Wh/day (4 hrs./day)	8000	16000
Lighting - Outdoor		
Lights/village	1	5
Wh/day (12 hrs./day)	480	2400
Television		
Sets/village	1	20
Wh/day (4 hrs./day)	80	1600
Refrigerators		
Refrigerators/village	1	10
Wh/day	1000	10,000
Grain Grinder		
Grain required/person	.4Kg	1Kg
Total grain/day	200	500
Communications		
Emergency radio sets per village	1	1
Wh/day	400	400
TOTAL Kwh/day	15.5	41.1
TOTAL Kwp Required*	4.0	10.7
Average Wp/person	8	21.4

* - Based on sunlight equivalent of 5 hours of noonday sun.

FIGURE 6

As you can see at the bottom of Figure 5, the two levels of electrification average out to individual electricity requirements of 8 Wp and 21.4 Wp per person, and 4 KWp and 10.7 KWp per village. In our opinion the majority of villages ultimately electrified will be somewhere at the upper end of the range between the two examples. For this reason, for future calculations we will use an average of 10 KWp per village or 40 KWHr/day electricity usage.

3.2 Cost per KWH comparison

For the purpose of comparison we assumed an electricity requirement of 40 KWH per day for a village located 30 miles (48 Km) from an electricity grid which will supply power at the rate of 10¢/KWH. It also assumed a delivered cost of diesel fuel of $2 per gallon (53 cents per liter). To simplify the calculation and to eliminate an unpredictable variable, the cost of money for financing the project was not included in any of the three options.

Also, for a consistent basis for comparison the cost per Kwh is based on 20-year system life.

Due to the fact that the majority of the PV investment and the grid extention investment is made at the beginning of the 20 year life cycle period, the financing costs would be higher for these options than for the diesel generator option. It is our contention that, all other things being equal, the other advantages of PV, primarily minimal maintenance and minimal down-time, would outweigh the finance cost differential.

If the reader is interested in pursuing the finance cost comparison, NASA Technical Memorandum 79097, entitled "Photovoltaic Power Systems for Rural Areas of Developing Countries" provides additional information on this subject.

3.3 Grid Extension

The first option considered when planning to electrify a village is usually extension of the utility grid. In the calculation below we assumed that new generating capacity was not required to satisfy the village needs. This is not always a valid assumption, since in many of the developing countries they do not hae enough generating capacity to satisfy the needs of the cities, much less the rural needs.

Assumptions:

Electricity required	:	40 Kwh per day
Distance from grid	:	30 miles (48 km)
Cost for extension	:	$10,000 per mile
Cost of electricity from the grid	:	10 cents/Kwh (low for many LDC's)
System life	:	20 years

Twenty year life cycle cost:

20 year electricity consumption	:	40 Kwh X 365 X 20 = 292K Kwh
Cost of electricity from grid	:	292K Kwh X $.10/Kwh = $29.2K
Cost of grid extension	:	30m X $10,000/m = $300K
20 year cost of electricity + extension	:	$300K + $29.2K = $329.2K
Cost per Kwh	:	$\frac{\$329.2K}{292K\ Kwh}$ = $1.13/Kwh

3.4 Diesel Generators

After grid extension, use of diesel generators is the usual option considered for remote electricity generated. As previously described, many factors other than cost are making it a less desirable option. Cost of electricity in larger systems do, however, point up an advantage for diesels in the near term. This analysis will show that as the cost of oil escalates and the cost of PV decreases, this cost-advantage rapidly disappears.

Assumptions:

Electricity required	40 Kwh/day
Diesel generator size	4 Kw
Operating at % rated load	75%
Hours of operation	14
Fuel consumption/hour	.326 GPH
Initial cost/generator	$5K
Generator life	10 years (alternate use of prime and backup)

Twenty year life cycle cost:

4 generators (2 primary 2 backup)	$20K
Fuel (102K hrs @ $2 gal. delivery)	67.7K
Maintenance, lubrication, oil, etc.	46K
Freight, installation, etc.	2K
TOTAL 20 YEAR COST	$137.7K
Electricity generated (20 years)	306K Kwh
Cost per Kwh	$.43

3.5 Photovoltaic Power Systems

The cost of a photovoltaic power system varies by location, dependent upon the availability and intensity of sunlight in the area. For the purpose of this comparison we have used the equivalent of 5 noonday sun hours per day. Most areas between the 30th parallels have at least this much sunlight, some much more. Obviously for areas having greater than 5 sun hours per day, the cost will be lower than the example, sometimes significantly lower.

Assumptions:

Electricity required	40 Kwh/day
Sun hours/day	5
Aray size required	10 Kwp
PV system cost/Wp -	
Module	8.00
Power conditioning & instrumentation	.45
Support structures	.85
Batteries	1.50
Freight, installation, etc.	1.75
TOTAL System Cost Per Wp	13.15

Twenty year life cycle cost:

Total system cost (10K Wp X 13.15/Wp = $131,500
10K Wp X 13.15/Wp = $131,500
Total power generated
(20 years) = 306K Kwh
Cost/Kwh = $.43/Kwh

3.6 Comparison

The previous analyses show that grid extensions for small amounts of power over long distances result in quite expensive power costs. For the same amount of electricity delivered, both the diesel and the PV power systems are more economical, $.43/Kwh vs. the grid extension cost of $1.13/Kwh.

