Future Energy Sources

National Development Strategies

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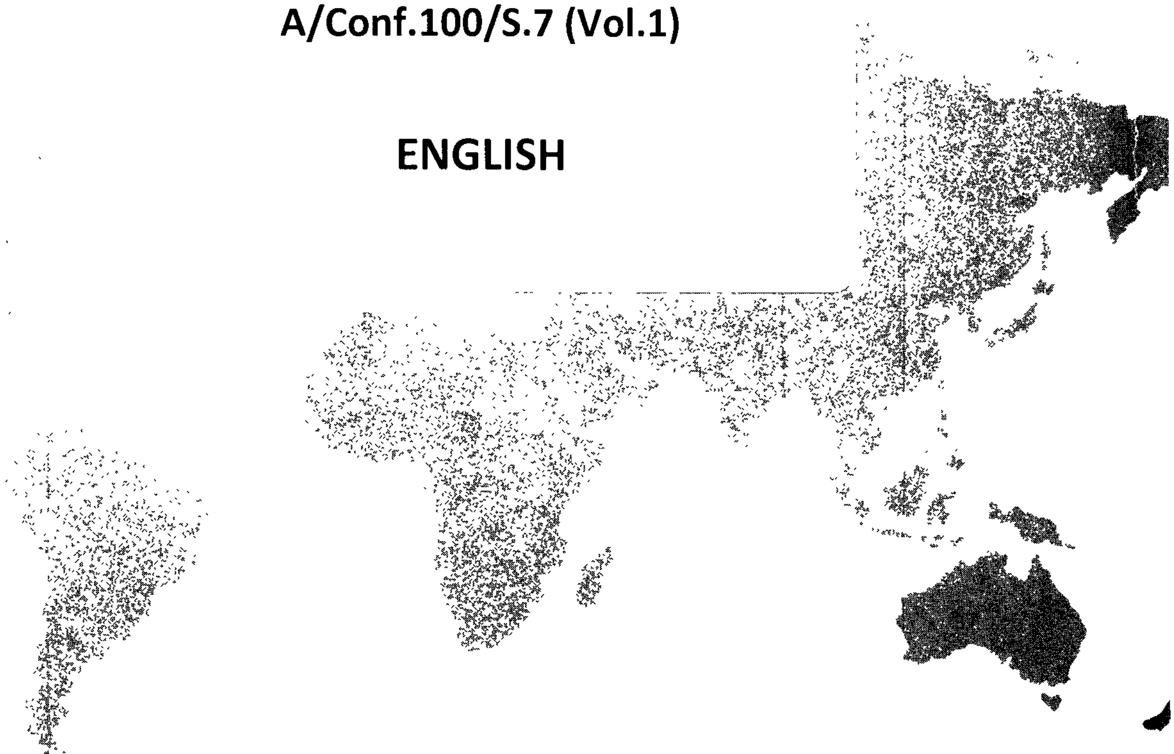

Volume 1
Mideast and Africa

From McGraw-Hill, Publishers of
Coal Week ▪ Platt's Oilgrams ▪ Fuel Price Analysis

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Future Energy Sources: National Development Strategies

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Introduction

The world has consumed more commercial energy since 1940 than in all its previous history. Energy consumption will continue to rise, but energy sources will be diversified.

The finite nature of petroleum resources, increasing demand, and soaring prices have combined to force nations to look for new and renewable energy sources that will safeguard their futures. Economic, social and industrial development, as well as national security, is at stake. For developing countries, the stakes are especially high.

How nations are attempting to reduce their dependence on oil by developing alternate sources of energy is the subject of *Future Energy Sources: National Development Strategies*. This three-volume series is a compilation of reports detailing ongoing projects and development plans for renewable resources in 29 countries. The reports are edited and abridged versions of documents prepared by national governments for the United Nations Conference on New and Renewable Sources of Energy, held August 10-21, 1981 in Nairobi, Kenya.

Renewable energy sources discussed in these reports are: solar, geothermal, wind, hydro power, biomass, fuel wood and charcoal, oil shale and tar sands, ocean energy and peat. Most country reports focus on plans for developing the more universal energy sources -- solar, hydro power, biomass and geothermal energy. However for some areas, particularly Africa and the Mideast, great attention is paid to developing wood as the projected energy base.

Although the reports vary in length and detail, most assess present energy supply and demand patterns, and outline the methods that will be used to shift to secure, indigenous and renewable sources. They describe each country's policy for the transition and pinpoint individual energy development projects underway or on the drawing board.

In creating their national documents for the U.N. conference, governments were asked by U.N. officials to specify technologies of particular interest to their country; identify major constraints to their implementation; state means of overcoming the constraints; and outline the possible scope for international cooperation.

At the conference, 89 national documents were presented. McGraw-Hill energy editors carefully reviewed the documents, selecting for inclusion in the *Future Energy Sources* series the papers containing the most specific information about energy development plans.

In editing and preparing the materials, the editors clarified language and condensed reports where it was felt these changes were appropriate. For example, strictly geographic country descriptions, and the report chapters calling for international cooperation, were deleted or condensed if they overlapped other material or were already widely known. However, the substantive meaning of the papers was in no way altered. The information in the national papers was assumed to be accurate, and was not independently verified.

It should be noted that, because the papers were prepared by the various governments, certain political tones may be apparent in some. These do not reflect the opinions of either McGraw-Hill or the United Nations.

McGraw-Hill has grouped the reports geographically into three volumes. (The U.N. document numbers of the original documents are listed at the back of this book.) The volumes and countries covered in each are:

Volume 1: Mideast and Africa

Egypt, Israel, Jordan, Kenya, Liberia, Nigeria, Pakistan, Sierra Leone, Sudan and Turkey

Volume 2: Far East and the Soviet Union

Australia, Bangladesh, China, Indonesia, Japan, Sri Lanka, Thailand and the Soviet Union

Volume 3: Western Europe and North America

Austria, Canada, Denmark, France, Ireland, Italy, the Netherlands, Norway, Sweden, the United States and West Germany

Within each volume, reports are arranged alphabetically by country. To facilitate use, the volumes are indexed by energy source and a comprehensive Table of Contents appears for each country.

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INTRODUCTION

Present Energy Demand

The commercial primary energy demand in Egypt has increased during the period 1952-1981 from nearly 3 million tons of oil (with no hydro power) to nearly 17 million tons of oil equivalent (Mtoe), with hydro power accounting for nearly 20 percent. Petroleum products account for the remainder. Of the 80 percent petroleum share, nearly 16 percent goes into thermal electricity generation, bringing the total share of electricity to 36 percent. A rough estimate of present non-commercial energy sources may be in the order of 3 Mtoe, bringing the gross total primary energy demand in 1981 to about 20 Mtoe.

One of the most alarming aspects in recent years has been the fast growing rate of energy consumption, as indicated by the figures in Tables 1 and 2, reflecting electricity and direct petroleum products consumptions. For the period 1975-1981, the average annual rate of growth in consumption has exceeded 11 percent for petroleum and 14 percent for electricity. As two-thirds of the Nile's ultimate hydro power potential already is developed and utilized, thermal power generation has been growing in recent years at an annual rate of nearly 21 percent per annum.

Future Demand Forecasts

Several efforts have been undertaken during the past few years to assess energy to the year 2000. Two of these studies already have been published. The first was undertaken in 1976 by the Specialized National Councils and is available in Arabic. The second was completed in 1978 by a joint Egypt-U.S. group and is available in English. A third study is still in progress and is carried out by one of the working groups of the Supreme Council for Energy.

Total projected demand for primary commercial energy by the year 2000 is tentatively estimated at nearly 65 Mtoe. This is nearly 3.8 times the current primary commercial energy consumption, or an average rate of consumption growth of nearly 7.5 percent per annum during the period 1980-2000.

A rough break-down of the 65 Mtoe would be as follows:

- Demand for electricity is expected to reach nearly 105 billion KWh based on the assumption that the per capita share will increase from its current level of 450 KWh to the world average of 1,600 KWh. Expressed in terms of primary energy requirements, this may range between 28 Mtoe and 30 Mtoe.

A breakdown of electricity demand is expected to be:

-- Hydro power: 15 billion KWh or nearly 14 percent. Currently, 10 billion KWh are provided by the existing hydro power system. An additional amount of some 5 billion KWh is planned to the year 2000. This is equivalent to nearly 1.5 Mtoe.

-- Nuclear energy: 40 billion KWh or nearly 38 percent.

-- Thermal generation by oil, natural gas or imported coal: 50 billion KWh or nearly 48 percent.

- New and renewable sources of energy (NRSE), other than hydro and non-commercial, are expected to provide nearly 1 Mtoe by 2000. If added to this, the above mentioned 1.5 Mtoe of new hydro power, the total commercial NRSE would account for about 4 percent by 2000.

- Direct consumption of oil and natural gas is expected to be in the order of 34 Mtoe to 36 Mtoe. If added to this, thermal electricity generation, which is estimated at nearly 13 Mtoe to 15 Mtoe, the total oil and natural gas requirements would amount to nearly 50 Mtoe.

Energy Supply

Several energy sources are available in Egypt with varying potential. The most important of these are oil, natural gas, hydro power, solar, biomass, coal and wind.

Oil

Exploration activities have been intensified since 1973, and a number of new discoveries have added nearly 2.5 billion barrels to proven reserves. More than $1.1 billion has been spent on oil exploration during 1973-1980. Production of oil and natural gas has increased during the period 1974-1981 from 7.5 million tons to 32 million tons. However, as previously mentioned, domestic consumption during the same period has grown from 6.5 million tons to nearly 13.5 million tons, and may reach nearly 50 million tons by 2000.

Natural Gas

Recent exploration activities have resulted in the discovery of several fields of dry natural gas. A pipeline is already under construction to gather and utilize associated gas which has been increasing with growing oil production. Hence, the amount of natural gas produced and utilized has increased rapidly from 33,000 tons in 1975 to nearly 2 million tons in 1980. It is anticipated that natural gas will play an increasingly important role in the energy mix. To accelerate this role, the Egyptian concession terms have been modified recently to allow for more incentives to encourage foreign companies to explore for natural gas.

Hydro Power

Two-thirds of the Nile hydro power already has been utilized with the installation of nearly 2,475 MW at the High Dam and Aswan Dam. Ongoing plans aim at the construction of a second station at Aswan and the utilization of several mini-hydro sites along the river. A pumped-storage project at Suez is being studied with a view to meet peak loads, and the planned Qattara Depression Project may provide additional capacity of nearly 600 MW before 2000.

Nuclear Energy

Because it is cheaper to generate electricity by nuclear reactors than by oil-fired stations, Egypt plans to build nuclear reactors with a total capacity of nearly 8,000 MW by the year 2000. These would provide nearly 40 percent of the country's demand for electric power.

Agreements for bilateral cooperation in the field of peaceful uses of nuclear power recently have been concluded with France and the United States. Legislative measures are being taken to allocate nearly $500 million per annum from oil revenues to help finance the nuclear reactors program, which has financial requirements that may exceed $20 billion during the period 1980-2000. Uranium, thorium and other radioactive material have been discovered in Egypt, but a great deal of effort is needed to evaluate the techno-economic feasibility of such deposits and to explore for new ones. A special authority for nuclear materials is being established under the chairmanship of the minister of industry to accelerate such activities.

Coal

Few coal deposits were discovered in Egypt, with estimated reserves in the range of 80 million tons. The Al-Maghara coal mine in Sinai is being studied for immediate development and utilization (with nearly 35 million ton reserves). A program for coal exploration in several areas is underway, and Egypt may soon be importing coal for electricity generation.

Coal already is imported as a feedstock for the steel industry in amounts totaling 1 million tons at present and expected to reach 5.5 million tons by 2000.

New and Renewable Energy

Egypt has very good prospects in several new energy sources. The most promising of these are solar energy and biomass. Wind energy is available with good potential and geothermal energy is being explored to assess its potentiality.

INSTITUTIONS AND POLICIES

Until the mid-1970s, energy activities in Egypt were handled on the production side by two separate ministries: the Ministry of Petroleum and the Ministry of Electricity. All other energy consumers, public or private, merely contacted either one for their needs and little was done to coordinate such activities.

However, the alarming acceleration of energy consumption since the mid-1970s and the global energy developments during the past few years have created a strong recognition of the need for overall energy planning and coordination. One of the top priorities has been to enhance Egypt's capabilities for integrated energy analysis based upon both energy resources and production factors on the supply side and energy consumption, conservation and economic planning factors on the demand side. To address these issues -- among other development considerations -- institutional changes were introduced.

The Production Sector: In May 1980 a new cabinet was established on the basis of regrouping ministries into three main groups, each to be headed by a deputy prime minister. The Production Sector, which is headed by the deputy prime minister for production and the minister of petroleum, includes in its membership the ministers of electricity, industry, agriculture, irrigation, transportation and communications, and military production.

A coordinated and integral approach to the questions of national production is being applied both at the ministerial level and at the level of the operating departments and bodies. A weekly meeting of the Ministerial Production Committee brings the member ministers together to discuss all production policy matters. Among the key issues, subject to discussion and policy making, are energy questions of top priorities such as conservation and the choice of new technologies proven to be energy-saving.

Some of these issues already had been considered and operative measures were taken; others still have to be considered or reconsidered, as the case may be. In brief, energy has become one of the top concerns of the Production Sector and the energy-consuming sectors are becoming increasingly aware of the energy impact and related problems.

The Supreme Council of Energy: In 1979, Decree 1093 was issued by the prime minister establishing this council as the top-level body responsible for energy. Under this decree, the council, which is headed by the deputy prime minister for production and the minister of petroleum, is given principal responsibility for planning short- and long-term energy programs and for addressing and bringing to the president's attention major issues regarding energy.

One of the major concerns of the council is to develop a strategy and a plan for the period 1980-1990. The plan should address the resources, production and consumption of energy needed to meet requirements of the economy, socio-economic development and the conservation of energy. The council also is empowered to follow up the implementation of the plan and to amend it whenever necessary. The council's rapporteur, who is the minister of electricity, is entrusted with communicating the council's resolutions to the prime minister and other concerned parties, and with proposing the necessary measures for implementing these resolutions.

In addition to the chairman and rapporteur, the council includes in its membership the ministers of industry, irrigation, transport and communications, housing and reconstruction, finance and planning, as well as the president of the Academy of Scientific Research and Technology and three selected members.

The Technical Secretariat of the council is responsible for preparing the agenda of the council and for coordinating the efforts of three work groups entrusted with three main areas of concern: resources, production and consumption. Each group is led by a rapporteur who is responsible for the execution of the jobs entrusted to his group. The group members are primarily representatives of the member ministries, but the group is empowered to entrust on a job basis any study to any individual or organization. Because the rapporteurs are also members of the Technical Secretariat there is assurance that the efforts of the individual work groups will be coordinated. Moreover, whenever the need arises, a subcommittee within the work groups is established to address special topics of joint interest.

The responsibilities of the work groups are briefly summarized as follows:

Energy Resources Work Group

- Preparing data about energy resources available in Egypt and carrying out studies to predict future resource availability.
- Following up global developments in new, nontraditional energy resources.
- Proposing a plan for utilization of traditional energy resources and carrying out the studies related to it.
- Proposing a realistic plan for utilization of expected energy resources, specifying the priorities.

Energy Production Work Group

- Studying different energy production plans.
- Proposing plans for energy production projects during 1980-1990 based on information about available energy resources and demand. Consideration is to be given to the balance between demand and production in light of energy production economics for different resources. Varying assumptions about resource availability should be made to consider the extent to which external resources would be required to achieve the required balance.

Energy Consumption Work Group

- Studying historical energy consumption of the various kinds of energy for all sectors and providing indications that may help to estimate future consumption.
- Carrying out studies that may help to identify ways to conserve energy in different sectors.

Energy Research and Development

Several bodies and institutions have been, for a long time, active in the field of energy research and development. Some of the most important of these institutions are universities, the National Research Center and its Solar Energy Laboratory, the Egyptian Petroleum Research Institute and the Agricultural Research Center. The Academy of Scientific Research and Technology also has initiated specialized research councils including, among others, the Research Council for Energy, Petroleum and Mineral Resources.

Much of the research activities of these institutions in recent years has been directed to address the pressing need to develop new and renewable energy sources. The national energy strategy entrusted with the Supreme Council of Energy envisages the provision of more additional financial and technical support to these institutions, as well as a stronger degree of coordination.

NRSE In Application

Several ministries and companies, public as well as private, are undertaking the responsibility of demonstration and commercialization activities in the field of NRSE. The most important among these institutions is the Ministry of Electricity, which initiated several bodies to handle various aspects of these responsibilities: a council headed by the minister to deal with policy matters, an authority to monitor implementation and a company to manufacture equipment. More recently, with financial support of the European Community, the Ministry of Electricity is undertaking a feasibility study to establish an independent body for NRSE.

NEW AND RENEWABLE ENERGY SOURCES IN EGYPT

Background Experience and Activities

A variety of new and renewable energy sources is available in Egypt. These include: solar, wind, hydro and biomass. Other prospective resources encompass oil and carbonaceous shales and geothermal, which have yet to be evaluated. Several Egyptian institutions are active in the field of new and renewable sources of energy. Activities cover the domains of research, development, demonstration and fabrication of equipment.

Solar Energy

Because of its location and dry climate, Egypt has a very high incidence of solar radiation. In winter the sun shines for between 7 and 9.5 hours. In summer, sunshine is available for 12 hours. Direct solar intensity varies between 260 and 420 cal per cubic meter per day in winter, and is about 710 cal per cubic meter per day in summer. Storms are the main cause of obstruction of direct solar insolation.

Basic Studies: These encompassed resource evaluation and solar mapping, as well as a number of design and performance studies on solar stills; solar heating; central tower receivers systems; solar pumping; solar dehydrating; refrigeration and solar equipment manufacture in Egypt.

Research and Development: Egypt has an extensive research and development program, basically in the solar energy laboratory of the National Research Center, in addition to the universities and the Ministry of Electricity.

At the National Research Center:

- Different models of solar water heaters and solar stills were designed, manufactured and tested.

- In collaboration with the Federal Republic of Germany, a distillation plant incorporating five stills of different designs is under investigation for performance and economics.

- Various designs of solar concentrators have been investigated. These included: north-south fixed axis parabolic trough, vertical axis parabolic trough, heliostat-parabolic dish combination designed for steam generation, and combined parabola-cylinder-parabolic concentrator.

- Operation, testing and development of a 10 KW power generation plant were carried out through agreement with the Federal Republic of Germany.

- With support from IDRC of Canada, a vegetable dehydration unit was designed, built and successfully operated, completely by local efforts.

- An ammonia-water absorption cold store is in operation in collaboration with the Federal Republic of Germany.

- Investigation of CD and CD-TE solar cells by the NRC Solid-State Laboratory and the Laboratory of Bellevue (France).

Egyptian universities are embarking on extensive research and development programs. At Cairo University, investigations are being carried out on field flat plate collectors, solar concentrators and solar energy electro-chemical storage. Ain Shams and Helwan Universities recently have started research and development programs on solar heating and dehydration systems. Alexandria University is undertaking a program including water heating, dehydration and sea water desalinization, and very recently concluded an agreement with the University of Eindhoven (Holland) for semi-manufacture of solar silicon cells and modules assembly as a start for the manufacture of solar cells in Egypt. El-Minia University started a research and development program in 1978 for crop drying and thermo-chemical hydrogen production.

Through the Ministry of Electricity, in cooperation with CEA of France, a solar heliothermic laboratory for the evaluation of flat-plate solar collectors performance recently has been established. In addition, a heliometric lab for the assessment of solar and wind resources has been in operation for two years, tegether with six mobile recording units in different sites of Egypt.

The Ministry of Electricity also is testing solar water heaters under different

Egyptian climates. Several investigations also are being carried out on such aspects as the effect of environmental conditions on flat photovoltaic panels and evaluation of night cooling phenomenon.

Demonstration Projects: Several demonstration projects have been executed or are planned by various institutions to enhance the public awareness, train technical personnel and, above all, to assess the technical and socio-economic feasibility of the new technologies under actual Egyptian conditions.

The Ministry of Electricity has imported 1,000 solar water heaters of different types and sizes and distributed them on a rental basis with very soft payment terms to encourage public use of solar water heaters and promote market penetration.

Through bilateral cooperation with France, three heaters with capacities of 150, 1,500 and 5,000 liters per day were installed at a hospital in Cairo.

The Egyptian-French agreement also included the supply, joint installation, operation and testing of:

- A solar reverse osmosis desalinization plant with a capacity of 60 cubic meters per day of fresh water, which already has started operation at the Al Hamrawain phosphate mining site on the Red Sea coast.

- A 10 KW sofretes deep freezing unit operated by solar power and installed at the High Dam Lake in Aswan for fish preservation. The cooling water of the plant is used for irrigation of the adjacent area.

The cooperation agreement between the Ministry of Electricity and the Federal Republic of Germany includes:

- 10 KW photovoltaic demonstration plants as follows: 2 KW irrigation pump, 2 KW desalinization plant, 2 KW water purification plant, 1 KW drinking water pump, .12 KW 2 sea buoys, .03 KW television set, .5 KW spraypaint, 1.3 KW food cold store and 1.26 KW water electrolysis unit. Some of these are already in operation.

- A 50 KW solar absorption air conditioning system for a section of a hospital.

Through the National Research Center, the Federal Republic of Germany donated 80 solar water heaters of 120 liters per day capacity, which were installed in a village in the middle of the Delta.

In the context of its rural development program in the Governorate of Giza, the National Research Center started demonstration of a dehydration unit in one of the Giza villages.

The American University at Cairo has two solar demonstration projects:

- El Basaisa Project: In cooperation with the U.S. National Science Foundation, the University introduced different solar devices in the village of Basaisa. Social studies also are going side by side with the training of villagers in the use of these techniques.

- Sadat City Project: Sadat City is one of the new desert cities intended to absorb portions of the increasing population. The university, in cooperation with the Ministry of Energy, initiated a demonstration project on 200 acres. The object is to demonstrate the possibility of meeting the energy requirements of small and medium-sized farms, as well as small agri-industries, entirely from renewable energy sources including solar, biomass and wind systems.

Manufacturing Capabilities: Four firms for producing solar water heaters have started their activity within the past two years. The rated capacity of each is about 3,000 to 4,000 heaters per year. Heater capacities vary from 150 to 500 liters per day.

Wind Energy

Egypt has several locations with average daily and annual wind speeds high enough to be considered for the development of wind-power generators. The available data indicates that the Mersa Matruh region on the Mediterranean Sea has an annual average wind speed of about 20 kilometers per hour and the Hurghada region on the Red Sea Coast has an annual average wind speed of about 22 kilometers per hour.

Basic Studies: The Ministry of Energy and Electricity and the University of Oklahoma, with support from the U.S. Agency for International Development (AID), have conducted a research program to measure wind speed and duration in Egypt. This program has two phases.

Phase one started in 1972 and was basically a resource availability study. It dealt mainly with the gathering of existing wind data to select the promising areas for wind energy exploration. Phase two started in 1978 and dealt mainly with measuring wind speeds and duration in pre-selected locations. Such measurements have been taken in Mersa Matruh, Ras El Hekma, Sidi Abdel Rahman along the north coast (Mediterranean), Safaga, Hurghada and Ras Gharib along the Red Sea coast.

Several basic studies concerning design performance of different windmills and generators suitable for electricity generation under the unsteady wind conditions are underway at Cairo, Alexandria and Helwan universities.

Research and Development: The Mechanical Engineering Laboratory of the National Research Center and the Intermediate Technology and Development Group (ITDG) of the United Kingdom are undertaking a project to develop a new design of a wind-turbine driven water pump of the low lift type for irrigation purposes. Modification and development includes facilities for local manufacture of the prototype, site selection for installing the prototype, and preliminary testing under the field conditions. The tests aim at determining the performance capabilities and identifying the development needs.

A project to select and test the most suitable commercially available type of windmills under Egyptian climate is underway as a joint work between the Ministry of Electricity and Cairo University. The main object is to introduce the necessary design changes in the selected type in order to facilitate its local manufacture.

Several other experimental and basic research studies on the laboratory scale are being conducted at the universities.

Demonstration and Manufacture: The manufacture of windmills in Egypt started in the early 1960s when the Helwan Company for Military and Civil Industries built almost 1,000 wind-powered irrigation pumps (with a turbine diameter of 2.45 meters). Most of them have been installed and demonstrated along the northwest coast. Some weakness in the design, coupled with the lack of maintenance, caused production to cease.

Hydro Power

Large-Scale Schemes: Egypt has long experience in the field of large-scale hydroelectric power schemes. This is manifested by the fact that about 55 percent of the present electric energy demand is supplied through hydroelectric generation.

The existing hydroelectric power facilities on the Nile River are at the High Dam and the Aswan Dam, with installed capacities of 2,100 and 345 MW, respectively. Currently, two-thirds of the available hydro power is utilized. Existing plans include the Aswan II Hydro Power Station, with 270 MW installed capacity. The Qattara Depression project is under study and may be constructed with a base capacity of 600 MW before 2000. Moreover, there is potential for pumped-storage generation on the Red Sea. A capacity of about 2,000 MW in the Suez area has been investigated and found feasible for development.

Mini-Hydro Power: Agriculture in Egypt depends mainly on the Nile River with its branches, major and minor canals. In some places in the Delta, the intakes to the main canals are operated at heads which would reasonably allow small-scale hydro power installations.

A series of tests has been carried out and relevant data has been collected and analyzed covering about 34 possible sites. The preliminary techno-economic assessment indicated that a total production of 250 GWh per annum may be developed at competitive costs. Two-thirds of this 250 GWh, represented by sites of Damietta and Rosetta branch barrages, Zefta barrage and Dairout Drain barrage, refers to heads in the range of 3 to 5 meters, which can be harnessed with conventional turbines. However, at another 10 sites of heads in the range from 1.3 to 2.1 meters, the only economically justifiable layout appears to be with "water wheel" turbines, mounted immediately downstream of the gates of the present intakes.

