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Solar Energy Commercialization for African Countries

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Prepared by:
PRC Energy Analysis Company
McLean, Virginia

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U.S. Department of Energy
Assistant Secretary for Conservation
and Solar Applications
Office of Solar Applications
and Commercialization
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SUMMARY

As part of the information acquisition task for the DOE International Solar Commercialization Working Group (ISCWG), Team C conducted a three-week survey of six African countries in June-July 1978. Team members were John L. Sloop and Mamadou Watt of PRC Energy Analysis Co.; Pandit Patil of Systems Consultants, Inc.; and Norman W. Lutkefedder, Department of Energy; all of whom contributed to this report.

The six countries visited were Kenya, Cameroon, Nigeria, Niger, Ivory Coast, and Senegal (figure 1). All these countries are rich in solar energy and are friendly to the U.S. They represent a wide range of geographic features, climatic conditions, and energy resources. Table I outlines the main results.

NEEDS AND MARKETS

The greatest immediate need for solar energy is for rural applications. A primary need and potential market is water pumping for drinking and crop irrigation. Eight sub-Saharian nations--including Senegal and Niger--are experiencing severe drought. The other countries visited have seasonal water problems. Even in countries with ample rainfall, as in Kenya and Cameroon, there are some areas where people must walk as far as 12 kilometers to get water.

Food and crop preservation is another major need and market potential for solar energy. In some areas, present methods of food preserving often result in 60 or more percent spoilage rates. In other cases, a lower quality product may result from uncontrolled drying techniques. Officials in some African countries recognize the potential of solar energy for these applications and attendant beneficial results.

Providing modest levels of electrical power to remote villages can greatly enhance the quality of village life. Basic communications, educational television, and lighting for educational and community social functions are just a few examples of highly beneficial low power applications.

Use of solar radiation or biogas for cooking, as a supplement to wood/charcoal, applies to urban as well as rural activities. All countries visited are becoming increasingly concerned with the problems of deforestation and desertification. Not many years ago, a

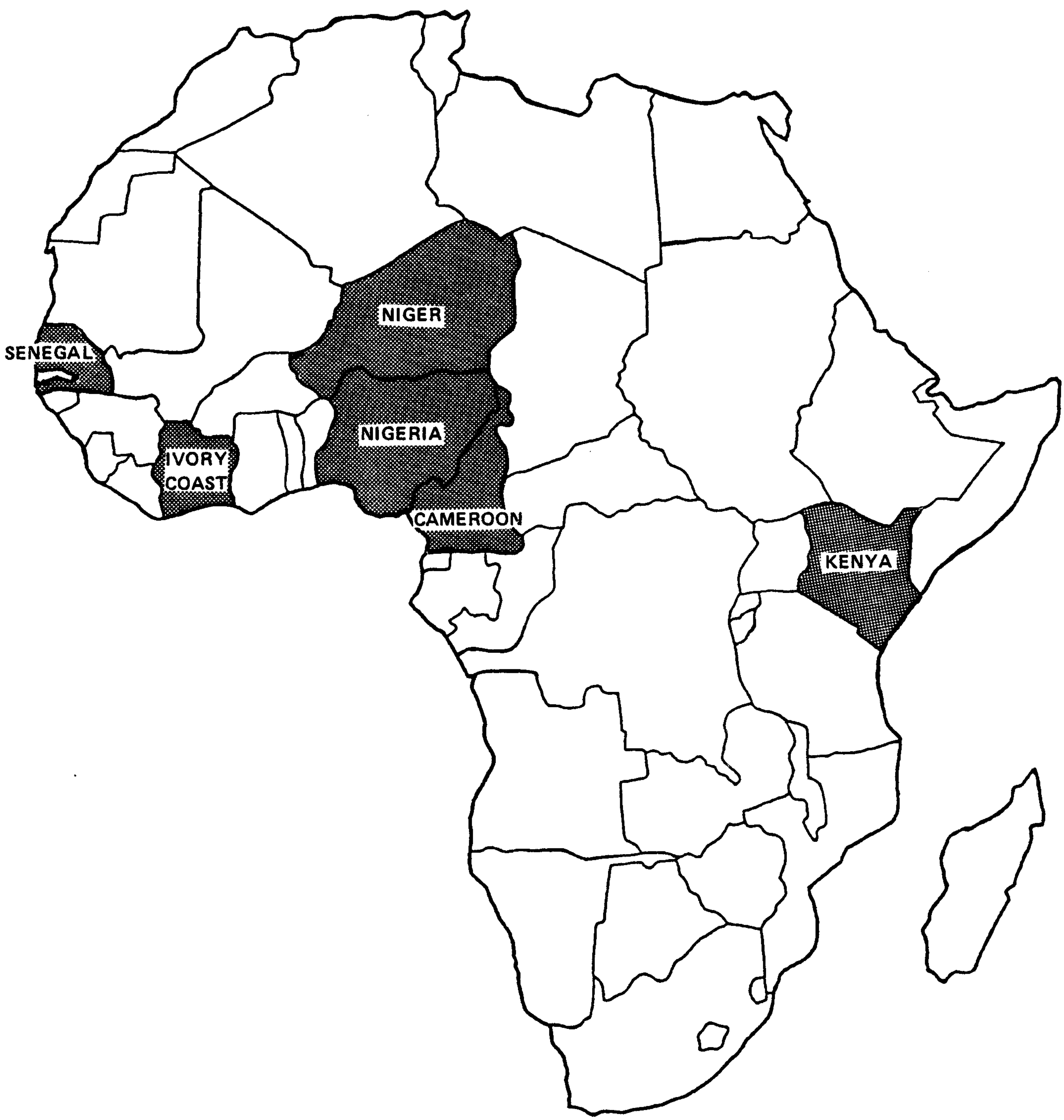


Figure 1 African Countries Visited During June-July 1978

Table I

SOLAR ENERGY COMMERCIALIZATION FOR AFRICAN COUNTRIES

COUNTRIES: KENYA, CAMEROON, NIGERIA, NIGER, IVORY COAST & SENEGAL

GREATEST NEED: RURAL APPLICATIONS

MARKETS

- WATER PUMPING
- FOOD/CROP PRESERVATION/PROCESSING
- ELECTRICITY FOR COMMUNICATIONS, EDUCATION & SOCIAL ACTIVITIES
- SUPPLEMENT TO WOOD/CHARCOAL FOR COOKING
- HOT WATER, HEATING, COOLING FOR BUILDINGS & INDUSTRY
- SUPPLEMENT FOR CONVENTIONAL POWER SYSTEMS

MARKETABLE SOLAR SYSTEMS

- PHOTOVOLTAICS
- SOLAR THERMAL
- BIOCONVERSION
- WIND
- HYDRO
- OCEAN THERMAL

RECOMMENDED APPROACHES FOR COMMERCIALIZATION

- BETTER COMMUNICATIONS
- COOPERATIVE TRAINING/DEMONSTRATIONS
- JOINT-VENTURE MFG./SALES/SERVICE

family could gather firewood within a short distance of home; now it must either buy it or make journeys as long as two days to get wood.

Hot water, heating, and cooling applications are primarily for urban areas where demand and ability to pay exist.

MARKETABLE SOLAR ENERGY SYSTEMS

Photovoltaics were found by far to be the most marketable solar energy product, with indications pointing to rapid growth in the next few years. It is being used now for experimental water pumping and for educational television. Photovoltaic-powered educational television represents a very large potential market during the next decade. Photovoltaic cells produced by American companies are competitive in price and quality with other manufacturers.

Another large potential market for photovoltaics is for power needs for remote villages for the combined needs of water pumping, refrigeration, television, lighting, and grinding grain.

Solar thermal systems built by the French are pumping water in several African countries. Recently an American company, Thermo-Electron of Waltham, Massachussets, teamed up with a French company, Sofretes, for a $1.25 million water pumping project in Senegal. Many low-temperature thermal applications exist in food and crop drying (e.g. cocoa or fish). The French are developing a high temperature concentrator system for brickmaking.

Bioconversion of wastes to generate methane, as practiced in China, is an alternative to diminishing supplies of wood and charcoal for cooking and low level lighting. There are social customs to overcome in Africa however, and adoption may be slow. Best market opportunities in bioconversion are in technical services and large plant fuel production.

Some wind machines are used in Africa for water pumping but not as extensively as needs indicate.

Low-head hydro potentials have not been exploited, primarily because emphasis has been on large dams.

Potentially good sites for ocean thermal energy conversion along the African coast, coupled with the present interest of Ivory Coast, make ocean thermal technology and joint-venture experiments good possibilities for U.S. companies.

RECOMMENDED APPROACH FOR COMMERCIALIZATION

- Better communications should be established between U.S. and African government officials, and the private sector to help assess the total energy situation and optimum way of fulfilling immediate and long-range energy goals. Better communications are needed to make African companies and consumers aware of U.S. solar energy capabilities and for technology transfer.

- Cooperative training and demonstration projects offer positive methods for technology transfer and acceptance of practical solar energy systems.

- Joint-venture manufacturing, sales, and service are the most effective ways for American companies to become involved in the African market. All three of these recommendations are consistent with their strong nationalistic policies of self-sufficiency.

INTRODUCTION

In April 1978, an International Solar Commercialization Working Group (ISCWG) was established by the Department of Energy's Office of Conservation and Solar Applications to provide the international component of the solar commercialization plan to:

- Define the scope of an international program,
- Accelerate worldwide commercialization of solar energy systems, and
- Stimulate export of U.S. solar products as an integral part of the DOE solar commercialization plan.

The first task of the ISCWG was to determine the scope of Federal Government interest in international solar commercialization, the status of present and planned international projects, including bilateral and multilateral agreements, prepare a plan of activities, and coordinate with other federal agencies. This task culminated in a conference on May 25 in which the ISCWG and participants presented their current activities. Participants included representatives of the Departments of Energy, State, Commerce, Treasury, and Agriculture; the Agency for International Development; the International Communications Agency; the National Aeronautics and Space Administration; the Solar Energy Research Institute, and four systems contractors. Contractors sensitive to industry considerations helped in the ISCWG action plan to ensure consideration of industry's role in commercialization.

Preliminary strategy for a commercialization plan was developed and included the following actions:

- Identify, through market research and surveys, the most attractive foreign markets for U.S. solar products and services;
- Involve U.S. industry and government agencies in cooperative efforts to accelerate commercialization and export of solar energy products and services; and
- Conduct joint venture programs between U.S. participants and cooperating countries that create or expand the market for U.S. solar products and services, and also builds a capability within the market country.

The second task of the ISCWG, which is still in progress, is information acquisition and analysis relevant to the first strategy. The first phase of this information acquisition task was conducted during May, June, and July 1978 by market research studies and visits to selected countries in three primary regions - Europe, Middle East, and Africa; and attendance at two international workshops. Interviews and discussions of country solar energy activities and needs, and relevant problems were conducted by ISCWG teams in the following countries:

<u>Europe</u>	<u>Middle East</u>	<u>Africa</u>
France	Saudi Arabia	Kenya
Federal Republic of Germany	Israel	Cameroon
Italy	Iran	Nigeria
Greece	Kuwait*	Niger
Spain	Turkey*	Ivory Coast
Switzerland	Egypt	Senegal
Great Britain		

*Discussions held at Cairo Workshop

This report is limited to information-acquisition task visits to the six African countries listed above. The persons interviewed are given in Appendix A.

1.0 KENYA

1.1 SUMMARY

Kenya is an energy importer with no oil, gas, or coal resources (table II). Imported crude oil is refined, and in 1977 the value of petroleum products exported was a little over 70 percent of the import value. Kenya has vast untapped hydropower resources with feasible use estimated at three times present capacity. (A map showing Kenya's annual rainfall is presented in figure 2.)

Kenya has shown little interest in solar energy and no government programs were identified. There is interest in exploiting the geothermal potential of the Rift Valley where experimental and exploratory operations are underway.

Major potential applications of solar energy are in rural areas. One of the most important potential applications is water pumping for people distant from water sources. Kenya is placing great emphasis on water services for hydroelectric power, drinking, and irrigation. Expenditures for rural water supplies more than tripled from 1976 to 1978. Some people have to travel 10 km or more for water during the dry season; Kenya has a goal of supplying running water to every household by the year 2000. In sparsely populated areas, using solar energy for water pumping offers considerable promise. Kenya also has a considerable problem with deforestation, but as yet no economical or socially acceptable substitute has been found for wood or charcoal for cooking.

With strong self-sufficiency goals, Kenya is more interested in solar technology transfer and manufacturing plants than importing solar products. Photovoltaics offers the greatest potential export to Kenya for water pumping, communications, and low-level power purposes in remote villages. Better communications with Kenya on solar energy potentials and progress of U.S. programs are of first order importance.

1.2 ENERGY RESOURCES

Kenya's major energy resource is hydropower, with large untapped reserves and ample rainfall. In 1977, 28 percent of Kenya's hydroelectricity was imported from Uganda. The Tana River, beginning in the Aberdue Mountains and augmented by tributaries from Mount Kenya, has an estimated power potential of 15,350 gigawatt hours (GWh) per year, of which about 3,570 GWh appear feasible for use, allowing for irrigation and other losses. The areas

Table II

KENYA

ENERGY RESOURCES

- OIL, ELECTRIC IMPORTER (74% OF CONSUMPTION)
- LARGE, UNTAPPED HYDRO, AMPLE RAINFALL
- GEOTHERMAL

SOLAR ACTIVITIES

- ENERGY STUDY
- NO GOVT SOLAR PROGRAMS
- LOW LEVEL COMMERCIAL ACTIVITY
- SOME UNIVERSITY RESEARCH

POTENTIAL SOLAR APPLICATIONS

- WATER PUMPING, FOOD/CROP DRYING, PRESERVATION, REFRIGERATION OF MEDICINE, COMMUNICATIONS, COOKING, H/W, HEATING, COOLING

POTENTIAL COOPERATION

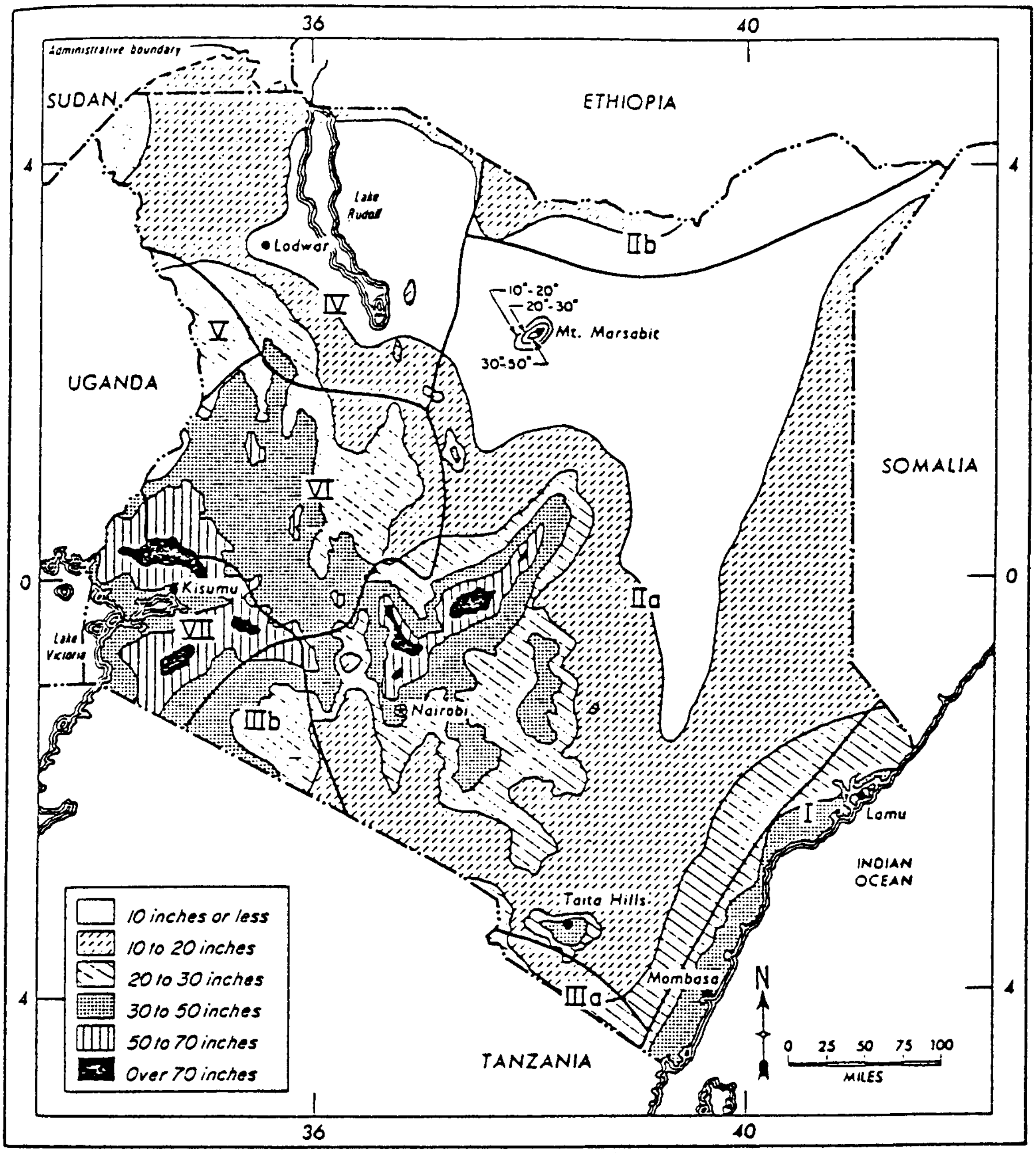
- ENERGY ANALYSIS, INSOLATION & WIND DATA, SOLAR R&D FOR RURAL APPLICATIONS, DEMONSTRATIONS, TRAINING

POTENTIAL U.S. EXPORTS

- PHOTOVOLTAICS, WIND, SOLAR THERMAL, TECHNOLOGY TRANSFER, SOLAR PLANTS, LOW-HEAD HYDRO

RECOMMENDATIONS

- BETTER COMMUNICATIONS TO GENERATE GREATER INTEREST
- COOPERATIVE DEMONSTRATIONS & TRAINING



I April-July--Maximum in May
IIa March-May and October-December--Maximums in April and November
IIb March-May and October-November--Maximums in April and October
IIIa Derember-May--Maximum in March
IIIb December-May--Maximum in April
IV March-May--Maximum in April
V March-October--Maximum in May
VI March-September--Maximums in May and August
VII January-December--Maximums in April and December

} Rainy seasons and maximums.

Source: Kaplan, I., Area Handbook for Kenya, GPO, Washington, 1976, p. 61.

Figure 2 Mean Annual Rainfall, Kenya

of Seven Fords and Middle Tana have discharges of 2,000 feet and numerous dam sites are within 150 miles of Nairobi, the principal city.1/

The Rift Valley offers considerable geothermal energy potential. Three main areas have been identified for more detailed studies. The power potential is estimated to be in the range of 170-500 MW. A 9 MW plant is in operation, and another plant of 15 MW is planned by the Kenya Power Company at a total cost of $55 million with partial funding ($35 million) by the World Bank.2/

Firewood is the traditional and most common fuel in rural areas; charcoal also is used for cooking and by industry, and some charcoal is exported. In 1975, fuel wood production was 10.9 million cubic meters.3/ Like other African countries, however, wood depletion (deforestation) is a serious problem. The sugar industry uses bagasse as a fuel.