All three of these options have variables that can significantly affect their costs. Figures 7 and 8 graphically display the sensitivity to the primary variables.

Figure 6 shows the sensitivity of the cost of grid extension for different distances, and compares those costs with the cost/Kwh of PV systems for different PV system prices. The PV system prices are based on the following module and balance of system (BOS) price projections:

Module Price $Wp	12.00	8.00	4.00	2.00
BOS Prices $Wp				
Power conditioning and instrumentation	.50	.45	.40	.30
Support structures	1.00	.85	.75	.50
Batteries	2.00	1.50	1.00	.75
Freight, installation, etc.	2.00	1.75	1.50	1.00
Total system price (installed)	17.50	12.55	7.65	4.55
Cost/Kwh	$.57	.41	.25	.15

These price decreases in modules are expected to take place over the next 5 to 7 years, depending on how quickly some of the ribbon or sheet processes currently in R & D come on stream. Some of these processes may be in full production in the next 2 to 3 years, which could accelerate the price reductions.

The BOS price reduction is less dramatic. Improvement in module efficiency will result in lower BOS prices per watt. The power conditioning and instrumentation prices will decrease slightly due to improvements in performance and reduction in the cost of semiconductor components used in them. Support structure prices may be reduced by using lower cost, lighter weight materials. Currently steel and aluminum are most widely used. Plastic and possibly even wooden structures will find use, particularly in developing countries. The price per watt in freight costs will be reduced due to the reduced weight of structures, and due to supply of the heavier system components such as batteries and structures from distribution points closer to the customer, as the market develops.

The battery price per Wp reduction displayed assumes minimal real cost reduction in batteries. Any breakthroughs in that area will further reduce the storage price per watt. The reduction in price per watt shown is mainly the result of lower cost of modules, making it more cost effective to use more modules to cover seasonal weather variations, instead of using additional battery storage, which is the typical approach today.

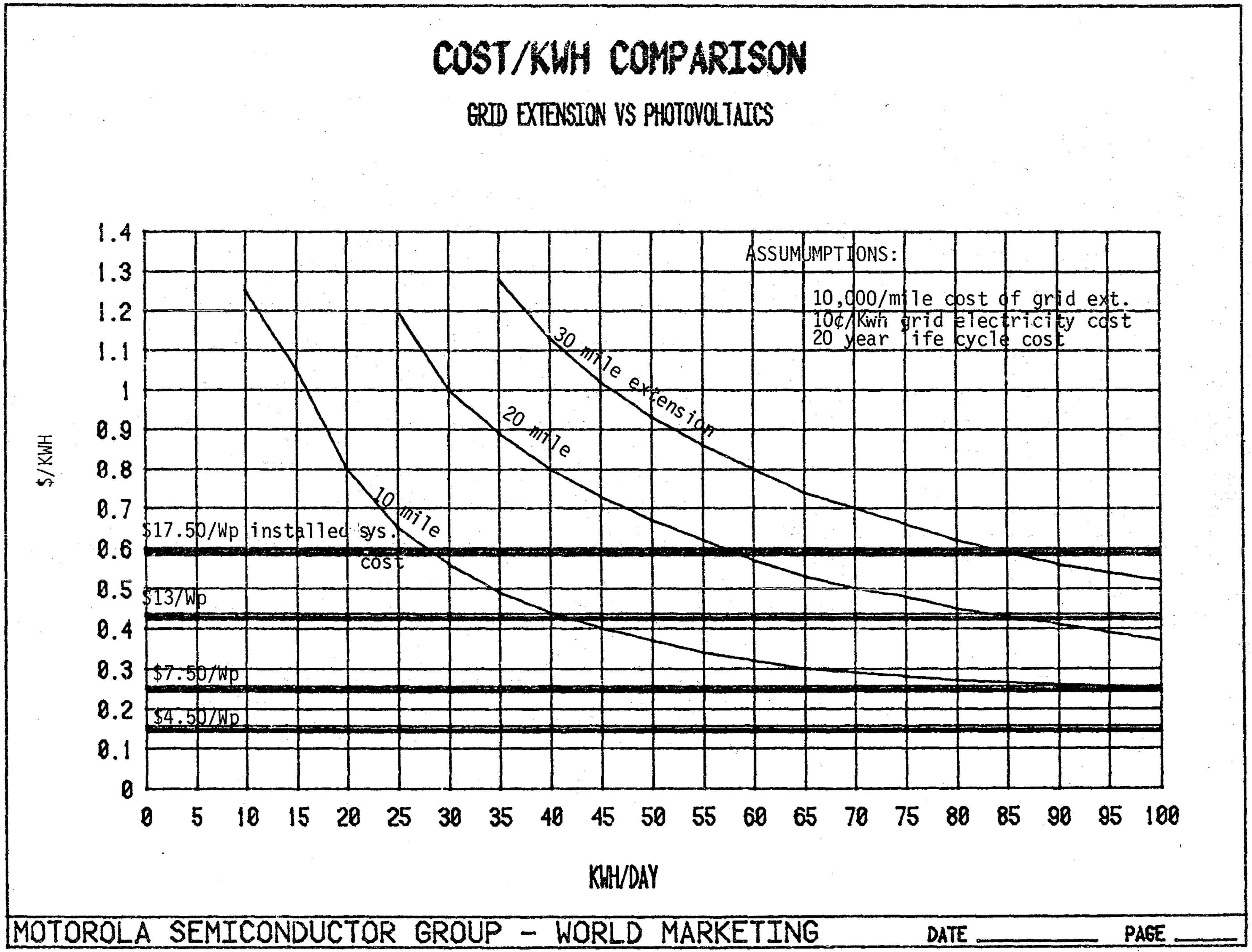
COST/KWH COMPARISON
GRID EXTENSION VS PHOTOVOLTAICS
ASSUMUMPTIONS:
10,000/mile cost of grid ext.
10¢/Kwh grid electricity cost
20 year life cycle cost
30 mile extension
20 mile
10 mile
$17.50/Wp installed sys. cost
$13/Wp
$7.50/Wp
$4.50/Wp
$/KWH
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
KWH/DAY
MOTOROLA SEMICONDUCTOR GROUP - WORLD MARKETING
DATE
PAGE