Biomass Energy

Egypt has a good deal of experience in the production of alcohols and acetic acid by fermentation. At present, some 76,000 tons per annum of molasses are fermented to ethanol and acetone/butanol for hospital and specialized use rather than for fuel uses. Its uses as fuel under the current local energy pricing system would hardly be justifiable. The main activities in the field of biomass energy presently are concentrated on biomethanation relating to biogas systems for rural areas use.

The major sources of energy available to most Egyptian villages are the non-commercial sources (dung cakes and agricultural wastes), which are estimated to have provided about one-fifth of the total energy consumption in Egypt in 1975. The present use of biomass in Egypt often involves open fire, which is inconvenient and poses a health hazard due to heavy concentration of smoke in the building. Consequently, rural people tend to switch to kerosene or butane stoves as soon as finances permit. In fact, there is a significant demand on commercial energy sources in rural areas, and consumption of petroleum products is increasing very rapidly, almost doubling every six years. It is worthy to note that these petroleum products are very heavily subsidized by the government.

Agricultural and food industry wastes are another source. Substantial quantities of urban refuse and sewage also are available and can be used as an energy source.

Basic Studies: A number of basic studies have been conducted by the National Research Center and the Agricultural Research Center to examine the technical, social and economic feasibility of biogas systems.

A rough estimate was made of the biogas that could be produced by utilization of crop residues already used as energy sources as well as animal and human wastes available in Egyptian villages. This indicated that biogas could provide the major portion of the residential rural energy requirements, substituting for all the non-commercial sources as well as kerosene and butagas. Furthermore, an additional amount of organic fertilizer equivalent to more than 12 million tons of farmyard manure would be produced, which otherwise would be lost through the direct burning of crop residues and dung cakes. This is very important because it is estimated that the present deficit in farmyard manure in Egypt is more than 80 million tons per year.

Preliminary cost-benefit analyses indicate that rural biogas systems may be feasible under certain conditions, particularly if the unit is connected directly to both the latrine and animal shed. Under these conditions, a payback period of fewer than five years is anticipated.

Research and Development: Although laboratory-scale work on the anaerobic fermentation of animal wastes started in Egypt in the 1950s, research endeavors on biogas production from agricultural animal and human wastes only intensified in universities and research institutes since the early 1970s.

A great deal of multidisciplinary research and development work has been conducted in the National Research Center since 1978 as a component of a national research and development and demonstration program financially supported by U.S. AID.

Considerable digestibility research work was done to determine optimum conditions conducive to greater efficiency, highest pathogen destruction rates and diminishing the effect of toxic and inhibitory materials. Various substrates including cow dung, sewage and agricultural wastes (weeds, water hyacinth, maize and cotton stalks) were investigated at different mixing ratios, organic loading and temperatures. Certain pre-treatments, including pre-composting, also were examined. Laboratory research was conducted on two relevant problems: the selective inhibition of hydrogen sulfide, and destruction of ova and embryos of ascaris.

A sizable portion of work was done on the evaluation of digested products as fertilizer and soil conditioner, as well as on their handling, storage and application.

The engineering and development work was directed toward design, construction, operation and testing of three family-size prototype units at the demonstration site of the National Research Center as well as development of local appropriate gas-use devices. The first prototype unit is a fixed-roof 10 cubic meter rectangular digester of Chinese design. The second is a 6 cubic meter cylindrical wide, shallow-type, dome-roofed Chinese digester. It is anticipated, after the experience gained with construction of the second prototype and its successful operation for almost a year, that this type has good prospects as a family-size unit in rural areas of Egypt. It presently costs about U.S. $300, using locally available materials and skills. The third prototype unit, which has been constructed recently, is a newly adapted design combining the features of both plug flow and the Indian movable cap types. Its effective size is about 7 cubic meters and it costs about U.S. $500. Provisions for solar heating of feed water, composting of the digester effluent on the top of the plug flow part, and attachment to both a latrine and an animal shed were incorporated in the unit. This type seems readily expandable to the community size. The National Research Center demonstration site, with all the biogas systems present, also is utilized for training as well as for publicizing the biogas technology.

Thirty-three units (.3 cubic meters each) of both the Chinese fixed dome and the Indian movable gas holder types are being tested under various operating conditions by the Agricultural Research Center.

Demonstration: Few field demonstrations have started to assess the technical, economic and social visibility of biogas technology in rural areas of Egypt.

The National Research Center demonstration program started with two family-size units (10 cubic meters each) of the Indian and Chinese types in a traditional village in Giza. The newly developed Egyptian type also will be demonstrated. A community-scale unit is under consideration as well.

The Ministry of Agriculture has initiated a locally funded demonstration program. Three 10 cubic meter Indian type units have been installed recently, in addition to a 45 cubic meter unit attached to a chicken farm (the gas is used for heating the chicken chambers). Recently, the FAO has strengthened these activities by releasing a "TCP" project for one year, whereby 50 biogas units will be constructed and demonstrated.

Oil and Carbonaceous Shales

Oil shale deposits have been located in four places, but no reserve estimates have been made. Available data indicates that the shale is of low quality and could be exploited only if there were a severe lack of alternatives. Some carbonaceous (lignitic or coal) shale also is available in limited quantities, but it has not been evaluated for extent of reserves or potential uses.

Geothermal Energy

Very limited information is available on the extent of geothermal energy sources in Egypt. Its potential, however, has been noted by the presence of hot springs on the eastern and western sides of the Gulf of Suez and in several cases by higher than normal heat flows along the west coast of the Red Sea, by hot wells in the Western Desert, by evidence of extinct geysers east of Cairo toward Suez, by mineral springs in the Helwan area and evidence of extinct hydrothermal activity in the Qatrani area.

The Egyptian Geological Survey and Mining Authority, in collaboration with Southern Methodist University, undertook a two-year joint geophysics project. Results indicate that most promising areas for geothermal development in Egypt are along the Red Sea coast.

Potential Applications

In a recent joint Egyptian-U.S. AID assessment of renewable energy resources and priorities, some areas with good prospect for application in Egypt have been identified. These are:

- Solar domestic water heating.
- Solar collectors for industrial process heat.
- Solar desalinization.
- Rural biogas digesters.
- Photovoltaic for remote application.
- Passive solar architecture for new settlements.
- Solar flat plate collectors for refrigeration and cooling.
- Wind systems for water pumping and electrical generation.

Future Work in the Field of NRSE

Future work in the field of NRSE will involve technical and economic assessments of technologies and their wide implementation under local conditions. Among other things, this would include institutional restructuring that better meets the future needs, establishing a reliable data base as well as intensifying and widening educational and training programs.

The following is an outline of the areas that are of special importance in the future research and development and demonstration program:

- Enhance designing and local manufacturing capability of flat plate solar heaters for domestic hot water and preheating in industrial processes.

- Design and construction of solar thermal systems to replace conventional energy sources for industrial process heat, including the enhancement of industrial capabilities of moderate temperature solar collectors (100°C to 250°C).

- Demonstration and development of different bioclimatic building designs to suit the different climates and cultural conditions.

- To enhance Egyptian design capabilities, and construct and operate solar desalinization plants on the Mediterranean and Red Sea coasts.

- Development of solar drying of agricultural products.

- Technical and economic assessment of solar-wind power generation systems for different applications with emphasis on demonstration plants in remote areas.

- Technical and economic assessment of available solar pumping systems including demonstration testing under Egyptian conditions.

- Investigation of direct and indirect utilization of solar energy for hydrogen production.

- Production of less costly photovoltaic cells, and investigation of the most appropriate storage systems.

- Investigation of the feasibility of solar pond systems in Egypt.

- Use of municipal wastes and garbage for biogas production in big cities.

- Investigation of integrated biogas systems incorporating algae, fish and fertilizer.

- More active demonstration of small biogas systems in rural areas.

- Energy farming in semi-arid and arid land.

- Amelioration of alcohol productivity from agricultural wastes, including the bioconversion of the lignin component of the waste and other aspects.

- Studies on the most proper types and designs of wind energy systems for water pumping and electricity generation.

- Assessment of oil shales and tar sands in Egypt.

- Feasibility study on the prospects of geothermal energy in Egypt.

MAJOR CONSTRAINTS AND POLICY MEASURES

Technologically, Egypt has wide and diversified experience in the field of conventional energy as well as in several fields of NRSE. Solar energy research has been going on in universities and specialized laboratories for more than 25 years. Biomass and wind energy also have received special attention. However, the energy impact of recent years has created an urgent need to intensify and redirect research and development activities to meet the fast accelerating future energy demands.

There are several constraints to the new course. Under the present energy system, the pricing of petroleum products is characterized by a great deal of rigidity. Domestic prices do not exceed one-third of the international energy prices and for some products, such as fuel oil, may not exceed 10 percent. Tacit subsidies in domestic oil consumption are estimated at $2.33 billion for 1980-1981. Much has to be done in restructuring the energy pricing system, but there are serious obstacles that need to be tackled first:

- Because most wages and prices for necessary commodities are controlled by government actions as a measure against inflation, wages and costs have to be reconsidered to match and balance energy price restructuring. This problem is receiving utmost consideration at all political and social levels.

- Alternative energy sources are lacking. Solar water heating, which is being developed at a fast pace, may provide only partial help by offsetting part of the ever-increasing butagas consumption. Butagas consumption, which is partly imported and subsidized, has been growing at an annual rate of about 20 percent.

The fast development of natural gas may help relieve the problem but it does not offer a long-range solution in view of its depletable nature.

Despite these obstacles, a partial restructuring of oil prices has been initiated during 1980. For certain projects with products that do not affect the low-income classes, a phased-out system to bring the prices of their energy requirements up to the world level in five years has been adopted and accepted by the projects' managers. Parallel measures are being considered to bring all energy prices to the required level without affecting the real incomes of the low-income classes.

The fact that Egypt had not faced in the past a severe energy crisis, and that oil had been available in quantities to meet the relatively low level of consumption, has hindered to some extent the pace of energy assessment and planning. Now, the challenge is becoming greater and the past policies are increasingly changing. Senior officials and their staffs exhibit a high level of awareness about the major policy issues and are dedicated and competent. And, as was mentioned before, Egypt has taken important steps in integrating its economic goals with its energy prospects by the establishment of the Supreme Council of Energy and by regrouping several ministries in the form of a Production Sector, both under the chairmanship of one deputy prime minister. What may make it easier to plan and to implement is that the greater part of economic and development activities is undertaken by public sector personnel who can easily comply with public policies, once ratified by public authorities. Luckily, many development projects and much of the housing reconstruction program, including the establishment of several new cities, is to be achieved in the future. The chance is there to choose the energy-saving technologies.

The energy assessments carried out to date have to be updated and an energy data system is being considered to meet the new requirements. There is a great chance in this area for regional and international cooperation, part of which already has started on a bilateral basis. Needless to say, the Egyptian infrastructure in the field of energy research and development and manpower training could serve as a solid base for new regional energy centers once the technical and financial support is available in adequate amounts.

In brief, the need for comprehensive energy planning centers around a number of critical issues that must be addressed in the context of a broader national perspective. These issues include:

- Subsidies in energy prices and the need to restructure these prices within the specific framework of economic and social structures that prevail in Egypt.
- The role of energy in the economy.
- Planning for the development of new and renewable resources of energy.
- Ways and means to effect energy conservation.
- Investment in power generating capacity and the need to replace oil in this field by cheaper sources of electricity generation.
- The need to accelerate regional and international cooperation in the above fields, taking into consideration the special qualifications of Egypt as a member of both ECA and ECWA.

TABLE 1. DOMESTIC CONSUMPTION OF MAIN PETROLEUM PRODUCTS, (1952-1981)

(Units = 1000 Metric Tons)

Year	Natural Gas	Buta-Gas	Gasoline	Kerosine	Gas Oil	Fuel Oil	Lubricants & Asphalt	Total
1952	-	4	252	665	343	1754	39	3057
1960	-	20	262	736	786	2783	158	4745
1965	-	59	287	928	1124	2974	209	5581
1970	-	108	444	820	1176	3005	297	5850
1975	33	179	656	1188	1335	3639	231	7261
1979	946	381	1148	1569	2175	4704	350	11273
1980/ 1981 Est.	-	-	-	-	-	-	-	13500

TABLE 2. DOMESTIC CONSUMPTION OF ELECTRIC POWER (1952-1981)

Year	Power Consumption (million KWh)			Peak Load
	Thermal	Hydro	Total	MW
1952	929	-	929	110
1960	2829	250	3079	533
1965	3262	1738	5000	750
1970	2225	4690	6915	1100
1975	3009	6790	9799	1733
1980/1981 Estimate	8500	10000	18500	3600

Israel

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(Editor's note: Israel's plan to tap hydroelectric resources by building a canal to link the Dead Sea and the Mediterranean, described in this report, has generated considerable opposition from neighboring nations.)

INTRODUCTION

Israel, with a population of 3.9 million and GNP of $17 billion, is almost totally dependent on the import of crude oil for providing its energy requirements. Total energy consumption in 1980 was about 8.2 million tons of oil equivalent (Mtoe). Domestic consumption excluding exports, marine bunkers and stock change will amount to 7.4 Mtoe. Local crude oil production provides .4 percent of the total, local natural gas provides another .7 percent, while solar energy, utilized primarily for domestic water heating, contributes an estimated 1.2 percent (100,000 tons of oil equivalent).

Approximately 36 percent of primary energy is converted to electricity, while the remainder is marketed as distillates and goes to industrial and petrochemical firms; residential, commercial and public users; agriculture and water pumping; and transport, as shown in Table 1.

Energy Consumption Characteristics in Israel

Energy intensiveness in Israel has not changed radically since 1960, although a slight increase of about 10 percent has occurred with annual variations, reflecting economic performance. An energy elasticity of GDP of about 1.1 thus is recorded, which suggests the industrial development stage the country has attained.

Electricity intensiveness, however, has increased significantly -- by about 45 percent since the 1960s, making Israel a relatively highly electrified country, reflecting a long-run electricity elasticity of 1.4 to 1.5. Per capita energy consumption has doubled and electricity consumption almost tripled since 1960.

Because oil still accounts for almost all primary energy resources, and almost all of it is imported, the burden on Israel's economy has increased in recent years, particularly in 1979 and 1980.

It is the question of market vulnerability coupled with these high costs to the economy that stimulates Israel and other oil import dependent countries to search for options that would increase their energy utilization efficiency and break away from oil.

Problems and Prospects

Israeli energy policies are based on the following:

- Israel's utmost dependency on the import of fuel.
- The relatively high component of fuel purchases on the spot market.
- The severe burden on the Israeli economy in financing these imports.
- The dichotomy of growth: the need for increased energy inputs against the necessity of reducing energy consumption.
- The lack of considerable reserves of fossil resources or significant quantities of techno-economic proven alternatives (hydroelectric power).
- The characteristics and structure of energy consumption: there is no dominant consuming sector, a fact that does not enhance conservation efforts.

In view of these severe problems and constraints, Israel is prudently focusing its national energy objectives on reducing oil imports. In order to reach these objectives, Israel is mobilizing its available resources -- the abundance of sun, the low calorific content fossil resources, the highly developed research and development infrastructure and the scientific ingenuity of professionals at governmental, academic and industrial institutions.

Israel has thus adopted the following policy:

- Effective management of all systems through the introduction of conservation measures.
- Diversification of the energy mix by the introduction of coal in all future power generation plants and for energy-intensive industrial users.
- Expansion of the use of solar and other renewable forms of energy.
- Research and development and commercial demonstration of oil shale use.
- Intensification of oil and gas explorations.

Israel is determined to adopt any available or developing technology as a substitute for oil to overcome the supply problems of the next 20 years.

ISRAEL'S ENERGY FUTURE

Since 1960 there have been three distinct kinds of annual growth rates in energy consumption -- a high rate of 9.2 percent between 1960 and 1967, an accelerated figure of 12.3 percent between 1967 and 1972 and a slow growth of about 2.8 percent between 1972 and 1978.

These rates correspond with the pace of economic growth in the country, and the impact of the oil crisis since 1973.

Electricity generation increased by 11 to 12 percent during the first two periods, and by a lower figure of 5.5 percent between 1972 and 1978, which was still much more than the total energy growth in those six years. This reflected again the higher electricity intensiveness and elasticity of the country.

Because energy demand may be roughly assumed to be the product of population, economic activity in terms of GDP and energy intensiveness, different projections have been made (see Table 2).

Three secondary scenarios have been assumed:

- Basic scenario -- corresponds with the hypothesis in Table 2.

- Moderate energy scenario -- the expected 3 percent annual rise of real energy prices above all other inputs will reduce total expected basic demand by 10 percent due to a price elasticity assumption of -.3.

- Low energy scenario -- an additional 10 percent reduction in demand is expected due to the success of various conservation actions.

Any combination of the two last scenarios may be realized by different weights in the respective components.

Electricity projections are based on the expectation that Israel will increase its electricity intensiveness to 45 percent of its share of total primary energy resources by 1990 and 50 percent by the year 2000, as shown in Table 4.

The projections imply that in 1990 energy demand will total 1.6 to 2.3 times the 1978 consumption, and in the year 2000 between 2.3 and 4.1 times the 1978 level.

Electricity is expected to grow 2 to 2.8 times by 1990 as compared with 1978 consumption, while in the year 2000 the demand will be 3.5 to 5.5 times the 1978 figures.

The Options -- Reducing Oil Dependency

How are we going to supply this demand? What are the prospects of reducing oil consumption subject to these scenarios? What are the options for providing this projected energy need adequately, reliably and at minimum cost?

How should we act to overcome prospective socioeconomic stagnation and reduce geopolitical insecurity?

On the demand level we may distinguish two major directions:

- A national and economically efficient price policy.
- An aggressive yet cautious conservation policy.

A pricing system that charges consumers the real costs provides the best way for efficient allocation of energy resources. It establishes the correct criterion for making beneficial investments while providing the public with the right signals for their future consumption pattern. Even with relative low short-term, and somewhat higher long-term, price elasticity of demand, the chances are that at the current high level prices, waste will be eliminated, inefficiency in use decreased and total consumption growth reduced.

The government is currently determined to follow as closely as possible this policy: Price equals real cost.

Electricity peak load and shadow pricing in the oil products sector are becoming important components of energy pricing policy in Israel.

The introduction of long-term social overhead costs accounting for risk aversion as well as environmental costs will smooth out or levelize the pricing trend, thus providing the consistency to safeguard the economy.

Currently, a directive of a 3 percent to 5 percent real annual price increase of oil above all other inputs' cost is practiced in Israel to account for future prospects in investment.

Secondly, an aggressive conservation policy should be adopted to promote and enforce efficient use of energy where pricing measures do not sufficiently affect consumer behavior. These conservation steps should be directed toward the public sector, price-regulated industries, cases where private benefits from savings do not coincide with social benefits, and cases where capital outlays for energy saving means competition with other government-backed investments.

Yet such a policy should be conducted with the utmost caution, to avoid misallocation of funds, and the introduction of additional distortions in a highly regulated, complicated economy. It is most important not to augment the public sector budget, the major cause of the imbalance between resources and uses in the Israeli economy.

Energy conservation efforts are followed mainly in these directions:

- A most vigorous program to accelerate the spread of solar energy for domestic and industrial use.

- The technological promotion of the use of waste heat in industry.

- Initiated training to eliminate waste in all forms of domestic, industrial and public utilization by the introduction of technological improvements and conservation awareness.

- Conversion to non-oil uses, wherever possible and economically justified.

Demand management has intrinsic uncertainties, and direct conservation means are plagued by the unreliability inherent in mass behavior. Thus the activities should be highly selective and should concentrate on:

- Regulating and standardizing energy-saving products, building codes, etc.

- Providing incentives for demonstration plants and pilot projects.

- Disseminating technical and financial information about the saving options available in any of the production processes or consumption practices.

Diversification policy implies the use of coal as a near-term substitute for oil in future power plants, as well as the introduction of nuclear power stations, oil exploration, the use of solar and other renewable energy forms, oil shale, biogas and geothermal energy as long-term substitutes.

The Role of Electricity

The lack of confidence in the reliability of a long-term fuel supply and the enormous price escalation basically changed the energy policy of the electric utility. It became mandatory to save energy and look for alternative energy sources to oil, such as coal, nuclear energy, hydro and low calorific fossil fuels (oil shale and lignite).

The rise in price of fuel changed the relationship between investment operation and maintenance costs. This led to a reevaluation of policy and considerable changes in intermediate and short-range planning methods.

As the fuel component rose to two-thirds of the operating costs of the Israel Electric Corp. (as compared to one-third prior to the October 1973 war) energy saving in general and the reduction in the fuel oil conservation in particular, became a primary objective.

Oil consumption is being cut in the following ways:

- Optimizing electricity generation, transmission and distribution systems, and energy saving and conservation on the consumer side.

- Replacing of fuel oil by alternative energy sources for electricity generation.

- Intensifying the shift to electric power in all fields of energy utilization such as transportation, space heating, process steam and direct heat.

The following measures have been taken to optimize the electricity generation process system operation and maintenance:

- Improvement and computerization of the loading program of power generating units.

- Reducing the specific fuel consumption of generating units by introducing new operational parameters, such as higher steam pressures and temperatures and lower flue gas exit temperatures.

- The somewhat higher wear and tear involved, causing increased maintenance expense, has been well compensated by the savings.

- Close supervision and strict control of operational parameters, which requires high alertness on the part of the station operators and technical personnel.

- Introducing incentive pay programs for operation and maintenance personnel based on those factors in order to enhance economic operation of the power stations.

The changes in operating procedures and design policy introduced after October 1973 had tangible effects. The amount of fuel used for the production of a kilowatt/hour has dropped due to the more efficient use of available equipment. Moreover, a higher reliability of supply gas has been obtained due to the extra overall availability of the equipment achieved under the new maintenance policy.

During the period 1975-1976 to 1976-1977[1] the specific fuel oil consumption decreased from 244.4 grams per kilowatt/hour to 241.9 grams per kilowatt/hour. Thus, a reduction of 2.5 grams per kilowatt/hour has resulted in a saving of about 25,000 tons of fuel oil.

The standard power factor of the electricity consumers has been increased to .92. The results obtained so far are very encouraging, showing considerable energy savings and improvement of the operational behavior of the system.

A program is being prepared to substitute a significant amount of the fuel oil burned in industry by coal.

Assuming that by 1986-1987 all water heating will be achieved by solar energy, a total savings of about 500×10^6 KWh can be attained, which is equivalent to 120×10^3 tons of fuel oil. However, as solar heaters replace electric heaters, which are operated at off-peak hours, a degradation of the system load factor and the base load unit plant factors is expected. Moreover, on cloudy days the electrical back-up of solar water heaters will increase the winter peak, thus lowering the reliability of supply and increasing fuel oil consumption for peaking units. These drawbacks of solar heating can partly be overcome by load management measures.

Pumped Storage

The Israel Electric Corp. (IEC) has undertaken surveys of potential sites. Three possible sites have been indicated on the shores of Lake Galilee. A preliminary estimate would suggest a power station comprising 2 x 150 MW.

The pumped storage system is envisaged after the commissioning of nuclear units. It has been calculated that 213 million KWh can be produced per year at a rate of 300 MW, with an overall efficiency of 78 percent. The construction will take seven years and it will cost $1,000 per kilowatt.

This plant could replace the equivalent of 59,000 tons of fuel oil per year.

Taking into account the available energy sources for electricity generation, the following assumptions have been made:

- Fuel oil is not to be used for base-load electricity generation.

- Because nuclear power will not be available before the 1990s, the base load should be supplied by coal-fired power plants until then.

- Peak load power will be generated by hydroelectric plants and, whenever feasible, gas turbines and combined cycle units.

The generation expansion plan, based on the above assumptions and on IEC's official, low alternative demand forecast, leads to the following conclusions:

- Were IEC to depend on fuel oil as the whole energy source, the fuel oil consumption would increase from less than 3 million tons in 1978-1979 to more than 14 million tons in the year 2000.

- According to the present expansion plan, the demand for fuel oil will decrease rapidly, at a rate of about 5.6 percent per year, reaching 1 million tons in the year 2000.

The successful execution of the expansion plan will enable a considerable decrease in the dependence on fuel oil consumption, accompanied by significant economic benefits.

The cumulative (1979-1980 equivalent) quantities of fuel oil substituted by coal will total 7.5, 21 and 59 million tons in the years 1985-1986, 1990-1991 and 2000-2001, respectively.

The Shift to Electric Energy

Apart from the consideration that electric energy is the main method for significant utilization of alternative energy sources, there are other factors in favor of its broader use, namely:

- Ecological considerations encouraging the use of electric energy in highly populated areas.

- Technological development allowing controlled automatic and efficient processes in the use of electric energy.

If the national goal is to speed up the reduction of the dependence on oil, an intensive shift to electric energy is mandatory.

The major areas where electrical substitution for oil and gas seems possible are:

- Transportation (passenger cars, trains, industrial vehicles).
- Space heating (heat pumps).
- Process steam (combined electricity-steam generation).
- Direct heat.
- Cooking.

A thorough investigation should be carried out in all energy sectors in order to determine their potential shift into electricity. In each case, the economic and technical feasibility, and the suitable timing of such a shift, should be studied. The forecasts for electricity demand should be modified to account for the additional potential, so that the generation expansion can meet the requirements.

CONTROL OF DEMAND -- CONSERVATION AND MANAGEMENT

Pricing Policies

Prices of energy products and services should reflect the real economic marginal cost to the economy, in order to ensure efficient allocation and consumption.

The Ministry of Energy considers the market mechanism as a major means for the efficient use of energy and conservation efforts in the country. For this purpose a modified price system is currently under consideration in order that prices to the consumer will reflect marginal costs. Even if the objective of identity between prices and costs cannot be achieved completely, it is absolutely necessary to adopt as far as possible the relative prices of energy products in relation to their marginal costs.