Kenya imports all of its oil and coal. Approximately 85 percent of the energy consumed is obtained from oil, about 3 percent from coal, and hydroelectricity provides the remainder. Oil exploration presently is being conducted in the northeastern province.4/

A summary of Kenya's 1977 energy situation (except firewood and charcoal), converted to a common equivalent in thousands of metric tons of oil, is as follows:

	Import	Local Production
Coal and Coke	43.8	-
Oil (for consumption)	1605.9	-
Hydroenergy	65.2	167.4

The total annual energy consumption was 1,882,000 tons. Per capita energy consumption in kilograms of oil equivalent was 131. Imported fuel provides 74.4 percent of the energy consumed.1/

The estimated insolation is 400-535 cal/cm^2 (7-9 hours of sunshine per day). Winds are prevalent 45 percent of the time with velocities of 8-18 mph during December to March. Professor Rajni Patel of the University of Nairobi is compiling wind data from several areas and this should be available in a few months.4/

1.2.1 Electrical Power

Half of Kenya's 339 MW installed power is hydroelectric (168 MW), and the growth rate of installed power during the past 4 years was 23 percent for hydroelectric versus 6 percent for thermal plants. Energy generated also shows a trend to more hydropower; in the past 4 years the energy generated by thermal plants remained essentially the same level (386 vs. 400 GWh) whereas hydroenergy nearly doubled (from 408 to 797 GWh). During the same period, energy imports from Uganda declined from 38 percent of local generation to 23 percent. Electric energy consumption in 1977 was 1441 GWh, of which 21 percent was by residences, 21 percent by commercial and light industry, and almost 40 percent by industry (the remainder includes losses, street lighting, and unallocated uses).[1/]

Kenya is considering a 1000 MW nuclear plant, almost three times present electric capacity.[2/] Figure 3 geographically illustrates Kenya's actual and potential electric power.

1.2.2 Energy Costs

Wholesale prices as of September 1977, computed on an exchange rate of 1 KSh = $0.126 (December 1977), are as follows:[1/]

	KSh	$
LPG (per 100 kg)	3100	390
Premium motor gasoline (per 1000 l)	2615	329
Regular motor gasoline (per 1000 l)	2505	315
Illuminating kerosene (per 1000 l)	1326	167
Power Kerosene: Tractor Fuels (per 1000 l)	1680	211
Light diesel oil (per 1000 l)	1746	220
Industrial diesel oil (per 1000 l)	1185	149
Fuel oil (per 1000 l)	825	104

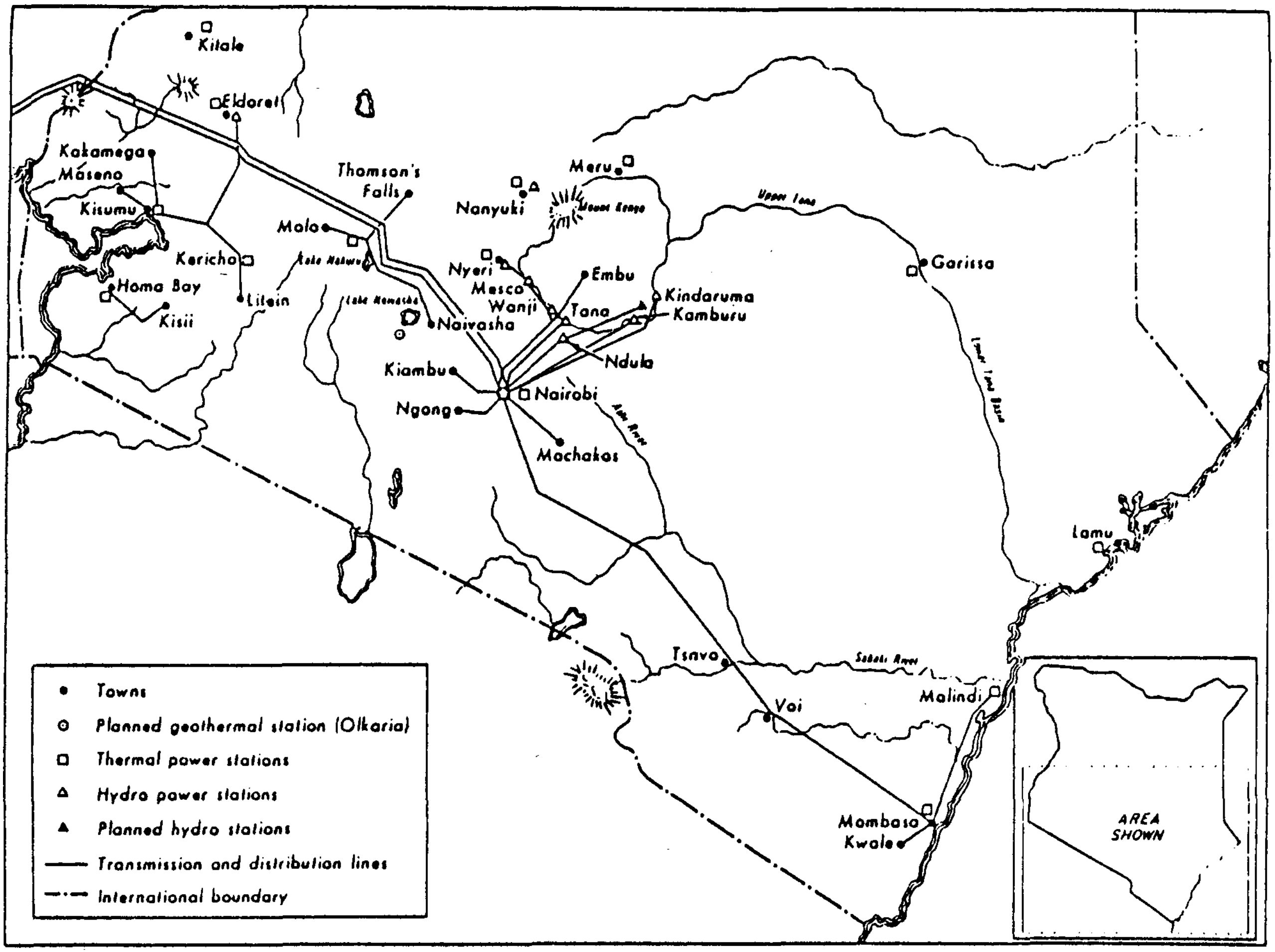
(Nairobi retail prices the same month show premium and regular gasoline about 10 percent higher than wholesale.)

1.3 SOLAR ENERGY

1.3.1 Solar Energy Activities and Plans

Kenya contracted with the U.N. for a one-year, one-man study of energy needs. The study is being made by Thomas Tuschak, attached to the National Council of Science and Technology.[2/]

The first part of the study is focused on rural energy needs, particularly on alternatives to using wood or charcoal for cooking. These fuels are in short supply and forests are being depleted rapidly. The general consensus of those interviewed is that solar cookers are not a suitable substitute for charcoal; it would mean changes in family social life - something that would be difficult to accomplish. Methane, from anaerobic digestion



Source: Kaplan, I., Area Handbook for Kenya, GPO, Washington, 1976, p. 359

Figure 3 Actual and Potential Electric Power of animal waste, also faces problems of dung collection and acceptance. Solar cookers and small anaerobic digesters presently cost on the order of $100, which is beyond the means of those needing it most and, therefore, would require a government subsidy or incentive program.

Faculty and students at the University of Nairobi Engineering School are experimenting with low technology solar equipment, with simplicity and use of local materials as major requirements. These projects include solar water heaters, solar distillers, solar cookers, solar refrigeration, wind machines, biogas, and modification of an automotive engine to use methane from anaerobic digesters. Wind data are being compiled.[4/]

Two Nairobi firms are engaged in assembling and installing solar hot water heaters; some installations have been made for remote hunting lodges. A Swedish consulting firm in Nairobi also is doing design and engineering for solar hot water systems.[5/]

1.3.2 Solar Energy Capabilities

Faculty at the University of Nairobi keep abreast of solar technology. There is no reason to believe there would be any problem in implementing solar energy projects if the Government of Kenya decided it was of sufficient priority to do so. The Kenya Development Plan 1974-1978 Part I, in discussing sources of energy, makes this pessimistic comment: "...and prospects for development of electricity from other sources including solar heat or windpower are not promising."

1.3.3 Potential Solar Energy Applications

Water pumping, water distillation, educational television, cooking, food and crop drying, grain grinding, refrigeration, heating water, and space cooling are the most evident potential solar applications.

1.3.4 Areas of Potential Cooperation

Training programs, research and technology on simple solar equipment for rural applications, and demonstration projects are activities where cooperation is feasible and desirable.

1.3.5 Potential Solar Energy Markets

Photovoltaic arrays suitable for low power applications such as educational television, water pumping, lighting, and refrigeration are perhaps the greatest opportunities for solar exports, because the high technology required is not transferred easily to developing countries. Wind machines, solar heat engines, controls, and complete systems using several types of solar power also offer export opportunities. Services such as energy planning, training, and engineering offer additional opportunities.

1.4 OTHER ENERGY ACTIVITIES

The great hydropower potential of the Kana River is recognized and major developments are underway. Three main areas in the Rift Valley have been identified as potential sites for exploiting geothermal energy. Planned work includes drilling at selected sites, evaluation, and production runs. A 15 MW plant is planned.

2.0 CAMEROON

2.1 SUMMARY

Cameroon has the resources to be energy self-sufficient (see table III). With a dam planned in the south and one under construction in the north; estimated electrical demands for the next fifteen years will be met. Most of the electrical power is allocated for industrial growth so significant increases in domestic needs could be accommodated by a policy change. Additional hydropower potential still exists. Oil and natural gas discoveries and production also makes Cameroon self-sufficient in fossil fuels, with the potential for small amounts of exports.[1/]

In spite of its energy resources, Cameroon is quite interested in solar energy. A small government research group has been formed, and a technical school has a solar research program. The French have two water pumping projects, one a Sofretes unit and the other a Pompe-Guinard using Solerex photovoltaic cells. The main applications for solar energy are to provide electrical power in areas beyond the electrical grid, primarily for cocoa drying, and water pumping.

The National Office of Scientific Research and Technology (ONAREST), the government research institute, is planning energy studies and measurements of insolation and wind velocities, both of which offer cooperation opportunities. Training and demonstration projects are other areas of potential cooperation.

Because Cameroon is rich in energy resources and a small country--slightly larger than California with a population of 6.5 million--it is not a large potential market for solar energy. Photovoltaic systems for remote areas appear to be the greatest U.S. export potential.

USAID is planning a water conservation project in the Mandara Mountain region. Adding a solar energy water pumping electric and power project is recommended. Cameroon is seeking aid for the proposed insolation and wind measurements and USAID is considering assistance for this.

2.2 ENERGY RESOURCES

- Natural gas has been discovered; the reserves are estimated at approximately; 400 million m^3. Initial production will be at Logbaba.

Table III

CAMEROON

ENERGY RESOURCES

- RICH IN HYDROPOWER
- ENOUGH OIL FOR OWN NEEDS

SOLAR ACTIVITIES

- GOVERNMENT SOLAR RESEARCH GROUP ESTABLISHED
- TECHNICAL SCHOOL ACTIVE IN SOLAR
- FRENCH HAVE DEMONSTRATION PROJECTS

POTENTIAL SOLAR APPLICATIONS

- POWER FOR REMOTE NW AREA BEYOND GRID
- COCOA, OTHER FOOD/CROP DRYING
- WATER PUMPING

POTENTIAL COOPERATION

- INSOLATION & WIND MEASUREMENTS
- ENERGY STUDIES
- TRAINING
- R, D&D FOR RURAL AREAS

POTENTIAL U.S. EXPORTS

- PHOTOVOLTAIC SYSTEMS
- PLANNING & MGT & TRAINING SERVICES
- POWER SYSTEMS FOR REMOTE VILLAGES

RECOMMENDATIONS

- DOE & USAID INCREASE MANDARA MOUNTAIN PROJECT
- PROPOSE COOPERATIVE EFFORT ON INSOLATION & WIND MEASUREMENTS

- Offshore oil explorations have been conducted by 8 companies including: Elf Serepca, Mobil, Gulf and Shell. Production at Kole in the Rio del Ray region by Elf Serepca has started (1978) producing 400,000 metric tons of oil per year. Government of Cameroon (GOC) hopes to make Cameroon a small net exporter by 1981.
- Cameroon has a large potential in hydropower. Estimates are between 15-30 GW.[2/]

2.2.1 Electrical Power

SONEL (Societe Nationale de l'Electricitie de Cameroun) is the national electric utility.[1/] Present electrical capacity is 263 MW hydro and 51 thermal. Hydroelectric power is from the Edea dam in the south, which supplies power for Douala, Yaounde, and the western region. There is only an 8 MW reserve capacity at Edea and this will be needed within two years. In the past, small hydro plants, in sizes from 160 kW to 2 MW, were used but they were abandoned as demand exceeded their capacity. Diesel generators of 40-50 kW capacity are used in isolated areas.

Two new major dams will boost hydro capacity. One in the south, at Song-Loulou, will have 8 units of 48 MW totaling 384 MW. Feasibility studies have been made by Italian and French firms with construction to start in 1980.* Financing is complex, and includes Arabian, European and local funding. Song-Loulou has a high priority in the Cameroon development plan.

The second new dam, Lagdo, is in the north, at Njack and is under construction by the Chinese, as a Chinese aid project. It will have a capacity of 54 MW.** The two new dams will fill Cameroon's electrical needs for an estimated 15 years. There are, however, problems of low water during the dry seasons that cut power levels which in turn affects industry (as, for example, the aluminum plant which uses 115-140 MW).

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*The Ministry of Mines and Energy gave the capacity as 288 MW and completion date as 1981.[3/]

** Another source quoted the capacity at 75 MW.[3/]

2.2.2 Energy Costs[4/]

- Hydroelectric busbar costs are 1 to 1.25 CFAF/kWh (about 5 to 6 mills).
- Electrical charges to industry, the main energy consumer, are subsidized. Alucam, for example, was reported to be paying only 1.6 CFAF/kWh (about 8 mills).*
- The cost of generating power from diesel generators was reported to be 132 CFAF/kWh (about 63¢).
- The country has four zones for consumer electric rates. Douala and Yaounde are 41 CFAF/kWh (about 20¢) for domestic consumers; Garounda, 50 CFAF; and secondary centers 44-54 CFAF. These relatively high rates make solar energy an attractive alternate, especially in competition with diesel generators.
- Retail gasoline costs are about 82 CFAF/liter or about $1.47/gallon.

2.3 SOLAR ENERGY

2.3.1 Solar Energy Activities and Plans

An energy research center has been established within ONAREST, with a very small staff. Two people have been assigned to make an energy study; one person is specializing in solar energy. Funds are sought for a proposed project to measure solar radiation, wind, and rainfall at 7 major stations.[6/]

Using solar energy for drying cocoa is of particular interest because present open drying often results in high spoilage and low quality. Obtaining water for drinking and irrigation is another major need. One of three programs at the National Polytechnical Institute is devoted to solar energy.

Two members of the faculty and its director have solar energy projects. One project involves a simple biomass digester that has been operating successfully on campus. It produced one cubic meter of methane per day using 10 liters of water and 10 liters of cow dung. Use of other organic wastes is being studied. The digester costs about $100, about two-thirds of which was the aluminum container for the methane.

Two experimental solar collectors have been built, one for liquids; the other using air for drying cocoa. The work is funded by ONAREST at about $8,000 per year.[7/]

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* Alucam and another company (SOCATRA) subscribed one-third of the capital for the Edea hydropower plant.[5/]

2.3.2 Solar Energy Capabilities

Cameroon has an aluminum ingot factory but imports processed aluminum products. An aluminum processing plant would be a logical industry to encourage. There already is a glass factory (Hevea) in Douala; thus if sheet aluminum were manufactured in Cameroon, the country would be able to mass produce simple solar thermal systems and the components for family-size biomass digesters. Cameroon has the nucleus of a competent staff for solar energy at ONAREST and the Polytechnical Institute. As in other African countries, however, Cameroon lacks adequate technical manpower.

2.3.3 Potential Solar Applications

Cameroon's greatest needs for solar energy are for agricultural applications, for water pumping in the remote regions particularly in the northwest; and for supplying electrical power for remote villages beyond the electric grid.

The southern part of Cameroon has great potential for biomass. Cassava, known for its high biofuel value, is the staple food of Cameroon. The Societe - Hevea - Cameroon (Hevecam) has a large agro-industrial complex in the Kribi region. In that region the World Bank is funding development of 5,800 to 15,000 hectares in rubber plantations.[8/] Rubber production is estimated to reach 25,000 tons in 1981.

2.3.4 Areas of Potential Cooperation

Cameroon is friendly to the United States and many possibilities for cooperation exist. An immediate interest is adding solar energy to an USAID project on water conservation in the Mandara Mountains. Cameroon is seeking aid in making insolation, wind, and rainfall measurements. Opportunity exists for assisting in accelerating the ongoing energy study and increasing its scope into a comprehensive energy plan.

2.3.5 Potential Solar Energy Markets

Markets for solar energy include design and engineering services, photovoltaics systems for water pumping and electrical power, and hot air systems for controlled cocoa drying. With its new dams, Cameroon will have ample electrical power, but solar generated power has a good chance of competing in regions of high grid extension costs and with diesel generators.

3.0 NIGERIA

3.1 SUMMARY

Nigeria is a dynamic, rapidly growing country, energy rich with petroleum dollars to pay for its expansion plans. The population is estimated at close to 100 million. It is the eighth largest oil exporter, it flares gas, and has considerable coal and hydropower reserves, although the latter is affected by drought. Electrical power is exported to Niger.

The government recently requested proposals for a comprehensive energy study in support of its 4th National Development Plan.[1/] The National Science and Technology Development Agency (NSTDA) was established by decree in 1977, and is studying new sources of energy.[2/] Solar energy research at a low level is underway at three universities: Lagos, Ibadan, and Ife. A summary of solar energy commercialization for Nigeria is shown in Table IV.

Solar applications are primarily for rural areas and regions beyond grid extension plans. These applications include electrical power for villages, water pumping, educational TV, and agriculture applications. In urban areas there is a considerable demand for space cooling, now being filled by conventional equipment.

Potential cooperative projects with Nigeria include energy studies, demonstration projects for rural applications, and training of technical personnel.

Nigeria is interested in building its own solar equipment capability and may purchase suitable plants.[2/] Photovoltaics and wind machines offer good U.S. export potentials, as well as management and technical services.

Joint-venture photovoltaic demonstration projects are recommended.

3.2 ENERGY RESOURCES

Nigeria is rich in energy resources, ranking as the eighth largest oil producing country in the world. Oil and other resources are as follows:[3/]

Coal (million tonnes)	235.8
Crude oil (billion tonnes)	2.6
Natural Gas (billion cubic meters)	2150
Hydroelectric (thousand MW)	17.6

Table IV

NIGERIA

ENERGY RESOURCES

- RICH IN OIL, GAS, COAL
- EXPORTS ELECTRIC POWER
- HYDROPOWER LOW FROM DROUGHT

SOLAR ACTIVITIES

- GOV'T PLANNING ENERGY STUDY
- GOV'T AGENCY ESTABLISHED FOR NONCONVENTIONAL ENERGY
- LOW LEVEL UNIVERSITY RESEARCH

POTENTIAL SOLAR APPLICATIONS

- POWER FOR REMOTE VILLAGES
- WATER PUMPING
- EDUCATIONAL TV
- FOOD/CROP PREPARATION/PRESERVATION
- H/W & SPACE COOLING

POTENTIAL COOPERATION

- ENERGY DEMAND-SUPPLY STUDIES
- RD&D FOR RURAL APPLICATIONS
- TRAINING

POTENTIAL U.S. EXPORTS

- PHOTOVOLTAIC SYSTEMS, WIND MACHINES, PLANNING, MG'T, & TRAINING SERVICES, SOLAR EQUIPMENT PLANTS

RECOMMENDATIONS

- PROPOSE JOINT-VENTURE DEMONSTRATION PROJECTS

Oil production in January 1978 was 1.6 million barrels per day (lowest since 1975). In 1975, two billion cubic meters of oil-associated gas was flared daily.[4/] Two liquefied natural gas (LNG) projects are planned to use this gas. One project is being negotiated now and will supply the U.S. market. Coal production is rising slowly as mines damaged by the civil war are rehabilitated.