FIGURE 7

Referring again to Figure 7, it shows that for villages 30 miles or more distant from the grid PV systems are more cost effective today unless the load requirements are relatively high (85 Kwh/day or more). Naturally, as the PV system costs come down, it becomes more economical for locations even closer to the grid.

Figure 8 displays the impact of the cost of diesel fuel on the cost/Kwh of diesel generated electricity and compares it with PV systems. Again, as fuel costs go up, larger and larger systems become cost effective for the PV systems.

In summary, PV systems are cost competitive in some village power applications and if present trends of PV cost reduction and oil price escalation continue, most remote village applications can be cost effectively served by photovoltaics.

4. Lack of Familiarity and Confidence in PV

Assuming that there is the need and the desire and the resources necessary, and that PV is a cost effective solution, there still remains a major barrier to development of the remote village market for photovoltaic power systems.

PV is a new technology. Many decisionmakers in developing countries, if they have heard of PV, think of it as something far back in the laboratories that may someday emerge to provide some useful functions. Even the better informed people are wary of it as being an unproven technology, some even believing it is yet another way the developed countries can get the developing countries "hooked" on an imported technology and thus increase their dependency on the developed countries.

This perception or lack of knowledge can only be overcome with a concerted, continuous information and education program. Our in-country visits made us acutely aware of the necessity of such a program, not only for the potential buyers of PV systems, but the financiers and even our own government people serving in these developing countries. The longer we wait to initiate an active information and education program, the longer we postpone development of this market.

5. Export Marketing Expertise

Both the U.S. government and most U.S. industry are faced with another problem. Our export experience, expertise, and performance is lacking, particularly when compared to some of the countries we will be competing with in the PV market in developing countries. France, Germany, and England still have strong ties with the developing countries which were once part of their colonial empires. These countries are also quite export minded, and their governments work hand-in-glove with industry to develop and penetrate export markets.

Because they have a long history of governmental and commercial ties, they are well aware of business practices, prejudices, and politics in these countries. This puts them at a decided advantage when competing with American companies in developing countries.

With a few exceptions, most American companies have little experience in this area. Most Third World countries want to trade with the U.S., but our tendency to want to conduct business just like we conduct it in the U.S. sometimes makes it difficult for them, especially when compared to some of our flexible competitors. Without going into great detail about the U.S. export problems and resulting trade imbalance, a few words must be devoted to this problem. Generally U.S. companies have succeeded in export markets when two conditions existed: (1) the U.S. products