Over the whole period from 1972 to the end of 1980, the burden of the increasing costs of imported oil to the country has not been fully transferred to the consumer. However, in the past two years, the objective of full transfer has been largely achieved, as can be seen from the following table:

Real Price Increases of Oil Products, Electricity and Crude Oil

	1/1/1972 to 31/12/1980	31/12/1978 to 31/12/1980
	%	%
Weighted average of real price annual increase for all oil products	13.7	24.5

Weighted average of real price annual increase for electricity	9.9	19.0
Annual price (CIF) increase of imported crude oil	26.8	34.0

While the concept of price-equals-cost has merits for economic efficiency, it may present problems with respect to the income distribution of the population, and the impact on the consumer price index. On the other hand, the sensitivity of the industrial consumers to prices is reduced due to the tax regulations which do not give enough credit to conservation efforts. All these become impediments in realizing the potential benefits of such a price policy.

However, even with these problems the price-equals-cost policy is being implemented.

Electricity rates are in the process of adjustment to reflect not only complete coverage of costs, but also the pattern of loading that the consumer imposes on the system. The time of day, tariff system (on peak-load pricing) and load management practices may cause significant changes in the consumption patterns, improve the electricity system load factor, "share off" peaks and consequently save energy and reduce the capital and operational costs of the system.

Likewise, marginal costing for oil products is under preliminary investigation employing mathematical optimization techniques for joint production.

These principles of pricing policies in the energy field should always be subject to the general lines of economic policy and the determination of the political level to implement them.

Regulations and Incentives -- Specific Conservation Policies

In January 1977, the Knesset adopted the National Energy Authority Act, which gives a broad base for regulating energy activities in all sectors of the economy. New regulations and legislation are being introduced. Some of these are listed below:

- Mandatory use of solar energy for water heating in all new homes.
- Mandatory metering of hot water in all new apartment houses (all cold water is metered).
- Expanding the use of diesel engines for most commercial vehicles (currently, the use of diesel engines is restricted to buses, taxi cabs and heavy trucks only).
- Mandatory automobile engine tune-ups twice a year.
- Increasing local taxes on large, heavy gasoline-consuming cars, to promote the use of smaller and economical vehicles.

- Requirement to maintain water pumping unit efficiency above a specified level.

- Reducing local taxes on energy-saving devices.

Several new laws and regulations relate specifically to conservation in the industrial sector. These include:

- Requirement to maintain industrial boiler thermal efficiency above a specified level.

- Mandatory preparation of an annual energy audit on all industrial plants consuming more than 50 tons of oil or 100,000 kilowatt tons per month.

- Capital investment in energy-saving measures will be recognized as eligible for special concessions awarded under the Law for the Encouragement of Capital Investments in Israel and the Law for the Encouragement of Industry.

- Government approval of investments in new, or the expansion of existing, industrial plants will be conditional upon the efficient use of energy.

- Government approval of price increases of controlled products will be conditional upon the presentation of an energy audit and the efficient use of energy in the applicant's plant.

Incentives and financial assistance are provided for demonstration projects of an innovative nature, large or communal solar water heating projects and potential energy-saving surveys for industrial plants. Among the demonstration projects are:

- Solar water heating in swimming pools and sports institutions.

- Solar pre-heating of feeder water for steam boilers in the textile industry, hatcheries and laundries.

- Solar water heating in hotels.

- Solar drying of spices.

- Passive solar utilization in hothouses.

- Waste heat utilization to generate electricity in the refineries and chemical industries.

Financial assistance is provided at the rate of 10 percent of total investments for centralized solar water heating systems in large apartment houses; 30 percent participation in the demonstration projects; and 15 percent grants, or 40 percent to 50 percent loans during six to 10 years, for the production of energy conservation measures in industrial plants, following feasibility surveys financed by the ministry at 50 percent of the expenses.

A major part of conservation activity is carried out by:

- Provision of technological information through the mass media and publishing of printed matter for technical staff.
- The establishment of advisory bureaus for individuals in the area of home heating and industry to increase the efficiency of energy uses.
- Operation of mobile teams to examine the efficiency of steam boilers and improve the exploitation of water pump stations.
- Introduction of a person responsible for energy in factories, institutions, offices etc. for the purpose of follow-up and improvement in energy use.
- Introduction of energy conservation as a subject in the school curriculum.

It is expected that following these direct measures and the impact of the pricing policy, within 10 years we may realize the following savings:

	Expected Savings (Mtoe)	Percentage Savings %
Industry	500 - 600	13 - 17
Agriculture and Water Pumping	100 - 140	10 - 15
Residential, Commercial and Public	400 - 600	12 - 16
Transportation	200 - 250	15 - 20
Energy Sector	175 - 250	5 - 7
Total	1375 - 1840	9 - 13

With an energy elasticity of 1.1 in Israel, a reduction to an elasticity of .7 to .9 within the next 20 years should be attainable.

Oil Exploration -- The Big Challenge

In the framework of the efforts to get away from absolute dependence on imported energy sources, there has to be a concentrated professional and financial effort to explore for oil in Israel that would make the prospect of finding oil in the country reasonably certain.

Oil exploration has been going on for 30 years. So far, 288 drills have been carried out, including 105 experimental and production bores in the Heletz and Zohar areas and 183 exploration drills (excluding Sinai).

Oil exploration has yielded three relatively small discoveries of oil and gas, the main one being the Heletz field (from which 16 million barrels have been extracted) and the gas field at Zohar. Geophysical data, geological surveys and findings from drills carried out in Israel have provided a picture that indicates a good prospect of discovering oil and gas.

As far back as 1962, the unofficial report estimated that there were reserves of between 500 million and 2,000 million barrels of oil in the country. Another report carried out in 1973 confirmed these estimates.

The evaluations were reinforced recently by two further estimates of Israel's oil potential, which concluded that Israel's oil and hydrocarbon reserves totaled 330 million barrels on land (excluding the Dead Sea area). From the geological point of view, the Dead Sea basin is unique and the oil reserves there are estimated tentatively at several hundred million barrels more.

One of these estimates was carried out by oil and geological experts led by the well-known American geologist James Wilson. The other work was carried out by the U.S. company Neptune, which acted as a contractor for oil searches and extraction in South Sinai. These parties reevaluated all existing data in Israel concerning oil exploration. There also was a reevaluation of the data from the point of view of the prospects of maintaining economic oil and gas reservoirs in Israel.

TRANSFORMING THE SUPPLY BASE -- EXPLORATION AND DIVERSIFICATION

In the wake of government decisions in 1975, oil exploration work was intensified, with the stress being placed on searches in the Gulf of Suez area in the Sinai. As a result, the Alma field in South Sinai was discovered and developed. When it was handed over to the Egyptians, it was producing about 40,000 barrels of oil a day, about 20 percent of Israel's oil consumption. Other exploration work was focused on the coastal plain and, as a result, gas fields were detected at Sadot and Shikma with indications of oil and gas at Gan Yavneh and Ashdod. Similarly, a number of initial searches were carried out in the Mediterranean continental shelf. These discoveries, not all of which were checked or developed, still indicate prospects of finding this important source of energy in the country's soil.

Policy Guidelines

- Oil exploration in Israel during the next four or five years is starting to be recognized as a national project to boost the financial, technological, professional and human infrastructure.

- Fast implementation of a comprehensive oil exploration program that includes the whole coastal area, particularly the southern coastal zone and the Dead Sea basin.

- On the background of this approach, the necessary budgets for carrying out a multi-annual plan will be assured at the rate of about 20 to 25 drills a year at an overall annual investment of $30 million to $35 million during the next four to five years.

- Development of scientific, management, financial and organizational tools for processing current data, extension and updating of geological and geophysical data as well as repeated and current checks of the estimated potential for finding oil sources in the country.

Coal: The Intermediate Solution

Israel, a country without domestic coal resources, is determined to convert its electricity generation, and some industrial production processes, from fuel oil to coal because of its anticipated higher dependability, lower purchase prices per unit of energy input, and the diversification objective of primary energy supplies.

Following the October 1973 war, Israel Electric Corp. initiated thorough examinations of all the aspects involved in using coal for electricity generation in Israel. Because coal technology has not been used so far in the country, it was necessary to study all the implications very carefully.

The year 1981 will mark the beginning of the coal era in Israel, with the operation of the first of four generating units of 350 MW at the new Hadera power station. This will be followed by the use of coal in industrial production processes, initially in the cement industry.

Currently, it is planned to use about 9 million to 10 million tons of coal by the end of the decade according to the following time schedule:

Year	1981	1982	1983	1984	1985	1987	1990
Coal use (1,000 tons)	500	1200	2500	3300	4000	6000	9000
Share of electricity of total coal consumption (%)	80	77	83	85	82	85	80

The conversion to coal thus is conceived along the following lines of action:

- Implementation of the development program of the electric power sector based solely on coal-fired generation stations within this decade. This conversion will follow a dual technology of coal and fuel oil to secure maximum flexibility as a response to the changing conditions of the world oil and coal markets.

- In 1985, the coal-fired M.D. power station will be able to provide a net capacity of 1,400 MW, thus achieving a significant reduction of the dependence on fuel oil --

about 45 percent of the electric energy will be generated from coal.

- Initiation of cogeneration regional combined heat and power stations which will burn coal and save 15 to 20 percent of the direct fuel inputs in industrial plants. In this way, another 300,000 tons of oil used directly in industry will be substituted by coal.

- Promotion of gradual conversion to coal of industrial factories, first the more energy intensive ones -- the cement, potash and phosphates industries -- and later medium-sized plants. The expansion of the usage of coal in industry, subject to strict environmental control, is nothing but the fast implementation of the required infrastructure -- inland transportation, technological know-how and managerial skills -- which makes coal a feasible energy source for its potential users. The amount of coal in industrial use in 1990 may reach about 1 million tons.

- Adaptation of proven coal technologies which are available elsewhere and can be employed in the country subect to a relatively short period of study and training. These technologies include the introduction of medium-size and small boilers for steam generation, a coal-oil mixture as an option for expansion of coal usage in modified oil-fired power generation units, and coal slurry technologies for the transportation of coal by pipes.

- Finally, establishing a research and development program for the liquification and gasification of coal in order to introduce future technologies of coal utilization for additional expansion in the next decade.

Coal is the immediate option for Israel and will remain the major substitute for oil, on an interim basis, as long as nuclear power does not materialize and new and renewable resources are not technologically available and economically feasible.

Lignite: Low-quality lignite is available in the Hula valley below the surface, under a top layer of peat, which is younger than lignite and contains much more water. Peat also has a low fuel content.

Lignite was first found in drills carried out in 1952. Since then, several proposals have been made to examine its fuel possibilities, but it was only in the mid-1970s that it was decided to check the potential economic and technological exploitation of lignite.

Three drills were carried out in the Hula valley in 1976, and in the wake of the findings a team was entrusted with the task of preparing a preliminary evaluation of the potential for establishing a power plant run on lignite.

The geological reserves are estimated at 500 million tons and the minable quantity of lignite at about 440 million tons. The ratio between the amount of unusable material and the lignite is 1:3.22. A power plant based on lignite would contain three 200 MW units and use up 10 million tons of the brown coal during 5,000 operating hours annually. In 30 years of operation, about 305 million tons of lignite would be consumed. The net electricity output during the 5,000 hours of operation annually would be 2.705×10^9 per kilowatt/hour.

Investment in the Hula lignite project would amount to $1 billion and the average production costs per kilowatt hour are 60 percent more than in a coal-fired plant. A significantly real increase in the cost of coal of 3 percent or more per annum during the lifetime of the project would influence its feasibility and attain the economic break-even point.

The first unit could be introduced in the early 1990s, if the fuel prices justify the project and if ecological and cooling water problems are solved.

<u>Nuclear Energy -- A Problematic Necessity</u>

Nuclear power is conceived as a major part of the program for diversification of energy resources. Nuclear energy will be one of the components of the "energy basket" of Israel starting in the middle of the next decade.

Nuclear energy is not new in Israel, since a primary technological infrastructure already has been developed at the IEC and the Atomic Energy Commission. However, it is necessary to update the expertise available in the country and the assessments involved in the introduction of nuclear power stations in Israel.

The policy of the ministry and similar agencies is based on the following principles:

- The preparation of an appropriate structure of manpower and know-how by use of the existing frameworks, such as the Electric Corporation and Atomic Energy Commission, and the creation of joint or new set-ups.

- The preparation of physical conditions by laying the groundwork of power plant sites including solutions for appropriate cooling means and study of the vulnerability of unprotected atomic plants and their influence on the population.

- The preparation of an infrastructure for nuclear fuel, the extraction of uranium from phosphates and production of fuel rocks. The ministry also is aiming at developing safe sources of nuclear fuels.

- The installation of plants in the framwework of electricity production systems will be based on the use of proven technologies, by purchasing or adapting existing plans. The policy aims at involving Israeli planners in the work with maximum involvement in the production of components and systems.

- In the short and medium run, nuclear energy cannot serve as a supplier of electricity for the Israeli grid, mainly because of the long time it takes to build a nuclear power plant (10 to 12 years). During the next 10 years, there will be a need to deepen the infrastructure and decide on further preparation for the introduction of nuclear plants. However, it is still planned that by the middle of the next decade, the first nuclear unit of 900 MW will be operating.

- Other energy sources with a large-scale potential utilization for the beginning of the next century are the breeder and fission reactors.

TRANSFORMING THE SUPPLY BASE -- NEW AND RENEWABLE ENERGY RESOURCES

It is unlikely that research and development in alternative energy resources can solve the problem of energy supply completely. But there is no doubt that a proper research and development policy can help in furthering five national energy goals:

- Creation of indigenous energy sources that will reduce dependence on imports substantially.

- Introduction of sufficient flexibility in the national energy system to allow the use of alternative resources.

- Development of high professional capability to allow the proper selection and cooperation of new technologies developed elsewhere.

- Development of processes and equipment to facilitate entrance into the expanding world energy market.

- Minimization of environmental damage.

The research and development projects and the allocations of manpower and budgets are examined in relation to the following criteria:

- A substantial potential contribution to the national energy balance. (Larger potential contribution will carry higher preference.)

- Compatibility with Israeli technical, economical, organizational and industrial capabilities.

- The measure of innovation.

Perhaps as compensation for the lack of indigenous fuels, Israel is endowed with plenty of sunshine. The average solar insulation over Israel ranks among the highest in the world. This probably supplied the early drive for research, development and application of solar energy.

HYDROELECTRIC POWER

The Mediterranean Dead Sea Canal

Historic Background and Physical Considerations

Some 1.2 billion cubic meters per year of sweet water used to be fed into the Dead Sea by the Jordan River system, prior to the pumping of water from the Sea of Galillee into the Jordan-Negev pipeline, the diversion of the Yarmukh waters into the Ghor canal (in the Hashemite Kingdom of Jordan), and the extensive agricultural development of the Jordan Valley itself. The yearly inflow has been reduced to about 25 percent of that amount, and this will be further cut down to 150 million to 200 million cubic meters per annum, if and when the Jordanian Maqarein High Dam is built. The level of the Dead Sea has dropped from about 393 meters below sea level to approximately 402 meters below sea level, and may reach -410 meters by 1990.

Economic Considerations

A detailed economic analysis has shown that a hydroelectric power project, based on a sea water 35 to 50 cubic meters per second canal from the Mediterranean to the Dead Sea -- utilizing that 400 meters difference in levels between the two seas and making full use of the evaporation capacity of the Dead Sea surface -- would be economically justified and physically feasible. This conclusion holds good for several routes and in various versions. The direct energy benefits are the installation of some 600 MW, applied at peak load -- an especially suitable role for hydroelectric power stations.

In addition, there may be several attractive secondary benefits, particularly as regards the southern (Qatif-Massada) route. These would enhance the overall profitability of the project considerably.

The conclusions with respect to the hydroelectric project itself are based on an estimate of $497 million to $946.6 million overall capitalized benefits in fuel savings, in the various versions, and an additional $306 million through economics in projected construction (all sums capitalized at 6 percent to January 1, 1990). Fuel savings are estimated over a 50-year period, but would accrue mainly in the first 20 years. An increase of 1 to 3 percent per annum (in real terms) has been assumed in the price of all fuel categories, in excess of the January 1, 1980 prices of $290 per ton for jet fuel, $160 per ton for heavy oil and $46 per ton for coal. Total investments are estimated between $583 million and $685 million depending on the choice of route. The scheme is planned to produce 1,220 million KWh per year at a rate of 546 MW during the first 12 years, and 725 million KWh per year at a rate of 337 KWh afterwards. The construction will take eight years and the capital costs total $1,200 per kilowatt.

The earliest possible year of exploitation is 1990. This plan would save the equivalent of 300,000 tons per year during the first 12 years and 175,000 tons of fuel oil in the following period. The SCIC is having these figures re-examined by international experts.

Routes

Initially, a variety of routes was considered, including a conduit originating in the Red Sea. Several schemes (including the latter) were eliminated for economic and other considerations. More detailed studies have centered upon the following:

- A northern route, through the Jezreel and Jordan Valley, including the truncated version, consisting of a Jezreel canal and the channeling of the sea water to the Dead Sea through the Jordan River bed.

- A southern route involving a canal-tunnel combination, from Qatif to Massada, or from Ziqim to Massada if the Gaza area is bypassed.

The economic analysis is based upon a dynamic model of future power generation in Israel, developed by the Israel Electric Corporation Project Working Group (PWG) under a Ministry of Energy contract. The PWG also has graded the alternative routes and versions economically. The Qatif-Massada plan takes first place at an estimated investment of $550 million at 1977 prices (or $685 million at 1980 prices).

It is therefore proposed to focus, at this stage, upon the southern route by further studies and more advanced planning, unless unexpected technical difficulties or new factors arise. The final report will include more definitive recommendations.

Solar Energy from the Dead Sea

The development of electrical energy production in solar ponds in Israel opens up the possibility of utilizing all the Mediterranean water supplied by the canal to generate up to 1,500 MW of solar energy, thus exploiting the Dead Sea as a solar lake. This possibility depends upon the results of further research and development, relating to the development of large (2.5 square kilometers) ponds, as compared with the existing ones (.007 square kilometers). Solar ponds require for their operation a 1 to 2 meter upper layer of less dense water, and the solar lake project is conditional upon the cutting of an Interseas canal.

Cooling of Thermal Power Stations

The impossibility of building new sites for thermal power stations along the Mediterranean coastline (where all present units are situated) has created an interest in prospective inland sites, involving the pumping up of some 35 to 40 cubic meters per second per 1,000 MW for cooling purposes. The Mediterranean Dead Sea canal thus could provide important savings and much simplification, in the next stages of the country's energy development program, should the siting involve the northwestern Negev. This region is especially suitable for nuclear power stations, due to safety considerations.

Importance of the Project for Israel's Energy Program

It is thus possible that some 3,000 MW of future installed power will depend on, or be strongly coupled with the canal. Supply in the year 2000 is expected to reach a figure of 10,000 MW as compared with the present 2,600 MW. We are thus dealing with about 30 percent of Israel's installed power capacity in the not too distant future (20 to 30 years from now).

Effect on the Dead Sea (Potash) Works

Dilution of the highly concentrated soft water in the Dead Sea by the inflowing sea water from the Mediterranean may lead, after some years of operation, to a slight reduction in the output of the existing potash plant. Such a decrease might only occur if complete mingling of the two kinds of water should take place throughout the full depth of the Dead Sea -- an extremely unlikely eventuality that would have to be prevented in implementing the solar lake project. The upper limit of such a temporary production loss is estimated at some 300,000 tons of potash per million, which amounts to about 15 percent of the present annual production, or about $20 million per year (at 1980 prices).

Should the mixing take place as conjectured in a relatively thin upper layer only, very simple technological solutions for preventing losses could be applied, such as drawing quasi-original and "normally" concentrated Dead Sea water for the potash plant from a greater depth (in the northern part of the Dead Sea).

The committee has initiated an appropriate research program and a more precise evaluation may be available in the final report.

Long-Term Investigations

Some investigations may take years to complete owing to the long-term nature of their data collection and interpretation. An example is provided by the "whitening phenomena" that might occur through the precipitation of gypsum in the Dead Sea as a result of the inflow of Mediterranean water. Other examples include studies of evaporation rates and the stratification of the Dead Sea and effects of nutrients contained in Mediterranean water on biological processes in the Dead Sea. It is assumed that the results of most of these studies will become available in 1982.

Establishing a New Steady Level for the Dead Sea

The final level at which the Dead Sea will reach its quasi-steady state (in the year 2010) has been tentatively set at 393 meters below sea level to suit the crest levels of the dikes of the Israeli Dead Sea Works, now in the process of being raised to -391.8 meters. A further rise is planned in about 20 years time. The ground level of the production plant proper lies between -388 meters and -389 meters.

It is possible that the rate at which the Jordanian Potash Works dikes will be raised will force a five- to 10-year delay in attaining the final (steady-state) level of -393 meters. This should not affect the economics of the project seriously. The committee also has examined the possiblity of adopting a steady-state level of -400 meters, for the sake of economic comparison. This level might be prolonged if progress in the normal operation of the Jordanian plant should come to a stop at an early stage, a rather implausible eventuality.

Future Jordanian Cooperation

The above-mentioned five- to 10-year delay in reaching -393 meters may be obviated should the Jordanian Potash Works be willing to raise its dikes earier.

A proposal for a Binational Park along the Jordan River provides for the development of the unique fauna and flora of the deeper Jordan River valley, with extensive tourist, ecological, scientific and historical programs, in addition to coordinated agricultural development on both banks.

With Jordanian cooperation it also should become possible in the 1990s to undertake a joint feasibility study of a gradual raising of a dam across the Lissan strait, to allow for some further rise of the water level in the northern part of the sea. This would increase the evaporation area and ensuing power production, without damaging the potash works and other facilities in the southern area (though flooding the lower Jordan Valley in both Israel and Jordan and possibly losing agricultural areas). Surveys of the sea bottom and the Lissan area, and specific engineering studies are required in view of the geological and seismic conditions.

Almagor Plant

The idea of exploiting the Jordan River for electricity generation is based on the shifting of the river bed north of the Galilee Sea.

A 1.6 million cubic meter basin at an altitude of 251 meters (which is the difference in latitudes between the Jordan River and the Sea of Galilee), could supply 265 million KWh per year at a maximum rate of 100 MW. This plant could save about 65,000 tons of fuel oil per year, and its construction time is about five years.

SOLAR ENERGY

Interest in solar energy began on a small scale in the late 1940s and early 1950s. Prof. Robinson of the Haifa Technion was running a solar laboratory, studying solar radiation and collection and experimenting with possible applications. A substantial step forward was taken with the pioneering research of Dr. Tabor, then the director of the National Physical Laboratory, who in 1955 developed the first selective surfaces for solar applications. Soon systems of solar water heaters began to appear on rooftops, first on single homes and later on large apartment buildings. It must be noted that this process proceeded on a commercial basis with no special government incentives.

Today, a visitor in Israel would be impressed by the large number of houses and buildings equipped with solar water heaters. More than 500,000 households get their hot water from solar energy. That accounts for approximately 50 percent of total domestic water heating. From an energy balance point of view, solar water heating saves more than 5 percent of the electricity generation and accounts for more than 1.5 percent of the total primary energy supply. This makes Israel a front-runner in the use of solar energy.

As early as 1958, Dr. Tabor and his group started research on non-convective solar ponds. Two experimental solar ponds were constructed in early 1960. At the same time, turbines using organic vapor were developed for utilization of solar energy. Competition from cheap and abundant oil brought most of the research to a stop in late 1960, but the foundation was laid for subsequent work.

Solar research and development picked up considerable momentum after 1973, with the escalation of oil prices. An extensive program for research and development of solar and other alternative energy sources was adopted. In 1977, the new Ministry of Energy and Infrastructure took over responsibility for all the energy programs, including solar.

At present, there are several groups in industry, universities and research institutions which are actively engaged in research, development and applications of solar energy.

Thermal systems have, so far, made the largest impact on solar energy utilization. It is no wonder that a variety of programs fall under this heading.

Flat Plate Collectors

Flat plate collectors are used extensively in Israel. There are a few dozen firms that produce and market collectors or systems incorporating them. There is, however, still a margin left for improvement of performance, design and costs.

Research is carried out in universities and scientific institutions with the aim of fully understanding the flow characteristics of the collector, both under thermosiphonic free convection and under forced convection.

Israel was first to market commercial collectors with selective coated surfaces. Since then it has become common practice. Research is continuing on improving the coating so that a more uniform layer will be formed with better stability against heat and corrosion. Attention also is given to glass coating to reduce the reflection in the visible light region while increasing the reflectivity in the far infrared. A reduction of solar reflectivity from 8 percent to 2 percent was attained in laboratory tests.

Considerable effort is made, mainly in industry, toward development of new designs of collectors. An example is a fine copper tube collector that acts as a solar radiation trap, even for rays with large incident angle.

Another novel idea is the free flow collector. It replaces the usual internal fluid passages with a thin film of light oil flowing freely down an inclined surface, covered by a black thin aluminum foil, which acts as the absorbing surface. The good contact between the oil and the foil ensures high collection efficiency, while the absence of tubes allows much lighter weight and less corrosion.

Several other designs claim advantages of low costs and long service life. Research continues toward collectors with lower cost per calorie.

Shallow Solar Ponds

Shallow ponds are made of large plastic bags with black bottoms and transparent tops. They are filled with approximately 10 cm of water, which is heated during the day and stored at night. Such ponds are studied at the Weizmann Institute, with a view to applying them to central water heating in large buildings. Indications are that it may offer considerably less expensive heat than the usual flat plate collectors.

Concentrating Collector

The main interest is in the development of essentially non-tracking or partially tracking collectors. At the Technion, a concentrating collector having a stationary spherical reflector was developed and is now in the process of commercialization.

The reflector that constitutes the major part of the structure is stationary, making it easier to design, with fewer problems in wind storms. The sunlight always is focused into a radius in line with the sun and the center of the sphere. A small absorber arm is made to track this focal radius allowing a concentration ratio of 50:1 and more. In a test where water was used, a temperature of 150°C was reached with 50 percent efficiency. The temperature was limited by the saturation pressure of the water. Tests to allow utilization of a higher range of temperatures by using liquid metal in the absorber now are being conducted. These collectors, which can be produced at a reasonable cost, may offer a good source for domestic heating and air conditioning as well as electric power generation.