3.2.1 Electrical Power

The Nigerian Electric Power Authority (NEPA) generates 98 percent of the country's power. NEPA grid capacity in 1976/77 was 987 MW of which 560 MW were hydro (at Kainji), 407 MW were turbine and 20 MW were diesel. Approximately a 10 MW peak load is available to Niamey, Niger, over a 132 KV line.[5/]

For the year ending in March 1977, total energy sales were 3266 GWh distributed as follows:

	GWh	SHARE %	ANNUAL GROWTH %
Residential	1357	41.5	33.8
Commercial	751	21.8	19.1
Industrial	1198	36.7	9.3
TOTAL	3206	100.0	62.2

To meet the growing demands, NEPA plans to include a fourfold expansion in thermal (turbine) power during its third National Development Plan, ending in 1980/1981. This appears consistent within its rich resources of oil and gas and reduced hydro capacity because of the prolonged drought (the low flow of the Niger River in 1977 was lower only twice before during the past one hundred years). The drought and power shortages forced NEPA to buy three 20 MW oil fired thermal plants from the U.S. to help alleviate power losses from the hydroplants.

In the long term, however, Nigeria is still counting on hydropower as a primary energy source; in the next decade, hydrocapacity will increase almost sixfold. Installed and projected capacity, in MW, for hydro, turbine, and diesel generated power are as follows:[5/]

	1976/1977	1980/1981	1985/1986
Hydro	560	800	3245
Turbine	407	1703	1516
Diesel	20	29	0
	987	2532	4761

While Nigeria's expansion plans for supplying power are impressive, increases in demand continue to create immediate problems. Power blackouts are common and have set off a boom in the sales of standby diesel generators.[6/]

NEPA is faced with an "acute shortage of technical manpower" to carry out its expansion plans. A staff of 28 full-time instructors are training technicians and engineers, but the shortage continues. For example, NEPA estimates a need for adding 80 student engineers a year for the next 10 years, but in 1976 only 25 were recruited and 10 of these have quit.[5/]

NEPA was operating 25 diesel generators in isolated areas in 1977 with a capacity of 36,340 kW. Two more were under construction and two have been closed down. NEPA's plans call for extending its transmission and subtransmission facilities to replace these isolated stations, and expects to close all but a half dozen units that are located at extremities of long, single transmission lines.[5/] This is part of Nigeria's rural electrification plan in which the various Nigerian states select towns to be electrified and NEPA studies the feasibility. If uneconomic for NEPA, the states may provide financing.[7/] The third Nigerian Development Plan (1975-1980), calls for extending the grid to about 400 towns and villages. Several state governments have awarded contracts for installing diesel generating systems to towns and villages beyond the grid. This practice is expected to continue and offers an opportunity for solar electric power to successfully compete with diesel generated power on an economic basis.

Nigeria has established an Atomic Energy Commission with responsibility for nuclear development including uranium prospecting and nuclear power plant construction. The shortage of scientists and engineers, however, appears to be a deterrent to building and operating a nuclear power plant.

3.2.2 Energy Study

NSTDA is sponsoring research on Nigerian energy needs and competing methods to supply the demand. A study of this type was done in 1972-74; the new study will consider hydropower, fossil fueled thermal systems, and nonconventional energy systems. The study, intended to help develop national policy, will involve three universities. A 10+ man effort seems necessary, but is handicapped by lack of skilled personnel.[2/]

A more positive approach to the same problem is a recent (June–July 1978) request for proposals by the Ministry of Finance and Economic Development for a special energy study to support the Fourth National Development Plan, 1980-85. The study will examine various sources of energy in Nigeria, determine their extent, and propose optimal utilization of these energy resources for the 1980-2110 period. This study is to be in four parts:[1/]

- An analysis of the present energy situation; existing plans for energy development; and the production, storage, conversion, distribution, and consumption of energy from basic sources.
- Determine energy demand forecasts, with projections up to the year 2010 using various forecasting techniques. The demand analysis will be divided into types and sources of demand, including sectorial analysis of energy consumption. Also included will be a world market demand forecast for energy resources including oil, natural gas, coal, lignite, thorium, and uranium, with demand forecasts for major consuming areas of the world, including Western Europe, North America, and Japan, and Nigeria's estimated contribution to their import demands.
- Estimate proven and potential energy supplies in Nigeria and the technical feasibility of their commercial exploitation.
- Consider the economics of combination of energy sources, including nonconventional energy, to meet projected demands. Unconventional energy sources include solar energy, but wood, wind, and oil shale were singled out as having only passing interest. This energy study offers a good opportunity to participate and assess in detail Nigeria's energy demands and supplies.

3.3 SOLAR ENERGY

3.3.1 Solar Energy Activities and Plans

Although the official position of the Federal Ministry of Mines and Power, as expressed by its Permanent Secretary, is that a positive interest exists in the potentials of solar energy, solar activities are still at a low level.[8/] The National Science and Technology Development Agency (NSTDA) supervises energy research, including solar. The rapid increase in urban demand for power, fed by petroleum dollars, has delayed rural electrification, so the rural sector is receiving the most attention in NSTDA planning. Emphasis has been placed on simple solar energy devices such as hot water, crop drying, irrigation, and pumping drinking water. Institutes have been established to measure solar radiation, and to design and fabricate solar hot water systems for rural applications. At present no Nigerian company is making solar collectors, however, NSTDA expressed interest in the purchase of a complete solar manufacturing plant.[2/]

Present levels of solar energy research at Nigerian Universities are small. The work at the University of Lagos, under Drs. Akinsete and Adenubi, appears to have peaked in previous years. Research has been conducted on hot air collectors, flat-plate hot water systems, water distillation, and Savonius wind machines.[9/] Insolation measurements presently are underway. Professor Williams of the University of Ife is interested in photovoltaics, and the University of Ibadan was reported to have solar energy work underway. Professor E. O. Ezlilo of the University of Nigeria is seeking support from NSTDA to support a solar research team.[2/]

In summary, NSTDA is oriented towards less complex solar conversion systems, research, and training, and recognizes the need to go beyond R&D.

Other solar converters are in operation in Nigeria including at least two units in Kano including a photovoltaic powered water pump by ELF Oil Company.[9/] Wind pumps are in operation in the Kano at the Emir's Palace and other areas.

3.3.2 Solar Energy Capabilities

Nigeria has the basic capability for utilizing solar energy; the problem is that other, more urgent needs command a higher priority. NEPA, for example, showed no interest in solar energy, which is hardly surprising as they already have a severe shortage of technical manpower for their conventional power expansion. There is an opportunity, therefore, for the U.S. to supply both technical skills and solar products until Nigeria's manpower situation improves.

3.3.3 Potential Solar Applications

The greatest needs for solar generated power are in rural areas where it could be used to power educational television, pump water, dry or preserve foods, dry crops, and furnish electrical power to remote villages. In urban areas, solar hot water and space cooling systems could lessen the demand for electrical power. The new Federal Capital City, with its projected population of 1.6 million, by the year 2000, is an outstanding opportunity to incorporate solar hot water systems and space cooling systems in all buildings.

3.3.4 Areas of Potential Cooperation

Friendly U.S.-Nigerian relations, trading, and Nigeria's expansion plans using petroleum dollars offer a wide range of potential cooperation activities. These activities include: energy analyses, training programs for solar applications, research and development of solar equipment for rural applications, and demonstration projects.

3.3.5 Potential Solar Energy Markets

The Nigerian market for solar products is great; demand for electrical power alone is growing at an average annual rate of over 20 percent. Solar energy applications can bolster a lagging rural electrification plan, and lessen the demand on other energy resources. The plan to build a completely new capital offers a huge potential solar market. Nigeria offers a market for all types of solar products and, for its size, to a greater degree than the U.S. domestic market.

4.0 NIGER

4.1 SUMMARY

Niger has some coal and considerable uranium resources, but has no hydropower (See table V). It imports oil and electrical power. Niger's per capita electrical power consumption is 15 kWh/yr, one of the lowest in Africa.[1]

Niger is one of the most active African countries in terms of using solar energy. It has a government-supported research laboratory, a factory for making hot-water systems, and a training center.[2] The research laboratory is well equipped with various solar energy systems and modern instrumentation. Projects include hot-water systems, solar cookers, distillation units, and a steam-engine system using flat-plate collectors as preheaters and a parabolic-linear concentrator. A high-temperature material laboratory, using a central receiver system, is planned with some equipment already having been constructed. The modern factory produces 6 hot water systems a day, and is capable of producing 30.[3] The training center draws attendees from African and Mideast countries; the current group numbers 13.

Niger began experimental photovoltaic powered educational television in 1968 with assistance from CATEL, an Ivory Coast firm. At present there are 100 photovoltaic television installations.

A Niger-French solar driven water pump is operating at a village 10 km from Niamey. It uses Nigerian-built flat-plate collectors, and a Sofretes engine and pump system.

Present solar applications in Niger are primarily for water pumping, educational television, and crop drying.

Good potential for U.S. - Niger cooperation exists in demonstrating photovoltaic-powered systems for small villages to provide power for water pumping, refrigerators, educational television, and lighting. The best potential U.S. exports to Niger are photovoltaic systems.

It is recommended that the U.S. contribute towards the proposed materials laboratory, which will use a central receiver, and propose a cooperative photovoltaic demonstration project.

Table V

NIGER

ENERGY RESOURCES

- IMPORTS OIL & ELECTRIC POWER
- NIGER RIVER LOW FROM DROUGHT

SOLAR ACTIVITIES

- GOV'T SUPPORTED SOLAR RESEARCH & TRAINING LAB.
- GOV'T SUPPORTED FACTORY FOR H/W SYSTEMS
- JOINT FRENCH-NIGER PUMPING DEMONSTRATIONS

POTENTIAL SOLAR APPLICATIONS

- WATER PUMPING, COMMUNICATIONS
- CROP DRYING, FOOD PRESERVATION

POTENTIAL COOPERATION

- ENERGY DEMAND-SUPPLY STUDY
- RD&D FOR RURAL APPLICATIONS
- SUPPORT FOR EXPANDED RESEARCH/TRAINING FACILITY

POTENTIAL U.S. EXPORTS

- PHOTOVOLTAIC SYSTEMS, WIND MACHINES
- PLANNING & MG'T SERVICES

4.2 ENERGY RESOURCES

Niger has important uranium mines and some coal but it imports oil. Mines containing about 20,000 tons of uranium will provide an important source of uranium to industrial (noncommunist) countries towards meeting an estimated demand of 400,000 tons between 1966 and 1980. A company, jointly owned by French, German, and Italian interests and the Niger Government, is in charge of the exploitation and commercial production of the uranium. Important contributions Niger could make are financing and manpower. The uranium production went from 430 metric tons in 1971 to 1800 metric tons in 1975.[4/]

Wood used directly or transformed into charcoal for cooking is another major source of energy. The extensive use of wood has already resulted in damaging consequences, which, added to the drought, make Niger one of the most wood-scarce Sahelian countries. For instance, where it used to take 20 minutes to fetch wood for cooking, it now takes 2 to 4 days by camel.[3/]

Niger has no hydropower. It is a land locked country and does not have particularly abundant surface water resources; only a small portion of the river Niger crosses the southwestern part of the country. Also, a part of western Niger borders on Lake Tchad.

In addition to oil, Niger imports 0.16×10^6 metric tons of coal, equivalent to 800,000 bbl and it also imports a large amount of electricity from Nigeria. A 132 kV line extends from Kainji dam in Nigeria to Niamey, the capital of Niger.

In 1975, the total electricity generation capacity was 20 MW, all of which was thermal. Niger's annual consumption of electrical energy was 70 million kWh and per capita consumption was 15 kWh, which makes Niger one of the lowest electrical energy consumers in Africa.[1/]

4.3 SOLAR ENERGY

4.3.1 Solar Energy Activities and Plans

Republic of Niger is one of the most active African countries in the field of solar energy. Through its ONERSOL (Office de l'Energie Solaire), Niger is engaged in various solar energy activities, including research demonstration, production, and training. Niger was the first foreign country to use solar energy to power educational TVs. ONERSOL was created by an Act on May 15, 1965. That Act was modified by an ordinance, followed by an order in council, which established its statutes on May 15, 1975. ONERSOL is an independent agency that depends upon the President of the Republic of Niger. Its mission is:

> ...to create and manage a solar-energy experimental center for prototypes, installations, apparatuses development, and results dissemination; and ...to ensure the popularization of these installations and apparatuses, as well as their manufacture and commercialization both inside and outside the Niger Republic.2/

ONERSOL is administered by a Board of Directors; and run by a director, Dr. Abdu Moumouni Dioffo, and two assistant directors - one in charge of the research section and the other in charge of the manufacturing and commercialization section. Total staff for both the research and production facilities is approximately 40 members. This indicates some activity, but it is far from reaching the full capacity of ONERSOL. In fact, lack of sufficient personnel is one of the major problems of ONERSOL. The office lacks engineers and trained technicians. Growth in personnel has been slow, until the recent years; for 5 years there were only 3 researchers and 12 technicians. Resolution of these problems largely depends upon the budget. Prior to 1971, the budget was 16.6 million CFAF, of which 6.5 million CFAF were from AID programs, and 2.3 million from sales of hot water systems. Presently ONERSOL operates with a budget of 27 million CFAF ($120,000) for research, production, and commercialization activities. Throughout the year, as the result of the insufficient ONERSOL budget, ONERSOL has been unable to hire high level technicians, to engage in expensive but necessary research and development of solar prototypes.2/

4.3.1.1 The ONERSOL Research Section

The research facilities are mainly comprised of an office and laboratory building, a workshop, and various solar energy systems. The offices and laboratory are located in the main building. The laboratory is equipped with high precision instruments, including integrating and recording devices for data gathering and applied research. A small scale model of the proposed solar thermal research facility also is displayed in the laboratory.

The first prototypes of hot water systems, parabolic troughs, and solar cookers were constructed in the shop. Their quality was quite good, despite the lack of funds and personnel.

Since 1966, basic data on solar radiation, ambient temperature, pressure, and relative humidity have been recorded. Solar radiation measuring devices are installed in various parts of the country: Niamey, Agadez, Zinder Maradi and Tahoua (See map, page 91). The results observed during a typical year are:

- Mean daily global solar radiation is approximately 750 watts per square meter per hour.

- There is an average of 8 to 10 hours of sunshine per day.[1/]

In addition to the collection of data, ONERSOL is engaged in the development of many solar systems.

- Solar Cookers - Solar cookers developed at the laboratory are based on Farrington Daniel's (Wisconsin, U.S.) design. They have a parabolic shape with a 1.5m diameter and are made of fiberglass covered with aluminum foil. In Niamey, a solar cooker can cook 3-4 kilograms of rice in one hour at midday. A solar cooker costs about $100, which makes it uneconomical to the average Nigerian. ONERSOL developed a steam cooking vessel and demonstrated its use to the population of a small village near Tera. A steam vessel also was used for producing gypsum for the Niamey Hospital.

- The Solar Hot-Water Systems - Hot-water systems were developed at the research institute and are manufactured at the ONERSOL plant. The hot-water systems are composed of flat plate collectors, approximately 1m x 2m, and a 200-, 400-, or 1000-liter capacity cylindrical tank. Tubing and collector plates are made of aluminum. Hot-water systems provide temperatures in the range of 60^{o} - 70^{o} for single glazing, and 70^{o} - 80^{o} for double glazing. Glass wool is used as insulating material despite its high cost. Night losses are about 5^{o}C.

- The Bossey-Bangou Installation - ONERSOL has installed a solar pump system at the village of Bossey - Bangou, 10 km from Niamey. The system pump uses a Sofretes pump and ONERSOL collectors, which have replaced the previous Sofretes collectors. Installation observations and data measurements are collected hourly by ONERSOL personnel. The characteristics of the solar installation are as follows:[5/]

  - 48 flat plate collectors, about 1 x 2m, have a $80m^2$ total area.

  - A Sofretes Rankine 2-cycle, 240-rpm engine drives a double acting pump that operates a jet pump in the adjacent 12-m deep x 1-m diameter well. A reinjection pump pumps water through the collectors and heat exchanger. The working fluid is Freon 114 heated to 75^{o}C, 7 atm at entry and cooled to 62^{o}C, 2 atm in the condenser. The well pump brings water to the condenser at 31^{o}C and water out of the condenser is 33^{o}C.

  - Pump capacity is 1/3 HP.

  - Flow rate is 6 to 7 m^3/h, or 30 to 35 m^3 per day.

  - Pressure height is 18-m.

  - A cylindrical water storage tank has a 16-m height, and a capacity of about 100 m^3.

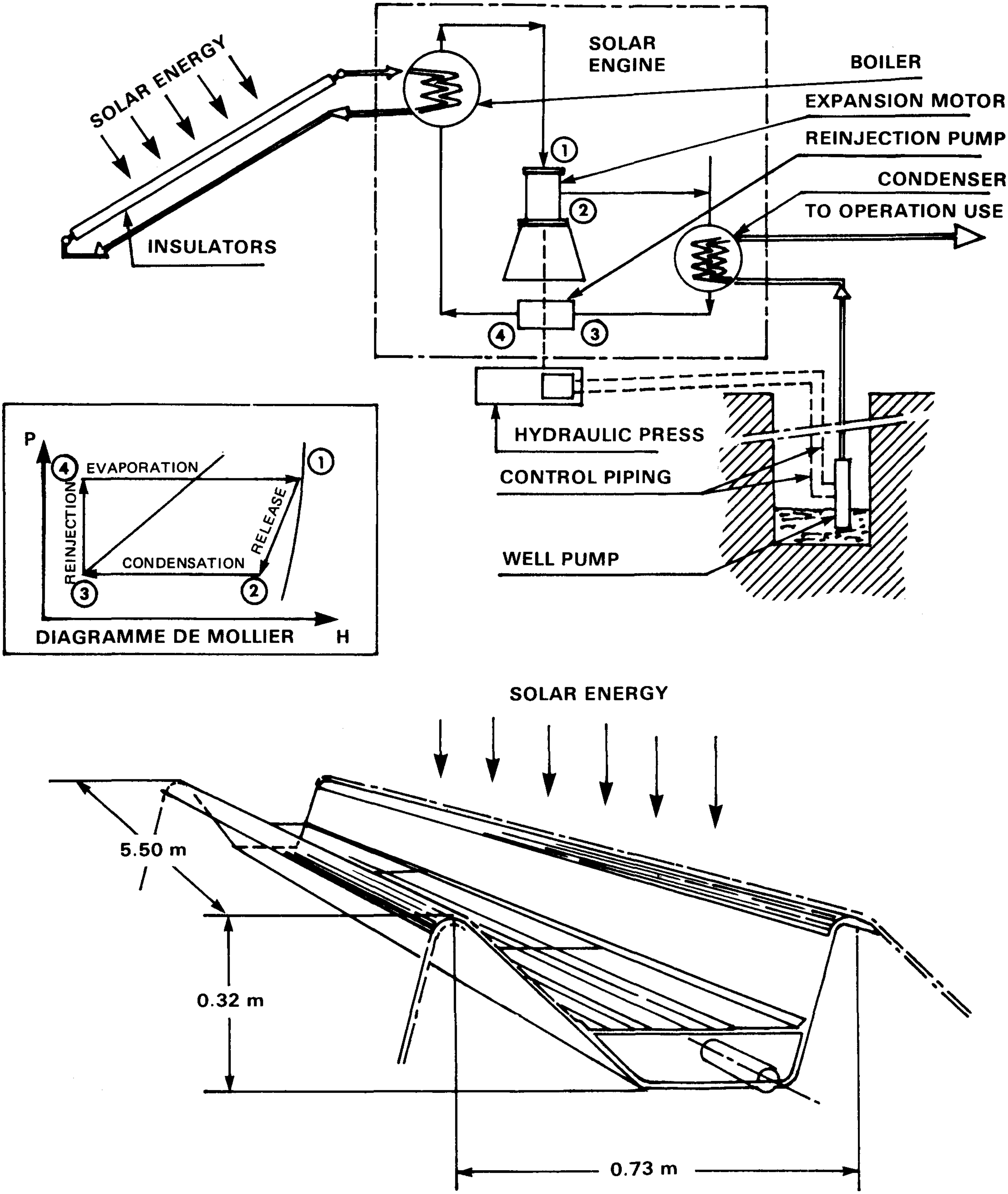

Figure 4 Solar Engine Working Principles

- The Parabolic Linear Concentrator - A 6-m long and 1.20-m wide parabolic concentrator was developed by Dr. Moumouni in 1971. The collector is aluminum, is insulated with glass wool, and is covered with a thin aluminum sheet. Water pumped from a 15-m deep well is preheated by an adjacent flat plate collector, and vaporized at 200°C by the concentrator. The system operates like an alternating steam engine. Freon is the working fluid, which follows a cycle similar to the Rankine cycle. The parabolic linear concentrator system was built and operated by ONERSOL staff. The system is still in the development stage, but is expected to become very useful for pumping applications in Niger and Sahelian countries.