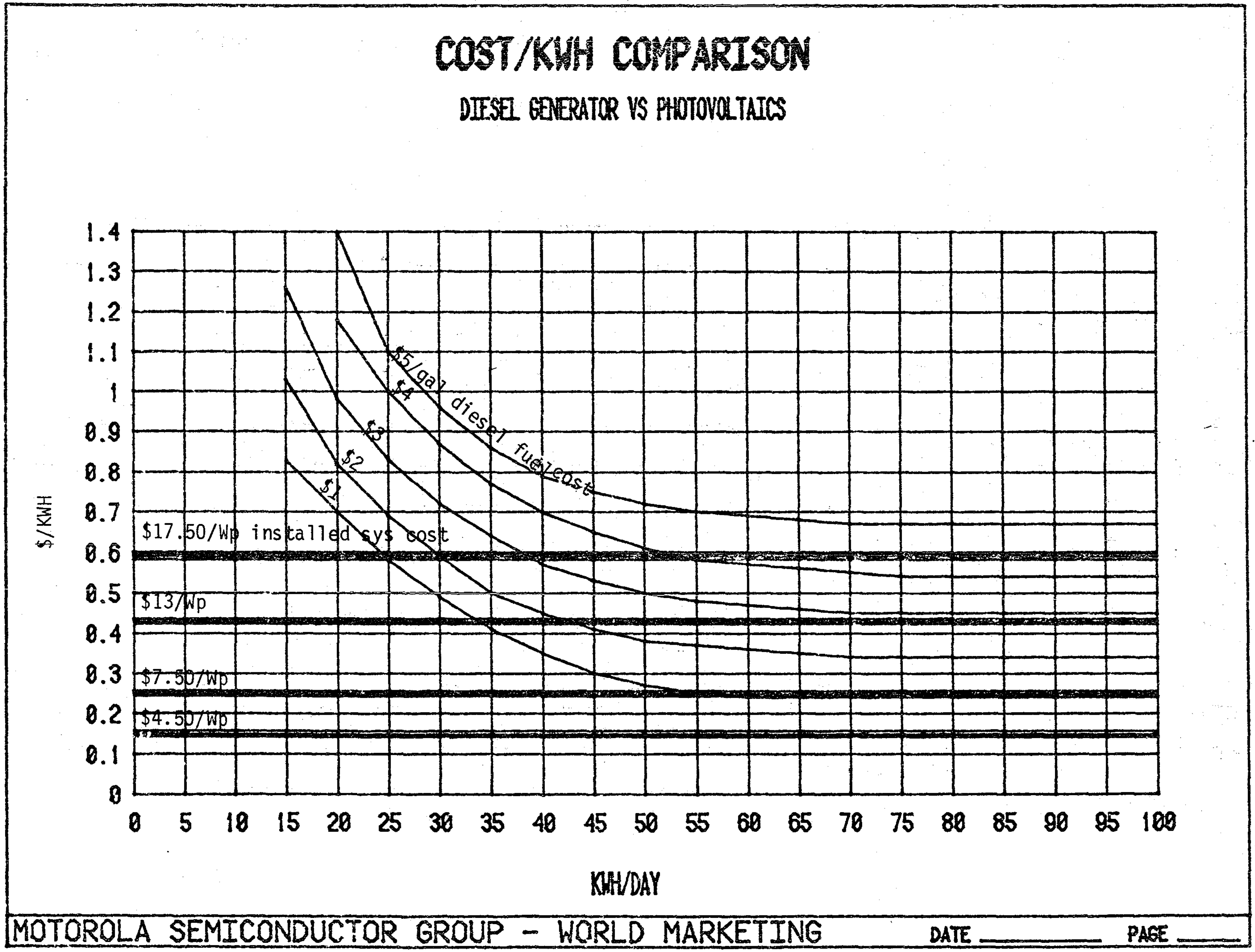
COST/KWH COMPARISON
DIESEL GENERATOR VS PHOTOVOLTAICS
$/KWH
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
KWH/DAY
$5/gal diesel fuel cost
$4
$3
$2
$1
$17.50/Wp installed sys cost
$13/Wp
$7.50/Wp
$4.50/Wp
MOTOROLA SEMICONDUCTOR GROUP - WORLD MARKETING
DATE
PAGE

FIGURE 8

had a technological superiority and (2) the U.S. companies had built up a significant manufacturing base in satisfying domestic needs. In the case of photovoltaics, current American technology is still superior but not by a great deal, and the first large markets wil be outside the U.S., not within. This says that we have a new set of conditions which government and industry have to work together to solve. This represents a unique challenge, again compared to other countries, because the U.S. government and industry have not worked that well together, nor have either government or industry been that effective in the export markets.

6. Foreign Competition

Another barrier, associated with the preceding one, has to do with competition from France and Germany. As mentioned, both of these countries have strong ties to their ex-colonies and both are very active in the export market, especially in developing countries. One or both of them were found to have some sort of PV program going in almost every country visited. Their involvement ranged all the way from sponsoring PV R & D programs in universities, to installing water pumping systems, to a grant of a 5.5K Wp village power system. The governments of these countries work quite closely with their commercial firms on these export programs, often tying sales directly to aid programs.

The Japanese were not yet in evidence to a large extent, but with the amount of effort they are putting into R & D they can be expected to become a factor before long.

7. Alternate Technologies

As previously described, there are numerous other alternate energy sources which will compete with PV for some of the village power market. Wind and minihydro will probably succeed in those areas where the availability of wind and water are adequate and consistent. In some cases these technologies may be compatible with PV and used in combined systems.

The primary appeal that most of these alternative energy approaches have compared to PV is relative ease of technology transfer and the attendant increase in local content and independence.

8. Political Instability of Some Developing Countries

A probable, but unpredictable barrier to development of this market is related to the relatively unstable situation existing in some countries and regions in the developing world. Current and past problems in Iran, Iraq, Zimbabwe, Uganda, Jordan, Israel, Egypt, Vietnam, Cambodia, Laos, etc., give fair warning of the risks of investing in projects in these areas. Hopefully the impact of these situations, as long as they are not widespread, may only be a temporary delay in implementation of their rural development programs.

9. Summary

To summarize, there are barriers to the development of the remote village market for photovoltaics, but none of them are insurmountable, and there are actions that can be taken to minimize the effect of these barriers. These actions will be described in Section VIII of this report.