An inexpensive low concentration stationary collector (with a ratio of approximately 3:1), which can supply medium temperatures, was developed and is being tested at the Weizmann Institute.

Air Heaters

Air heaters have many advantages for space heating. Special designs which minimize the heat losses are being investigated at the Technion and at Ben-Gurion University.

Another concept of integrating the solar air heater as part of the roof structure was developed in cooperation with Miromit, a company which has 20 years' experience in solar energy.

Standards of Testing

Proper standards and testing facilities are essential counterparts of the solar energy industry. The Israel Standard Institute is engaged in developing (or adapting foreign) standards to suit the local conditions and export purposes. Several test facilities are available to the industry. The Standard Institute itself offers such services. The Technion has a lab used mostly for research. The Weizmann Institute has developed a sophisticated test facility. These aids are used by the local manufacturers.

Storage

Thermal storage is of a major importance for most solar energy applications. It is used to bridge the gap between demand and supply.

In addition to hot water tanks and pebble bed storage for hot and cold air, more sophisticated systems are being investigated.

Systems of paraffins and salt hydrates, which change phase at appropriate temperatures, are under study at the Technion and Ben-Gurion University. Special attention is given to the heat transfer mechanism and the proper distribution of the tubes in the heat exchangers. Additives that suppress the tendency of the salt hydrate to crystallize are being investigated.

A novel system, making use of changes in muscibility gaps with temperature, is the subject of a research program at Tel Aviv University. The idea is to select a mixture that mingles in any proportion at a given temperature but separates into two phases at somewhat higher temperatures. The division is achieved by using solar energy and each phase is stored separately. When heat is required, the two phases are made to mingle, thus releasing the heat of mixing. Such a system may offer a long-term storage, because there is no need for insulation.

Seasonal storage systems, using the ground soil as a medium, are being studied at Ben-Gurion University.

Finally, a research program has begun to investigate the possible use of large aquifers as a cooling medium for large power plants while using the heat during the winter for agricultural purposes.

Water Heating

Increasing the use of solar water heating, to cover more than 60 percent of the households by the mid-1980s, is a declared policy of the Ministry of Energy. This step implies a greater use of centrally applied hot water and other services in larger buildings, as well as the improvement of the systems and the installation.

A major thrust has been in expanding the normal individual installation to central systems supplying hot water. Problems of flow distribution in the collectors field, minimization of plumbing and control had to be considered. Various methods of supplying the hot water have been devised. At present there is slow but increasing penetration of the central system market on a commercial basis. The largest system, involving 144 square meters of collector area, has been installed in a hotel at Eilat.

Heating and Cooling (Passive and Active Systems)

Desert climate is most suitable for passive systems because there is a large differential between day and night temperatures, and plenty of sunshine. Properly designed night cooling can keep buildings comfortable during summers, while solar trapping can keep the buildings warm, day and night, during winters. A research program on passive systems is being conducted at Sde-Boker (Ben-Gurion University). Several experimental small houses were built to allow the data acquisition and comparison of various methods.

Another group is interested mostly in fenestration and proper shadowing. Work also is being done on thermal modeling of buildings.

Space Heating: Only a few places in Israel actually are heated by solar energy. The Mechanical Engineering Department library at the Technion is the first attempt at solar space heating. The heat transfer medium is water, and two days shortage is supplied by hot water tanks. Also in the space heating domain, the Miromit prefabricated roof panel concrete collectors create a continuous absorbing surface. The heated air is transferred from the solar panels to a rock-heat storage, or directly into the house. The structural roof member includes selective surface absorbing plate, cover glass, insulation and architectural finish. The ratio of collector area to total floor area is 1:2 to 1:1, depending on the specific house layout, design, insulation and other parameters. Following field tests made at the Building Research Station at the Technion, a commercial demonstration program was initiated, comprising three homes in which space heating will be provided by roof panel concrete collectors.

No detailed cost analysis has yet been made, and therefore it is premature to predict the impact of such development on the primary energy balance.

Climate Control Systems: The largest project in heating and cooling is conducted at Tadiran. It was initiated in 1974 with the specific purpose of marketing climate control systems in Isreal and abroad and supplying hot water, space heating and air conditioning, with the sun as the major energy source. To meet the performance requirements it was necessary to develop a flat plate solar collector yielding its energy at a higher temperature than the state-of-the-art flat plate collectors. The second major component is a hot water-fired lithium-bromide absorption chiller, designed to operate at an inlet temperature range of 65°C to 95°C and still maintain a high coefficient of performance. The third major component is the control subsystem to balance the solar energy input, the conventional energy drawn from the backup, and the building load. The fourth component is the combination of energy storage, hot and cold, and conventional backup. Following the development effort, a 50 ton prototype was completed in 1976, with performance exceeding those of comparable machines. It was still operating with a good coefficient of performance, even with a low generator temperature of 60°C, thus demonstrating the viability of the system.

A full-scale commercial-type demonstration was completed in December 1980, comprising a 200 ton unit to supply air conditioning, space heating and hot water to a hospital ward near Tel Aviv. As an energy source it serves a 3,500 square meter array of Tadiran developed collectors.

Economic analysis of around-the-clock solar climate control systems, with conventional backup, including allowance for component and installations cost reductions with increased volume of sales, show that such systems will be competitive with conventional, electrically driven climate control methods. The full-equivalent consumption for industrial, commercial and institutional climate control systems is estimated, annually, at 200,000 tons, or 2.5 percent of Israel's total energy consumption. It is assumed that in the latter part of the 1980s an increasing portion of new industrial, commercial and institutional buildings will go solar for their climate control, and there will be some retrofitting on existing buildings. The impact on the primary energy balance, allowing for fuel oil consumed for backup, may be approximately 1 to 1.5 percent. It should be stressed that air conditioning is used primarily during peak hours. The savings, therefore, is not only fuel, but also in electric peak loads.

Cooling with Desiccants: Yet another method of producing cold air is by an extension of the desert cooler to conditions of higher humidity. The basic process involves four steps.

- Drying the air by using desiccants.
- Cooling the dried air to outside temperature.
- Wetting the air adiabatically, thus bringing it to the desired temperature and humidity.
- Regenerating the desiccant using solar energy.

A research program to develop the system is being carried out at the Technion.

Industry

Some application of solar energy has been made by the food processing industry, especially in spice drying. Recently some interest was indicated in applying solar energy to supply low-temperature heat requirements, such as for plating baths and low-temperature steam. Possible utilization of newly developed concentrating collectors is being considered and some demonstration systems are to be erected next year.

Agriculture

A greenhouse in Israel will require an average of 2 kilograms of fuel annually per square meter to master the cold winter nights. At the same time there is excess heat during the day when the sun shines.

Research is being done to store the daytime heat for use at night, thus saving fuel. One system is to make the water flow through the roof of the greenhouse and then through the ground underneath, thus cooling the greenhouse during the day and heating it at night. The ground stores the heat.

Solar Ponds

Work on non-convective solar ponds is probably the most exciting and significant research and development in solar energy that is being conducted now in Israel. Proper application of solar ponds may allow large-scale utilization of solar energy and thus probably has the potential of substantial contribution to the national energy balance.

The idea of non-convective solar ponds for collection of solar energy was first suggested more than 20 years ago by Prof. Bloch. It came from observing nature. The phenomenon of a natural solar pond exists at several places in the world including a few miles south of Eilat. Temperature differential between the bottom and the top may exceed 40°C. Artificial solar ponds essentially replace the metal, glass and plastic of conventional collectors with a mass of water, thus reducing by order of magnitude the cost per calorie collected. It also has a large inherent storage ability, up to months of storage, depending on the design of the ponds.

Normal bodies of water can support only small temperature differences under solar radiation because convection currents mix the water. By creating and maintaining a density gradient, by differential dissolution of salts, with increasing concentration from top to bottom, the usual convective currents that occur in homogeneous ponds can be reduced greatly. The result is that hot water can accumulate at the bottom with the top layer acting as an insulator. Temperatures close to the boiling point can be reached. The only loss mechanism is by conduction through the stagnant layer of water, and therefore it is kept at a low value. The average collection efficiency may exceed 20 to 25 percent.

The research and development of large-scale solar ponds is by its very nature a slow process. It takes more than a year until a long-term steady state of the pond is attained. Also, many problems are yet to be solved, such as methods of construction and sealing, maintenance of the salinity gradients, effects of wind, ground conduction, opacity created by dust and algae growth. None of these problems seem unsolvable, however.

At present, there are three experimental solar ponds under investigation. A 1,500 square meter pond, at Ormat plant in Yavneh, was put into operation in 1978. It is now providing a heat source, from the bottom layer at 88°C, and a heat sink, from the top layer at approximately 30°C, to an organic fluid turbine generating up to 8 KW day and night. A second pond was constructed in Eilat by compacting the local clay soil without any additional sealing agent.

The third and largest pond, 6,500 square meters, was completed in June 1978 at Ein Bokek on the shore of the Dead Sea. A year later a 150 KW organic fluid turbine was installed and the combined system inaugurated in December 1979. In addition, an experimental flash chamber for producing low-pressure steam to be used for desalting water has been installed and operated.

The successful operation of this pilot system has prompted a decision to go for the next stage of substantial upscaling. A two-year program has been approved to build and operate a combined system of a 250,000 square meter pond with a 5 MW turbine. The system will be operational in 1983. Up to 1,500 MW of solar energy could be generated from the Dead Sea, and such a program also would fit nicely with the Mediterranean Dead Sea project.

It is too early to present an accurate economic evaluation of the solar pond, for there are still many imponderables. However, it is estimated that the cost per installed kilowatt, including the pond and conversion system, would be $1,700 to $2,200, and this figure probably can be reduced even further. This, coupled with low requirements for maintenance, makes the solar pond competitive with other means of electrical generation from solar sources. Moreover, the production of low-temperature heat would become economical even earlier.

Indeed, it is hoped that if the program is successful, solar ponds will be used extensively to supply domestic, commercial and industrial hot water, generate electricity and provide desalted water. It may contribute significantly to the energy balance of Israel in the 1990s.

Thermal Conversion

There is no question of the importance of efficient and dependable means for converting low-temperature heat to electricity.

A sealed organic fluid Rankine cycle turbo-generator was developed back in the 1960s at Ormat. Originally it was meant for using solar energy, but, again due to the availability of cheap petroleum, actually was used on conventional fuels. The generators were marketed as small (up to 3 KW), dependable, maintenance-free turbo-generators for use in remote locations where professional people were not available. Millions of maintenance-free running hours, accumulated at installations all over the world from Africa to Alaska, have earned a unique reputation for these units. Now, with a return to solar, turbo-generators from 2 KW to 5 MW are being developed on the basis of the long experience gained in this subject.

A novel idea of making use of a magnote-hydrodynamic (MHD) generator to produce electricity from low-temperature sources is being researched at Ben-Gurion University. It consists of a fuel cycle of liquid metal heated by solar energy and mixed with an organic fluid. The mixture is then accelerated in a specially designed two-phase nozzle, due to the evaporation and expansion of the organic fluid, and is made to flow through the MHD generator, producing electricity directly. The organic fluid in the gaseous phase then is separated from the liquid metal, condensed and pumped back to the mixer. The liquid metal is made to go through the solar collector to complete its cycle. First stage theoretical and experimental work has been completed and in the next year a pilot system should become opearational.

Photovoltaic

The current world approach to the utilization of photovoltaic is that it is a very large-scale, sophisticated and expensive technology, beyond the means of a small country like Israel. Therefore, there is no real effort toward large-scale production of solar cells.

The research in this subject concentrates on the physical and chemical development of new types of surfaces and cells, and on system integration, with and without concentration.

Surfaces and Cells

A research program, for producing inexpensive photovoltaic surfaces, is being carried out at Tel Aviv University. It was found that an oriented crystalline film may be obtained by evaporating silicon, under high vacuum, onto a suitable single crystal substrate. After detaching the film an inexpensive photovoltaic surface is obtained.

Photo-electro-chemical cells are developed at the Weizmann Institute. The cells consist of semiconductor electrodes in a suitable electrolyte. Upon illumination, electric current is produced. The cell provides controllable built-in storage, so that excess electricity may be stored for periods of no sunshine, thus allowing a constant load independent of the instantaneous illumination.

Systems

A small 10 watt photovoltaic battery charger is produced by Tadiran mostly for military purposes. It uses conventional silicon cells.

Development is underway at the Weizmann Institute of a solar cell system using Fresnel lenses to concentrate solar light, by a factor of 50:1, on special silicon cells, greatly enhancing the production of electricity per cell. A tracking system, which takes the signal from the sun, also is being developed. This system requires many fewer photovoltaic cells per unit of electricity, thus reducing the cost of the most expensive component; however, it has the added complication and cost of a concentrating and tracking system.

Application of the spherical stationary concentrator to electricity generation by solar cells is being investigated at the Technion.

An exciting new method for improving the utilization of solar cells is under study at the Hebrew University. Solar cells can convert only a narrow band of wavelength into electricity. The rest of the radiation only heats the cell. When a specially doped glass is exposed to sunlight, excitation occurs inside the glass and the re-emission is essentially in a narrow gap that may be made to fit the silicon cell. Moreover, most of the re-emitted light is at such angles that it is reflected back from the glass surface and eventually emerges from the side of the glass plate at a greatly increased intensity in the suitable range. Thus, if silicon cells are to be placed on the side of the plate, they enjoy effectively higher illumination with very little heating effect.

Hydrogen and Fuel

A research program to produce hydrogen from water by using solar radiation is underway at the Hebrew University in Jerusalem. By adding solar sensitive chemicals to water and exposing the mixture to sunlight, a chain of reactions takes place resulting in a reduction of the water to hydrogen and oxygen with good theoretical efficiency. This research is in its initial stages, and so far with meager results.

Another idea of producing fuels and chemicals from carbon dioxide using solar energy is being studied both at the Hebrew University and the Weizmann Institute.

BIOMASS

Agricultural Wastes

The abundance of organic wastes, manures and vegetation, coupled with environmental problems and high energy costs, has led to a project aimed at the introduction of a novel approach to the ancient idea of producing methane gas from agricultural wastes. This project is directed by the Research and Development Institute of the Kibbutz Industries. Bioconversion by anaerobic digestion is the basic process whereby organic wastes are affected by bacteria that are active when no oxygen is present. The resulting biogas contains 60 to 65 percent methane, 30 to 35 percent carbon dioxide and some traces of sulfides.

The project team concentrated its efforts on solving four problems:

- The collection of the wastes.
- The improvement of the digester efficiency.
- The transport and utilization of the gas.
- The proper disposal of the slurry.

It turned out that the kibbutz agricultural structure is suitable for resolving the collection, gas transport and slurry disposal problems. An energy survey, currently in progress, indicates that a kibbutz can meet 65 to 90 percent of its energy needs by properly utilizing its agricultural wastes.

The residual slurry could be used as fertilizer, fish food, cattle and other livestock food, soil conditioner, hard boards and insulation. An intensive program is being carried out aimed at ascertaining the uses and values of the slurry. It is apparent that its value as food is higher than its use as fertilizer, fill or conditioner.

The project is now in its sixth year. A substantial improvement was achieved in the digestion process, causing a reduction of the required residence time, coupled with a substantial increase in the gas production rate. A rate of five volumes of gas per day per volume of digester can be routinely obtained and the rate can probably be pushed upwards to 8 to 10.

Sixteen bench-scale digesters allow testing of various combinations of conditions and feeds simultaneously, while eight systems of 1 cubic meter pilot plants give important information on the operation of the system. Demonstration units of 12 to 200 cubic meters have been completed, and the technology is considered ready for commercialization.

The investment cost for the construction of a biogas plant for a kibbutz with a cowshed of 500 head of cattle is estimated at U.S. $250,000. Savings in fuel and electricity is estimated at U.S. $40,000 per year. Utilization of the slurry would be an added advantage. The impact of biogas conversion on Israel's energy balance is somewhat difficult to estimate. It certainly could not exceed 1 percent by far. However, this project should be looked upon as an all-around solution to several problems, and as such may make an important contribution.

Algae

Much research on algae is carried out in Israel. Algae are studied as a source of protein, as a means of purifying sewage water and as a source for chemicals and fuel.

Extremely interesting research programs resulted from the discovery of certain halophillic algae that grow in highly saline water and contain more than 30 percent of their dry weight as glycerol. Their rate of growth depends on solar energy and the environmental condition.

One group is interested in the production of glycerol, which may turn out to be cheaper than that produced by alternative methods.

The other group aims at the production of liquid fuel which can be extracted by pyrolitic processing of the algae.

Both groups study the growth rate with and without CO_2 addition. Problems in concentrating and harvesting the algae still need to be resolved.

OIL SHALE

To date, oil shales are the only known and identified fossil energy source indigenous to Israel. High priority is placed on the development of oil shale as a potential replacement for imported oil.

Early work on oil shale was carried out in Israel in the 1950s, when bitumen from Ein Bokek was used for various experiments of material handling and grindability as well as combustion characteristics. The work was discontinued, mostly due to the cheap competition of crude oil.

The interest in oil shale was renewed in the mid-1970s and it picked up more momentum in the past two years.

A program has been undertaken by the Ministry of Energy and Infrastructure (MOEI) to lead to a commercial exploitation of Israeli oil shale at a rate of 20,000 to 40,000 barrels per day by 1990.

Several avenues are being considered, including retorting to produce synthetic fuels (oil and gas), direct combustion for the production of steam and electricity and ash utilization (cement, building materials and aggregates).

The program involves resource and exploration evaluation, an estimate of adaptation of existing technologies in Israel's conditions and research and development for newly improved technologies. It is carried out by contract with government and industrial companies and universities.

Geological Survey and Exploration

Oil shales were encountered in Israel in early water drillings and at several other locations. In the past few years more efforts have been made to identify the resources, quantities and qualities.

The recoverable reserves in the five major fields already identified are:

Efe	0.6×10^9	tons	
Oron	0.6×10^9	"	
Hartuv	1.0×10^9	"	(minimum)
Bigat Zin	$.7 \times 10^9$	"	"
Znifim	1.5×10^9	"	"
Total	4.4×10^9	tons	

All these deposits are of similar nature with an overburden ration of .5 to 1, an average kerogen content of approximately 15 percent and Fisher Assay yields of 15 to 18 GPT. This oil yield accounts for only about 40 to 45 percent of the oil organic matter; an additional 20 percent is obtained as gas and the rest is fixed carbon.

These known reserves potentially could produce more than 200 million tons of oil with additional quantities of gas and other products.

There are good indications that more fields exist even though they have not been completely investigated.

Development Program (Retorting)

The program for the near future can be divided into three phases. Phase 1 is technology selection, Phase 2 is the industrial module and Phase 3 is commercialization.

Technology Selection

The objectives of technology selection in progress are adoption of a technology for the retorting of the oil shale, and adoption of the method and technology for improvement of the oil to make it suitable for refining into commercial distillates. The estimated duration is two to three years.

This phase of the program, started last year, is concentrating on the evaluation of the existing technologies with respect to retorting the Israeli oil shale. The criteria for the evaluation will be:

- Yield of oil and gas.
- Quality of the oil and gas.
- Degree of utilization of the fixed carbon.
- Technical suitability, reliability, maintenance and operations.
- Possibility of beneficiation of the oil.
- Costs.

Production tests will be carried out at existing pilot plants in the United States and elsewhere after a preliminary study and evaluation of the technology and its potential for retorting Israeli oil shale.

An evaluation of the required modifications or improvements in existing plants, to better fit the above-stated criteria, will be made. Repeat tests may be required.

It is hoped that an existing technology, possibly with some modifications, will be found to give adequate answers to the requirement. However, research and development for the development of a new technology as part of the total project will continue. During this phase, construction of a small pilot plant may be indicated as a substantial aid in the selection of the technology.

Industrial Module

The industrial module objectives are demonstration of the technology applicability to industrial-scale of production and design, construction and operation of an industrial retort module with the accompanying equipment (including mining material handling, pretreatment, disposal of spent shale and oil beneficiation). The estimated duration is four to five years.

This phase is crucial in the development of a viable technology for oil shale utilization. A module of an industrial scale (2,000 to 8,000 barrels per day), which could be repeated in a commercial plant, will be constructed, operated and evaluated. This phase will supply all the necessary information (technical, operational, economical and environmental) for the factory.

A detailed plan depends on the results of Phase 1.

Commercial Plant

Plants with a capacity of 20,000 to 40,000 barrels per day are considered as most suitable for the size of fields found in Israel. These factories will consist of a number of modules, as required for full production.

This phase will be based on the demonstrated technology, and could be considered mostly as a commercial enterprise beyond the scope of research and development.

It is expected that by the end of the 1980s, one full-scale production plant will be operating.

WIND POWER

The development of wind power currently is under study, as new evidence with regard to its technoeconomic feasibility has been established. Although implementation still is far from realization, some experts believe it ultimately could save between 5 and 10 percent of the fossil fuel used by the Electric Corporation.

Most people in the field estimate that wind power generators can be economical in locations where wind velocities average 6 meters per second (about 13.5 miles per hour) or more. Several areas in Israel qualify under these terms, including the Hermon mountain slopes (9 meters per second), the mountains of Upper Galilee (7 meters per second) and the Negev plateau and the Sdom area (6 meters per second). In each instance, the wind velocities occur at a point only about 10 meters above ground level; they increase as one goes higher.

Under these conditions, wind power generation will be economical, once equipment becomes available at $750 or less per installed kilowatt capacity. That stage has not yet been reached. Prices as low as $500 per installed kilowatt capacity are expected within the foreseeable future and will thus make wind power a viable option.

A major problem inherent in wind power is the fact that air currents are far from uniform and production therefore tends to fluctuate. However, working in tandem with other renewable energy systems could overcome this problem; in fact solar energy systems might be a good compliment, since wind velocities often stand in inverse proportion to insulation rates.

The study of wind power generation in Israel is at its initial stages, yet the program calls for the first 200 KW demonstration wind-powered generator to be installed next year.

GEOTHERMAL ENERGY

Preliminary studies, based largely on data obtained from oil well records, suggest that it may be practical to utilize geothermal energy in Israel.

Data obtained from oil exploration drillings in the Ashdod area indicate that large amounts of hot brine can be pumped from the Upper Jurassic formation there. At a depth of about 8,000 feet, brine was found at temperatures of about 110°C. It seems that at about 11,700 feet below the surface, temperatures not less than 140°C can be reasonably expected.

In Ashdod, one potential customer is the Joint U.S.-Israel Desalination Project, which has indicated its interest in a continuous supply of at least 85 million kcal per hour, at a maximum cost of $7.5 per 1 million kcal. Estimates suggest actual production cost will be significantly lower.

The next step will have to be an engineering appraisal, based on precise data, regarding each well's production capacity, the water's stable temperature and its chemical composition. Two abandoned dry wells in the Ashdod area can be used for this purpose, one for pumping tests and the other for observation. In addition, the hot brine can be used to heat homes during the winter and boost agricultural production in nearby hot houses.

It is also believed that similar reserves of hot brine can be found in other parts of Israel, including many likely coastal plains locations.

CONCLUSION

Despite its efforts of diversification and use of alternative sources of energy, Israel still will be 30 to 40 percent dependent on oil in the year 2000. As far as electricity is concerned, the share of oil-fired plants will be 10 percent or less, coal will provide 50 to 60 percent, nuclear power 30 to 40 percent and hydro and solar power the rest, provided that electricity does not exceed 45 percent of all energy resources.

Only a higher rate of electrification involving the introduction of new technologies (such as the electric car), perfection of existing technologies (coal gasification for small industries) and heavy investments in infrastructure to change current structural patterns (electric mass transportation) will further reduce oil dependency, but they require determination, technological progress and additional financial resources.

[1] No new unit was added to the system in 1975-1977.