- The Central Receiver Model - A miniature model of the proposed central receiver is exhibited at the laboratory (see figure 5). The central receiver will be composed of 2 heliostats of 85m^2 each, a central receiver and, a parabolic reflector that will be located at the back of the research building. The system will have approximately 100 kW capacity and will be used for material research. More funds are needed, however, to start the project.

4.3.1.2 ONERSOL Solar Manufacturing and Commercialization Section

ONERSOL's manufacturing and commercialization section is housed in a modern, well-equipped structure, completely separate from the Research Center. The manufacturing unit has been in operation since 1976. It employs about 30 persons and produces 6 solar hot-water systems per day, but has a capability for producing 30 systems per day. The price of a 200-liter hot-water system is about $800, which is affordable to government workers. The payback period for such a system is estimated at about 18 months. ONERSOL produces hot water systems ranging from 200 liters to 1000 liters. These systems are made of 1100 type aluminum imported from Canada and France. Systems are sold to the government for office buildings and hospitals. Systems are also sold for installation on private residences and in neighboring countries such as the Republic of Benin and Upper Volta.

Distillation units are also being sold in a small quantity. Other systems, such as solar dryers, developed or perfected by the ONERSOL Research Section, will be transferred to the manufacturing and commercialization section.

4.3.1.3 ONERSOL Training Center

This third section reflects a wider impact of ONERSOL activities on other African countries. As a result of decisions made at the UNESCO General Conference held in Nairobi, Kenya in October, 1976, the "Office de l'Energie Solaire" has been entrusted with organizing a specialized training course involving different levels of solar energy utilization.

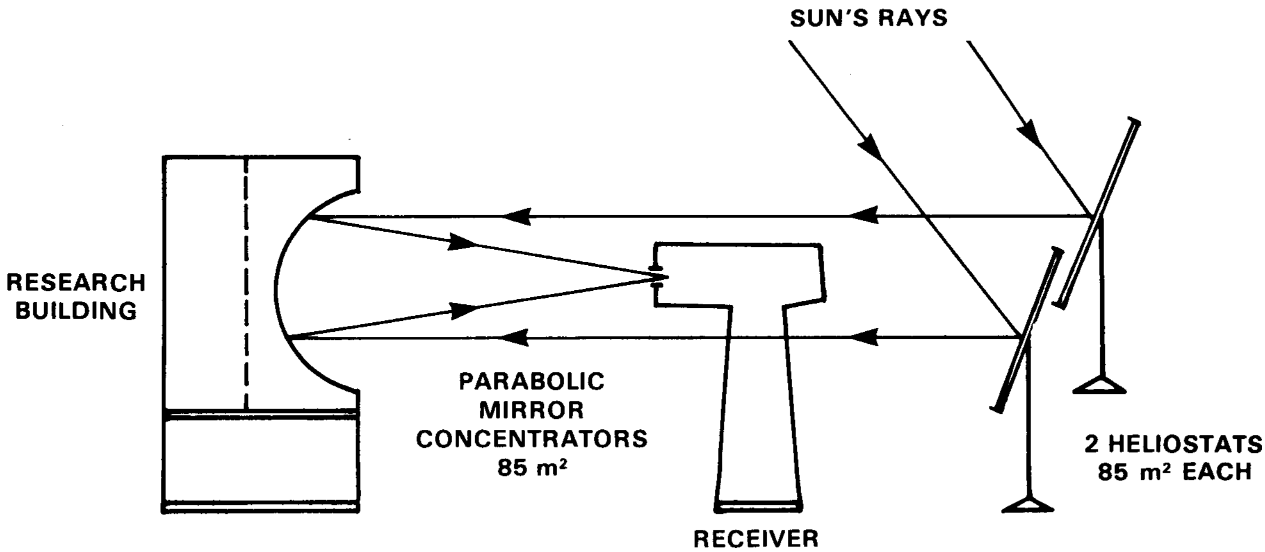

Figure 5 Proposed Central Receiver Model

This training is intended for students, researchers, and technicians of West African countries. At the research specialist level, candidates are graduates or post-graduates; at the technician level, candidates must have completed secondary school studies. Technicians are to be trained in solar energy, laboratory-measurement techniques. Training lasts for three to six months. At the end, an ONERSOL-UNESCO Certificate of Training in Solar Energy is delivered.

4.3.1.4 Photovoltaic Power TV for Schools

In Niger the first experimental photovoltaic system was installed in 1968 to run educational TV in a school near Niamey. The Success of this operation led to an installation of 22 more photovoltaic systems for educational TVs. In 1976, Nigerian school television programs were being broadcasted to some 9000 pupils in 214 classes. It is projected that 90 percent of the classes will be using photovoltaic power. Installation cost of a solar array of six modules, with frame, storage batteries and charge regulator, in 1976, was 15000FF ($3460) without taxes in Niamey. This translates into 0.64FF ($0.15) per hour for solar cells, assuming a lifetime of 10 years; or 2.05 FF ($0.47) per hour for an alkaline battery, as are being used in some areas, with a 2000 hours of operating time.

Model CATEL CI 17 receivers are equipped with 61 cm screens and are completely solid state. Power consumption is very modest for their size, approximately 32 watts.[4/] Each TV receiver is connected to a 40 amp - hr storage battery.

CATEL (See page 44), an educational TV company, based in Abidjan, Ivory Coast, has undertaken a series of insolation measurements, and installed experimental stations equipped with a solar panel, a load resistance, and an ampere-hour meter in various regions of Ivory Coast, Gabon, and Togo.

4.3.1.5 Solar Energy Systems Production in Niger

Hot-water Systems

1 Production Facility

Staff: about 30 persons

Production Rate: 6-7 per day with a capability to produce 30 hot water systems per day

Cost of Hot-water Systems: (1977 factory prices)

Solar Hot-Water Systems Capacity	Single Glazing	Double Glazing
200 liters	$ 803	$ 855
400 liters	$1143	$1264
600 liters	$1618	$1801
1000 liters	$2484	$2788
		($1 = 220 CFAF)

Sales: In Niger, Upper Volta and Benin

Solar Distillation Systems

10 liters/day------------------------------------$380

20 liters/day------------------------------------$818

4.3.2 Solar Energy Capabilities

The most important economic activity in Niger is agriculture. This activity uses 90 percent of the labor; but because four-fifths of Niger is arid desert, only 3 percent of the land is used in addition to nomad pasturelands.

The industrial activities include to mining operations, cement, textiles and agricultural products. Industrial development is seriously inhibited by lack of an adequate transportation system, and the high cost of electric power generation. Another major handicap for economic growth is the high cost of transporting goods between Niger and the coastal ports of Benin or Nigeria.

Despite difficulties, the Government of Niger has had a sustained interest in solar energy. As the result of more than 10 years of activities, ONERSOL has passed from an artisan workshop to a modern manufacturing and research facility. However, the development of ONERSOL is handicapped by a lack of adequate finances.

ONERSOL staff is capable of conducting all operations pertaining to fabrication and installation of flat plate collectors, solar hot-water systems, solar stills, and solar cookers. Although commercial activities may be limited by the purchasing power of the average Niger citizen, it appears that a strong marketing capability needs to be developed.

4.3.3 Potential Solar Applications

Lack of water is the single most important problem in Niger. Two-thirds of Niger receives less than 4 inches of rain per year. The southern part of the country enjoys a small part of the Niger River and rainfall of about 30 inches per normal year. Therefore, the greatest potential for wide-scale solar application is the tapping of underground water resources.

The second basic goal of the Government of Niger is to diversify agriculture and foodstuff production. This leads to the belief that agricultural applications of solar energy also hold good potential.

As mentioned earlier, photovoltaic cells are already being used to power educational TV and relay stations. There are multiple potential applications of photovoltaics, and ONERSOL is pushing hard to develop capabilities in that field.

Use of wood for cooking and subsequent desertification is a major concern to all Sahelian countries. It takes more than a two-day camel ride to collect a week's wood supply for a family. Alternatives to cooking with wood must be found. The local population does not seem to accept solar cookers, because they are slow and would require changes in cooking and eating habits, and thus it is appropriate to consider biomass. Furthermore, one of the major economic activities in Niger is animal husbandry. Livestock and its derivatives constitute an estimated 30 to 40 percent of the country's exports. Reluctance of the Peuls (the main stock raisers) to sell their cattle, which they regard as a symbol of wealth rather than a source of income, may well favor the development of biogas industries.

Joint agreement between Niger and the French government to measure and assess wind energy potential throughout the country indicates good possibilities for utilizing this source of energy.

4.3.4 Areas of Potential Cooperation

Niger has special relations with France, and maintains good relations with EEC, Canada, and its neighboring African countries. Niger also has joint agreements with Nigeria for resources development, uranium mining, and electrification programs. In addition, as part of the Lake Chad Basin Commission, which includes Cameroon, Nigeria and Chad, Niger is engaged in eight joint projects to develop the Lake Chad resources. One of these projects involves solar water pumping for irrigation.

Cooperation for economic development between the U.S. and Niger has been established since Niger's independence in 1960. The U.S. has increased its aid to Niger to develop an agricultural base and to reduce the effects of the drought.

In the field of solar energy, the U.S. can undertake many cooperative programs with Niger. These programs could range from energy-needs assessment and RD&D to commercialization. ONERSOL has expressed the desire to obtain U.S. aid for its planned central receiver facility and for an expansion of its summer seminars. ONERSOL maintains extensive international relations with research centers and universities in various countries including the U.S., U.S.S.R., France, U.K., and Canada.

4.3.5 Potential Solar Energy Markets

Needs for solar energy systems are easier to define than the capabilities of Niger citizens to purchase them. Niger has one of the lowest GNP per capita--$130--in Africa.[7/] It also will be difficult to sell new systems to the rural people—even if they would be appropriate. People often are reluctant to buy or use systems which they know nothing about or are not accustomed to.

Therefore, the first major client will be the Government that could purchase worthwhile quantities of solar products, through its multiple energy-related projects. The market for hot-water systems would certainly be taken by ONERSOL. However, there would remain sizeable markets for water pumping, electrical usages, agricultural applications, and cooling.

5.0 IVORY COAST

5.1 SUMMARY

Ivory Coast is an energy importer, having no oil of its own. Oil comes from Nigeria, Gabon, and Arab countries, and is refined at Abidjan, the principal city and port of the Ivory Coast. There are considerable hydro resources although somewhat limited by the drought. Wood also is plentiful and in sufficient supply to be exported. Table VI outlines Ivory Coast's energy resources and potentials.

Electric power is generated by thermal, hydro, and diesel generating plants. Electrical consumption is projected to increase from 962 million kWh in 1975 to 5 billion kWh by 1985. Present installed capacity is 440 MW, a little over half of which is hydro. By June 1979, another 210 MW hydroelectric plant will be ready and other hydro power installations are planned. The present drought, the worst in history, has reduced effective hydro power considerably.

A deep ocean hole off Abidjan makes the possibilities of an on-shore ocean thermal conversion plant appear attractive. A 25 MW plant was recently proposed by an American firm.

The government has no solar energy projects underway, but it is interested and has a feasibility study due in December 1978 as part of the rural development effort. The electric utility is planning a solar energy laboratory. A private company is promoting photovoltaic powered educational television sets, a very large market. Two French companies are active in photovoltaic powered water pumps.

Solar applications currently in use are for educational television, water pumping, crop drying, and bioconversion processes. Small hydro-power plants are used in combination with small thermal plants using wood waste, and ocean thermal energy conversion.

In Ivory Coast, great potential for cooperation exists in photovoltaic power systems, forest management, and ocean thermal energy conversion projects. The best potential U.S. solar energy export to Ivory Coast is photovoltaics, as a rapidly expanding market is foreseen. Planning and management services and ocean thermal conversion technology are also good possibilities.

The presently expanding business of photovoltaic-powered educational television and its projections leads to the conclusion that photovoltaics is on the verge of explosive growth.

TABLE VI

IVORY COAST

ENERGY RESOURCES

- HYDROPOWER LIMITED BY DROUGHT
- ON SHORE OTEC POTENTIAL

SOLAR ACTIVITIES

- NO GOV'T PROJECTS IDENTIFIED BUT FEASIBILITY STUDY UNDERWAY; GOV'T INTERESTED
- ELEC. UTILITY PLANS SOLAR HOUSE-LABORATORY
- PRIVATE COMPANY VERY ACTIVE IN PV-POWERED TV
- PV POWERED WATER PUMPS BY 2 FRENCH FIRMS

POTENTIAL SOLAR APPLICATIONS

- PV POWERED TV, WATER PUMPING, COOKING, CROP DRYING, FOOD PRESERVATION, OTEC

POTENTIAL COOPERATION

- ENERGY DEMAND-SUPPLY ANALYSIS, INSOLATION, WIND DATA, SOLAR RD&D FOR RURAL APPLICATIONS, OTEC

POTENTIAL U.S. EXPORTS

- PHOTOVOLTAIC SYSTEMS, PLANNING & MG'T & TRAINING SERVICES, OTEC TECHNOLOGY

CONCLUSIONS

- PV SYSTEMS FOR EDUCATIONAL TV ON VERGE OF EXPLOSIVE GROWTH

RECOMMENDATIONS

- STRENGTHEN LEAD IN PV SYSTEMS
- STUDY FEASIBILITY OF JOINT OTEC VENTURE

For this reason, it is recommended that the U.S. strengthen its position in photovoltaic technology. Feasibility studies on developing photovoltaic-television components and/or systems is also recommended.

5.2 ENERGY RESOURCES

Ivory Coast's energy situation is characterized by:

- Rapidly increasing consumption;
- Heavy reliance upon petroleum products, both for direct consumption and for production of electricity; and
- Consequent heavy dependence on imports (to date, Ivory Coast produces no oil of its own).

Taking into account the anticipated new large industrial projects (iron ore, paper pulp), Ivorian electricity consumption is projected to increase from 962 million kWh in 1975, to 3 billion kWh in 1980, and to 5 billion kWh in 1985 (see table VII).[1/]

Table VII Ivory Coast Energy Consumption
(Kilotons of Petroleum Equivalent)

	1970	1975	1980	1985
Wood and Charcoal	385	438	500	580
Electricity	158	287	857	1400
Petroleum Products	400	591	859	1218
	943	1316	2216	3198

Ivory Coast's objective in the energy sector, for the coming years, is to assure itself of sufficient energy supplies to sustain its ongoing economic development program at the lowest possible cost. To this end, the five-year plan calls for a massive energy development program over the coming 15 years, based heavily on hydraulic, as opposed to thermal energy generation. Relevant aspects of the development program include:

- Completion of the Taabo dam on the Bandama River downstream from the Kossou dam by 1979;
- Completion of the Buyo dam on the Sassandra River (to supply electricity to the iron ore mine) by 1980;

- Evaluation studies of possible dam sites on the Cavally (in cooperation with Liberia) and the Comoe rivers;

- In 1976-77, construction of a power line between Ivory Coast and Ghana to permit sharing of electricity; and

- Construction of the Sombre dam downstream from Briyo, beginning in 1980.

The Plan outlines several other measures to protect Ivory Coast's strategic energy interests:

- Search for and development of alternative energy sources, including off-shore drilling for oil, commercial charcoal production, consideration of the possibility of developing the bituminous Eboninda shale deposit, and solar energy;

- Diversification of Ivory Coast's sources of oil imports beyond Nigeria and Iraq to include perhaps Saudi Arabia, the United Arab Emirates, Iran, and Venezuela, and negotiation of long-term supply contracts to assure the stability of those imports;

- Gradual extension of available electricity (from 330 localities in 1975 to 600 in 1980 and 1,000 in 1985);

- Favorable energy pricing policies for large industrial consumers; and

- Initiation of energy conservation programs, including promotion of mass transit.

The cost of this program, for purposes of the five-year plan, is estimated at 149.3 billion CFAF.

5.2.1 Energy Costs[1/]

- Low Voltage Electricity (220 - 380 Volts)

Table VIII Electric Energy Costs*

	Domestic Use**	Professional Use***
First Level	38.20	43.90
Second Level	29.40	31.90
Third Level	19.70	21.80

* All costs are in CFAF per kWh and include the municipal tax of 1 CFAF per kWh. ($1 = 208 CFAF).

** Domestic consumption levels are: First level up to 90 kWh, second level from 91 to 180 kWh, and third level above 180 kWh.

*** Professional consumption levels are: First level up to 150 kWh, second level from 150 to 300 kWh, and third level above 300 kWh.

- High Voltage Electricity (15,000 Volts)

High Voltage electricity is used in industrial applications and the charges depend upon time of use of electricity and on the amount of power drawn from the grid (table VIII). If a particular industry is a large consumer of electricity, a contract for special rates can be negotiated between Energie Electrique de la Cote d' Ivorie (EECI) and the industry concerned.

Table IX High Voltage Electricity Costs

In CFAF	Power Drawn By Client in kW 0-249	250-499	500-999	1000-1999	Over 2000
Rate annually fixed by utility per kW of power drawn	8250	7250	6450	5750	5200
Price of kWH consumed					
a) Regular Hours 7:30 a.m.-7:30 p.m. 10:30 p.m.-midnight					
- First block	23.70	20.70	18.80	16.70	15.50
- Excess	17.70	15.90	14.50	13.10	12.40
b) Peak Hours 7:30 p.m.-10:30 p.m.	32.10	30.20	27.20	23.40	22.40
c) Off-Peak Hours Midnight to 7:30 a.m.	11.60	10.80	10.20	9.30	8.60
Monthly size of first block (in kWh per kW)	50	80	100	120	120

- Petroleum Products

All the following costs are in CFAF.