VI. QUANTITATIVE RESULTS

In this report, far more time and attention has been paid to the qualitative aspects of the market than the quantitative. This is for good reason. The potential market is huge, but the qualitative aspects previously discussed, and how they are addressed, will determine how much of this potential will become a real market and how quickly it will develop.

Previous estimates by the U.N. and the World Bank have indicated huge potential markets for PV in developing countries. The U.N. has estimated that there are one billion people living in two million remote villages without electricity. Their estimate of 30 - 50 Kwp of electricity required per village results in a total potential PV market of 60 - 100 million Kwp. Similar numbers result from the World Bank estimate of 300 million households without electricity in developing countries.

Extrapolation of the data from our survey of 27 developing countries resulted in similar estimates of the number of unelectrified villages in the developing countries. Our analysis does, however, provide a more conservative estimate of the electrical demand per village. As previously covered in the section on village requirements, we believe that approximately 10 Kwp per village is a more realistic demand. This 10 Kwp per village, multiplied by the estimated 2 million unelectrified villages results in a total potential of 20,000 Mwp. This is probably a conservative estimate of the total village power potential, particularly in consideration of the fact that we have not included the potential for replacement of diesel generators already installed and providing power to a large number of villages in the world. For the reasons specified in earlier pages of this report, these villages may in fact represent the earliest villages to be penetrated by photovoltaic village power.

Assuming that the 20,000 Mwp estimated potential is relatively accurate, the next question is, "How much of it can be penetrated?" Based on all of the factors discussed in the qualitative results section of this report, it is our contention that in the near term, the next 10 years, not more than 5% (1 Gwp) of this potential can be penetrated. The primary reason for this somewhat pessimistic estimate is that moving a new technology into a market having limited financial resources and that is somewhat slow to accept new ideas will take time. The first 5 years of the period will be devoted to proving that photovoltaics is truly a viable alternative. The last 5 years of the decade will be the beginning of true commercial market growth. The above projection assumes that there will be some market stimulation on the part of both the U.S. government and the PV industry. If this does not happen, the penetration will occur more slowly and will probably amount to about 1 percent of the total potential in the 10 year period. Figure 9 graphically depicts the range of possibilities in the development of this market.

If the 5 percent penetration rate is made to happen, it results in cumulative sales of over 1 Gwp at a total value in excess of $1.5 billion. At this level it represents a quite respectable export market, and a significant production base.

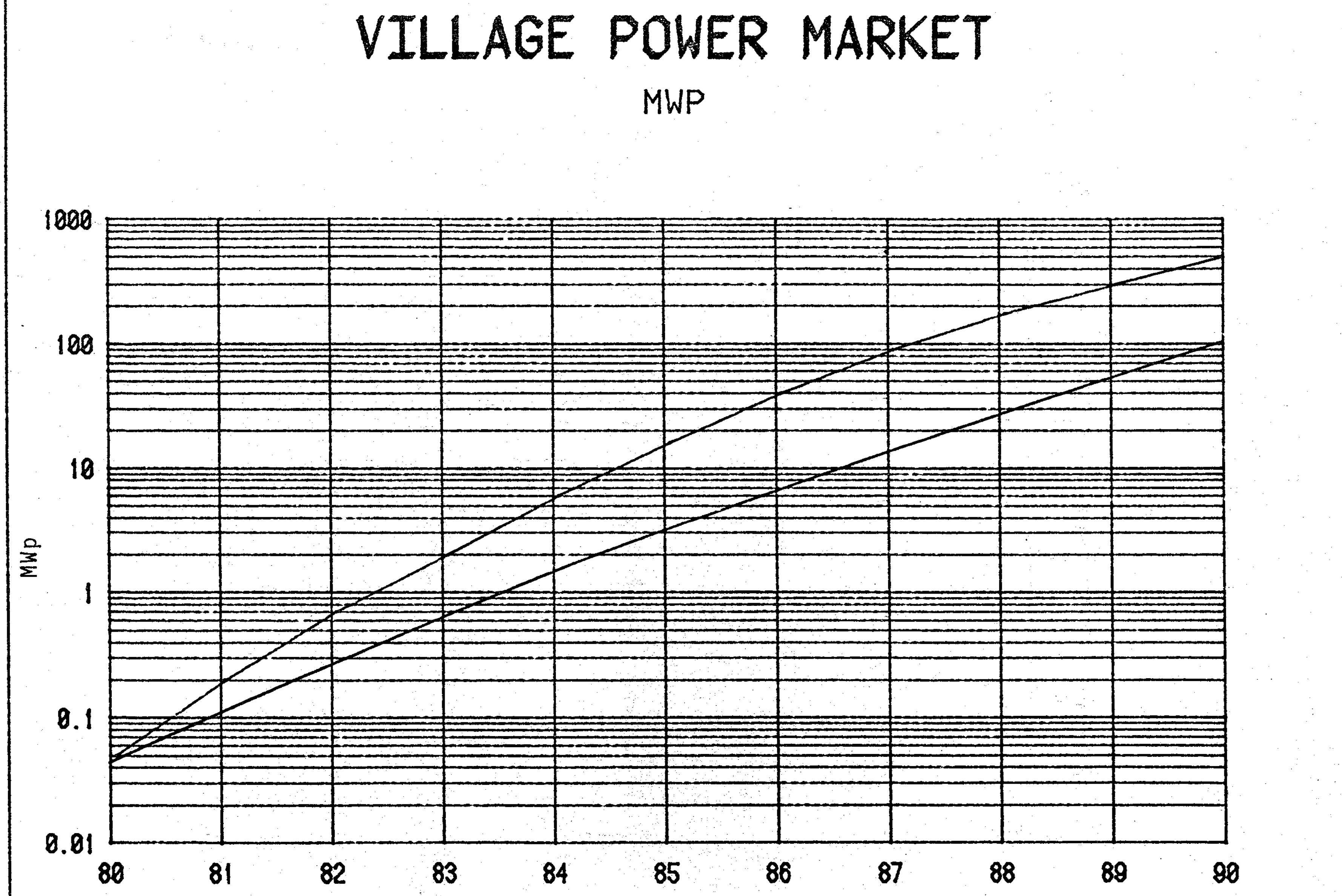
VILLAGE POWER MARKET
MWP
1000
100
10
1
0.1
0.01
MWp
80
81
82
83
84
85
86
87
88
89
90