TABLE 1. PATTERN OF GROSS DOMESTIC ENERGY CONSUMPTION, 1978
(in percent)

	Oil and Gas	Electricity	Total
Electricity	36.0		
Industry (including petrochemical)	19.9	27.0	29.8
Residential, commercial and public	14.9	43.0	30.1
Agriculture and water supply	2.2	18.1	8.8
Transport	19.6	-	19.6
Losses (refineries & elec generation)	7.4	11.9	11.7
	100.0	100.0	

TABLE 2. BASIC HYPOTHESIS ON PROJECTIONS

Annual Population Growth Rate-- 2.5%

Annual GDP per capita growth rate	Reasonable 4%		Slow 2%	
	1900	2000	1990	2000
Energy elasticity of income or GDP	1.1	0.9	1.3	1.1
Scenarios	I		II	

TABLE 3. ENERGY PROJECTIONS
(Mtoe)

Scenario	Secondary Scenario	1978	1990	2000
I	Basic	7.3	17.0	30.0
	Moderate		15.3	27.0
	Low		13.8	24.3
II	Basic		14.7	24.0
	Moderate		13.2	21.6
	Low		12.0	19.5

TABLE 4. ELECTRICITY PROJECTIONS

Year		1978		1990		2000	
Scenario	Secondary Scenario	Million TOE	10^9 KWh	Million TOE	10^9 KWh	Million TOE	10^9 KWh
I	Basic	2.67	11.4	7.6	31.7	15	62.5
	Moderate			6.9	28.8	13.5	56.3
	Low			6.2	25.8	12.15	50.0
II	Basic			6.6	27.5	12.0	50.0
	Moderate			5.9	24.6	10.8	45.0
	Low			5.4	22.5	9.75	40.6

FIGURE 1. THE ACTION TREE -- OPTIONS FOR ENERGY DEVELOPMENT AND MANAGEMENT

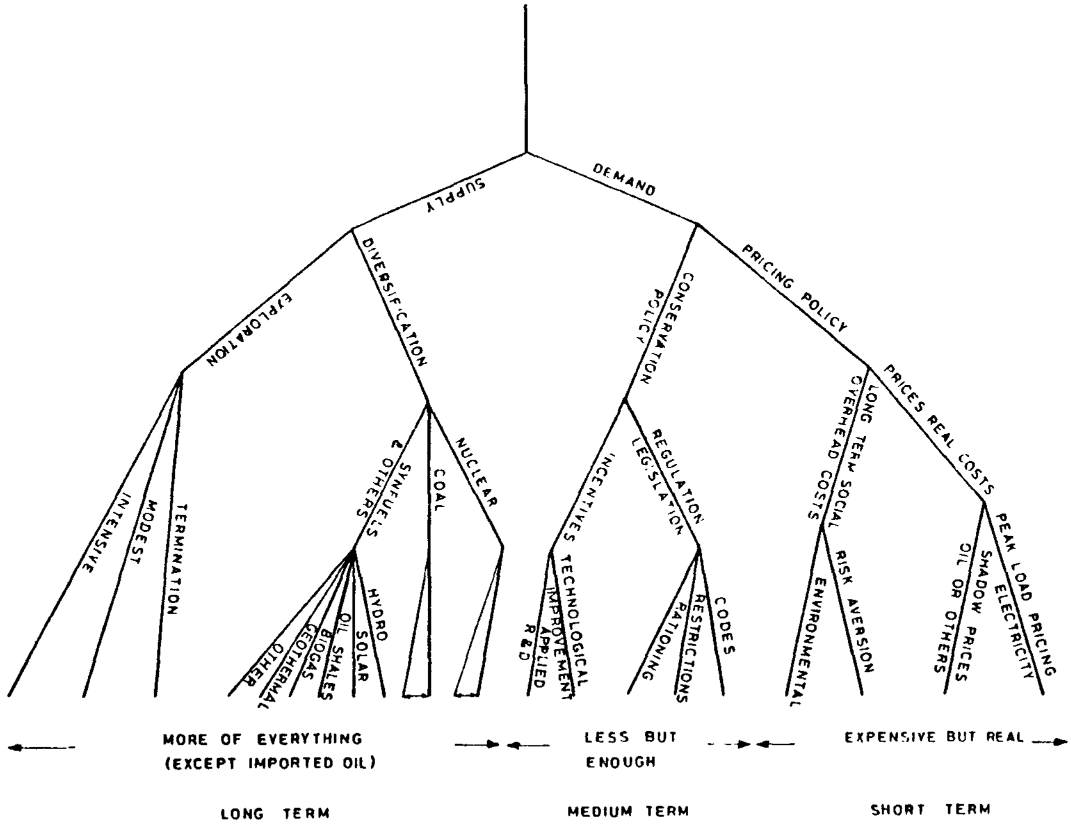

FIGURE 2. PRIMARY ENERGY INPUT DISTRIBUTION FOR ELECTRICITY

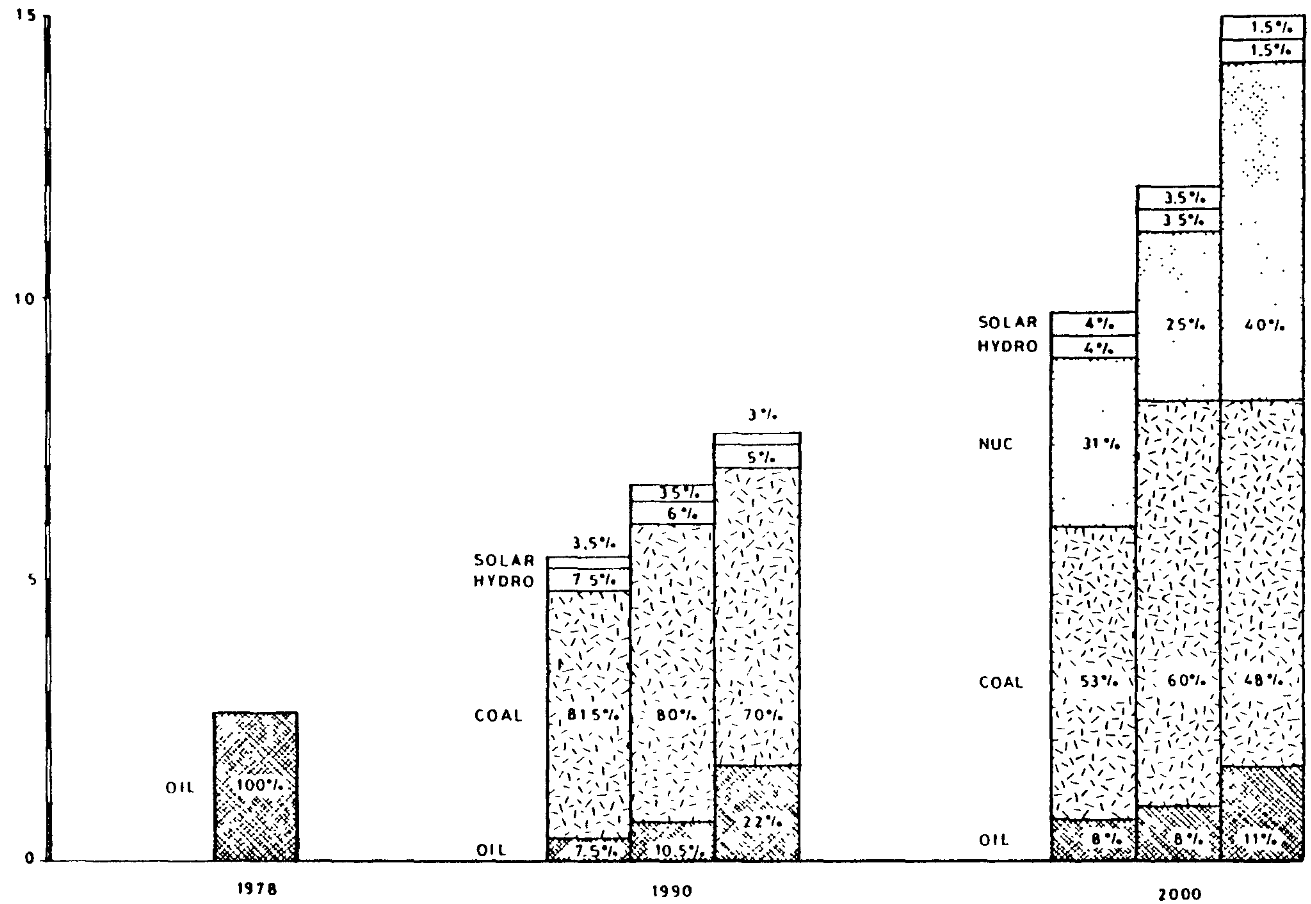

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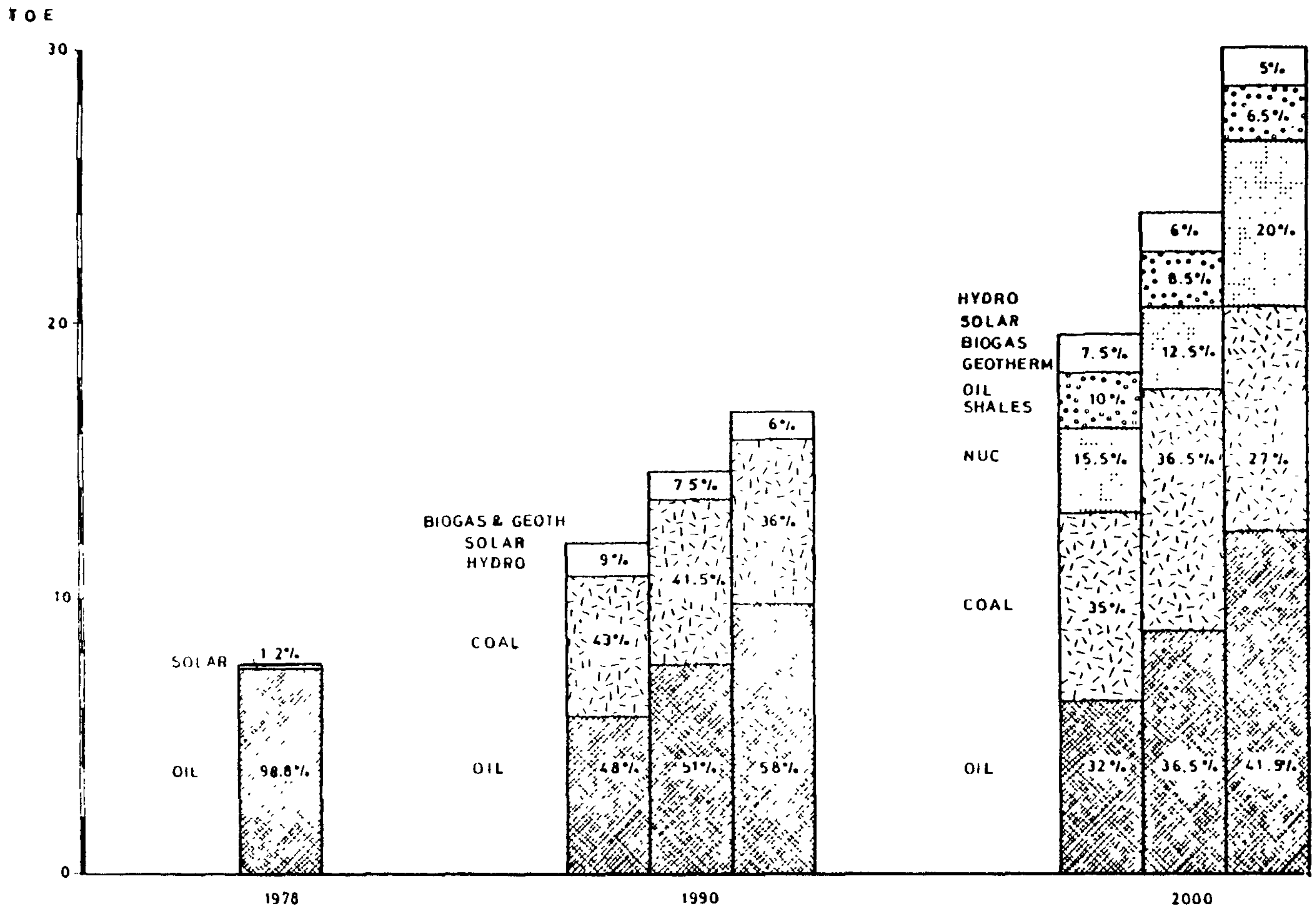
FIGURE 3. TOTAL PRIMARY ENERGY RESOURCES DISTRIBUTION



Jordan

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INTRODUCTION

As a developing, non-oil producing country, Jordan is deeply affected by the world energy situation. Due to the continuing oil price increase and the ever increasing energy demand, the country's energy requirements are becoming a real burden on its national economy. In 1980, the cost of primary energy imported in the form of crude oil exceeded 11 percent of the GNP (as compared to 1 percent in 1970) and amounted to more than 100 percent of the total exports (as compared to 25 percent of the total exports in 1970). Table 1 shows the development of energy costs in Jordan through the past decade.

The average annual growth in primary energy demand over the past decade has been about 13 percent. However, the expected energy demand and the associated cost of energy during the coming 10 years is even more alarming, assuming that the same pattern of consumption will hold. For example, the annual per capita energy consumption is expected to rise from 883 kilograms of oil equivalent (KGoe) to 1,350 KGoe by 1990, with a total consumption figure of 4 million tons of crude oil. If Jordan continues to be 100 percent dependent on oil for its energy needs, its energy bill is expected to top U.S. $10,000 million for the period 1980 to 1990. By that time, the nation's energy bill is expected to swallow almost 20 percent of its GNP.

The government of Jordan is fully aware of the critical energy situation in the country and efforts are gathering momentum to introduce a number of radical measures, on the organizational level, and major projects with the objective of:

- Reducing the country's energy dependence.
- Reducing the imported oil bill through the development of local resources.

This paper is intended to give a general survey of the energy situation in Jordan and illustrate the current and planned activities in the field of new and renewable energy resources.

Although the very nature Jordan assumes a number of constraints on the energy activities in the country, all efforts are directed towards expanding these means through regional and international cooperation.

THE CURRENT ENERGY SITUATION

Structure of Energy Supply

Due to the fact that Jordan has no indigenous, commercial-scale source of energy all energy supplies now are imported.

Non-commercial energy supplies are very limited, and they play a decreasing and insignificant role in the national energy package. The government is discouraging non-commercial energy fuel (mostly wood fuel and charcoal) due to the deforestation effect it is inflicting on the countryside.

The present era of socio-economic development in Jordan started in the early 1950s, and flourished in the past 30 years during an era of cheap oil; hence, the energy imports were directed toward oil.

The energy supplies structure for the year 1980 is as follows:

Imported oil:	99.5%
Non-commercial fuel: (wood fuel and dung)	.5%

Oil is imported from neighboring Saudi Arabia via Tapline, a pipeline that extends from the eastern coast of Saudi Arabia to the Lebanese port of Sidon on the Mediterranean. The crude is fed to the only refinery in the country via a bypass. The local demand for the refined products is totally satisfied by the refinery, which has a current capacity of 12,000 tons per day. This refining capacity is expected to meet the country's needs for oil derivatives until the turn of the decade, provided no unexpected jumps in the present curve of growth rate develop in the future, a phenomenon which is to be expected in developing economies. Table 2 illustrates the development of crude oil imports during the period of 1970 to 1980, while Table 3 gives the development of the refining capacity in the oil refinery.

Structure of Energy Demand

The structure of energy demand has developed in conjunction with available supplies. Hence all industries that require primary energy supplies had to be oil-oriented, because no coal or gas quantities can be obtained. Small industries have to use electricity or oil derivatives. The structure of demand for the year 1980 was as follows:

Primary Energy (Crude oil, derivatives, etc...)	75.5%
Electricity (Central and private generation)	24.5%

PRESENT PATTERN OF ENERGY CONSUMPTION

Consumption of Oil Products

Total primary energy consumption amounted by the end of 1980 to more than 1.8

Mtoe, indicating a growth rate of 15 percent over the year 1979. This remarkably high rate reflects the speed at which the Jordanian economy is developing. The year 1980 was not exceptional -- the average growth rate during the past decade was more than 15 percent. Yet it must be very clear that the energy share per capita in Jordan, which was 855 KGoe in 1980, is still quite modest and very much below the level of developed countries (see Table 2 for details).

There were no signs that this rate of growth will be dampened during the present decade unless a comprehensive energy conservation policy is adopted in conjunction with a more effective pricing policy and the introduction of new and renewable energy resources.

A shift in investment policy from energy-intensive to less energy-intensive industries will help to slow the growth rate as well.

The consumption of oil products shows that there is an increasing demand for light distillates in the same manner as for heavy ones. Table 4 shows the development of consumption of commercial oil products for the period 1970 to 1980.

Sectoral Distribution of Consumption

The major sectors in Jordanian energy consumption are transportation, electricity, industry and domestic.

Other sectors, such as agriculture, services and commercial activities, are of smaller concern.

Transportation in Jordan is the dominant energy consumer -- 50 percent of the energy package is used for transportation, with 36 percent for road transportation and 14 percent for air transportation. This imbalance can be attributed partly to the lack of rail transportation.

Domestic usage of energy amounts to about 2 percent of both primary energy and electricity. The dependence on oil products for domestic purposes is quite evident. Table 5 details the sectoral energy distribution of the year 1979, a pattern that persisted for the year 1980.

Consumption of Electricity

Electricity generation consumed some 16.7 percent of the country's oil input in 1980. It is expected, however, that electricity will increase its share of oil consumption to 18 percent by 1981, to reach 27 percent of the total consumption by the year 1990. This intensification of electricity is due to the fact that there is a suppressed demand that could not have been met in the past. Expansion of nationwide rural electrification schemes, and expansion of industries and services in addition to natural growth all contribute to the increasing share of electricity.

The installed capacity in Jordan amounted to 300 MW in 1980 and is expected to reach 600 MW by the turn of the century. Tables 6, 7 and 8 give the detailed figures of electrical energy in Jordan.

Rural electrification programs are receiving serious attention in Jordan.

Due to intensive efforts during the previous years, some 40 percent of the rural population now is supplied with electric power, against 92 percent of town and city dwellers. It is expected that this percentage will double to reach 80 percent on the completion of present and future planned programs during the next seven years.

Rural electrification plans are aimed at increasing the number of electrified villages within a short period from 131 to 380 over a three-year period. By 1992, all villages in Jordan will be connected to the National Grid. Table 9 gives characteristic figures concerning electrical generation and distribution.

When examining the development of demand for electricity, one can see that consumption increased at an average annual rate of about 19 percent between 1975 and 1979, increasing from 355 GWh in 1975 to about 723 GWh in 1979.

Peak load increased from 88 MW in 1975 to 188 MW in 1979, representing an average annual rate of growth of about 21 percent. Table 10 shows sectoral consumption of electrical energy in Jordan.

NEW ENERGY RESOURCES IN JORDAN

Jordan is one of the few countries in the Arab world where conventional primary sources, starting with oil and ending with hydroelectric potentials, are quite scarce.

Yet one should admit that the efforts and investment allocated for oil exploration, for example, in the past 20 years were not intensive enough due to technical as well as economical reasons. Because of the continuing energy demand growth and the burden such a growth imposes on our economy, there is an urgent need in the country today to develop the sources of energy indigenous to the country.

Apart from oil possibilities, Jordan has a number of potential new energy resources that could act as an energy base in the next decade and later. The technology and finance such sources require are formidable. Table 11 summarizes the potential energy resources in the country.

Oil Exploration

The first reports on the possibility of oil being found in Jordan were published in 1947. Between 1954 and 1973, seven foreign firms obtained concessions for exploration, but only four performed field operations over a period of about nine years. During this period, 13 deep exploratory wells were drilled, but only traces of oil were found in two prospect areas. The National Resources Authority (NRA) signed an agreement in 1975 with a U.S. firm for oil and gas exploration within an area of 8,400 square kilometers. The firm carried out several geological and geophysical studies, the results of which were not encouraging.

Several new studies were carried out between 1975 and 1978. Due to the lack of financing and interest shown by the international oil firms, the oil exploration work in Jordan still is limited. At present, no one company holds exploration concessions in Jordan. NRA is planning to sell the results of its independent seismic study for review and bidding. Any talks with oil companies regarding the oil exploration will be under a production sharing type of agreement.

Oil Shale

Oil shales, as it is well known, are fine, grained sedimentary rocks containing solid organic matter which, on heating, disintegrate into oil and gas, but which do not contain any free oil. The liquid fractions resulting from heating shale resemble crude oil and can be refined to yield conventional petroleum products such as gasoline, diesel oil and fuel oil. At higher temperatures, more light products and also more gas are formed.

The direct burning of crushed shales as a lowgrade "coal equivalent" has been known for several decades and it is still used in the Soviet Union and a few other countries. It is mainly used for power generation by means of specially designed boilers.

Oil shale exists in large quantities in northern, central, and southern Jordan. The largest deposits are at El-Lajjoun, about 100 kilometers south of Amman. The geological oil shale reserves are estimated at 30 billion metric tons (MT), which mainly are lying in the northern and central parts of the country.

The total proven reserves of the El-Lajjoun oil shale deposits amount to 1.2 billion tons of bituminous marl with an oil content of 115.5 million tons.

In order to have a reliable and up to date quantitative and qualitative evaluation of El-Lajjoun deposit, Technopromexport of the Soviet Union and the Klocknet-Lurgi group of West Germany currently are conducting technical and economic feasibility studies for the utilization of oil shale in Jordan along two lines:

- The direct combustion process for generating 300 to 400 MW of electricity.

- Retorting of the shales for production of 50,000 barrels of shale oil per day.

The results of these studies, which are considered complementary to one another, are expected to be available within 12 months. Based on the results, a full feasibility study will follow. However, making actual use of shale oil in Jordan is not expected before the turn of the decade.

It is worth mentioning here that Jordan is trying to establish two-way links of cooperation with countries having experience in this field, such as Morocco.

Technology, Economics and Politics

The cheap oil era did not help the technology of oil extraction from shales to develop in proportion to its potential role as a fossil fuel carrier. Apart from extraction technology, shale oils do not require any major changes or modifications in the consuming system, a very attractive merit that many new energy resources do not enjoy.

Three major technological, as well as ecological, problems have to be solved before shale oil can take a good share of the world energy supply problem.

- Raising the efficiency (as a percentage of fuel content) of extraction at reasonable costs and by reasonably available techniques.

- Solving the ecological problems emerging from the huge amounts of ashes.

- Minimizing the water requirements for the whole process.

Due to the fact that oil shale is part of the oil industry, its economics are relative in the commercial and political sense.

Oil shale, like oil, was and still is subject to oil companies' views and interests regarding commercial feasibility. The huge funds and complex know-how involved make it difficult for any developing country to test the credibility of oil company estimates regarding the costs of oil if it is to be extracted from shale. One can notice, with or without surprise, that although oil shale is not in the market yet the "estimates" go up parallel to the oil prices, as shown in Table 12.

As for Jordan, the economics of shale oil production is still not determined, awaiting the results of some technical studies. It is useful for the sake of illustration to give here a rough picture of the possible economics of shale in Jordan in the form of a hypothetical case study:

1.	Required crude shale oil for 3,000 MW plant:	About 345,200 tons per year, or 2,325,000 barrels per year

Thermal efficiency, annual average load factor and annual operating days are supposed to be 37 percent, 65 percent and 330 days, respectively.

Gravity of the crude shale is supposed to be 20°API, or .934 specific gravity.

2.	Required oil shale mining:	About 3,836,000 tons per year

Crude shale oil content is supposed to be 9 percent by weight.

3.	Required oil shale retorting plant capacity:	About 12,000 tons per stream day

Annual operating time is supposed to be 330 days.

Investment cost and production cost as of 1980 for 345,000 tons per year of crude shale oil production plant have been roughly estimated in the following:

4. Estimated total investment cost: U.S. $226.2 million

		U.S. $ millions
1.	Mining, crushing and spent shale disposal (mining capacity: 4,000,000 tons per year)	22.8
2.	Retorting plant (capacity: 12,000 tons per stream day)	101.3
3.	By-product recovery	22.5
4.	Utility and auxiliary facility	45.0
	Subtotal	191.6
5.	Interest during construction (Dept: 70%, Interest: 10%/yr)	20.6
6.	Start-up expense (5% on subtotal)	9.6
7.	Working capital	4.4
	Total	226.2

5. Estimated crude shale oil production cost: $33.9/barrel, or $228.6/ton

		Million U.S. $ Per Year	$/barrel
1.	Direct operating cost	23.4	10.0[6]
2.	Depreciation[*1]	22.2	9.5[5]
3.	Profit before tax[*2]	33.3	14.3[2]
	Total	78.9	33.9[3]

[*1]Depreciable capital investment cost and depreciation period are U.S. $221.8 million and 10 years, respectively.

[*2]15 percent on depreciable capital investment cost.

Tar Sands

Tar sands consist of sand or sandstone, impregnated with a heavy viscous asphaltic oil. They usually are exposed at the earth's surface or covered by only a thin overburden.

Due to technical difficulties, methods of treatment of such sands are still rather costly. Known methods for obtaining oil do not yield more than 5 percent of the oil available in the sand. Efforts should be continued to improve methods of sand treatment. Many arguments regarding the actual commercial viability of shale oil apply for oil sands.

In Jordan, tar sand was found in Wadi Isal, located on the eastern side of the Dead Sea. All tar sand in Jordan to date is considered to be very limited and its commercial value has to be investigated through a well-defined and financed program.

Radioactive Minerals

Exploration for radioactive minerals in Jordan started in 1973. Radiometric surveys by hand and carbon scintillometer supplemented with gamma ray legging of boreholes have covered a large area in central Jordan. The important anomalies existed in the outcrops of phosphorites and in the areas where the phosphate is covered by this allovium.

A comprehensive exploration program was commenced in the fall of 1979. An airborne spectroradiometric survey was conducted for the whole country. Existence of natural radioactive minerals in the surficial deposits was delineated. The survey shows more radioactive anomalies of uranium sources in the phosphorite and thorium anomalies in the paleozoic sandstones.

Uranium: The aeroradiometric map of the country shows a large area of uranium anomaly coinciding with the phosphorite distribution. The anomalous areas also include the overlying Chalk-Marl Unit, which is partly phosphatic and contains huge quantities of oil shales that are slightly radioactive.

Other surficial uranium has been detected by scintillometry recently in the areas of Zarqa, Ma'an and Zara on the eastern side of the Dead Sea, and in Mukheiba hot springs area in the southeastern side of the Yarmouk River.

Uranium minerals, autunite, tayamunite and possibly others are disseminated in the phosphorite section. Their concentrations generally show a decrease from north to south within the phosphorite unit. The concentration of uranium in the upper phosphorite unit increases with an increase of P_2O_5 percentage.

The uranium content (U_3O_8) in the phosphorite section ranges from 24 ppm to 204 ppm.

Reserves of uranium are estimated to be 5 million MT. Only about 200,000 tons of this amount are contained in the minable phosphate beds.

Thorium: Thorium has been discovered in the Paleozoic sandstones in the southeastern desert. Anomalous area is covered by Ordovician and lower Silurian sandstones and sandy shales. The strongest thorium anomaly is found in the Graptolite Sandstone Unit.

The semi-quantitative spectrographic analysis gave high values of zirconium (300 parts per million), strontium (200 parts per million), barium (200 to 700 parts per million) and rare earths (La, Y. Nb, to 500 parts per million), tungsten (300 to 1000 parts per million), Litanium (.2 to .7 percent). The gamma ray spectrometry indicates about 400 parts per million of thorium oxides in these deposits. Thorium is possibly contained in the zircon and monozite minerals in this unit.

Radium: Radium has been detected in one location near the Rift Valley by gamma ray spectrography using a semiconductor device. The radium occurs in a recent hot spring deposit, composed of a dark, earthy unconsolidated material that is rich in magnesium and iron and contains calcium and magnesium carbonate.