Table X Petroleum Costs

Product	Retail Cost
Butane (12.5 kg bottle)	1850
Premium gasoline (per liter)	105
Regular gasoline (per liter)	100
Kerosene (per liter)	68
Diesel oil (per liter)	65
Distillate diesel oil (per liter)	36.3
Fuel Oil 1500 (per ton)	26670
Fuel OIl 3500 (per ton)	17468

5.3 SOLAR ENERGY

5.3.1 Solar Energy Activities and Plans

The Office of National Rural Promotion (ONPR) was created by the President. ONPR has no solar projects at the present time, but it is very much interested in solar technologies. They are conducting a feasibility study on bioconversion, crop drying, and waterpumps using photovoltaic power sources. This study will be completed by the end of 1978.[2/]

There is considerable interest in the OTEC system. The French apparently conducted experiments in the 1930's and 1950's. A deep hole off Abidjan makes OTEC particularly attractive. The U.S. Embassy, in Abidjan, has a well prepared 25 MW OTEC proposal by Pacific Power and Protein, Inc., New York, to Cote d' Ivoire dated May 3, 1978. It uses a shore-based plant, a cold pipe laid along the bottom of the sea canyon, and warmer water from a lagoon to get a mean temperature differential of 20^{o} - 70^{o}C.

A large potential market for photovoltaics exists in the Ivory Coast. The photovoltiac (PV) system is considered by them to be better than the Sofretes heat engine. Energy

Electrique de la Cote d' Ivoire (EECI) will electrify all "county"-seat villages of 5000+ population by 1985, and these may be prime candidates for photovoltaic systems. Compagnie Africaine de Television (CATEL, see page 33) did an economic feasibility study for the operation of remote TV sets. The study concluded that solar cells would double the cost benefit as compared with alkaline batteries. CATEL is an independent profit making company, with shares owned by the Government of Ivory Coast, and private investors in the Ivory Coast and France. It's objective is to supply educational TV receivers for Africa. They have been working with American as well as French solar firms for five years. CATEL has installed photovoltaic powered TV sets in Niger and the Ivory Coast. The TV sets installed in Niger require 50 watts and are for daytime use only. A 40 watt/24 volt TV set is under development.*

They are selling the entire system (TV, PV, antenna, and batteries). CATEL sells TV sets to governments and also acts in an advisory capacity. CATEL will not get into other markets but other organizations in Ivory Coast could use PV in such activities as health and national relay stations. Zaire alone represents a potential of 20,000 to 30,000 TV sets for educational purposes according to CATEL. Ivory Coast has three schools that use PV powered TV sets, out of 2500 schools with educational TV. About 500 more PV powered TV sets are planned for 1979. CATEL presently is conducting life-cycle testing of 9 PV arrays from different manufacturers, which include Optical Coaling Laboratory, Inc., Solarex, Solar Power, and Motorola.[3/]

Wind machines do not hold much promise in the southern part of the country because of low prevailing wind speeds. Wind speeds on the southwest coast average about three meters per second (6.6 mph).

Plans for solar thermal conversion are very fluid; interest does exist, however, in solar space conditioning, domestic hot water, and crop drying. In October 1978, EECI will build a solar house to test the feasibility of solar cooking, space cooling, and refrigeration. The objective is to assess the potential of solar energy for household applications. The solar house will be located in the northern part of the country, but no specific site has been selected yet.[4/]

ONPR also is interested in forest replanting and management, and in bioconversion processes similar to those being used in India and China.

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* This is slightly higher than mentioned in Niger reference.[4/]

5.3.2 Solar Energy Capabilities

At present, there are no facilities for the manufacture and development of solar hardware.

5.3.3 Potential Solar Applications

- OTEC looks very promising for application on the Ivory Coast, especially because the OTEC plant can be located on shore;
- Photovoltaic systems have the best chance of succeeding. In the near future the applications will be limited to power supplies for TV operations and pumping of water;
- Drying of food and vegetables;
- Bioconversion processes for methane production, and
- Solar cookers and refrigeration of perishables.

5.3.4 Areas of Potential Cooperation

- An energy supply-demand analysis is urgently needed and should include matching energy resources with end uses of energy;
- Data collection and analysis of insolation and wind speed, to determine the potential of direct solar and wind energy towards meeting the energy demands;
- Solar RD&D for applications in rural areas; and
- Ocean Thermal Energy Conversion.

5.3.5 Potential Solar Energy for Export Markets

- Photovoltaic systems;
- Ocean Thermal Energy Conversion Technology; and
- Planning, management, and training services.

5.4 OTHER ENERGY ACTIVITIES

Electricity consumption is projected to increase from 962 million kWh in 1975, to 3 billion kWh in 1980, to 5 kWh in 1985. Most of this increased demand will be supplied by hydroelectricity. Several dams are in the planning stages or under construction to meet this growing demand. Work also is in process for development of Eboinda shale deposits, commercial charcoal production, and off-shore oil drilling.[1/]

6.0 SENEGAL

6.1 SUMMARY

Senegal's heavy reliance on imported oil is a considerable burden on its foreign currency exchange and subjects its economy to the negative effects of international inflation (table XI). Prospecting for both oil and uranium has not revealed commercially exploitable quantities. The reserves of natural gas found in the vicinity of Dakar are estimated to be less than 50 million cubic meters. Hydroelectricity, with large dams, holds good promises for Senegal and its neighbouring countries. Financing is now available* and the hydroelectric project will be managed by the Organization de la Mise en Valeur du Fleuve Senegal (OMVS) and Organization de la Mise en Valeur du Fleuve Gambie (OMVG).

The Government of Senegal (GOS) is sponsoring several solar programs, has plans for many others, and is cooperating with the UNEP, USAID, and France in solar demonstration projects.[1/] Solar energy R&D is sponsored at the University of Senegal and a government laboratory. In addition, a government sponsored company is manufacturing solar systems.

The devastating drought makes solar energy water pumping a major potential application. Some areas have good winds which could be used for water pumping. Other areas can use photovoltaic or thermal powered systems. Major applications for solar energy include fish drying and peanut drying which would reduce the normal high spoilage levels. Other applications are educational television, biogas as a substitute for wood and charcoal for cooking, and integrated power systems for remote villages.

Senegal is very interested in developing solar energy systems and capabilities, and has so many unfunded plans, that the field for potential cooperation and joint ventures is large. Insolation and wind measurements, energy analyses, training, and RD&D for rural applications are possible areas for cooperation.

Although Senegal has established a manufacturing facility for solar energy products; photovoltaic systems, large wind machines, central receiver power systems, and bioconversion appear to have good U.S. export potential. Planning and management services would also be needed to implement such projects.

The planned USAID project, for an integrated solar-powered system for a village, is an excellent step and should be accelerated. A survey of the feasibility of wind, water-pumping systems is also recommended.

*Source: Senegal Embassy, Washington, D.C.

Table XI

SENEGAL

ENERGY RESOURCES

- HYDROPOWER LIMITED BY DROUGHT
- OIL IMPORTER

SOLAR ACTIVITIES

- ACTIVE GOV'T SPONSORED SOLAR PROGRAMS
- MORE PROPOSALS THAN FUNDS
- UNIVERSITY & GOV'T LAB RESEARCH ON PHOTOVOLTAICS, SOLAR THERMAL, WIND MACHINES
- COMPANY ESTABLISHED TO MANUFACTURE SOLAR SYSTEMS
- FRENCH-SENEGALESE WATER PUMP PROJECT
- USAID, UNEP, FRENCH DEMO PROJECTS PLANNED

POTENTIAL SOLAR APPLICATIONS

- WATER PUMPING, FISH DRYING, PEANUT DRYING, EDUCATIONAL TV, COOKING, & INTEGRATED POWER SYSTEMS FOR REMOTE VILLAGES

POTENTIAL COOPERATION

- INSOLATION, WIND DATA, ENERGY STUDIES, TRAINING, RD&D FOR RURAL APPLICATIONS

POTENTIAL U.S. EXPORTS

- PHOTOVOLTAICS, WIND MACHINES, SOLAR THERMAL SYSTEMS, BIOCONVERSION, PLANNING AND MANAGEMENT SERVICES

RECOMMENDATIONS

- PLAN & INITIATE COOPERATIVE DEMONSTRATION PROJECTS

6.2 ENERGY RESOURCES

Major sources of power available in Senegal are charcoal (for cooking), peanut shells, and petroleum products. Small amounts of natural gas are exploited near Rufisque.

Hydroelectric power is being developed on the two major rivers, Senegal and Gambia. Hydroelectricity will become available when the 150-MW Manantali dam on the Senegal river becomes functional, and if drought conditions improve. Many projects have been proposed for providing power required for mines close to the Senegal River, for irrigation, and for domestic use. The Senegal River runs through four different countries (Senegal, Guinea, Mali and Mauritania), therefore, political arrangements and economic planning must be accomplished between all four nations before the projects can be started. In addition, projects on the Gambia River must be coordinated between the Government of Senegal and that of Gambia.

Several feasibility studies have been performed for these hydroelectric projects that are internationally financed for their construction. The phased production of hydroelectric power is as follows:[2/]

First phase: Manantali dam with 150 MW of installed capacity.

Second phase: Construction of Galougo and Gourbassi dams with a capacity of 300 MW.

Other sites include: Felou (50 MW), Petit Gouina (70 MW) and on the Gambia River, the Samba Ngalou, the Kekreti and the Mako sites.

These dams will be designed to produce power for agricultural and industrial installations and to regularize river flow.

There is large-scale use of wood charcoal in Senegal. The production of charcoal increased from 580,000 metric tons in 1971 to 931,000 metric tons in 1975;[3/] the latter figure is the equivalent of about 90 square kilometers of forest area. The Senegalese Government is looking for alternatives to the use of charcoal and is taking measures to stop the cutting of trees.

Senegal has no coal resources and imports oil. However, several billions of CFAF (23.5 billions by 1971) have been invested in petroleum prospecting off the coasts of Senegal. Another prospecting activity is for uranium in the eastern Senegal region. But neither of these activities have proven to be commercially practicable up to the present.

6.2.1 Other Energy Activities

Senegal has to import oil for its energy needs. This oil is transformed into petroleum products or electricity. Senegal imports all of its oil as crude; in 1974, 774,000 tons of crude oil were imported at a cost of 17.58 billion Francs CFA, equivalent to about 26 percent of all imports. Two firms, the "Societe Africaine de Raffinerie" (SAR) and the "Iran Senegal Societe" (IRASENCO) import and refine crude oil. Petroleum products, derived from crude oil by the Societe Africaine de Raffinerie, also are used to power diesel or gasoline engines employed in power stations. Approximately 29 percent of the oil is used to generate electricity, 29 percent for transportation, and 25 percent for mines and industries.[3/] Peanut shells, either along with or in conjunction with fuel, are used by one oil factory to produce electricity.[4/]

Many companies, Senegalese and foreign, are involved in oil prospecting in Senegal. In 1968, heavy oil deposits were discovered off the coast of Casmance. The reserves are estimated at about 100 million tons of heavy oil (density 1). Pumping this oil, which was expensive at the time of discovery, seems to become more and more probable as fuel prices increase.

The two major electrical companies in Senegal are: Societe Electricite du Senegal (EDS), and Societe Senegalaise de Distribution Electrique (SENELEC), which have eight power stations. Ninety-seven percent of the power is provided by SENELEC, which operates the EDS installation. Electricity is consumed mainly in the Dakar area (64 percent). Electric consumption per capita is 94 kWh/yr. Most of the electrical energy produced is consumed by the mining industry (Taiba-phosphates); power consumption for lighting is still small and mostly concentrated in the Dakar area (97 percent).

Production of electricity is done through vapor turbines at the Bel-Air and Cap-des-Biches plants located in the Dakar area, and through diesel engines in the secondary rural centers. Various productions units include:[3/]

- The Cap-des-Biches plant with 104 MW of installed capacity (a 16.5 MW gas turbine is used for emergency or peak loads);
- The Bel-Air plant with 62.7 MW of installed capacity;
- The Saint Louis plant with 1.2 MW capacity (will be extended to 7.5 MW);
- The Kaolack plant with 1 MW capacity;
- Twenty other secondary centers of 3.9 MW total capacity are distributed in the rural areas; and

- The Richard-Toll agro-industrial center in the north produces its own power.

During the period 1963 to 1973 the electrical energy demand growth rate was 7 percent per year. This growth was 2.28 percent for lighting, 7.86 percent for domestic applicances, 3.96 percent for low voltage applications, and 7.56 percent for high voltage applications. However, due to the recent rapid increase in the cost of oil, electrical energy consumption growth decreased from 7 percent to 5.4 percent a year. The electrical energy consumption was 363 million kWh in 1974, 381 million kWh in 1975, 474 million kWh in 1976, and 443 million kWh in 1977.

The government development plan includes a twofold increase in installed capacity by 1984, or an increase from 85.5 MW in 1977, to 92 MW in 1978, to 115 MW in 1980, to 168 MW in 1985.

To satisfy the needs for this power growth, planned projects include the Kayar plant (60 MW), the Kaolack plant (15 MW), and three solar energy centers of 40 kW total capacity.

Average cost per year of electrical energy projects amounts to three billion CFA (approximately $14 million U.S. dollars).

In Senegal electricity is seen as an essential factor for development and individual well-being. To research these electrical energy development objectives, it is required that builders and distributors provide solutions adapted to the particular conditions in Senegal. Major objectives set by the Government of Senegal for energy development are:

- To reduce electrical energy cost by price uniformization, normalization, and by development of simple production methods;
- To promote commercial activities;
- To train technicians and to educate the population on energy usages; and
- To develop alternative energy sources.

6.2.2 Energy Costs[4/]

Table XII Senegal Energy Costs

Thermal Electrical Energy		
* Fuel oil 1500	30, 712 CFA/TM	$140
* Fuel oil 3500	16, 537 CFA/TM	$ 75
Average busbar cost	10.09 CFA/kWh	$0.04
Installed power cost	140,000 CFA/kW	$636
Gasoline	98 CFA/l	$0.44
Diesel Generated Energy		
* Price of diesel fuel	24, 307 CFA/TM	$110
Average energy cost	146.93 CFA/kWh	$0.67
Cost of diesel generating station	28.85 F/kW	$0.13
Installed power cost	183,000 CFA/kW	$832

* 1976 prices

New Electrical Energy Selling Prices (1978)[5/]

Domestic uses 17.09 to 57.69 CFA/kWh	($0.08 to $0.26)
Commercial uses 26.70 to 35.25 CFA/kWh	($0.12 to $0.16)

(Special tariffs are set for small consumers and heavy industry.)

6.3 SOLAR ENERGY

6.3.1 Solar Energy Activities and Plans

There have been more than 20 years of solar energy activities in Senegal. In 1968, Professor Henri Mason of the Institut Physique de Meteorologie (Institute of Meteorological Physics) of the University of Dakar, built a 88-m^2 solar pump. This pump worked 5 to 6 hours a day and pumped 25 m^3 of water from a 30 m deep well. The Government of Senegal did not have the capability of influencing commercialization at that time. It was then left to French companies to develop the first prototypes of the solar pumps.[6/]

The recently created government agency Delegation Generale a la Recherche Scientifique et Technique (DGRST) has been actively engaged in development of solar energy in rural areas.

6.3.1.1 Solar Research Centers & Programs

Solar energy research in Senegal is divided among three research centers, each with a different emphasis.

- The Institute of Meteorological Physics (IPM):

This Institute is a part of the Faculte' des Sciences, University of Dakar. It has 5 researchers and 7 technicians. The Institute has been the national center of solar radiation measurements.

Research is conducted mainly on solar pumps, food drying, solar stills and solar hot-water systems.

- The Semiconductor Laboratory of the University of Dakar:

This laboratory emphasizes photovoltaics research and training of researchers.

- The Institut Universitaire de Technologie (IUT):

The mission of this Institute is to train engineers and technicians for Senegalese industry. Its solar energy programs include:[7/]

- Studies of solar energy use in dwelling, using local materials and adapted to local conditions;
- 100 m^2 flat plate collector systems;
- Concentrating solar collector system;
- Food processing using solar energy;
- Wind energy;
- Photovoltaics for pumping applications; and
- Storage systems.

6.3.1.2 Solar Energy in Rural Areas

Four solar pumps are in operation in the villages of Marina Dakhar, Niakhene, Meouane in the region of Thies, and Diagle in the river region. These, added to the two experimental pumps at the IPM and IUT, make a total of at least six solar pumps in operation in Senegal.[4/]

The Government of Senegal is interested not only in small power pumping systems, but also in systems of larger capacity. A one kW solar pump is being developed for the village of Kanel in the River region. Other pumps range from 1.3 kW in the Diourbel region, to 10 kW for the City of Dahra, and 60 kW for the Bakel area.

6.3.1.3 The Government of Senegal Solar Energy Program

The GOS long-range goal is to extend applications of solar energy in all areas. More than 6 billion CFAF (approximately $27 million) are planned for development of new energy sources. These projects include:[4/]

- A 30 kW solar irrigation system in Bakel area of Northern Senegal; with an estimated cost of 300 million CFAF (USAID financing 150 million CFAF);
- Rural development projects involving 10 solar pumps projected for 1981, with an estimated cost of 2000 million CFAF ($9 million);
- New settlement project involving 6 solar pumps with the following estimated costs:
  - 1978 - 1979 = 84 million CFAF ($0.4 million),
  - 1979 - 1980 = 84 million CFAF ($0.4 million),
  - Total = 168 million CFAF ($0.8 million);
- Cattle raising projects using 13 solar pumps costing about 2256 million CFAF between 1978-1985;
- NGodiba Sodeva vegetable growing projects by women of the NGodiba village costing 40 million CFAF;
- Tiekene irrigation project using one solar pump (800-900 m^3/day) in 1978-79, estimated to cost 225 million CFAF;
- Sodeva solar-water pumping project for domestic use and irrigation for the village of N'Dieum Fall, with an estimated cost of 90 million CFAF in 1978-79;
- A SAED-DEP 60 kW solar-irrigation system in Northern Senegal for irrigation of 100 hectares, to cost about 315 million CFAF in 1979-1980; and

- SENELEC rural electrification project to replace 6 diesel generating plants with solar systems at an estimated cost of 1265 million CFA.

Total cost of the SENEGAL projects is 6609 million CFAF or U.S. $30 million ($1 U.S. = 220 CFAF).

6.3.1.4 Solar Research

Approximately 130 million CFAF ($600,000) will be spent on research during the period of the fifth development plan. Solar energy research areas include:[4/]

- Combined systems of wind and photovoltaics for electricity production;
- Solar cooling;
- Solar food processing (drying and refrigeration);
- Collector studies;
- Development of rural energy centers, at Ndiagoureye (appropriate technology; see figure 6), and at Ndiaga Wolof (electric system);
- Solar thermal systems for brick production; and
- Solar thermal systems for electricity production to replace diesel systems.

6.3.1.5 Other Solar Activities

Foreign activities in solar energy are dominated by French firms, mainly Sofretes. $5.8 million in French aid will be spent on a joint Senegal-Mali project to study suitable areas for tapping solar power to pump water, and to build pumping installations for village water supplies and irrigation purposes, and other university research projects.[4/]

The U.S. is getting more involved in solar energy development in Senegal by USAID funding studies of alternative energy sources and by a joint-venture such as the 60-kW solar irrigation project at Bakel.[8/] This 300 million CFAF ($1.25 million) project is financed half by the French FAC and the other half by the USAID. Three different companies are in charge of the irrigation system development and construction: a French company (Sofretes), an American company (Thermo-Electron), and a Senegalese company (SINAES). Management of this project will be performed by a Senegalese company, SAED, with the assistance of Sandia Laboratories in New Mexico.