FIGURE 9

VII. CONCLUSIONS

A. Many developing countries do want to improve the standard of living in the rural areas, and provide village electrification, in order to slow down the migration from the rural areas to the cities.

B. There are funds available for rural electrification programs if high enough priority is placed on these programs.

C. The relative priority of rural electrification varies from country to country, with some giving lip-service to it, while others have aggressive programs.

D. Where village or rural electrification programs do exist the first alternatives considered are grid extension and local generation by diesel generators.

E. In some cases photovoltaic power systems are cost-competitive with grid extension and diesel power today and will become increasingly advantageous as PV costs decrease and oil costs increase.

F. Minimal maintenance requirements is one of the most desireable characteristics of PV in developing countries.

G. Little is known about photovoltaics in developing countries; therefore, it is not considered as a viable energy option for either short or long term planning.

H. Before they will invest their limited foreign exchange on a new, unknown technology, the developing countries will have to see it operating successfully in their environment for an extended period of time.

I. With effective implementation of an information, education, and demonstration program coupled with a continuing cost reduction program, a significant market for photovoltaics in remote village applications can be developed. It can represent sales over the next 10 years of as much as $1.5 billion.

J. Having the most advanced technology, American firms are now and should continue to have a major share of this market. However, the French and German government and industry are advancing rapidly in technology, and are more aggressively marketing in the developing countries. The Japanese have not yet entered the market aggressively, but can be expected to do so soon.

k. The time to initiate a market development program in parallel with the technology development is now, so that as the new low cost processes are put into production there will be a sizeable market available to absorb the output.

VIII. RECOMMENDATIONS

Under normal circumstances, a market with the characteristics previously described should be allowed to develop on its own, without government intervention. In this case, since it is in the National interest to ensure that photovoltaics picks up part of the U.S. energy load as quickly as is economically feasible, the appropriate role for the government is to accelerate the development of the market, as it is accelerating the development of the technology.

Extreme care must be taken, however, that the government involvement does indeed accelerate, not retard or interfere with, the natural development of the market. This is not an easy task, especially in a free-enterprise, open-competition environment such as we are accustomed to in the U.S. Another factor which complicates the situation is the involvement in the early market of very small companies and very large corporations. Some companies have extensive international experience, while others have none, and will need government export assistance. Some companies are privately owned, while others are partially or totally owned by large oil companies, and others are partially foreign owned.

The difficult role for the government is to ensure maximum industry involvement and exposure, and yet not show favoritism or interfere with ongoing commercially initiated negotiations. For this reason it is quite important that the government have a continuous dialogue with the industry as plans and programs are formulated and implemented.

A. INFORMATION AND EDUCATION PROGRAM

As previously discussed, there is a dearth of knowledge about photovoltaics in the developing countries. Generally what little is known is either outdated or incorrect.

To correct this situation, a comprehensive information, education, and promotion program should be established. There are three primary targets for this program:

1. U.S. Overseas Personnel

Our own U.S. government representatives assigned to these developing countries should be our first line of information on photovoltaics. It is not necessary that the commercial attaches or the AID personnel become experts in PV, but they should have up-to-date information at their disposal. This information should include the advantages of photovoltaics, the comparative costs of generation of electricity, particularly comparing PV with grid extension and diesel generation, and should include up-to-date lists of manufacturers and suppliers of PV components and systems.

This can be implemented by regular distribution of DOE/DOC PV bulletins, but will be most effective if augmented by in-country visits and presentations as suggested in the following section.

2. Potential Customers

In most developing countries the primary customers for PV systems will be the local government. Preferably the information and education program should be initiated by in-country seminars and presentations, with PV industry participation, followed by a regular updating by means of newsletters and follow-up visits. Since many of the first PV installations will not be village power, but may be single function systems solving basic needs, the program should be addressed to the following types of local government agencies:

Energy
Rural development
Rural electrification
Education
Agriculture
Health
Communication
Utility power

Presentations to these groups of people will be most effective if they include active demonstrations.