The strong radiation of this deposit is due to radium (226) which is a disintegration product of uranium. The radium in that location is supposed to have been derived from a deeper uranium source reached by hot circulating groundwater that preferentially dissolved radium compounds which then was deposited on the surface when thermal water cooled down and changed chemically.

Jordan Fertilizer Industry Co. Ltd. has been investigating the possibility of extracting the uranium from the high-grade phosphate (TCP 73 to 75 percent). If the investigations come up with positive results, an amount of 80 to 100 tons of U_3O_8 (yellow cake) per year might be produced from 1.3 million tons of phosphate.

RENEWABLE ENERGY SOURCES

Geothermal Energy

Jordan has limited geothermal resources in the form of hot springs in two major areas. The surface temperatures of the two areas are 45°C and 63°C, and the combined discharge of these two springs into the Dead Sea is approximately 2,000 cubic meters per hour. Some further geophysical and geochemical studies still are necessary before a decision of utilization can be made.

Hydro Power

The lack of water resources in Jordan and scarcity of rivers or waterfalls make the hydro power potential (with the exception of Red Sea-Dead Sea hydro link) quite modest, amounting to about 50 GWh per annum, or the equivalent of 15,000 tons of fuel oil in a conventional steam power station. Yet the Jordan government is looking seriously to the development of the hydro power potential of the country as part of enhancing the degree of energy independence in addition to the obvious economical return.

King Talal Dam: This is a small dam on the Zarqa River. The dam already is built, and studies now are going on to introduce some structural and hydro modifications, including the construction of a small hydro power plant of 2 MW capacity designed for six hours per day during the peak period. The estimated cost of the power plant is about U.S. $8 million.

Makaren Dam: The Makaren Dam is on Yarmouk River in the northern part of Jordan. The available head is expected to be in the range of 200 meters, and the hydro power plant will be 2 kilometers off the dam body.

Feasibility studies for the project are completed. The power house will comprise two units of 10 MW each, producing about 50 GWh per annum.

The power station will be connected to the national grid via a 31 kilometer, 132 kilovolt single circuit transmission line. The estimated costs of the power system will be U.S. $15 million, while the estimated cost of the dam itself is U.S. $500 million, including the irrigation system and water canals.

Red Sea-Dead Sea Link: The general outline of the project under consideration calls for connecting the Red Sea with the Dead Sea through a system of open and closed hydrolinks making use of the head difference between the two, which is about 400 meters, to generate electricity.

Red Sea water first has to be pumped up from Aqaba to Gharndal, 85 kilometers north of Aqaba, via a system of reservoirs and then down to the Dead Sea by gravity via four hydro power plants.

Power generation capacity will be 334 MW for eight hours with a total net energy generation of 350 GWh.

The project is feasible to start in the 1980s, with a total estimated cost of U.S. $850 million.

The power output can be extended, depending on the final level of the Dead Sea.

Solar Energy

Jordan is blessed with a good solar energy resource. The average daily radiation is about 5 KWh per square meter, and the sunshine duration is about 3,000 hours per year. With the increasing burden of the cost of energy on Jordan's economy, since 1972 efforts have been made to harness solar energy, which is Jordan's major indigenous source of energy. Research and development activities in this field currently are carried out at the Royal Scientific Society (RSS) with the following objectives:

- To develop, adapt and transfer solar and wind energy technology to Jordan.

- To conduct research and development activities and to test pilot plants with the objectives of introducing and promoting the use of solar and wind energy in the country.

- To establish local scientific and technological bases in this field.

- To advise the private and public sectors on standards, production methods and quality control of equipment utilizing solar and wind energy.

Domestic Solar Water Heaters: The solar water heater's utilization for domestic use has increased in Jordan. This increase is indicated by the growth of the domestic solar water heaters industry. The number of the solar water heaters workshops increased from one in 1976 to about 20 in 1980. The industry currently is working with a capital of U.S. $2 million, and employing 102 technicians with a capacity of 85 units per day.

Agricultural Greenhouses: Jordan's utilization of solar energy for agricultural applications started in late 1970. The area cultivated in greenhouses in Jordan increased from 50 acres in 1970 to 1,500 acres in 1980. Two local manufacturers currently are producing the plastic covers needed for agricultural greenhouses with a capacity sufficient for local use.

Radio Telephone System Powered by Photovoltaic Cells: Jordan has installed 88 units of such a system in rural and remote desert locations. These units were acquired by direct purchase from the United States. Additional units are required to satisfy the great number of villages and long desert roads in Jordan. The system is providing an efficient, reliable and cheap method of communication.

Solar Evaporation Ponds for Potash Recovery: The Jordanian potash project is utilizing both the brine reserves of the Dead Sea and solar energy to recover about 1.2 million tons per year of potash and other byproducts. Three evaporation plans have been constructed with a total area of 76 square kilometers. The Dead Sea water is pumped into these ponds where the brine concentration and precipitation of salts take place. The total solar energy utilized in this process is estimated to be 3.21×10^{13} Kcal per year. This energy is equivalent to the energy available in 3.25 million tons of crude petroleum costing U.S. $749.1 million.

The RSS has a five-year research and development plan in solar energy with the following segments:

- Feasibility of renewable energy application.
- Technical and economical feasibility studies for solar water heaters industrialization.
- Water pumping using photovoltaic cells.
- Water pumping using wind energy.
- Electrical power generation using photovoltaic cells.
- Solar thermal power generation.
- Power generation using solar ponds.
- Solar cooling.
- Solar energy for agricultural purposes.

POLICY CONSIDERATIONS IN NEW AND RENEWABLE RESOURCES

Energy now ranks equally in importance with the classical factors not only of production but with those of survival in the sense of modern civilization. Short, medium and long-term planning for renewable energy is indeed complex. This is due to the complexity of energy planning as a whole, which is linked intrinsically to social and economic planning in a geopolitical frame. The identification of long-term energy needs also requires the ability for long-term social and economic planning. This, in cases of most developing countries, is complicated by the lack of detailed knowledge of the possible role of renewable and other sources of energy in the complex internal and external social and economic development processes. Hence, clear-cut solutions for each country cannot be readily made; extensive research is greatly needed in this area. Two broad approaches to energy planning can be adopted. The first is the energy system approach, which deals with three major and dynamically linked activities:

- Increased production of national resources.
- More efficient conversion processes.
- A more developed national conservation program.

The second approach assumes:

- Development solutions.
- Changes in development strategy.

Research and development has to play a vital role in the development of planning abilities and techniques and in implementation of renewable energy sources regardless of which planning approach is adopted.

The absence of proper energy plans in many developing countries is due mostly to the absence of appropriate energy institutions and to the shortage of competent energy planners within the farmework of the decision-making apparatus. The development of the capacity for energy assessment and energy planning for all sectors of the economy should take a high priority in science and technology as well as administration plans for each country. The development of such a capacity also can be enhanced through regional and international institutions to be established for this purpose.

Like most developing countries, Jordan rather recently started to give an increasing attention to the question of energy in the four known directions:

- Energy supplies.
- Development of local resources.
- Research and development.
- Organizational structure.

The increasing demand for primary energy supplies makes the availability of such supplies a very vital question. At the moment Jordan is using oil from one supplier at one supply point.

A program for diversification of fuel and supply point is under consideration.

The five-year plan for 1981 to 1985 has in its provision the expansion of the national oil pipeline network as well as the possibility of building an oil refinery in the southern tip of the country in Aqaba on the Red Sea.

Oil and gas exploration are receiving great attention in the coming five-year plan, with the aim of having a local energy resource. Encouragement is given to all interested exploration companies to work in Jordan, and the local capability for such operations is being built.

In addition to shale oil, which is now under study by both a German consortium and a Soviet enterprise, the development of solar energy as a local source is highly encouraged. Little work has been done on wind or other renewable sources of energy, but it is hoped that a comprehensive development program will be worked out to cover all potential energy sources in the country.

In many cases, lack of funds for research or development acts as a difficult barrier to overcome, yet Jordan is investing reasonably in training local personnel in different fields of energy technology.

The Royal Scientific Society (RSS) is taking the major share in research and development of new and renewable energy resources. A five-year research program was prepared, based on the following:

- Development of additional energy resources, such as solar, biogas and wind.
- Development of a more efficient and sensible energy end user.
- Development of better energy devices and systems.

However, it is relevant to emphasize here that the concept of research and development in this field is a practical one:

- To have a direct application of the developed device.
- To offer technological services to the energy-consuming public.

At present the organizational structure of the energy sector is rather scattered -- it belongs to the cheap oil era. There are about 12 bodies handling the energy question in one way or another. The government is realizing the importance of having a central energy planning and policy-making body. This new body will act as a national umbrella to the specialized institutions without eliminating or diminishing their role. The national five-year plan called for the establishing of a General Energy Corporation.

Table 1. DEVELOPMENT OF ENERGY
Costs in Jordan (1970-1980)

Year	Import of Crude Oil	Cost of Energy/ Gross National Income (%)	Cost of Energy/Export (%)
1970	6	1	---
1971	9	1	---
1972	11	1	31
1973	24	2.8	56
1974	50	5.8	49
1975	76	6.1	61
1976	92	5.1	62
1977	113	5.8	62
1978	129	5.7	69
1979	190	7.3	86
1980	360	11	100

TABLE 2. DEVELOPMENT OF ENERGY CONSUMPTION

Year	*Energy Consumption Mtoe	Annual growth %	**Energy Capita KGoe
1970	0.45	----	286
1971	0.53	17.8	331
1972	0.60	17.2	355
1973	0.67	11.7	383
1974	0.74	10.4	386
1975	0.84	13.5	524
1976	1.09	29.8	514
1977	1.22	11.9	553
1978	1.39	13.9	630
1979	1.60	15.0	730
1980	1.84	15	855

* Mtoe = Million tons of oil equivalent
** KGoe = Kilograms of oil equivalent

TABLE 3. DEVELOPMENT OF OIL REFINING CAPACITY IN JORDAN

Year	Refining Capacity Ton / Day
1960	1000
1970	2120
1975-1979	4900
1980-1995	12300

TABLE 4. DEVELOPMENT OF COMMERCIAL FUEL CONSUMPTION BY PRODUCT
(1000 Ton)

Product	Year						
	1974	1975	1976	1977	1978	1979	1980
Crude Oil	751	828	1 145	1 145	1 396	1 612	1 763
L.P.G.	24	29	37	36	43	45	53
Gasoline	136	159	203	211	248	274	317
Avtag	10	15	11	18	17	16	22
Avtur	50	58	88	109	127	172	176
Kerosine	109	113	160	107	148	153	167
Diesel	195	227	336	350	417	469	520
Fuel Oil	189	193	240	234	291	388	397
Asphalt	37	35	64	82	106	90	106
White Naphtha	0.3	--	0.5	0.3	0.4	0.5	0.5
Total	750.3	829	1139.5	1147.3	1397.4	1607.5	1758.5

TABLE 5. SECTORAL ENERGY CONSUMPTION
(1979)

Sector	Energy Consumed Mtoe	% of Total
Transport	778153	50
Domestic	227727	15
Electrical Generation	218432	14
Industry	234194	15
Agriculture	3260	2
Others	95908	6
Total	1,557,674	100

TABLE 6. POPULATION AND ELECTRICITY

Year	Number Of Population in(1000)	Percentage of Population Sup - plied by Electricity	Energy Generated (GWh)	Average KWH consumed per capita (KWh)
1971	1 723	32%	230	133
1972	1 774	33%	278	157
1973	1 831	35%	315	172
1974	1 890	37%	350	185
1975	1 952	39%	407	209
1976	2 037	40%	503	247
1977	2 126	43%	595	280
1978	2 217*	45%	703	317
1980	2 152**	55%	877	408

* Estimated

** Actual (Census 1979)

TABLE 7. DEVELOPMENT OF CONSUMERS
(1,000)

Year	Amman & Balqa	Irbid	Karak	Ma'an	Total
1971	61	19	3.0	3.7	87
1972	67	23	3.6	4.1	98
1973	82	25	4.1	4.4	116
1974	88	27	4.6	4.5	124
1975	95	31	4.7	5.1	136
1976	103	35	5.1	5.2	148
1977	111	40	5.4	5.7	162
1978	125	43	5.9	6.4	180
1979	149	50	9.3	7.6	216

TABLE 8. RURAL ELECTRIFICATION

Year	Rural Population (in 000)	Rural Population Supplied by Electricity (in 000)	Percentage Supplied by Electricity %
1974	738	120	16
1975	766	132	17
1976	795	212	27
1977	827	246	30
1978	860*	331	38
1979	882**	347	39

* (Estimated)
** Actual (Census 1979)

TABLE 9. ELECTRICAL GENERATION CHARACTERISTIC FIGURES FOR 1980

Generation	All Jordan 1980	All Jordan 1979	Interconnected 1980	Interconnected 1979 %	System Growth
Peak Load (MW)	196	183	163.6	153	6.9
Generated Energy (GWH)					
Steam Units	608	478	589	460	28
Gas Units	74	72	74	72	2.7
Diesel Units	588	230	148	118	25.1
Total Gen. Energy	1070	877*	811	650	24.7
Total Sold Energy	877	723	747	604	23.7
Loss Percentage (%)	18.04	18.3	7.97x	7.02x	
Generation Fuel Consumption (1000X Ton)					
Diesel	70	76	34	35	2.9
Heavy Fuel	233	175	209	162	29
Total Fuel Consumed	303	251	243	197	23.4
Generation Thermal Efficiency %	31	30.8	29.4	29.1	
Average KWH Consumed Per Capita	482	408			
No. of Consumers(thousands)	236	216			
Population Under supply (thousands)	1417	1298			
Percentage of Population Under Supply	64%	60%			

X Not including Loss of Energy in Dist. Networks * Not including Purchased Energy From Syria (8GWh).

TABLE 10. SECTORAL CONSUMPTION OF ELECTRICAL ENERGY (1980)

Sector	Total Consumed	% of Total
Domestic	321	36.6
Industrial	306	34.8
Commercial	107	12.2
Sewage & Water Pumping	76	8.7
Hospitals & Charities	40	4.6
Street Lighting	16	1.8
BroadCasting & TV	7	0.8
Others	4	0.5

TABLE 11. POTENTIAL PRIMARY ENERGY RESOURCES

	Source			
1.	Oil Shale	Geological reserve	30000	MT
		proved reserve	1200	MT
		Area of proved reserve (Lajjoun only)	26	Km2
2.	Uranium	Phosphate reserve	100 000 000 t.	
		Uranium to phosphate ratio	80-160/1 000 000	
		Uranium reserve	8000 - 16 000 t.	
3.	Solar	Average Sunny hours/year	3 300	
		Max. KWH/m2/hr	6 75	
		Efficiency-	theoritical	22%
			practical	12%
4.	Hydropower			
		Al Mukaran Dam 43-50	GWh/annum	
		Talal 3.5-4	GWh/annum	
		Red Sea Dead Sea Hydro Link 360	GWh/annum	
5.	Petroleum	Under exploration		
6.	Gas	Under exploration		
7.	Tar Sand	Exists in moderate quantities		

TABLE 12. DEVELOPMENT OF COST ESTIMATES OF SHALE-EXTRACTED OIL

		1960	1973	1974	1975	1979	1980
Oil	% Barrel	1.95	2.41	10.95	10.46	17	24
	% Barrel	----	23.5	354.37	4.47	62.5	42
Shale Oil	% Barrel	3	5.5	6.9	13	22-25	40-50
	% Rise	----	67	50	73	81	91
Shale Oil/ Oil	(%)	153.8	207	68	124	138	187.2

Kenya

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INTRODUCTION

Kenya has a population of 15.7 million with an annual growth rate of nearly 4 percent, which is one of the highest in the world. About 70 percent of this population (11 million people) live on 30 percent of the land area and the per capita income in 1979 was U.S. $242 at 1976 prices, which is among the lowest in the world. An official report published by Kenya's Bureau of Statistics, in 1977 indicated that 41 percent of the families engaged in small-holder agriculture.

The disappointing record in GDP performance in recent years reflects the disorder which has characterized international economic relations since the 1973-1974 oil crisis. Due to external factors, over which Kenya, being a net importer of production technology and energy, has no control, the country has had to revise downwards its development targets, set in the 1979-1983 Development Plan. This was done in "Sessional Paper No. 4 of 1980 on Economic Policies and Prospects," in which the projected annual GDP growth rate in real terms was reduced from 6.3 percent to 5.4 percent during the plan period. This growth rate is rather optimistic, as evidenced by the fact that in 1979 GDP grew by only 3 percent, which was 2.3 percent below the revised rate. The paper further indicates that, as a result of the poor external factors, there will be reduction in anticipated employment opportunities, decline in projected government revenues, and deterioration in balance of payments problems as the country will have to borrow funds from external sources, from time to time, to sustain a balanced demand of essential commodities and services such as oil, capital goods and spare parts and medical stores.

To uplift the standard of living of both rural and urban poor, and hence make advances in all aspects of social-economic development, the country will require increased quantities of energy in all sectors of the economy -- in particular in agriculture and manufacturing.

In realizing the importance of energy as one of the key factors of production, the government of Kenya through its Ministry of Energy has decided to prepare a comprehensive energy policy with the following major objectives:

- Increasing the supply of energy to meet the requirements of economy.

- Rationalizing the use of imported petroleum.

- Lessening dependence on imported fuels through vigorous conservation measures, aimed at increasing productivity of such fuels and utilization of new and renewable sources of energy to the extent possible.

- Developing indigenous energy resources.

In this connection, the government already has begun to introduce appropriate conservation measures, in a step-by-step fashion, and has prepared and provided funds for projects and programs aimed at extensive rural reforestation for energy production and for development of new and renewable energy sources of hydro power, solar, wind, geothermal and biomass. The Ministry of Energy also is investigating possibilities of substituting coal for oil for both industrial and household consumption because coal is in more abundant supply and is more widely distributed than oil, not to mention that it is much cheaper than oil in Btu terms.

Kenya's critical energy and development issues are rooted in two sets of circumstances. First is the pattern of land use, lifestyle and economy structure rooted in 80 years of colonial rule. Second is Kenya's limited endowment in natural resources.

In order to facilitate general development, particularly in the remote areas, additional fuels will be required although, with the projected switch from petrol to diesel and the development of mass transit systems, it is expected that switching from the current patterns of petroleum energy use will result in oil savings of between 10 percent and 15 percent per annum.

More than 22 percent of petroleum products are used in the commercial sector. A relatively high income market and developed urban infrastructure have attracted substantial amounts of foreign investment, although industry in Kenya tends to be located in a few areas spreading the benefits unevenly and exacerbating problems of rural to urban migration. However, the drive to decentralize industry, which is now part of government policy in industrial development, requires the provision of basic infrastructure, including energy, in increasing order of magnitude to reduce the extremely large gap that now exists between the rural and urban sectors of the economy.

Conservation measures have begun to be implemented by many industrial concerns. However, multinational firms, with easier access to capital and technology, are more efficient users of energy, strengthening their position against local producers. Energy audits of existing industry are being undertaken to emphasize the possibilities of conservation and fuel switching.

Agriculture, which is the backbone of the country's economy, consumes relatively few petroleum products. Kenya's modern sector depends for more than 80 percent of its energy requirements on imported petroleum. Small rural industries, informal urban industry, small farmers, and pastoralists rely mainly on wood and charcoal for their energy needs. Hydroelectric power is limited in supply.

As the price of oil continues to escalate, to some 37 percent of the value of total exports in 1979, even as the quantity imported remains constant, it has become absolutely necessary to devise an energy policy that moves toward increased pace of development and utilization of hydro power, geothermal energy and other new and renewable sources of energy. To realize such an energy policy, a number of projects and programs in the field of new and renewable sources of energy have been undertaken and continue to be undertaken by the government alone or in partnership with private enterprise. These projects and programs include, among others, the power alcohol industry, with the prime objective to achieve 20 percent alcohol replacement of gasoline in volume by 1985; and development of mini-hydro power potential, the investigation of which is being carried out in western Kenya with the help of donor assistance.

WOOD FUEL ENERGY

Wood fuel (fuel wood and charcoal) is the most important energy source in Kenya, accounting for about 75 percent of the country's requirements. This energy source is indigenous, mainly coming from the natural woodlands and forests, with only a small portion being supplied from government-owned plantations. These natural forest areas are being depleted, first to make more land available for agriculture and second, because in many areas more than the equilibrium supply of wood is removed, thus eating into the forest capital. Clearly, Kenya cannot go on using wood fuel as it does at present, without making adequate arrangements to renew this energy source. The only practical alternatives to wood fuel are oil products, including LPG and electricity. These require considerable foreign exchange to import or produce, and Kenya, like most other developing countries, has an acute shortage of foreign exchange. Therefore, the guaranteeing of an adequate wood supply to meet Kenya's future energy requirements is an essential part of this country's energy strategy.

The principal use of wood fuel in Kenya is in the household, fuel wood being used in rural areas and charcoal mainly in towns. Cooking is the most important application, accounting for between 60 and 75 percent of total household use. Space heating and water heating are the next two important uses, and, together with cooking, they account for about 95 percent of total household energy use. The remaining 5 percent of wood fuel is used for ironing and lighting. Non-household uses of wood fuel, including cottage industries, account for about 15 percent of total consumption, with agricultural crop drying -- tea and tobacco -- and beer brewing being the most important uses for this fuel. Other uses include brick and pottery firing, fish smoking and cooking in restaurants, canteens, butchers shops, schools and hospitals. Estimates of current annual consumption of wood fuel is of the order of 30 million cubic meters (22 million tons of air-dry wood), or approximately 7 million tons of oil equivalent, and is saving in terms of foreign exchange an estimated K-200 million (U.S. $485 million) per year).

If present use patterns continue, after making due allowance for people switching to more convenient fuels, and also taking into account the new uses of wood fuels and transfers to its use, the potential demand for wood fuel by the year 2000 may be of the order of 55 million cubic meters. However, if more efficient cooking stoves are fully accepted, and on the production side, more efficient charcoal production methods introduced, then it may be possible to reduce projected demands to the current demand level of 30 million cubic meters. However, in practice the potential demand will most likely be somewhere between these two limits. But on examining the supply side of the supply/demand equation, the tree capital already is being depleted and there is insufficient growing stock to meet the current needs on a sustained basis. If nothing is done about this state of affairs, the forest estate will diminish rapidly, the price of wood fuel will increase both in actual monetary terms and in the time taken to collect it, imported fuels will be substituted and, perhaps just as important, the removal of the tree cover will have adverse effects on the water flow, dam life, agricultural production and even local climate.

The only practical solution that is open to the government, and a solution that will create rural employment, save foreign exchange, and be the cheapest in terms of total expenditure, is to encourage the farmers to plant trees on their farms and establish village woodlots and fuel wood plantations. To this end, a presidential directive has been issued to the effect that every administrative location in Kenya should have at least one tree seedlings nursery, to supply seedlings to the local population. It also has been decreed that for every tree cut down, there must be a replacement.

An area equivalent to about 2 million hectares may have to be planted with tree species between now and the turn of the century, assuming an average growth rate of 15 cubic meters (11 tons) per hectare, if Kenya's wood fuel requirements are to be met, to say nothing of the area needed to meet the requirements of other wood users.

The common plantation wood fuel species, eucalyptus, is not suitable for growing in fields because for it allows no competition, is demanding on both surface nutrients and water and its leaves do not break down readily. On the other hand, many tree species are ideal for farming areas, such as species of Acacia, Leucaena, Cassia, Azadirachta, Nimosa, Prosopis, Grevilla and Cmelina. Many of these trees fix nitrogen, produce food and fodder, and do not compete with agricultural crops.

HYDRO POWER

The earliest application of hydro energy in Kenya was in connection with the running of water mills for grinding cereals like maize, wheat and millet. This technology was introduced in the early part of this century, and reached a relatively high plateau of utilization in the late 1950s.

The hydraulic ram is another device which has found wide utilization in the country. The device is basically a water driven pump which can be used for water supply and irrigation in the rural areas.

On average, hydroelectricity generation accounts for 80 percent of the total electricity supply. The most important application of hydro energy in Kenya is in the generation of electrical energy. Hydroelectric power generation is well established in Kenya. The main potential is concentrated on the River Tana, which has an estimated total energy potential of about 15,000 GWh per year. However, only 4,000 to 5,000 GWh per year (between 500 and 600 MW of electric power) can be exploited economically, which approximates the total forecasted load for the year 1990. The total installed hydroelectric capacity is about 410 MW, and this is expected to rise to 450 MW with the commissioning of a multipurpose project before the end of 1981.

As mentioned, exploration for mini-hydro power potential is being carried out in western Kenya. In total, the hydro power potential is estimated at 1,200 MW, out of which 750 MW can be harnessed economically at today's market prices.

Kenya's rapid socio-economic development has resulted in electricity demand growth rate of 8 percent per annum, on average, since independence. This rate of growth is expected to continue up to and including the year 2000. This means that the total hydro power potential, if harnessed exclusively for generation of electricity, will not meet the country's electricity demand by the year 1993. However, with the finalization of the national master water plan, the picture of the estimated total hydro power potential may change.

Feasibility studies on Kiambere hydroelectric power in the Tana River basin have been finalized. To this end, construction work for this project, which has a power potential of 130 MW, soon will commence and is expected to come on stream by 1986. Another hydroelectric power project in the Rift Valley province of Kenya, Turkwell Gorge, which has an estimated power potential is 120 MW, will be implemented as soon as detailed feasibility studies (including seismic studies) are finalized. It is anticipated that if the feasibility studies are satisfactory, this project will come on stream in or before 1990.