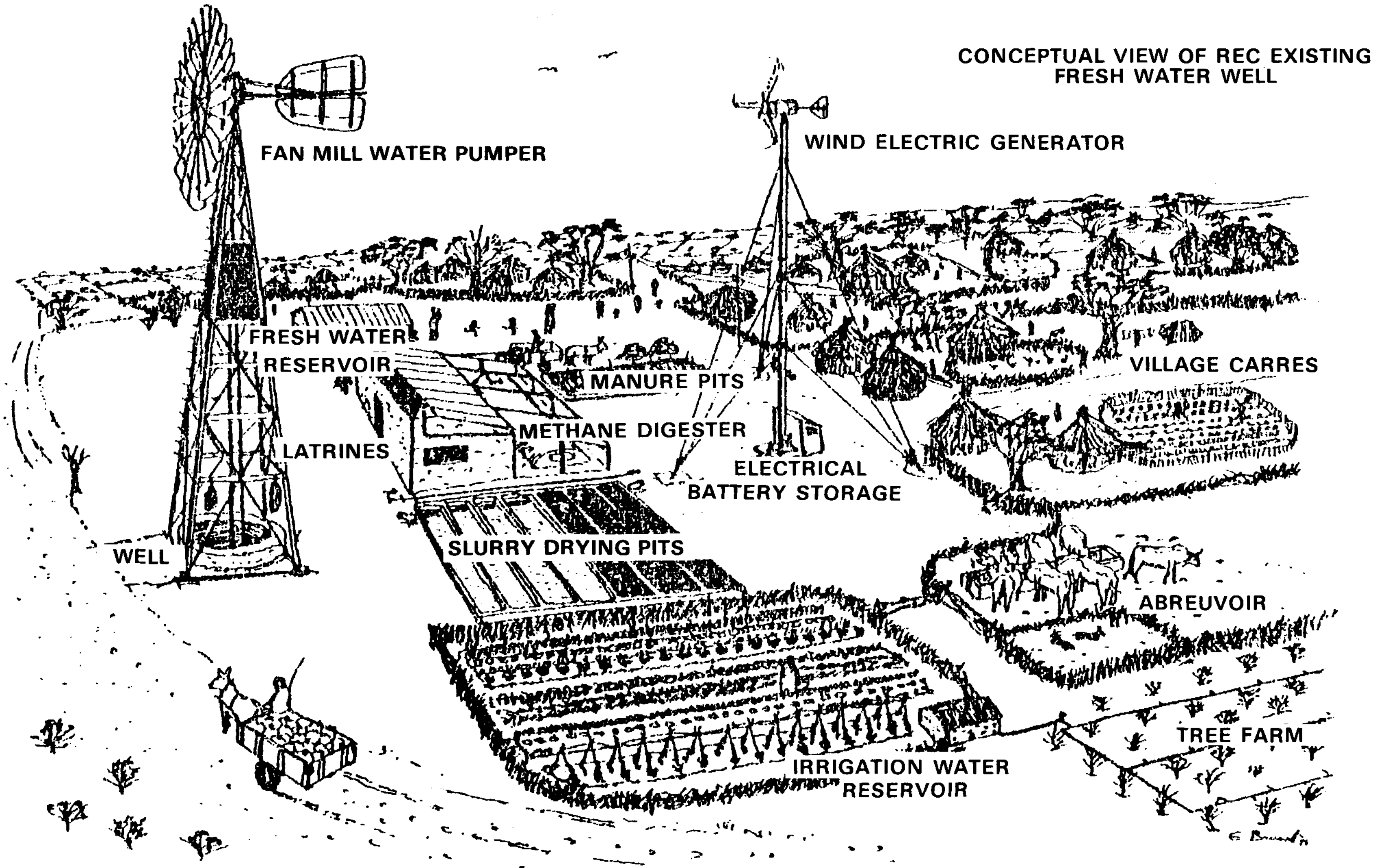

Figure 6 Rural Energy Center (NDIAGOUREYE) Basic Schematic

6.3.2 Solar Energy Capabilities

In developing countries such as Senegal, a lack or inadequacy of production facilities for finished goods is usually observed. Insufficiency in trained manpower and infrastructure are other characteristics common to all developing countries. Most governments are aware of this, however, and vigorous programs for education and technical training are underway. The current fifth National Development Plan of Senegal emphasizes technical training. College education enrollment in Senegal went from 3,947 students in 1971 to 7,301 students in 1976. There are 15 technical and professional training centers and institutes, in addition to the University of Dakar, the Institut Universitaire de Technology, and the Institut Polytechnique de Thies.

Communications and transportation systems are relatively adequate and considered one of the best in Africa.

Besides the mining industry (Taiba phosphates), there is a significant number of small industries including: edible oil from the peanut crop, cotton fabric, cement, and food industries. There also is one truck assembly plant.

Dakar has one of the largest port facilities in West Africa and an international airport. The Industrial Society for Solar Energy Applications (SINAES), with capital of 100 million CFAF ($400,000), was created in 1976 to develop a capability for the manufacture and commercialization of solar energy products.

6.3.3 Potential Solar Applications

Solar energy applications hold good promise in Senegal. As indicated by GOS solar projects, there are many areas in which low and high temperature solar systems, photovoltaics, wind, and biomass can be applied. Average insolation in Senegal is 6 kWh/m^2 per day, and the wind speed averages 6 m/s in the northwestern part of the country. Savonius wind systems were proven by the University of Dakar IUT to be 4 times more economical than the Sofretes solar pumps for wind speeds above 3 m/s. A peanut oil factory has been using pyrolitic conversion of peanut shell to generate its own electricity. There is also an important biomass project at Sangalkam in the Cap-Vert region.

Among all the possible applications of solar energy, water pumping for drinking and agriculture is most important. Due to the drought, the Government's priority is water sufficiency and this is true for all the Sahelian countries. The next important application indicated by Senegalese officials is drying of fish and crops, such as peanuts.

Overall, the possible solar energy applications can be classified as shown in the following diagram.

- Agriculture
  - Crop drying (peanuts, ...),
  - Water pumping for domestic and cattle use and irrigation,
  - Fertilizer production from biomass,
  - Greenhouses, and
  - Farming operations (grain grinding, ...);
- Industry
  - Food processing (fish, meat, ...),
  - Textile industries,
  - Small-scale industries*, and
  - Cold storage plants* for fisheries and milk products;
- Village
  - Lighting,
  - Cooking,
  - Water distribution,
  - Water purification,
  - Water heating,
  - Drying of food products,
  - Refrigeration of food products, and
  - Community applications (schools, medical center, most public places); and
- Urban
  - Heating, cooling, hot water for hotels, residences and resort areas, and
  - Aquaduct water pumping*.

*Long-term applications.

6.3.4 Areas of Potential Cooperation

Out of 409.698 million francs CFA of planned investments during the period 1977 to 1981, 150.672 billion (37 percent) will be financed by Senegal itself, and 258.926 billion (63 percent) will come from foreign or international sources. Senegal depends heavily on foreign assistance for its development programs. International assistance is provided primarily by France and other Western European countries. Some assistance also comes from other countries and organizations: AID (United States) is providing funds for improvement of the railroad system; West Germany is funding construction of roads; Denmark is financing installation of several factories; the World Bank and the European Bank for Investments is financing construction of large fertilizer plants; and the USSR has provided funds for improvement of the fishing industry. It also has bilateral relationships with countries such as Saudi Arabia, Belgium, Canada, the Republic of China, United States, Iran, Italy, and Kuwait.

Senegal already has some technical and financial cooperative agreements with France and the United Statres in regards to solar energy. The 60 kW solar irrigation project in the river region at Bakel is jointly undertaken by France, the U.S. and Senegal. USAID is funding an appropriate technology project for the rural energy center of the Ndiagoureye village. Another rural energy center at Nidiaga Wolof is being financed and developed by the United Nations Environment Program (UNEP). This project will use combined systems of wind, photovoltaic, solar thermal, organic waste, and pyrolysis to generate electricity from a central network for the village of Ndiaga Wolof. (See figure 7.)

The Government of Senegal is interested in developing its capabilities in solar energy systems production. GOS is aware of the high initial cost of these systems and of the necessities of international financing, to bring about faster energy growth and the resulting consequence in employment, agriculture, industry, and other areas. Senegal welcomes foreign investment, industries, and technical support, and has made provisions for adequate use and protection of these.

Potential areas of cooperation are the following:

- Water pumping projects,
- Solar drying and refrigeration,
- Solar electricity (small systems),
- University research and training, and
- Data acquisition and information exchange.

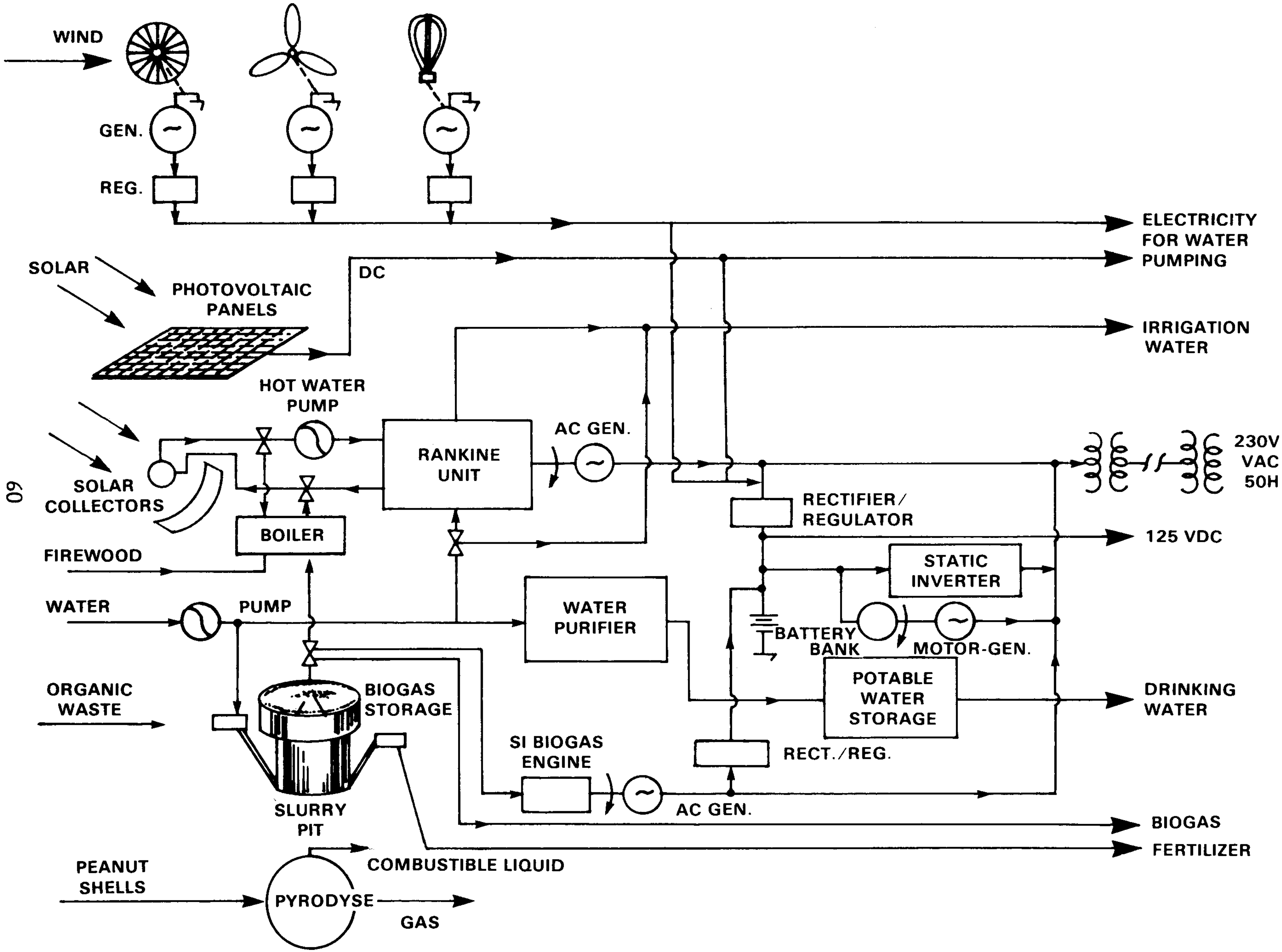

Figure 7 Rural Energy Center (NDIAGA WOLOF) Basic Schematic

6.3.5 Potential Solar Energy Markets

The primary market would be in the water pumping systems because of the need and the priority given to it by the Government of Senegal. Flat plate collectors for fish and agricultural crop drying, for hot water, and for cooling present a sizeable market. Photovoltaic powered educational television also could provide a large market.

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7 Interview with B.A.O. Adesanya, Director, Rural Electrification Department, NEPA, Lagos, July 4, 1978.

8 Interview with G.A. Fatoye, Permanent Secretary, Federal Ministry of Mines and Power, Lagos, July 4, 1978.

9 Interview with Professor S.O. Adenubi, University of Lagos, July 3, 1978.

REFERENCES--NIGER

1 "Energy for the Village of Africa," by Overseas Development Council, Washington, D.C.

2 L'Office de l'Energie Solaire, ONERSOL Publication.

3 Interview with Dr. Abda Moumouni Dioffo, Director, Office de l'Energie Solaire, Naimey, July 7-8, 1979.

4 Jeune Afrique, numero special, 1978.

5 Visit to solar pump installation, Bossey-Bangou, and notes from data taken by technician, July 7, 1978.

6 "Use of Solar Generators in Africa for Broadcasting Equipment," by S. Polgar, The Journal of Solar Energy Science and Technology, Vol. 19, No. 2, 1977.

7 World Bank Atlas, 1977.

REFERENCES--Ivory Coast

1 La Cote d'Ivoire en Chiffres, 1977-1978 edition, Ministere du Plan, Abidjan.

2 Interview with Philip Boncorps, Office of National Rural Promotion (ONPR) Abidjan, July 10, 1978.

3 Interview with Andre Poli, Director General, Compagnie Africaine de Television (CATEL) Abidjan, July 10, 1978.

4 Interview with Diby M. Krodo, Directeur a la direction Generale, Charge des Operations Nouvelles, Energy electrique de la Cote d'Ivoire (EECI) Abidjan, July 11, 1978.

REFERENCES--SENEGAL

1 "Note Sur le Development de l'Energie Solaire en Senegal," Souleymane Ndiaye.

2 SENELEC "Courants" magazine, November 9, 1978.

3 Senegal 5th National Plan of Development.

4 Interviews with Souleymane Ndiaye, Director of External Relations, Delegation Generale a la Recherche Scientifique, Dakar, July 12-13, 1978.

5 Interview with Daouda Diop, Director Technical Services, Senelec, Dakar, July 13, 1978.

6 Interview with Dr. Djibril Fall, Director, Institute of Meteorological Physics (I PM), Dakar, July 13, 1978.

7 Interview with Professor Andre Kergreis, Director, Institut Universitaire de Technologie (IUT), Dakar, July 13, 1978.

8 Solar Energy Intelligence Report, Vol. 4, No. 28, July 17, 1978, p. 216.

APPENDICES

APPENDIX A
ISCWG INTERVIEWS AND PLACES VISITED

ISCWG INTERVIEWS AND CONTACTS: KENYA

Kenya Government

Prof. Peter Gacii, Secretary of the National Council for Science and Technology (NCST), National Housing Corporation House, Nairobi, Telephone: 336173, June 27, 1978.

Tom Tuschak, Energy Advisor to the Government, National Council for Science and Technology, c/o UNEP, P.O. Box 30218, Nairobi, Telephone: 336173, x 11, June 26, 1978.

John Thomas, Ministry of Agriculture, Nairobi, Telephone: 335855 (by telephone), June 28, 1978.

United Nations

Dr. Essam El-Hinnawi, Chief State of Environment and Special Assignments Unit, United Nations Environment Programme, P.O. Box 47074, Nairobi, Telephone: 333930, June 26, 1978.

Robert W. Kitchen, Jr., Resident Representative, United Nations Development Programme, P.O. Box 30218, Nairobi, Telephone: 28776, June 23, 1978.

University of Nairobi

Prof. Rajni Patel, Dean, Faculty of Engineering, University of Nairobi, P.O. Box 30197; Home, P.O. Box 46793, Nairobi, Telephone: 63209, June 26, 1978.

Others

Ale Hald Nillsen, Managing Director, Bikroconsult Kenya, Ltd. (Consulting Engineers) Silopark House, City Hall Way, P.O. Box 45033, Nairobi, Telephone: 25535, 332601 and (home) 61181, June 27, 1978.

Stephen V. Allison, The World Bank, 1818 H Street, N.W., Washington, D.C. 20433, Telephone: (202) 477-1234 - (visitor), June 23, 1978.

Prof. Gordon Goodman, The Beijer Institute, Royal Swedish Academy of Sciences, Fack., S-10405, Stockholm, Sweden, Telephone: 160490 - (visitor), June 26, 1978.

Lee Schepper, Energy Specialist, University of California, Energy and Resources Group, Room 100, Bldg. T-4, Berkeley, California 94720, Telephone: (415) 642-1640 - (visitor), June 26, 1978.