3. Financial Institutions

Since the World Bank, the regional development banks, and the commercial banks are the primary source of financing for many of the energy and development programs in the developing countries, they must be convinced of the economic viability of photovoltaics before they will invest in PV systems.

Consequently a similar information and education program should be directed to them with more emphasis on the economic considerations of PV versus other energy options.

B. DEMONSTRATIONS

Because photovoltaics is a relatively new technology, and because PV systems require a significant initial investment, many developing countries will be hesitant to consider PV until they are convinced that it will perform as promised. In many cases this can only be accomplished by seeing PV systems operating successfully in their environment over a suitable period of time. "Seeing is believing" is a truism in this situation.

For this reason we are recommending that a substantial demonstration program be initiated. These demonstrations should be of two types: multi-function and single function.

The multi-function demonstrations should include, as a minimum, water pumping, lighting, refrigeration, food processing, and emergency or educational communications. These demonstrations would be intended for regional as well as individual country impact, for this reason they should be located in or near cities which are the cultural or trade centers of the region.

Examples of possible locations for these major regional demonstrations are:

West Africa
  Dakar, Senegal
East Africa
  Nairobi, Kenya
Arab & Middle East
  Cairo, Egypt
  Islamabad, Pakistan
Southeast Asia
  Manila, Philippines
  Jakarta, Indonesia
Latin America
  Mexico City, Mexico
  Sao Paulo, Brazil

Additional multi-function demonstrations should also be considered in those countries which either represent a major long term market, or have expressed sufficient interest and thus represent a near term interest. Examples of these countries are:

Gabon
Tanzania
Ivory Coast
Sudan
Cameroon
Thailand

Single function demonstrations, appropriate for the primary needs of the country, should be installed in every country which represents a potential market for photovoltaics. These also should be located in or near the major cities to ensure maximum visibility.

In all cases, the demonstrations should be carefully designed to provide maximum demonstrable performance and reliability and should include descriptive posters or signs and literature to explain the functional operation and advantages. Maximum participation of the local government is highly desireable.

PV industry should be brought into the projects as early in the design phase as possible and should have maximum involvement throughout the project.

C. COMMERCIALIZATION

In the early stages of development of the market, some customer countries are likely to be reluctant to spend their hard earned foreign exchange on a new, to them unproven technology. In these cases a risk-sharing program may encourage earlier acceptance. This risk-sharing could take the form of actually sharing the cost, or could be in the form of a deferred payment, after successful performance of the system over a suitable period of time.

A mechanism should be established by which a U.S. PV company, having found a customer desiring a risk-sharing program, can obtain this assistance from the U.S. government and yet retain the rights to the business. This function could possibly be performed by the Exim Bank.

D. WEATHER DATA

One of the biggest potential risks in PV system design and installation in developing countries is the possibility of undersizing or oversizing systems due to unreliable or often nonexistent weather data.

The U.S. government should offer to assist developing countries in setting up and operating a weather data measurement and recording system. This data should then be made available to the U.S. PV industry.

E. COMMERCIAL REQUIREMENTS

Commercial companies will find that the following items need to be considered to enable them to prepare to successfully participate in this market.

1. Have complete functional system packages available for sale.

2. Be prepared to assume turnkey responsibility for installation and maintenance of some systems.

3. Begin to establish distributor/agent contacts for local representation, installation, and maintenance in the countries to be penetrated.

4. Be prepared to be flexible in dealing with developing countries. Differences in language, currency, payment terms, general business practices, local politics, etc., can often be frustrating to companies inexperienced in exporting to these countries. Local U.S. government officials should be called upon for assistance.

All of the elements necessary to make the photovoltaic remote village market an important export market for the U.S. PV industry have been identified. This is a perfect opportunity for U.S. industry and government to work cooperatively in penetrating a market. With a constructive, cooperative effort on both sides, it can be accomplished.

APPENDIX 1

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APPENDIX 2

AFRICA TOUR - SUMMER 1979

LOCATION	ORGANIZATIONS	DATE	ATTENDEES
Dakar, Senegal	U.S. AID and Commerce	31 May	2
	Senelec	31 May	2
	Renewable Energy Center	4 June	3
	Institute of Technology	4 June	2
	University of Dakar	5 June	15
	Ministry of Science and Technology	5 June	2
			21
Abidjan, Ivory Coast	Electrical Energy Seminar	7 June	22
	U.S. AID and Commerce	8 June	2
	African Development Bank	8 June	5
			29
Lagos, Nigeria	Electrical Energy Seminar	12 June	36
	Ministry of Industry	13 June	3
	Water Resources Dept.	13 June	1
	Ministry of Power and Mines	13 June	2
	Ministry of Power and Mines	13 June	1
			43
Douala, Cameroon	Electrical Energy Seminar	15 June	46
Yaounde, Cameroon	Ministry of Mines and Power	18 June	2
	U.S. AID and Commerce	18 June	5
	Institute of Research and Technology	18 June	6
			13
Libreville, Gabon	Electrical Energy Seminar	21 June	34
	SEEG (utility)	22 June	5
	OCTRA	22 June	3
	EGEF	22 June	2
	OPT	22 June	3
			47
Lome, Togo	U.S. AID and Commerce	25 June	3
	Ministry of Planning and Development	25 June	2
	Ministry of Public Works	26 June	2
	University of Benin-Lome	26 June	1
	Ministry of Agriculture and Rural Development	26 June	2
			11
Nairobi, Kenya	U.S. AID and Commerce	27 June	6
	National Council of Science and Technology	27 June	2
	Ministry of Agriculture	28 June	2
	Village Technology Unit	29 June	2
			12
		TOTAL	222