GEOTHERMAL ENERGY

Geothermal areas in Kenya are located mostly within the Rift Valley, which runs south to north from Lake Nagadi near the Kenya-Tanzania to Ethiopia border. The Rift Valley has a nearly constant width, between 30 and 60 kilometers, and a total length of approximately 800 kilometers. The valley is considered to reflect incomplete breaking up of a continental plate, normally resulting in the formation of a new ocean floor. The resultant geological structures present a remarkable graben. Generally, Eastern Africa, except for the coastal regions, is topographically characterized by plateaus and mountains higher than 1,200 meters above sea level partly due to regional doming of the crust and partly due to the development of the Kenya volcanic dome and the central volcanoes. Also, micro-earthquakes are recorded in and around the Rift Valley. Recent geophysical work by several universities has observed a mantle dome under the Rift Valley reducing the crust thickness by about a half. In the Rift Valley, as already indicated, there are many areas of active geothermal manifestations, but only three of these areas have been well surveyed. These are Olkaria, Eburru and Lake Bogoria. Olkaria and Eburru geothermal fields are limited mainly to widespread fumalore activity. At Eburru, the fumalores have been used to supply the local settlements with water condensing the steam in sloping aluminium pipes and collecting the water in tanks before distribution. The steam is used by farmers also as a source of heat for drying pyrethrum flowers.

Geothermal exploration in Kenya started in the early 1950s, with Olkaria geothermal area chosen for exploratory drilling because the other sites selected had neither suitable access roads nor, more importantly, adequate sources of water supply. In May 1956, a well designated X-1 was spudded using a percussion rig. Temperatures recorded during percussion drilling reached 120^{o}C at 370 meters but apparently lower during notary drilling -- well X-1 eventually was abandoned in January 1958 at a depth of 502 meters. Prior to the abandonment of well X-1, work with the percussion rig started in August 1957 on a second well, designated X-2, 2 kilometers north of X-1 at an elevation of 1,975 meters. At this site, using mostly rotary drilling, the well reached 942 meters in July 1958, but similar problems to those of X-1 were experienced. In spite of many efforts to bring X-2 to production by air lifting, the well was unproductive and operations stopped in March 1959.

Interest in further geothermal exploration work revived in 1967 when a wenner configuration restivity survey was carried out in the Rift Valley between Olkaria in the south and Lake Bogoria in the north. The survey identified a number of anomalies and recommended exploration drilling. Flow tests were conducted using lip-pressure pipes with different diameters to obtain flow-back pressure characteristics. Initially, when operating at a well head pressure of 6 bars (abs), the well produced about 50 tons of steam per hour, which is equivalent to about 5 MW.

Today, drilling at Olkaria still is going on and so far 16 wells have been drilled at depths varying from 900 meters to 1,685 meters. Of the 16 wells drilled, the majority are potentially productive and some of the latter yielded as much as 90 percent dry steam. Spacing between wells is 200 to 250 meters and the equivalent output varies from zero to 3 to 3.5 MW. Calculations determined that 1.5 MW per well, compared to other energy sources, still was economical under Kenyan conditions. The average subsurface temperature at the geothermal locations currently being developed in Kenya (1 x 1 kilometers) was 280°C (maximum 304°C), and dry steam wells yielded a temperature range of 235°C to 245°C.

The Olkaria geothermal field has been proved to be a large one. Indeed, anomalously low resistivity values extend over 100 square kilometers, with surface thermal activity scattered over an area of 36 square kilometers. Based on exploration data obtained and certain geological assumptions, the estimated geothermal energy potential of the Olkaria field range from a conservative 4,200 MW years to an optimistic figure of 1,250 MW years. Stated in another way, this potential is equivalent to between 170 MW and 500 MW, available over a period of 25 years. However, there is a likelihood of some of the wells being nonproductive and hence the estimated upper limit capacity will correspondingly be lower. Construction work already has begun for the installation of two geothermal electricity plants of 15 MW each. The first plant is expected to come on stream by July 1981 and the second plant by 1982. Exploration work on the other two geothermal fields, namely Eburru and Lake Bogoria, which have been identified as potential sources of geothermal energy, will be undertaken in the very near future.

ENERGY CROPS FOR SEED OIL AND POWER ALCOHOL PRODUCTION

The country's power alcohol program is aimed at achieving some of the national energy policy goals. It is government policy to encourage investments, either from within the country or from external sources, and development of resources pertaining to production of power alcohol while at the same time maintaining harmony with other government policies in respect to land use and utilization of all important resources. Clearly due to the heavy capital investments involved, incentives must be given. Such incentives may take the form of government partnership, waiving of import duties, subsidizing price of power alcohol vis-a-vis gasoline price, sales tax exemptions, accelerated depreciation, income tax rebates commensurate with total income, guaranteeing foreign loans and providing the necessary infrastructure including land for power alcohol projects.

Availability of fertile land is a major issue to be considered in the development of power alcohol. There is a clear indication that Kenya must initiate and plan power alcohol projects and address other renewable energy resources away from the existing fertile land to avoid competition between food and energy crops. This means that energy crops will be assigned especially to poorer lands, such as low rainfall areas. There is also an urgent need to diversify primary resources for power alcohol production in order to minimize the need to base projects only on sugar cane. If sugar cane should remain as the major power alcohol resource new drought-resistant strains will have to be developed for cultivation on marginal lands. However, with good sugar cane husbandry, it should be possible initially to increase cane yields without necessarily requiring more land.

The existing power alcohol resources are of only one type -- sugar cane. Sugar cane is grown in the Nyanza Belt (Kano Plains and adjoining areas), Awendo in South Nyanza, Ramisi, at the coast and in Mumias and Hzoia in Western Province. The area under cane cultivation is estimated at 70,000 hectares, and it is estimated that Kenya produced 400,000 tons of plantation white sugar in 1980. Production of sugar requires expansion of the cane area to more than 105,000 hectares if the target of 650,000 tons of white plantation sugar is to be achieved by 1990. A further 120,000 tons of sugar could be produced when the Yala Swamp and Busia Sugar projects are implemented.

Today, there exist two ongoing power alcohol projects: the Kenya Chemical and Food Corporation (KCFC) in Kisumu, which will come on stream in July 1981, and the Agro-Chemical and Food Corporation (ACFC) in Muhoroni, which is expected to come on stream in 1983. The design capacity of each of the two distilleries is 60,000 litres per day. The Riana Ethanol Project, already proposed, is the first ethanol project planned to use direct sugar cane juice, at a production rate of 150,000 litres per day. It is also expected to come on stream in 1984-1985.

KCFC and ACFC projects are designed to use molasses as feedstock. Molasses is produced in seven sugar mills. The demand for molasses is greater than the supply. In view of this, Kenya already has started looking for the production of power alcohol without the use of molasses. The only alternative to molasses at present is sugar cane juice. However, the Kenya government also is aware that in choosing among alternatives a balance must be established between sugar cane productions for white sugar and for power alcohol. Riana Ethanol Project is conceived as a possible resolution of this dilemma. It will be based on the use of direct cane juice.

Some research geared toward production of power alcohol and seed oils from energy crops and fast growing trees currently is taking place under the general direction of the ministries of Agriculture and Environmental and Natural Resources. The Ministry of Energy coordinates these activities and will soon itself be engaged in active research, development and demonstration of all energy crops for production of both power alcohol and oils. These two energy sources are meant to partially replace petroleum-based fuels.

Research, development and production needs, relating to power alcohol, will be dictated largely by the degree of Kenya's determination to be self-sufficient in energy. Logically, new energy crops will have to be identified for basic and applied research. Of greater interest to Kenya's energy policy are the crops which could be cultivated for immediate use in the production of power alcohol and oils.

Improvement of sugar cane currently in use in Kenya's Sugar Belt may lead to increases of sugar content and therefore to an increase in power alcohol production per ton of cane. Although many types of cane are grown in the Sugar Belt, the following varieties have been recommended: CO 331, CO 421 and B 351. Of all varieties, CO 421 is the most suitable for western Kenya.

Research geared toward development of complementary crops will be quite significant in reducing the pressure of fertile lands. Cassava will form an important crop in respect to this goal. Also, "power alcohol" sugar beets could be intercropped between food crop seasons and used to provide supplies for distilleries.

Kenya's needs for expansion of power alcohol and seed oils production will be dictated largely by the following factors: (a) duration, and extent to which prices of petroleum-based liquid fuels will remain competitive with prices of power alcohol and substitute oils; (b) need of using power alcohol and seed oils projects as nuclei for the development of arid and semi-arid (marginal) regions or underdeveloped lands; (c) use of power alcohol and related industries to create job opportunities in rural areas; and (d) rate of utilization of industrial and automotive fuels.

SOLAR ENERGY

Solar energy is one source that is renewable and has relatively great potential, as Kenya lies approximately 4.5 degrees north and south of the Equator. Due to its geographical location, therefore, Kenya has an undisputed opportunity for utilization of solar energy to enhance its socio-economic development. The solar radiation data already collected indicates that, on average, some parts of the country have solar insulation of between 30 and 45 watts per square centimeter. The Department of Meteorology of the University of Nairobi recently published a map which indicates solar insulation of the various parts of Kenya.

The most widespread solar energy application in Kenya is in drying of agricultural commodities and miscellaneous other things, such as wet clothes. This application of solar energy has been in use since time immemorial. The method most commonly employed in drying is simply that of spreading crops either on the ground or on special drying beds raised some height above the ground, depending on user requirements. This traditional method has some limitations in that products tend to take a longer period to dry and are exposed to pests and contamination. Some crops, such as maize and groundnuts, which require relatively short drying periods, when subjected to longer drying periods result in aflatoxin contamination. Such contamination makes the crops unfit for human consumption because aflatoxin has been proved to be carcinogenic.

The second most widespread application of solar energy in Kenya is domestic and commercial water heating. Solar hot water systems, flat plate collectors of varying sizes and qualities, are being manufactured and assembled by several local firms in the country. On the average, about 1,000 units of flat plate solar systems are sold each year.

Depending on quality of material used, the cost ranges from U.S. $500 for a 1.4 square meter galvanized steel flat plate collector with a 140 liter storage tank. Mass production possibly could bring down the costs due to economies of scale, even though the solar hot water systems are both material and labor intensive and therefore their total costs are not expected to decrease proportionately with production costs. Nearly all the solar hot water systems that are being manufactured or in use are of thermosyphon type.

Despite the fact that solar hot water systems being marketed in Kenya have useful life spans ranging frmom 15 to 20 years, the high production costs have limited their extensive application. Fiscal incentives by the government, in the form of tax rebates, could make their application more attractive.

The pay-back period of the flat plate hot water systems, which takes into account time value of money and escalation of prices of energy commodities, has not been assessed with any degree of accuracy and the available information is simply a guestimate. As is argued by some of the local manufacturers, depending on the application to which a system is being put the pay-back period, without taking the time value of money into account, varies between three and eight years.

Industrial solar water heating systems dedicated to deliver process energy, depending on use, may supply water which has to be heated further to require temperatures by conventional energy systems. They have not gained any popularity, and this is an area in which the government will in the near future provide information on possible benefits and appropriate incentives to make the application attractive to the potential users.

Other types of solar water heaters, such as parabolic and evacuated tube concentrators, which are capable of attaining extremely high temperatures, are unlikely to find any market in Kenya in the near future for two major reasons:

- Their technology is still in the developmental stage and completion of this phase will take at least a couple of years.
- Even if the technological barriers were overcome, the question of manufacturing such systems and commercialization at competitive prices before the turn of this century is highly doubted by many experts.

Photovoltaic electricity generation has barely been tried in Kenya, even though expert thinking is that in countries in which villages are remotely located from the national grid and other forms of conventional energy supply, and infrastructure is lacking or is grossly inadequate, it is competitive with conventional systems (diesel-powered pumps and electric generators). Photovoltaic electric power at today's market price is between U.S. $6 and $10 per watt for water pumping.

Because of the high sophistication of the technology for the manufacture of photovoltaic cells, which is both labor and energy intensive, the possibility of manufacturing commercially viable photovoltaic cells in Kenya in the near future is rather remote. However, this is one of the solar energy sources that have a potentially wide-scale application in rural Kenya in the near future.

WIND POWER

A survey carried out throughout Kenya in May 1980 to collect information on the present use of wind energy indicated that this technology has been used for almost 100 years. The wind machines were imported from Southern Cross of Australia, Aeromotor and Dampester of the United States and Climax of England. However, the existing installations of these windmills are very few, because they were abandoned in favor of cheap diesel engines which have continued to dominate in water pumping application and electricity generation in various parts that are inaccessible by the national grid.

Efforts by various parties, including the government, to reintroduce wind power technology have met with little success due to the following:

- Essential data on wind regimes characteristics are inadequate. However, the Meteorological Department of the government of Kenya and the Department of Meteorology of the University of Nairobi have been collecting wind data based on user needs. The former has been collecting data for both the civil aviation and the national air force while the latter has been collecting data for academic pursuits. The data has not been analyzed.

- Available windmills (imported and locally fabricated) have not been tested for their suitability, durability and performance with any degree of accuracy, and some of the financially able potential buyers are reluctant to invest in this field. It also goes without saying that there is gross inadequacy of skilled manpower countrywide to maintain this renewable technology.

- The windmills currently available in the market are too expensive for the target group -- the rural population -- to afford. The available windmills for shallow well water pumping cost U.S. $1,800, on average, whereas the household income of 80 percent of the rural population, which accounts for 90 percent of Kenya's population, is between U.S. $244 and $365 per annum.

As part of the Kenya government's policy in developing indigeneous energy sources and in lessening the country's dependence on imported energy, plans are being implemented for countrywide collection of wind data as well as for development of cheap but reliable windmills that are affordable by the target group.

BIOGAS UTILIZATION

The biogas technology was first used in Kenya about 30 years ago by Messrs. Hutchingson, who subsequently started manufacturing biogas digesters in 1958. Apparently not much interest developed among farmers, partly because of abundance of alternative sources of energy and a relatively small population. With the present energy crunch in the country's rural areas, interest has been shown both by private enterprise and government to develop and commercialize this technology as an alternative fuel to wood fuel and other biomass materials that are burned directly, to provide primarily cooking energy and to a lesser extent energy for space heating.

In an effort to alleviate the rural population's total dependence on wood fuel and other biomass as the prime source of energy -- their continued consumption are posing serious ecological problems, such as destruction of water catchment areas with obvious results of destabilization of water table, deforestation leading to desertification, and siltation of rivers and dams -- the government is promoting and fostering the use of biogas as an alternative fuel for use in the rural areas.

The government, through the Ministry of Energy, has begun to look into the existing worldwide biogas technology, mainly of Chinese and Indian designs with a view to producing designs suitable for use in Kenya at the least cost possible.

Parallel to these efforts, studies on socio-economic and cultural implications soon will be commenced to overcome any such barriers that may hinder faster acceptability of the biogas technology. A small survey carried out by the Ministry of Energy in 1980, as part of Kenya's preparations for a position paper on the new and renewable resources, covered 195 people in certain administrative districts. It indicated that there was need for an extensive and intensive dissemination of information on biogas technology.

The summary of the survey's results indicate that:

- Farmers, and more especially the agricultural officers, felt that more information should be available to help in the adoption of biogas technology.

- There is need for reliable performance data and a source listing the range of options and equipment available. Widespread talk about the biogas technology is not a sufficient mechanism to propagate the technology effectively.

- Farmers require clarification in respect to comparative performances and, of course, the side-effects of the technology, as well as cultural beliefs and practices.

- The imbalance between the capital cost of the digester and the benefits derived was a problem common to most of the farmers interviewed. While the main concern focused on capital cost, the farmers also were concerned with operating costs, especially in areas where water for mixing the raw materials in an acceptable form was distant from the site of biogas digester.

- There is need to give loans for purchase and installation of biogas digesters as part of farm development credits that the government gives to farmers through its agricultural credit finance institutions such as the Agricultural Finance Corporation (AFC) and Agricultural Development Corporation (ADC).

It was a general feeling that biogas could alleviate hitherto commonplace problems in some parts of the country where women have to walk long distances in search of firewood, agricultural wastes and other vegetable wastes that are barely enough to meet cooking energy needs for more than a day.

Finally, the farmers and agricultural officers agreed that the biogas digester spent slurry could be a good fertilizer, and that the only problem that will hinder large-scale use of the slurry was the enormous effort that is required to transport it to farms.

EDUCATION AND TRAINING

At the moment, there is no well-organized training program for solar, wind and biogas energy personnel in Kenya. The sooner we make a start, the better it is for us. The University of Nairobi and its constituent college, Kenyatta University College, have planned for inclusion of these renewable energy sources in their teaching program at both under-graduate and post-graduate levels. Nevertheless, there are financial constraints that may hinder faster implementation of the training programs.

Regarding training in hydro power, the University of Nairobi offers three-year courses in electrical, mechanical and civil engineering, and it is from graduates in these fields that the electrical power industry recruits its high level personnel. The East African Power and Lighting Company, which is the only electric utility, trains its engineers and technicians both on-the-job and in its training school. Despite the availability of the training facilities in this field, there still is a shortage of both professional and technical manpower.

The Forestry Department of the University of Nairobi is now incorporating into its courses methods and practices of agro-forestry, and the Forest Training School, Ministry of Environment and Natural Resources, is training students in extension work in both forestry and agro-forestry. These training facilities are, however, inadequate to meet the countrywide reforestation program now being undertaken.

At present, there are no local training facilities in the field of geothermal energy and professional manpower has been and continues to be trainied overseas. With regard to sub-professional and skilled manpower, there are no formal training facilities either in Kenya or overseas. Such manpower has to be trained on-the-job. However, there is need to train more personnel in this area to cope with expanding geothermal development programs. Creation of a regional geothermal training and research center for Africa will go a long way in reducing the training problems at all manpower levels.

INFORMATION FLOW

A mechanism for a national information service capability, aimed at education of prospective buyers on the most appropriate new and renewable sources of energy that have reached commercialization, is at the moment lacking. However, the Ministry of Energy is considering setting up a data bank/library which will deal with information flow from the government to both the consumer and the manufacturing sector. The main energy resources that will receive high priority are reforestation, solar hot water systems, biogas digesters and windmills.

The question of standardization and quality control will be addressed to protect consumers from exploitation by unscrupulous salesmen.

In the field of reforestation, simple information brochures will be published in various local languages to inform the farmers about suitable types of trees for their particular area, seed and seedling source, how to grow and tend these trees and what they can be used for besides wood fuel, pole and sawn timber. On the consumption side, stoves models that are efficient and cheap enough for the rural poor to afford will be demonstrated.

The national political machinery and the country's provincial administration will be used to promote and foster the development and utilization of new and renewable sources of energy as far as possible.

Information exchange between and among countries should be encouraged and propagated through publication of papers and journals about research and any breakthroughs in new and renewable sources of energy.

RESEARCH AND DEVELOPMENT

Like training, research and development as a whole is yet uncoordinated, even though it has been undertaken by the University of Nairobi in solar and wind energy and by the Ministries of Agriculture, and Environment and Natural Resources in energy crops such as sugar cane and suitable tree seedlings for growing on marginal lands. The role of the Ministry of Energy in this respect will include coordination of research and development of new and renewable sources of energy.

The Ministry of Energy soon will establish an Energy Technology Institute. Its prime role will be testing, development, adaptation and adoption of new and renewable sources of energy technologies that have surpassed basic research levels.

TECHNOLOGY TRANSFERS

At the moment, Kenya lacks the machinery for transferring energy technology to manufacturers and end-users of new and renewable sources of energy. The Ministry of Energy hopes to set up, in the near future, an extension service network throughout the country to cater for the transfer of all forms of appropriate renewable and new sources of energy, to both manufacturers and end-users. There is also a need to set up a machinery at sub-regional, regional and international levels for transfer of technology between countries and among countries at a nominal fee.

FINANCING

Financing is an important aspect in the development and utilization of new and renewable sources of energy. Consumers could get soft loans from government financial institutions. Manufacturers also could benefit from the existing quasi-governmental financial institutions to get appropriate financing to set up manufacturing plants. There is also a need to explore the possibility of tapping bilateral and multilateral financing, on very reasonable terms, for developing new and renewable sources of energy.

RURAL ENERGY SUPPLY

At the moment, there is only one major government activity that caters to rural energy supply -- the rural electrification program -- and its project implementation is hampered by lack of adequate funds. Regarding the supply of wood fuel, solar and wind energy, the Ministry of Energy is embarking on a country-wide program to meet the rural energy requirements. Such a program calls for huge capital outlays that cannot be met in full from government revenue. Efforts will be made to tap bilateral and multilateral financial and technical assistance.

INSTITUTIONAL INFRASTRUCTURE

The Ministry of Energy is the prime government authority charged with the responsibility for energy development. In order to cater to the country's energy needs, which are as important as classical factors of production, the ministry has set up:

- A Policy, Planning and Monitoring Division charged with the responsibility for preparing policies, programs and strategies associated with energy activities.

- A Technical Division charged with the responsibility of all aspects of development of energy resources, as well as providing appropriate relevant infrastructure.

In addition to these two divisions, an Energy Development Fund has been set up to help promote and foster harnessing of biomass energy as well as other new and renewable sources of energy. It is expected that the Energy Development Fund would benefit both from bilateral and multilateral financial resources, and as time goes on the fund is expected to be self-financing and autonomous. It is expected to eventually become an energy development bank.

RECOMMENDATIONS

Subject to the foregoing, it is recommended that:

- Top priority be given to development of solar water heaters, cookers and wind and solar electricity generators to mainly meet the energy requirements of the rural people.

- A mechanism for the transfer, adaptation and acquisition of new and renewable sources of energy technology within the framework of United Nations programs be established.

- In order to provide essential financing for development of new energy technologies in developing countries, a special fund be created to which both developing and developed countries would contribute on terms to be determined by the United Nations Conference.

- Regional cooperation be encouraged among neighboring countries to address the development of new and renewable sources of energy in common areas of interest.

- To reduce the presently high cost of photovoltaic and windmill systems, which potentially have an important future in electricity generation and water pumping in Africa and tropical countries elsewhere, consideration should be given to setting up regional manufacturing plants to fully realize the benefit of economies of scale. The funds for establishing such plants should be borne by member countries; political differences between and among countries should not be allowed to interfer with such cooperative projects.

TABLE 1. PRODUCTION, TRADE AND CONSUMPTION OF PRIMARY ENERGY SOURCES

PRIMARY ENERGY BY TYPE	1974 000 tons oil equivalent	1974 % of total	1979 000 tons oil equivalent	1979 % of total
Coal and coke imports	46.6	2.9	11.3	0.5
Imports of crude oil	2,902	-	2,471.5	-
Net exports of petroleum fuels	1,458.8		713.4	
Stock changes and balancing items	91.4		80.6	
Total consumption of liquid fuels - local	1,352.1	84.5	1,677.5	79.7
Hydro energy local production of hydro power	131.3		314.0	
Imports of hydro power	71.0		38.4	
Total consumption of hydro energy	202.3	12.6	352.4	17.3
Total local energy produced	131.3		314.0	
Total imports	1,561.7	97.5	1,807.8	88.5
Use of stock and balancing item	91.4		80.6	
Total energy consumption	1,601.6	100.0	2,041.2	100.0
Local energy production as percent of total	8.2		15.4	
Per capita consumption in terms of kilogram oil equivalent	123		133	

SOURCE: Government of Kenya Economic Surveys, 1979 and 1980

TABLE 2. CRUDE OIL AND PETROLEUM PRODUCTS
(000 tons)

YEAR	IMPORT OF CRUDE & PETROLEUM PRODUCTS	EXPORTS OF PETROLEUM CRUDE AND PRODUCTS	NET IMPORT
1973	2,881	1,682	1,199
1974	3,134	1,652	1,482
1975	2,920	1,380	1,540
1976	2,508	1,431	1,167
1977	2,730	1,417	1,313
1978	2,693	1,213	1,480
1979	2,808	1,040	1,768

SOURCE: Government of Kenya Annual Statistical Report and Annual Economic Surveys.

Liberia

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INTRODUCTION

Liberia occupies an area of 43,000 square miles. The landscape of the country is plateau, almost all of which is covered with a tropical rain forest and has a general elevation of 1,500 feet. Large rivers flow across the country into the Atlantic Ocean perpendicular to the mountain belts. These rivers are proven to be suitable for hydroelectric power.

The population density increases around the industrial cities and mines, and is considered evenly distributed over the subsistence agricultural sectors.

The Liberian forest reserves can provide up to 1 million cubic meters of wood yearly; this is equivalent to more than 200 GWh of electricity annually. The country has ongoing reforestation programs, and this assured wood resource is seen as a possible energy reserve.

There is a major emphasis by the government to develop more hydro power for electrification, to extend the central grid and to replace, where possible, firewood and charcoal use. The government also is supporting offshore oil and gas exploration.

ENERGY CONSUMPTION IN LIBERIA

There are reports of the utilization of non-traditional sources of energy, including sugar cane trash (which is being used by the plant of the Liberia Sugar Corporation in Maryland County) and lumber scrap (being used at the Liberia Timber and Plywood Corporation in Sinoe County). Unfortunately, no study has as yet been made on these two cases to test their reliability. The four major energy sources being used extensively in Liberia are petroleum products, hydroelectricity, firewood and charcoal.

The commercial energy sector in Liberia today primarily relies on imported oil-based fuels refined and distributed in the country. Electrification relies on hydro and heavily on fossil fuels. Firewood, charcoal, and some kerosene and LPG are used throughout the country in households for cooking. A preliminary 1979 energy supply and demand balance for Liberia in thousands of barrels of crude oil equivalent per year, including the percent of coverage of demand by various sources of energy, is shown in Table 1. The total energy on input bases for 1979 is 6.6073 million barrels of crude oil equivalent.

PETROLEUM AND PETROLEUM PRODUCTS

Crude Oil Importation

Crude oil importation in Liberia is carried out by the Liberian Petroleum Refining Company. The refinery, which is a public corporation, is considered small by world standards, having a daily refining capacity of 12,000 to 15,000 barrels per day. It is, however, of average size for West African countries.

Importation of crude oil is presently under a three-year contract between Petroleum of Saudi Arabia and the Liberian Petroleum Refining Company. Meanwhile, there are negotiations going on with Nigeria, Mexico and Algeria for similar contracts. The refinery imports crude oil once a month with an addition of one shipment every three months. The total imported crude is on the average of 405,000 barrels per month. The cost of crude oil in 1979 was $120 million, approximately 20 percent of total national imports.