ISCWG INTERVIEWS AND CONTACTS: CAMEROON

U.S. EMBASSY, Rue Nachtigul, B.P. 817, Yaounde
Telephone: 221633/220512, Telex: 8223

Ambassador Mabel M. Smythe, June 29, 1978

William C. Mithoefer, Jr., Deputy Chief of Mission, June 30, 1978

John C. Holzman, Economic/Commercial Office, June 28, 1978

Peter B. Burke, Commercial Attache, June 28, 1978

Anthony W. Sariti, Ph.D., Cultural Attache, June 29, 1978

Earl Scarlett, Assistant to Ambassador, June 28, 1978

Barbara Scarlett, ICA, June 28, 1978

Erik Witt, Agricultural Economist, USAID, June 28, 1978

Marcel Ngue, Assistant To Erik Witt, June 28, 1978

National Office of Scientific Research and Technology
(Office National de la Recherche Scientifique et Technique - ONAREST)
B.P. 1457, Yaounde

Samuel Nelle, Deputy Director, Telephone: 22-13-70, 22-27-91, June 28, 1978

Djallo Soba, Director, Institute, Industries and Subsoil Technologies, (Institut de Recherches sur les Techniques, L'Industries et le Soiessol - IRTISS) B.P. 4110, Yaounde, Telephone: 22-00-08, June 28, 1978

Augustin Simo, Energy Research Center (Centre des Recherches Energitiques de l'IRTISS) B.P. 4110, Yaounde, June 28, 1978

MINISTRY OF MINES AND ENERGY, YAOUNDE

Johnson B. Agborsangaya, Deputy Director of Energy and Water, B.P. 1576, Yaounde, Telephone: Office, 22-18-64; Home 22-23-42, June 29, 1978

Samuel Mbakop, Under Director of Energy, B.P. 701, Telephone: 22-18-64, June 29, 1978

Banga Mba Aku, Director of Energy and Water, B.P. 1576, Yaounde, June 29, 1978

Nicoles Njapa-Kabe, Chief of Provincial Services, Bafoussam, June 30, 1978

Polytechnical Institute of Cameroon
(Ecole Nationale Superieure Polytechnique)

B.P. 728, Yaounde, Telephone: 22-12-26, 22-14-16, 22-45-47

Claude Marty, Director, June 29, 1978
Ntoko Nzumba-Mesape, faculty and researcher, June 29, 1978
Charles Minka, Ph.D., faculty and researcher, June 29, 1978

National Electrical Company (SONEL)
(Societe Nationale de l'Electricite) du Cameroon
63, Ave. De Gaulle, B.P. 4077, Douala

Justin, Ndioro A. Yambo, Deputy Director, Telephone: 42-54-44, June 28, 1978

ISCWG INTERVIEWS AND CONTACTS: NIGERIA

U.S. EMBASSY

1 King's College Road, P.B. Box 554, Lagos, Telephone: 57320

Harry A. Cahill, Head, Economic/Commercial Section, July 3-4, 1978
Reno Harnish, Commercial Officer, July 3, 1978
Larry Bewell, American Consulate, Kadune, July 5-6, 1978
Felix Agwaena, ICA American Cultural Center, Kano, July 6, 1978

MINISTRY OF MINES AND POWER

P.M.B. 12574, Lagos

G. A. Fatoya, Permanent Secretary, July 4, 1978
Akin Adebari, Principal Assistant Director, July 3-4, 1978
Okechakuri, July 3, 1978

NATIONAL SCIENCE AND TECHNOLOGY DEVELOPMENT AGENCY

P.M.B. 12595, Lagos

F. N. C. Oragwu, Director, Technology and Industrial Sciences, Research Department, July 3, 1978

NIGERIAN ELECTRIC POWER AUTHORITY (NEPA)

NEPA Hdq. Bldg., Lagos

L. A. Adeniji-Fashola, Director System Planning Department, Telephone: 51371/279, July 4, 1978
B. A. O. Adensanya, Director Rural Electrification Department, July 4, 1978

UNIVERSITY

Dr. V. A. Akinsette, Professor, Mechanical Engineering Department, University of Lagos, Lagos, July 4, 1978
Lateef Hussain, Department of Physics, University of Ibadan, Ibadan, July 8, 1978 in Niamey

KANO STATE, KANO

Alhaji Inawa Ringim, Permanent Secretary, Ministry of Agriculture for Kano State, July 6, 1978

Others

Sadiq I. Sanusi, Coordinator, Progressive Management Consultancy and Training Group, P.M.B. 3371, Kano, Telephone: 5540, July 5, 1978

Par O. Lefvert, Team Leader, United Nations Development Programme; Town Planner, Urban Development Board, Kano, July 5, 1978

Dr. W. J. Lebard, Dental Surgeon, Adventist Dental Centre, P.M.B. 3259, Kano, July 5, 1978

ISCWG INTERVIEWS AND CONTACTS: NIGER

U.S. EMBASSY
B.P. 201, Niamey
Telephone 72-26-61

Ambassador Charles A. James

Sidney Bliss, Commercial Officer

OFFICE DE L'ENERGIE SOLAIRE (ONERSOL)
B.P. 261, Niamey, Niger

Dr. Abdn Moumouni Dioffo, Director

A. Ba, Assistant for Commercialization

Mr. Wright, Assistant for Research

INSTITUTE POLYTECHNIQUE DU NIGER
ONERSOL SEMINAR PARTICIPANTS

Cheick Momar M'Bou & Oumar Diallo, Universite de Dakar, Laboratoire des Semiconducteurs et de l'Energie Solaire, Dakar, Senegal.

Boulmerka Haniza, Centre des Sciences et de la Technologie Nucleaire, BP 1017, Alger - Gare, Algeria.

Semanou Yao, Universite du Benin, Ecole des Sciences, B.P. 1515, Lome, Togo.

Mme Kaziende Nadia, ONERSOL, B.P. 621, Niamey, Niger.

Joseph M. Degbe, ONERSOL, B.P. 621, Niamey, Niger.

Abdoussalam BA, ONERSOL, B.P. 621, Niamey, Niger.

Hiri Abdelkader, Observatoire du Glob, Tamanrasset, Algeria.

Lateef Hussain, Department of Physics, University of Ibadan, Ibadan, Nigeria.

Mohamed Banmalek, CSTN, Laboratoire Christaux et couches Minces, B.P. $ 1017, Alger - Gare, Algeria.

Kouadja Komenan, Universite d'Abidjan, Faculte des Sciences, B.P. 4322, Abidjan, Ivory Coast.

Abderhamane Sotbar, Ecole Normale Superieure, B.P. 241, Bamako, Mali.

PLACES VISITED:

- ONERSOL Solar Energy Research Center, Niamey
  Flat plate collectors, solar stills, solar cookers, concentrating solar systems, model of the solar furnace, measuring devices, etc.

- ONERSOL Factory for hot water systems, Niamey
  Assembly of solar water heaters.

- Institut Polytechnique du Niger, Niamey
  Meeting with solar energy seminary students.

- Village of Bossey - Bangou (10 km from Niamey)
  A working solar pump with Sofretes engine and Nigerian collectors (locally made).

- National Museum of Niger, Niamey
  Solar System exhibit.

ISCWG INTERVIEWS AND CONTACTS: THE IVORY COAST

U.S. EMBASSY
5 Rue Jesse Owens, B.P. 1712, Abidjan
Tel. 32-46-30
Ms. JoAnne Arzt, Commercial Attache, Ivory Coast, July 10-11, 1978

Office of National de la Promotion Rurale (ONPR)
Ministry of Agriculture
B.P. VI 165, Abidjan
Philip Boncorps, July 10, 1978

Energie Solaire et Technologies de Development (C.R.A.U.)
B.P. 8892, Abidjan
Peter Stefan, Conseiller - Chercheur, July 10, 1978

Campagnie Africaine de Television (CATEL)
B.P. 20984, Abidjan
Andre Poli, Director General, July 10, 1978

Energie Electrique de la Cote d'Ivoire (EECI)
B.P. 1345, Abidjan
Diby M. Kroko, Directeur a la Direction Generale, Charge des Operations Nouvelles, July 11, 1978.

ISCWG INTERVIEWS AND CONTACTS: SENEGAL

B.P. 49 Avenue Jean XXIII Tel 20206, Dakar
Paul Behnke, Economic & Commercial Officer, July 12-13, 1978

Delegation Generale a la Recherche Scientifique (DGRST)
61 Blvd Pinet, Laprade, Dakar
Tel. 279-33
Souleymane Ndiaye, Director of External Relations, July 12-13, 1978

Institut Universitaire de Technology (IUT)
B.P. 5085, Dakar Fann, Tel 240-17
Andre Kergreis, Director, July 13, 1978

INSTITUT DE PHYSIQUE METEOROLOGIQUE (IPM)
B.P. 476 Hann, Dakar Tel. 345-08
Dr. Djibril Fall, Director, Solar Energy Research Center

Mr. L. Guenec, Researcher

SOCIETE SENEGALAISE DE DISTRIBUTION
D'ENERGIE ELECTRIQUE (SENELEC)
28 Rue Vincens, B.P. 93, Dakar
Daouda Diop, Director of Technical Services, July 13 and 17, 1978
Babacar Gueye, Engineer

PLACES VISITED

- Solar Energy Research Center at the Institute of Meteorological Physics, Hann Dakar, Flat plate collectors, SOFRETES solar pumps, solar drying, solar distillation.

- Solar Pump at the City of Meouane (region of Thies) 110 km from Dakar 7 m^3 Sofrates water pumping for the village of Meouane.

- Region of Niayes (Western Senegal) Agricultural Sahelian area, projected sites for wind energy farm.

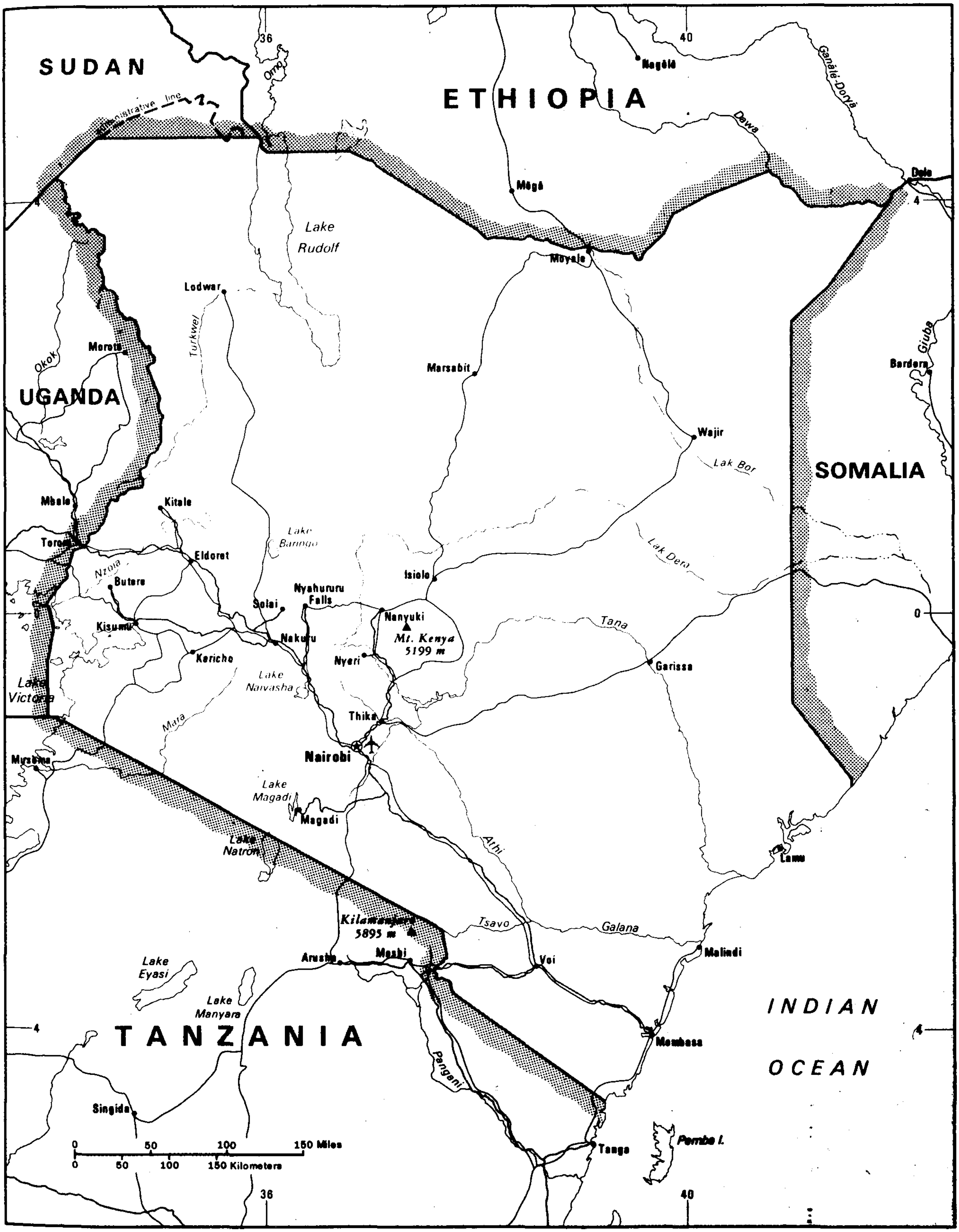
- Village of Kayar - 63 km from Dakar. Active fishermen village on the west coast of Senegal. Possibilities of fish drying.

- Institut Universitaire de Technology - Flat plate collectors, wind systems (Savonius) photovoltaics.