LOCATION	ORGANIZATIONS	DATE	ATTENDEES
Amman, Jordan	Ministry of Industry and Trade	Jan. 14-18	5
	U.S. Embassy		5
	Natural Resources Authority		6
	Jordan Electric Authority		5
	Dept. of Statistics		3
	U.S. AID		5
	Ministry of Agriculture		7
	Royal Scientific Society		10
	University of Jordan		3
	Jordan Petroleum Refining Corp.		3
			52
Cairo, Egypt	National Research Center	Jan. 21-25	6
	U.S. AID		6
	University of Ein Shams		6
	Ministry of Agriculture		6
	American University		25
	Rural Electricity Authority		4
	Qattara Depression Authority		5
			58
Khartoum, Sudan	U.S. Embassy	Jan. 28-Feb. 1	4
	Energy Research Institute		30
	University of Khartoum		6
	Rural Water Corporation		5
	Public Electricity and Water Corp.		4
	U.S. AID		6
	Arab Authority for Agricultural Investment and Development		10
	National Council for Research		4
	Sudan Telecom Corp.		4
	International Wolunteer Services		1
	Ministry of National Planning		10
	Sudan Airways		25
	Sudan Railways		6
	Arab Bank for Economic Development in Africa		6
			121
Sana'a, Yemen	National Electrical Corp. Assn.	Feb. 4-8	5
	U.S. Embassy		4
	U.S. AID		6
	Office of the Prime Minister		7
	Yemen General Electric Co.		5
	University of Sana's		40
	Yemen National Oil Co.		10
	Ministry of Agriculture		4
	Central Planning Organization		4
			85

ARAB-MIDEAST TOUR (continued)

LOCATION	ORGANIZATIONS	DATE	ATTENDEES
Abu Dabi, United Arab Emirates	Ministry of Foreign Affairs	Feb. 11-15	5
	Ministry of Communications	↓	2
	Ministry of Petroleum and		2
	Mineral Resources		2
	Government Planning Dept.		3
	Municipality of Abu Dabi		2
	University of Al-Ain		7
	UNDP		2
	AbuDabi National Oil Co.		2
			25
Islamabad, Pakistan	Ministry of Petroleum and Natural Resources (Energy Research Cell)		6
	Telephone and Telegraph Dir. Gen.		13
	Appropriate Technology Development Organization		5
	UNDP		10
	U.S. AID		6
			40
		GRAND TOTAL	381

SOUTHEAST ASIA TOUR - MARCH 1980

LOCATION	ORGANIZATIONS	DATE	ATTENDEES
Saipan	Trust Territories, Northern Marianas	3 March	6
Taipei, Taiwan	Energy Committee, Ministry of Economic Affairs	4 March	10
Manila, Philippines	Bureau of Energy Development	10 March	8
	National Electrification Admin.	10 March	6
	Ministry of Education } U.S. AID and Commerce }	11 March	10
	Asian Development Bank	11 March	12
			36
Bangkok, Thailand	National Energy Authority	13 March	25
	Kwg Mongkut Institute of Technology } Electricity General Authority of Thailand }	14 March	
	Provincial Electricity Authority	14 March	1
	U.S. AID and Commerce	13 March	5
			41
Kuala Lumpur, Malaysia	Telecommunications Department	17 March	25
	National Electricity Board	17 March	60
	Standards and Industrial Research Institute of Malaysia	18 March	10
			95
Jakarta, Indonesia	Agency for the Development and Application of Technology	19 March	7
	U.S. AID and Commerce	21 March	22
			29
Pago Pago, American Samoa	Territorial Energy Office	31 March	3
		TOTAL	220

LATIN AMERICA TOUR

LOCATION	ORGANIZATIONS	DATE	ATTENDEES
Lima, Peru	Geophysic Institute	7 Nov. 1979	7
	Army Communications Dept.	7 Nov.	7
	Ministry of Telecom	8 Nov.	3
	Ministry of Energy and Mines	8 Nov.	1
	Navy Communications Dept.	9 Nov.	1
	Institute of Technology	9 Nov.	8
			27
Bogota, Colombia	National Planning Institute	6 March 1980	2
	Electric Power Authority	6 March	2
			4
Mexico City, Mexico	Solar Energy Dept.	11 Feb.	6
	Ministry of Communications	11 Feb.	10
	Mexican Telephone Co.	12 Feb.	6
	Electrical Research Institute	12 Feb.	4
			26
		TOTAL	57

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