APPENDIX B

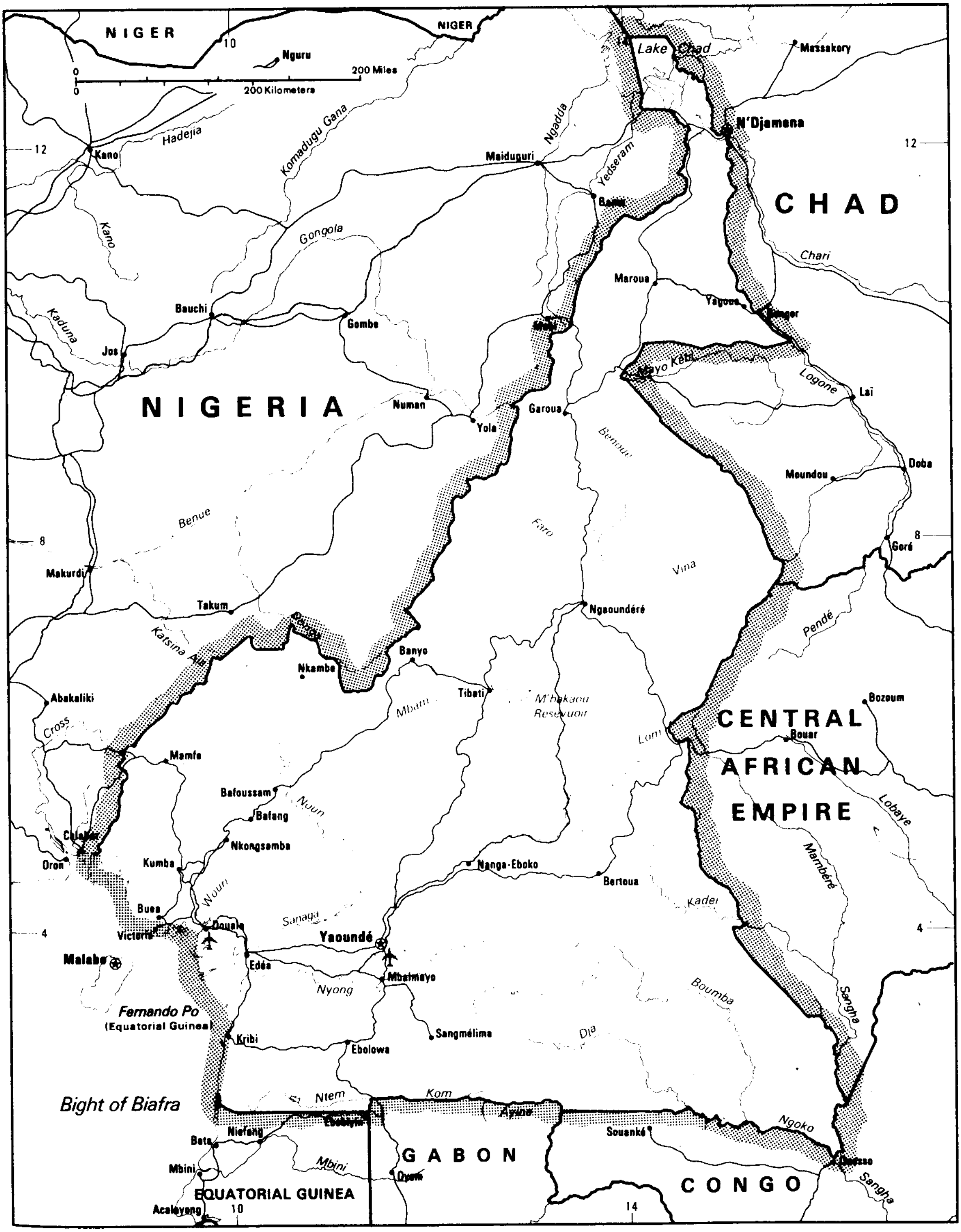
MAPS AND FIGURES

Kenya



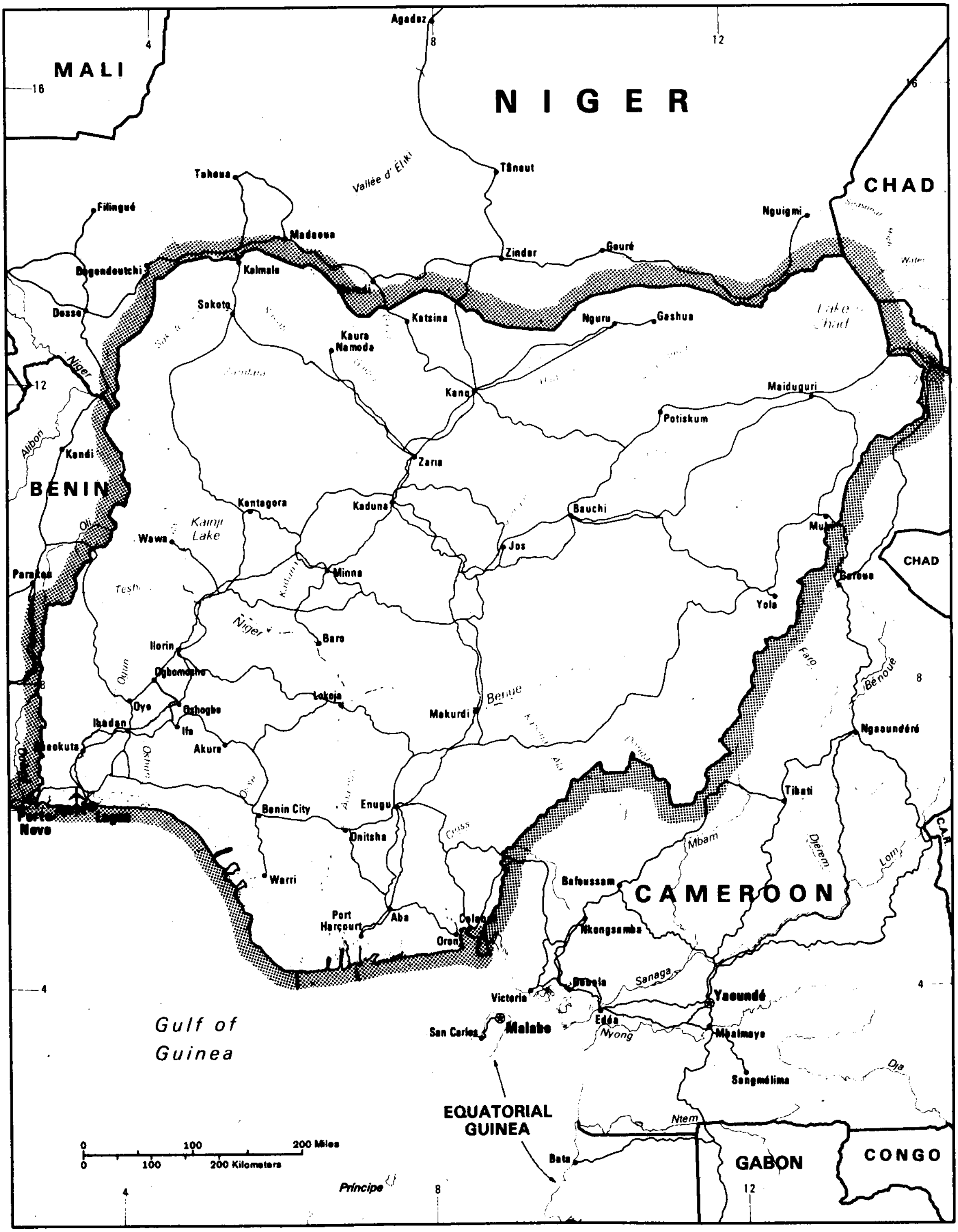
Mercator Projection
Scale 1:6,030,000

Cameroon



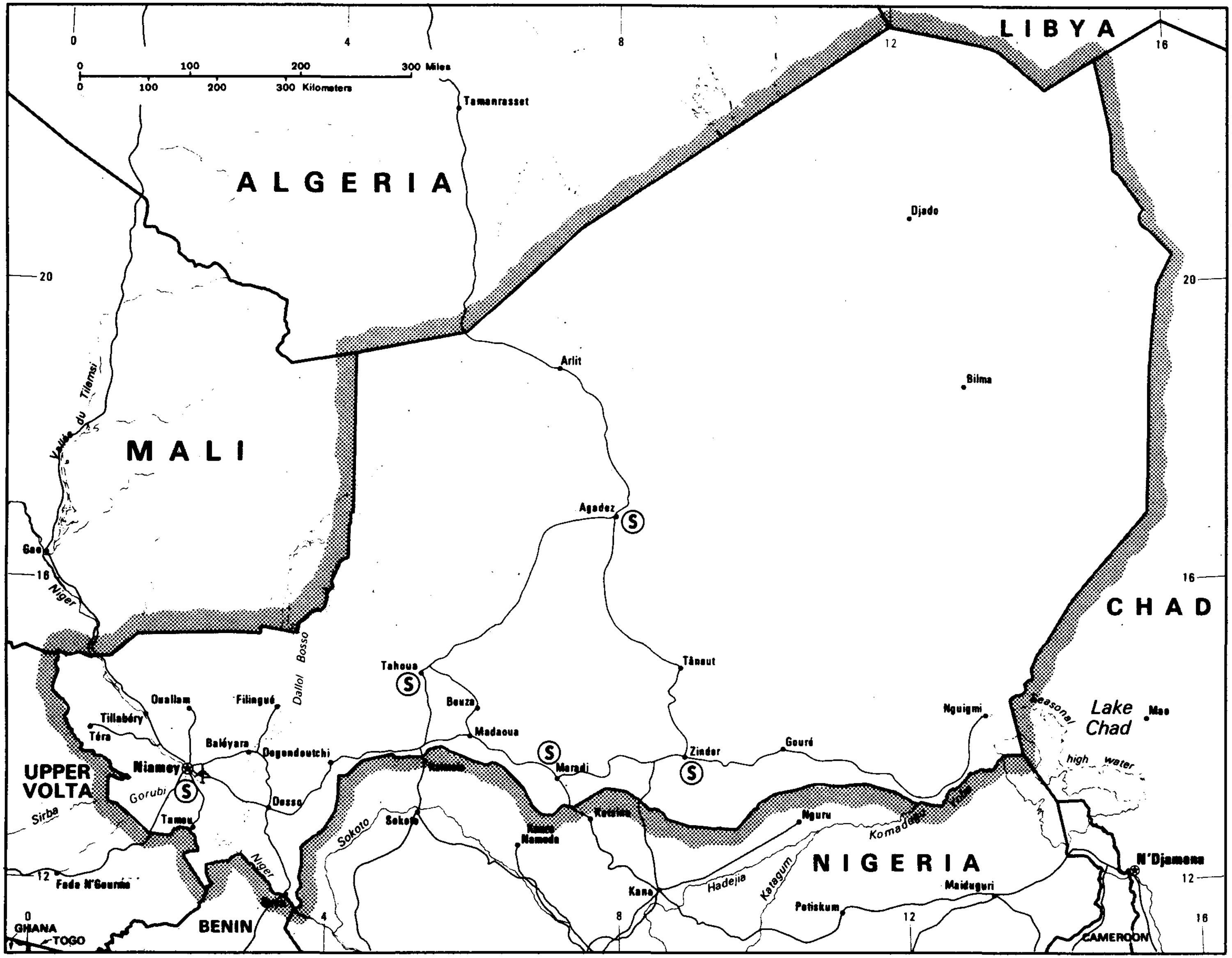
Lambert Conformal Projection
Standard parallels 8° and 32°
Scale 1:6,400,000

Nigeria



Lambert Conformal Projection
Standard parallels 8° and 32°
Scale 1:8,300,000

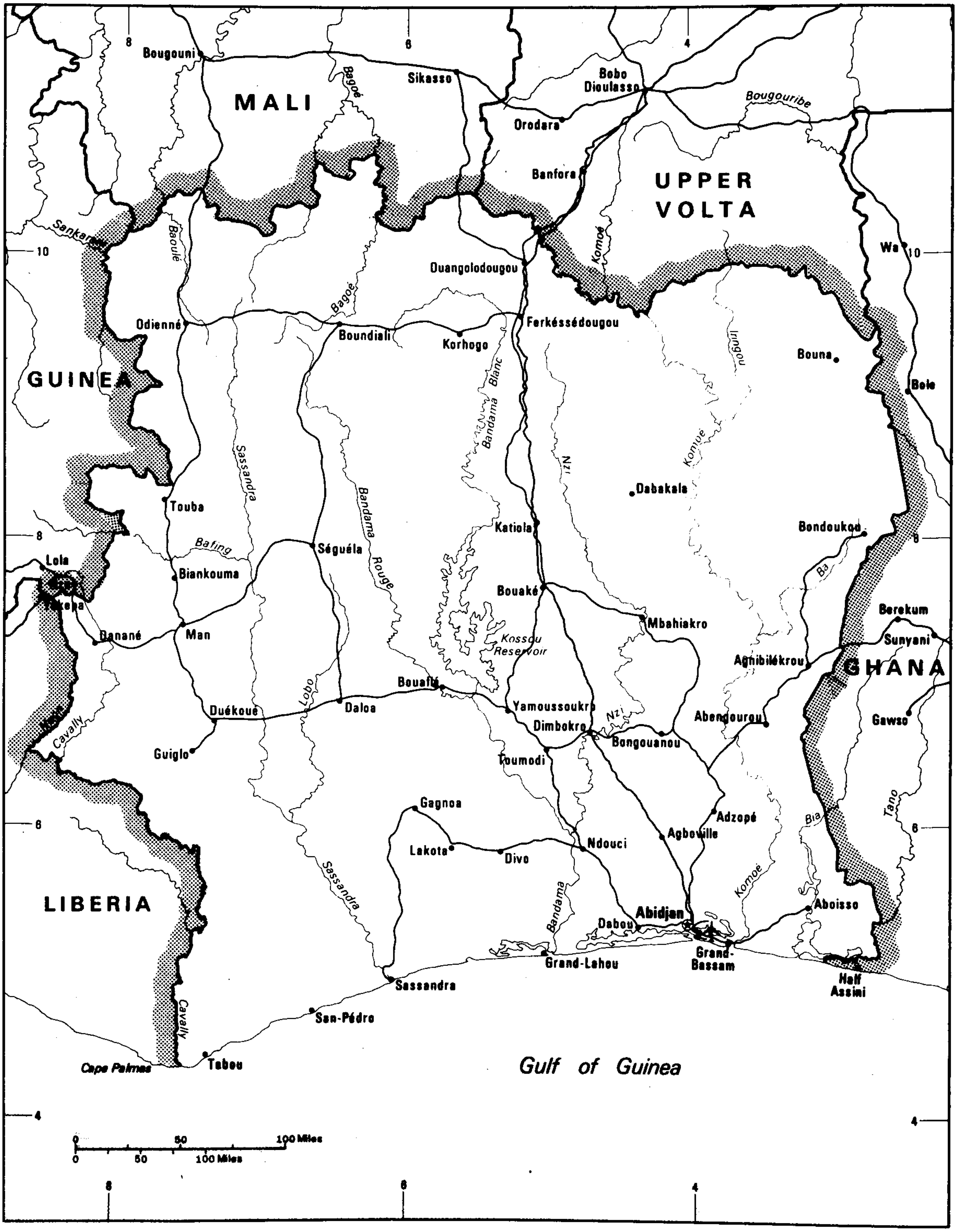
Niger



Lambert Conformal Projection Standard parallels 8° and 32° Scale 1:8,300,000

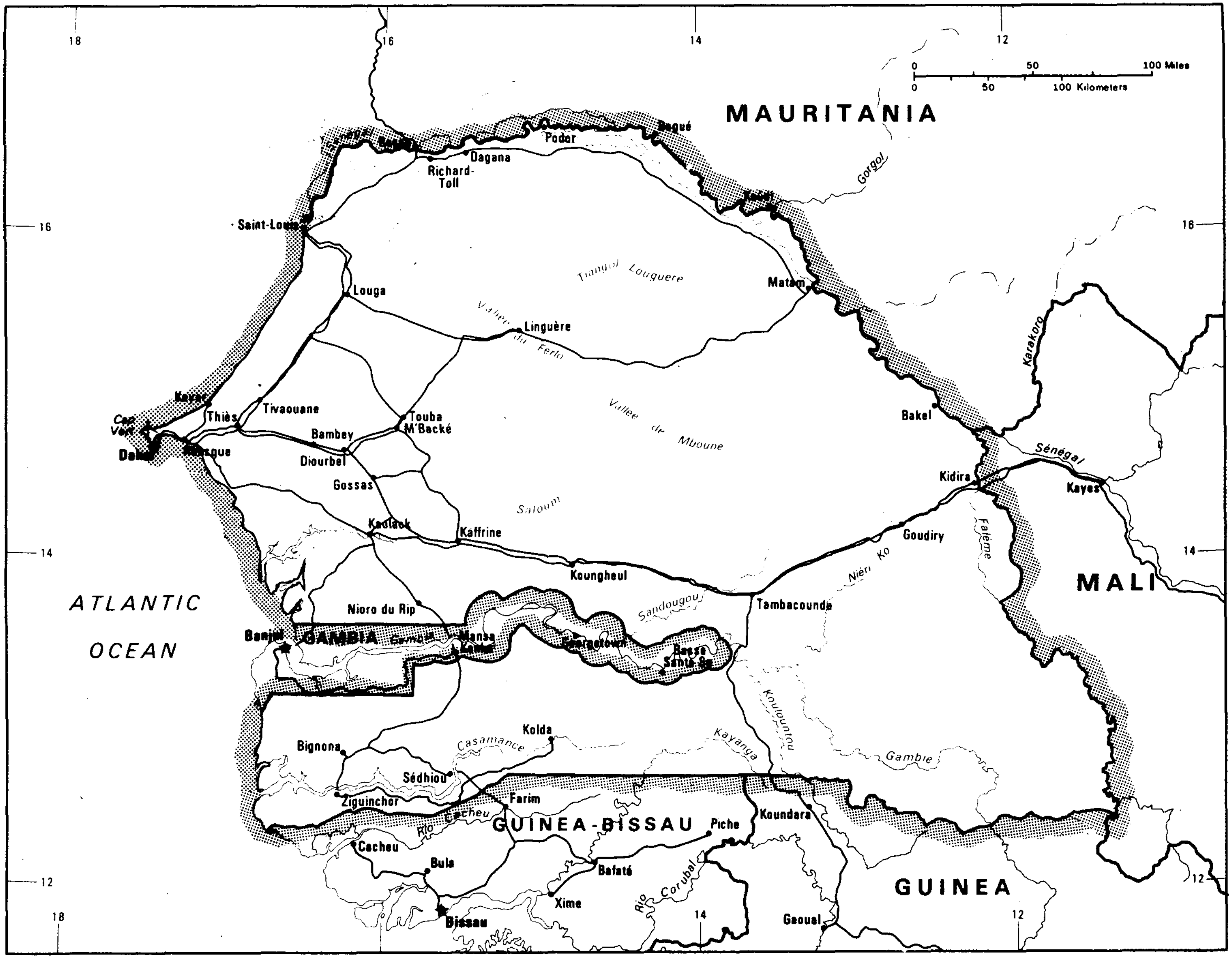
(S) : **Solar radiation measurement stations**

Ivory Coast



Lambert Conformal Projection
Standard parallels 8° and 32°
Scale 1:4,370,000

Senegal



Lambert Conformal Projection Standard parallels 8° and 32° Scale 1:3,800,000

APPENDIX C

ENERGY DATA

ENERGY DATA - KENYA

	1971	1972	1973	1974	1975	1976
Total Energy Production [a]	0.04	0.05	0.05	0.06	0.08	
Fossil Fuel Production	-	-	-	-	-	
Imports	4.04	4.07	4.30	4.55	4.31	
Exports	1.52	1.50	1.63	1.69	1.36	
Total Energy Consumption	1.67	1.62	1.85	2.21	2.33	
/Capita (kilograms)	148	134	148	171	174	
Fossil Fuel Consumption	1.59	1.53	1.77	2.11	2.21	
Total Energy Reserves						
Fossil Fuel						
Hydro						
Biomass						
Total Electric Gen. Capacity (MW)	216	213	220	227	282	
Thermal (MW)	141	138	145	142	110	
Hydro (MW)	75	75	75	85	172	
Nuclear (MW)	-	-	-	-	-	
Total Electricity Consumption 10^9/kWh)	0.92	1.02	1.10	1.17	1.23	
/Capita kWh	79	84	88	91	92	
Installed Industrial Capacity (MW)	17	17	17	17	17	
Installed Public Capacity (MW)	199	196	203	210	265	
Solar Energy Production						
Fuelwood Production [b]	10.5	10.6	10.8	10.9	10.9	
Charcoal Production [c]	0.06	0.01	0.03	0.03	-	
Uranium Production [d]	-	-	-	-	-	

a) Unless noted otherwise, energy figures are stated in million metric tons of coal equivalent. Energy production includes fossil fuel and hydroelectric production.
b) Quantities in million cubic meters.
c) Million metric tons.
d) Quantities in metric tons.

Source: United Nations Dept. of Economic and Social Affairs, World Energy Supplies 1971 - 1975, Statistical Papers Series J. No. 2, New York, United Nations, 1977.

APPENDIX C-2

ENERGY DATA - CAMEROON

	1971	1972	1973	1974	1975	1976	1977	1978	1980	1985	19[illegible]
Total Energy Production[1]	0.14	0.13	0.13	0.14	0.14						
Fossil Fuel Production	-	-	-	-	-						
Imports	0.45	0.49	0.50	0.48	0.57						
Exports	-	-	-	-	-						
Total Energy Consumption	0.51	0.52	0.54	0.56	0.67						
/Capita (kilograms)	87	86	87	89	104						
Fossil Fuel Consumption	0.37	0.39	0.41	0.42	0.53						
Total Energy Reserves											
Fossil Fuel											
Hydro											
Biomass											
Total Electric Gen. Capacity (MW)	221	225	225	225	225						
Thermal (MW)	28	28	28	28	28						
Hydro (MW)	193	197	197	197	197						
Nuclear (MW)	-	-	-	-	-						
Total Electricity Consumption (10^9/kWh)	1.2	1.1	1.1	1.2	1.2						
/Capita kWh	197	185	182	188	186						
Installed Industrial Capacity (MW)	204	208	208	208	208						
Installed Public Capacity (MW)	17	17	17	17	17						
Solar Energy Production											
Fuelwood Production[2]	6.5	6.7	6.7	6.7	6.7						
Charcoal Production[3]	-	-	-	-	-						
Uranium Production[4]	-	-	-	-	-						

1) Unless noted otherwise, energy figures are stated in million metric tons of coal equivalent. Energy production includes fossil fuel and hydroelectric production.
2) Quantities in million cubic meters.
3) Million metric tons.
4) Quantities in metric tons.

ENERGY DATA - NIGERIA

	1971	1972	1973	1974	1975	1976	1977	1978	1980	1985	1990
Total Energy Production[1]	113	135	151	165	131						
Fossil Fuel Production	112.8	134.7	150.3	164.8	130.7						
Imports	0.08	0.13	0.16	0.9	1.62						
Exports	106.6	129.8	146.1	160.1	125.2						
Total Energy Consumption	3.6	4.1	4.8	5.7	5.6						
/Capita (kilograms)	64	70	81	93	90						
Fossil Fuel Consumption	3.4	3.9	4.6	5.4	5.3						
Total Energy Reserves											
Fossil Fuel											
Hydro											
Biomass											
Total Electric Gen. Capacity (MW)	805	883	855	860	860						
Thermal (MW)	485	563	535	540	540						
Hydro (MW)	320	320	320	320	320						
Nuclear (MW)	0	0	0	0	0						
Total Electricity Consumption (10^9/kWh)	1.8	2.2	2.6	2.8	3.2						
/Capita kWh	32	37	44	46	51						
Installed Industrial Capacity (MW)	4	4	4	5	5						
Installed Public Capacity (MW)	801	879	851	855	855						
Solar Energy Production											
Fuelwood Production[2]	55.4	56.8	58.4	60.9	61.7						
Charcoal Production[3]	-	-	-	-	-						
Uranium Production[4]	-	-	-	-	-						

Unless noted otherwise, energy figures are stated in million metric tons of coal equivalent.
Energy production includes fossil fuel and hydroelectric production.
2) Quantities in million cubic meters.
3) Million metric tons.
4) Quantities in metric tons.

APPENDIX C-2

ENERGY DATA - NIGER

	1971	1972	1973	1974	1975	1976
Total Energy Production[a]	-	-	-	-	-	
Fossil Fuel Production	-	-	-	-	-	
Imports	0.11	0.12	0.15	0.14	0.16	
Exports	-	-	-	-	-	
Total Energy Consumption	0.11	0.12	0.15	0.14	0.16	
/Capita (kilograms)	27	29	34	31	35	
Fossil Fuel Consumption	0.11	0.12	0.15	0.14	0.16	
Total Energy Reserves						
Fossil Fuel						
Hydro						
Biomass						
Total Electric Gen. Capacity (MW)	15	15	18	18	20	
Thermal (MW)	15	15	18	18	20	
Hydro (MW)	-	-	-	-	-	
Nuclear (MW)	0	0	0	0	0	
Total Electricity Consumption (10^9/kWh)	0.042	0.05	0.057	0.065	0.07	
/Capita kWh	10	12	13	15	15	
Installed Industrial Capacity (MW)	-	-	-	-	-	
Installed Public Capacity (MW)	15	15	18	18	20	
Solar Energy Production						
Fuelwood Production[b]	2.2	2.3	2.3	2.3	2.3	
Charcoal Production[c]	-	-	-	-	-	
Uranium Production[d]	430	870	1000	1250	1200	

a) Unless noted otherwise, energy figures are stated in million metric tons of coal equivalent. Energy production includes fossil fuel and hydroelectric production.
b) Quantities in million cubic meters.
c) Million metric tons.
d) Quantities in metric tons.

APPENDIX C-3. -- ENERGY DATA - IVORY COAST

	1971	1972	1973	1974	1975	1976	1977	
Total Energy Production[1]	0.017	0.028	0.021	0.034	0.034			
Fossil Fuel Production	-	-	-	-	-			
Imports	1.42	1.76	2.05	2.13	2.06			
Exports	0.05	0.28	0.16	0.23	0.20			
Total Energy Consumption	1.4	1.5	1.7	1.8	1.8			
/Capita (kilograms)	314	331	365	370	366			
Fossil Fuel Consumption	1.37	1.47	1.68	1.73	1.75			
Total Energy Reserves								
Fossil Fuel								
Hydro								
Biomass								
Total Electric Gen. Capacity (MW)	179	299	357	350	350			
Thermal (MW)	129	133	133	126	126			
Hydro (MW)	50	166	224	224	224			
Nuclear (MW)	-	-	-	-	-			
Total Electricity Consumption (10^9/kWh)	0.60	0.69	0.80	0.85	0.86			
/Capita kWh	133	153	171	179	176			
Installed Indust. Capacity (MW)	-	-	-	-	-			
Installed Public Capacity (MW)	179	299	357	350	350			
Solar Energy Production								
Fuelwood Production[2]	5.1	5.2	4.6	4.8	4.9			
Charcoal Production[3]	-	-	-	-	-			
Uranium Production[4]	-	-	-	-	-			

1) Unless noted otherwise, energy figures are stated in million-metric-tons coal equivalent. Energy production includes fossil fuel and hydroelectric production.
2) Quantities in million cubic meters.
3) Million metric tons.
4) Quantities in metric tons.