Below is a listing of the yearly crude oil imports in Liberia between 1975 and 1980, as reported by the refinery:

Year	Total Crude in Barrels	Cost in U.S. $
1975	1,488,712	4,830,000
1976	1,559,850	5,950,000
1977*		
1978	2,904,808	8,460,000
1979	3,807,558	225,956,000
1980++	4,927,500	117,570,150

* No crude oil was imported in 1977 due to the refinery breakdown.

++ Projected by the Liberian Petroleum Refining Co.

Consumption of Petroleum Products

Approximately half the crude oil is refined to fuel oil, primarily for the use of the mines. Another 20 percent is diesel that is shared between the mines and the Liberian Electricity Corporation (LEC). The balance is distributed among transport, residential use and other small consumers.

ELECTRICITY

Power Generation

The LEC transmits and distributes electricity to several communities in Liberia. It operates a power grid within the Monrovia area consisting of an 11 MW diesel, a 64 MW gas turbine and a 64 MW hydro installation. It has recently added a 26 MW marine diesel generator and will add two 13 MW units in 1981. The LEC also operates nine out-stations not directly connected with the Monrovia system. The diesel generators in these towns range in capacity from 300 KW up to 2 MW, with the majority being small units. The total non-grid installed capacity is approximately 7 MW. In addition, several of the large towns have various diesel generators owned and operated privately. Many smaller towns are reported to have small diesel sets in the 10 to 100 KW range, owned and operated by private entrepreneurs.

The iron mines and rubber plantations have an installed capacity of 143 MW. This capacity is dedicated to the plant operations and local use.

Power Production

The most significant developments in the LEC systems date back to 1963 when a new diesel plant consisting of six sets with a total of 13 MW was commissioned. From that time until November 1980 a total of 155 MW of thermal and hydro facilities have been installed in addition.

Plant	Installed Capacity	Type of Engines
Bushrod Plant	13 MW	Diesel (Medium Speed)
Faulkner & Walker	64 MW	Hydraulic Turbines
G.T.	64 MW	Gas Turbines
Luke Plant	27 MW	Diesel (Slow Speed)
Total	168 MW	

In 1977, the peak demand in the LEC system was 74.3 MW and the total energy generated was 433.3 GWh. It has been estimated that by the year 2000, the minimum energy requirement in Monrovia will be approximately 1,895 GWh, while the entire country will need about 4,304 GWh, corresponding to a demand of about 309 MW and 67 MW, respectively. The 1,895 GWh is considered the maximum expected in the Monrovia system, while 7,304 GWh is the maximum estimated for the entire country corresponding to a demand of 309 MW and 1,076 MW, respectively.

At the present time, the Faulkner and Walker hydro plant on the St. Paul River is only adequate to handle the normal demands, with some thermal generation being added for peaking because the plant is a run of the river and has no storage facilities. Therefore it cannot be utilized fully during the dry season. The LEC, nevertheless, in 1979 generated about 70 percent of the total power in the Monrovia system by this plant.

LIBERIA'S HYDRO POTENTIALS

There are considerable plans for the further development of hydro power in Liberia. A 1975 preliminary study on hydroelectric power development in Liberia by the Japanese International Cooperation Agency (JICA) indicated that all of the major rivers in Liberia had some hydro potential. However, more detailed studies on three major rivers (Mano, St. Paul and the Cavalla rivers) have indicated higher potential than those suggested by the JICA report.

The Mano River has been shown to be capable of supporting a 160 MW plant, the Cavalla a 450 MW plant, depending on the dam height, and a storage basin with a potential well more than 1,000 MW has been identified on the St. Paul. This potential of the St. Paul River is not, however, located at one site. There are a total of six sites on the river suitable for hydroelectric power. By staging development, power can be put on stream as and when it is needed. Considering the St. Paul's potential alone, these rivers would be found capable of supplying the power needs of the country well into the next century.

NEW AND RENEWABLE ENERGY RESEARCH

Because of continuing energy demand growth and the shortages in the supply of petroleum, there is a serious need to introduce energy conservation activities and to develop Liberia's alternative energy, in particular renewable energy sources.

Potential renewable energy sources are solar energy, wind energy, biogas, wood, charcoal and hydroelectric. In addition, there is considerable potential for conservation through improved practices in the utilization of wood and charcoal. The introduction of biogas, wind energy, solar energy and mini-hydro projects is considered a positive step toward energy self-sufficiency. Recognizing this, the National Energy Committee and the Bureau of Hydrocarbons have embarked upon the following programs:

- Assessment of the demand, consumption and distribution of firewood, charcoal and other alternative sources of energy in Liberia.
- Construction of a pilot project of biogas digesters.
- Cooperation with the University of Liberia in the pilot study projects for solar and wind energies.
- Studies on energy conservation, environmental impacts and protection strategies, and demand and supply options.

Attention should be drawn to the fact that new and renewable energy research in Liberia is very new. Most research projects are in the planning stage or waiting to be implemented.

The government and other parties involved in the Liberian economy do not have sufficient data about the energy sector, especially renewable energy, to properly plan for its development or to manage and regulate its course. This lack of data also directly affects other sectors of the economy and could lead to serious problems in the future. This fact has been recognized and the government is attempting to do something about it through data collection programs. There is an immediate need for an energy sector plan.

Data on energy use or on the implication of energy plans to other sectors of the economy does not exist. Planning for most sectors often does not include energy considerations other than fuel costs.

A National Energy Commission has been formed to produce a national energy plan, but it has just begun its work. Emphasis on conservation and demand management is only beginning, and currently is not widely practiced. Some data on rural energy use has been collected. References and literature on renewable energy are not available.

Renewable energy training is just beginning in the university, and there is a need for more training resources.

Wood, Charcoal and Kerosene

As a result of escalating prices of petroleum products, there has been a shift to more traditional sources of energy, especially by household users in both urban and rural areas. The principal traditional sources used today include firewood, charcoal and kerosene. They are being used particularly in homes and small industries. The Bureau of Hydrocarbons is conducting a comprehensive study on the extent of usages of these sources of energy. A preliminary study of 10 rural cities indicated that there is a high demand for these sources and, suprisingly, availability of the products is a major constraint. Although a 10 city sample is insufficient to arrive at a meaningful conclusion, several trends were noted:

- There is a scarcity of petroleum products, wood and charcoal in most markets. This would indicate that the utilization of energy sources is based on their availability.
- There is a need for a better distribution system to meet the demand of local markets.
- Sawmills could process wood scrap for utilization as an energy source in rural areas.
- It would appear that of the three commodities, charcoal is preferred, and an industry could be developed for processing charcoal.
- Charcoal stoves and the iron and stone tripods used as wood stoves need serious improvement for better efficiency.

The report further revealed that in Monrovia the average per capita use of wood is .04 cubic meters per year, of which 47.93 percent is in the form of charcoal. In the rural towns, such as Sanyea, up to 5.5 cubic meters of wood per year is used per capita. Of this latter figure, only .15 percent is in the form of charcoal. Analysis shows that the cost of firewood, charcoal and kerosene for a family of five is about $262 per annum. It is known that the 1979 Gross Domestic Product (GDP) is $913 million. Based on a 1979 population estimate, the per capita GDP for the year was $514.80. Thus, 10.2 percent of the family's annual budget is being spent for these energy products.

The Bureau of Hydrocarbons, in collaboration with the University of Liberia Engineering Department, has completed plans for programs in solar and wind energy.

Wind Energy

The program for wind-powered installations for rural projects in Liberia has emphasized the need for the design of simple equipment that can be fabricated locally. The objectives of the programs are:

- To conduct a pilot project using wind-powered water pumping to demonstrate the feasibility of harnessing wind energy in Liberia.
- To study the wind pattern in the Monrovia area as a prelude to a national wind pattern study.
- To use the wind data to determine the forms, sizes and sites of possible wind-powered installations in Liberia.

Besides driving water pumps, wind power finds application for other uses, such as generation of electricity, grinding coffee (common in the country) and threshing rice. A later phase of this study could consist of fabricating and testing model wind-driven devices for electricity and other energy needs of the Liberian people.

Solar Energy

Due to the absence of global solar radiation information for Liberia, the present solar energy program consists of solar energy data collection and building locally constructed solar collectors.

Mini-Hydro

The U.S. Agency for International Development is installing a mini-hydro plant in a rural city of Lofa County. It is hoped that this pilot program will provide the information necessary for a meaningful mini-hydro program in Liberia. The German Technical Assistance Program to Liberia is financing a feasibility study on locations for mini-hydro throughout the country for the Liberian Electricity Corporation.

CONCLUSIONS

In view of the rising prices for imported oil to meet the energy needs and the consequent drain of the nation's foreign exchange, Liberia is placing major emphasis on the development of new and renewable energy technologies as part of its rural and urban development programs. There are, however, several existing constraints limiting the speedy implementation of the programs. Paramount, among these are:

- Technology: Present technological advances in new and renewable energy sources development are not available. However, several researchers, government and industrial agencies and institutions such as the University of Liberia and the Cuttington University College have shown considerable interest in developing the technical know-how of their personnel in the area and are open to the transfer of the technologies.

- Financial: Due to a recent change in government, Liberia is in a transition stage and the financing of its development programs is being rearranged. The nation is in a low financial situation, and the three existing energy programs need assistance both from international and other donors.

- Education and training: The training of both management and policy makers, as well as lower level technicians and specialists in the development and transfer of new and renewable energy technologies is seriously needed.

The higher institutions of learning in the country have expressed interest in introducing energy technology courses to their students, but lack funds, instrumentation and staff to do so. Government agencies and other corporations concerned with the energy sector do not have personnel trained in the disciplines. The Bureau of Hydrocarbons, a government agency concerned with the development of these energy sources, lacks staff in this area and needs training assistance for its personnel.

If our development goals must be attained, the public should be protected against insufficient supplies, instability of prices and prolonged interruption of services. Due to the dispersed nature of Liberia's rural population, technologies for producing energy from sources that are renewable need to be small scale and decentralized. Small bio-digesters, wood-fired steam generators, mini-hydroelectricity activities, energy conservation programs and labor-saving devices in rice production are areas with potential high energy savings and should be explored.

Several industries (such as wood processing companies, mining concessions, sugar factories and others) are developing in the country. At present, the consciousness of the need to install energy saving devces, and those that will rely on new and renewable energy sources, is not shown. Very few have developed plans to replace energy consumption with renewable sources. The government needs to require a number of them to do so.

The government's promises of greater social justice for the poor and a better life for the rural population implies more energy, especially electricity, additional fuels and stabilized prices. The new emphasis on energy already has been initiated by the formation of the National Energy Committee together with the recommendations of the DSI report.

The U.S. Agency for International Development has shown a lot of interest in the Liberian energy problems and it is anticipated that this interest will continue to grow. Other agencies and financial institutions that have shown interest in the energy and rural problems here are Kreditanstalt Fur Wiederautbau, the European Community, Japan International Cooperation Agency and the Economic Commission for Africa, to name a few. It is assumed that they will continue to show interest and that it will be possible to call on them for assistance in developing new and renewable sources of energy in Liberia.

TABLE 1. PRELIMINARY 1979 ENERGY SUPPLY AND DEMAND BALANCE

(10^3 barrels of crude oil equivalent per year)

Energy Demand Category	Total Energy on input basis	Percent of total	Percent of Coverage of Demand by various Sources			
			petroleum	hydro	firewood	charcoal
DIRECT HEAT						
Industrial	1905*	28.8	100			
Domestic	2139	32.4			65.1	34.9
TRANSPORT						
Road	541.4	8.2	100			
Ship	31.0	.5	100			
Air	319.7	4.8	100			
ELECTRICITY GENERATION						
LEC - Petro	282.8	5.8	100			
Hydro				100		
Private	452.0	6.8	100			
OTHER						
Naptha	16.4	.2	100			
Asphalt	19.1	.3	100			
Refinery	95.4	1.4	100			
TOTAL	6607.3	100.0				

* Data on industrial wood use is not available, however, this figure could be larger.

TABLE 2. CONSUMPTION OF PETROLEUM PRODUCTS BY SECTOR IN 1979

Consuming Sector	Product	Quantity BBL	Percent
Land Transport	Gasoline	541,436	14.22
Air Transport	Jet Fuel	319,650	8.40
Residential	Kerosene	4,261	.11
	LPG	4,256	.11
Ships	Bunker Fuel	30,986	.81
Refinery	Fuel Gas	95,405	2.51
Mining Comcessions (mostly electricity generated)	Fuel Oil	1,904,266	50.00
	Dieseal	451,983	11.87
Electricity Generation (LEC)	Fuel Oil	34,600	.91
	Diesel	348,200	9.14
Road Construction	Asphalt	19,104	.50
Other	Naptha	16,455	.43
		22,587	.63
Total		3,791,014	99.58

TABLE 3. SUMMARY OF PROPOSED HYDROELECTRIC POWER DEVELOPMENT SCHEME

		MANO RIVER		LOFA RIVER		ST. PAUL		ST. JOHN RIVER		CESTOS RIVER	
Item	Unit	No. 1	No. 1	No. 1	No. 1	No. 1	No. 1	No. 1	No. 1	No. 1	No. 1
Type of Generation		Dam Type	Dam Type	Dam Type	Dam Type	Dam Type	Dam Type	Dam Type	Dam Type	Dam Type	Dam Type
Catchment Area	km^2	7,600	6,300	8,590	8,180	20,780	16,010	15,610	11,160	10,400	7-250
Annual Inflow	$10^6 m^3$	8,606	7,077	8,467	8,061	15,832	15,250	15,250	10,902	4,834	3,347
Dam											
Type		Rock-fill	Rock-fill	Rock-fill	Rock-fill	Rock-fill	Rock-fill	Rock-fill	Rock-fill	Rock-fill	Rock-fill
Height	m	30	45	25	30	28	25	25	40	20	30
Crest Length	m	500	360	400	400	950	600	450	350	500	1,700
Power Production											
Effective Head	m	21.8	35.0	17.3	21.8	18.3	17.3	17.3	29.9	18.0	15.0
Maximum Discharge	m^3/s	67	129	70	106	167	70	127	159	108	122
Installed Capacity	KW	12,000	37,000	10,000	19,000	25,000	10,000	18,000	39,000	16,000	25,000
Annual) Energy) Production)	10^6	98.5	295.5	83.2	154.5	*229.5	83.6	149.0	308.1	125.7	188.6

TABLE 4. HYDROELECTRIC GENERATION

Plant	Installed Capacity (MW)	Primary Energy GWH/Year	Fuel Replacement Energy GWh/Year	Installed Cost $ (1978)
Vi-SP4	134	600	158	423,919,600
Mt. Coffee	128*	640*	88*	47,430,500+
SP2	214	1,047	166	188,406,400
SPO	188	942	131	202,317,100
SP1B	120	589	88	141,709,800
SP3	108	496	105	126,262,200
SP1A	204	1,015	140	279,204,500
T1	6	32	-	52,343,500
T2	10	56	-	92,892,000
T3	16	102	-	226,424,000
V2	29	165	-	80,631,000

* Mt. Coffee total plant including existing units plus addition

\+ Mt. Coffee addition only.

Nigeria

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INTRODUCTION

With the rapid rate of development in Nigeria, the immediate impact of the energy crisis has begun to strike the Nigerian public at large. Nigeria is slowly but surely reaching that turning point where it never again will be in a position to take energy supply for granted. The energy crisis has been slow in coming and it will be with us for sometime. The choices are going to be difficult in the future and will affect our way of life in no small measure.

When the role of petroleum in the Nigerian economy since 1973-1974 is considered, one is hardly surprised that the issue of petroleum and other energy sources has gained tremendous national interest. In terms of national economic growth, it is generally agreed that there is a definite and strong correlation between the aggregate demand for energy in a society and the Gross Domestic Product (GDP). In Nigeria, the GDP at 1962-1963 constant factor cost increased from N2,385 m ($4,186 m) in 1960-1961 to N5,280 m ($9,267 m) in 1973-1974. During this same period, the annual demand for electric energy increased from 360 GWh to 2,038 GWh. These figures represent a 6.3 percent annual growth of GDP and a 14.3 percent annual growth of electric energy consumption during the 13-year period. These figures should be seen alongside the annual growth of the GDP and electric energy consumption of 4 to 8 percent in the industrialized countries.

From the above, it is very clear that energy supply is an essential and vital input into national economic growth. Indeed, as the economy takes off from a simple agricultural base and becomes increasingly mechanized and industrialized, the farms and the factories will require increasing amounts of energy.

All these points show the need for a comprehensive policy on energy which would seek to systematically assess the national energy resources and reserves, and to draw up short-term, medium-term and long-term strategies for exploring, exploiting and utilizing the different and various resources for the purposes for which each is best suited in the overall national interest. Because some resources, such as petroleum products, coal and uranium, are major foreign exchange earners, the role of energy resources as sources of funds for the implementation of national development programs must also be considered in drawing up an energy policy. Equally important are the uses of some resources in fields such as food production and health care. Thus, an energy policy must be both theoretically sound and practically feasible. It must take into consideration both the socio-economic and political climate of the country in which it is to be operated.

Nigeria is known to be rich in petroleum products, coal and uranium. Despite this fact, it is essential that some diversification be encouraged, particularly in view of the fact that these resources are depletable. For example, it sounds reasonable that water heating and crop drying should employ solar energy where applicable. Other resources also have some part to play in the energy spectrum. Of course, these applications must be relatively economical, the overall objective being to improve the standard of living of the average Nigerian to a level not too low when compared with industrialized countries.

The main primary sources of energy in Nigeria are firewood and other dead plants, coal, oil, natural gas and hydroelectric. Other sources, mostly untapped, include nuclear and the various renewable sources.

The above sources are extensive in quantity so that in the context of available resources and their exploitation the situation in Nigeria is very encouraging. However, a realistic policy is required to ensure that each source is utilized in the most practical and economical manner.

HYDRO POWER

Among the 14 identified new and renewable sources of energy, hydro power is the one most widely used in Nigeria. Hydro sources form the mainstay of electricity supply in Nigeria. The story of the development of electricity supply in Nigeria is closely linked with the development of hydro sources.

Figure 1 shows the historical development of electricity sales in Nigeria. In the period 1951-1952 to 1976-1977, the sales grew from 54 GWh to 3,266 GWh, at an average annual rate of increase of 18 percent. This phenomenal growth, resulting in a demand doubling almost every four years, was interrupted only during the civil war. In the first years of the post-war period, extraordinarily high growth rates were experienced, due to the backlog demand. In the period 1972-1973 to 1976-1977, a certain stabilization took place with a growth rate of 17 percent, approaching the long-term average.

The very high demand growth resulted from the simultaneous action of two factors. First, the number of consumers grew from approximately 37,000 in 1951-1952 to almost 600,000 in 1976-1977, at an annual rate of increase of 12 percent. Second, the average sales per consumer in that 25-year period grew as well, at 5 percent annually from less than 1,500 KWh to almost 5,500 KWh.

In 1976-1977, most load centers were connected to the National Grid and only a small number of towns received power from isolated diesel power stations. Maximum demand in the National Grid exceeded 700 MW in that year.

In the first part of 1977-1978, the electricity consumption continued growing rapidly. From April to October 1977, an increase of more than 20 percent over the same period of the previous year was recorded. This development was interrupted in November 1977, when drastic load shedding had to be introduced in the entire power system. The reason was an unfortunate coincidence of an extreme drought period, reducing the power output of Kainji, and a delay in the implementation of a large thermal power station at Sapele. The situation normalized in September 1978, when additional thermal capacity was commissioned at Afam, Ijora, Sapele and Ughelli. The maximum demand started to grow again and exceeded the 1,000 MW mark in April 1979.

Load Forecast

Various facts indicate that electricity consumption in Nigeria is likely to maintain a high growth rate in the future. The present per capita consumption is very low compared with other West African countries:

Country	KWh per capita
Nigeria	60
Senegal	110
Ivory Coast	180
Liberia	230
Ghana	390

The bulk of consumption is concentrated in the Lagos area, with almost 50 percent of the total sales and more than 90 percent of the population having access to electricity service. In the rest of the country, the consumption is low. The service coverage for all the country is estimated at 20 percent only. This will improve in the near future, as soon as the extensive countrywide electrification program is completed. Another stimulus for demand growth will stem from the numerous large energy-intensive industrial projects, such as steel mills, and cement works, which are either underway or firmly committed.

The latest load forecast elaborated by the National Electric Power Authority (NEPA) reflects the impressive social and industrial development Nigeria is undergoing. According to this forecast, the maximum demand in the National Grid will grow from 705 MW in 1976-1977 to 4,040 MW in 1986-1987, at an annual rate of increase of 19 percent. Even with such a high growth rate, the average per capita consumption will reach only a relatively modest figure of about 250 KWh at the end of the forecast period, which is still substantially below the present consumption level in Ghana. This indicates that the load forecast is by no means exaggerated.

Large-Scale Hydro Plant

The hydroelectric station at Kainji has been the backbone of the generating system. Its installed capacity was extended several times and has reached its final stage of 760 MW now. Recently, additional gas turbines have been installed at Ijora, Afam and Ughelli (Delta), bringing their available capacity to 95 MW, 246 MW and 312 MW, respectively. A large 696 MW steam power plant has been constructed at Sapele. All these generating capacity additions will correct the hydro/thermal balance in favor of the latter and prevent the power supply from events similar to those experienced in 1977 and 1978. Sufficient thermal capacity will be available for the base-load operation backing up Kainji which, in accordance with its design characteristics, will be used to cover intermediate and peak loads.

With 760 MW at Kainji, 653 MW at the gas turbine stations at Ijora, Afam and Ughelli, and 696 MW at Sapele it will be possible to cope with the growing demand until 1980-1981. In that year, a further capacity addition will be required in order to have an adequate reserve. NEPA established the following expansion program for the early 1980s:

1980-1981	Gas turbine plant at Sapele (300 MW)
1982-1983 to 1983-1984	Shiroro Hydoroelectric Plant (600 MW)
1983-1984 to 1984-1985	Jebba Hydroelectric Plant (540 MW)

A comparison of the capacity of the existing and committed power stations, minus the required reserve, with the forecast maximum demand shows that there would be a reserve capacity deficit of approximately 300 MW in the years 1981-1982 through 1983-1984. NEPA is discussing appropriate measures, such as the installation of additional thermal units, to eliminate that deficit.

From 1984-1985 onwards, the current plant program no longer will be sufficient to cope with the rapidly growing demand. Major generation system expansion is therefore necessary. The hydroelectric projects under study have too long a lead time to be considered before 1986. Consequently, the only solution is to build a large thermal power plant with an installed capacity of about 1,000 MW. Preliminary studies indicate that the power plant should be located in the Lagos area, where the main load is concentrated, and should use gas transported by a pipeline from the oil fields in the Niger Delta.

With this large new thermal power plant, it will be possible to meet the incremental demand up to 1985-1986. In 1986-1987, a further major extension will be required. To this end, NEPA is considering various hydro options, including a 1,770 MW plant at Lokoja.

Small-Scale Hydro Plant

Much has been written and read at conferences on various sources of energy to help solve the energy requirement of the nation. The development of large hydroelectric schemes, a renewable source of energy, also has been given adequate coverage. Some specific projects, notably Shiroro and Jebba Schemes, have been translated from the drawing board to actual construction with millions of Naira being made available to sustain these projects, while Ikom and Makurdi are yet to be awarded and the Lokoja scheme is being considered in spite of the numerous environmental impacts. Small hydro power sites in Nigeria always have been recognized as capable of providing a very useful source of energy, but the development of such schemes has not received the attention it deserves apart from the one harnessed by private enterprise for electricity generation on the escarpment of Jos Plateau.

Hydro power generation on Jos Plateau dates back half a century, when a 2 MW station was commissioned at Kwall Falls on N'Gell River, a tributary of Kaduna River, situated about 28 kilometers west of Jos. Also at Kurra Falls, about 60 kilometers southwest of Jos, a 4 MW station was built using the impounded water at the confluence of rivers Tenti and Gnar, which flows into River Sanga and eventually joins other rivers to flow as a tributary of River Benue. The increase in energy demand, especially for the tin mining industry on the plateau, led to development of both schemes, at Kwall to 6 MW and at Kurra to 19 MW. To achieve this increase in generation and to enable generators to operate at increased load factors, a number of impounding reservoirs have been created by constructing dams.

The Kurra Scheme utilizes Tenti Dam, Ankwil Dam and a small diversion dam at the upper section with two power stations, Kurra Dam at the middle section with one power station, and two diversion weirs with two power stations at the lower section in the Jekko area. It is interesting to note that through the long dry season, during which no rainfall occurs for about five months, the same water impounded at Tenti Dam that passes through the first generator at the first Ankwil Station also passes through the remaining four stations down the line, thereby generating electricity at five stations before it finally runs off into Benue River.

As for the Kwall Scheme, it utilizes Kwall Stream Dam, Gyell Dam and Ouree Dam on Ouree River, which is approximately 6 kilometers south of Gyell River. A canal of nearly 11 kilometers in length conveys water from the Ouree Dam to Kwall Stream reservoir. The impounded water permits operation during four to five months of dry season at an average monthly load factor of 23 percent.

Apart from the existing schemes described above, the Plateau State has other small potential hydro power sites, including Sha Falls (which could be developed by N.E.S. Co.), and the Shemankar and Mada rivers, which could be developed with Lower Benue River Basin Development Authority schemes.

It is estimated that the total electrical energy that can be provided from existing schemes and schemes for which full hydrological investigation has been completed in the Plateau State is some 300 million KWh per annum. Other sites that have not been investigated will possibly have a further development potential of between 200 million and 300 million KWh per annum. Furthermore, the cost per installed kilowatt of capacity in some of the schemes examined is cheaper than the installed cost per kilowatt of the much larger hydroelectric projects.

Consideration certainly should be given to a reappraisal of government policies, which over the past 15 years have inhibited the development of small hydroelectric power schemes by the private sector.

Potential small hydro power resources are not peculiar to Plateau escarpments in Jos or Mambila, but such resources include:

- River sites, with or without dams, where sufficient specific hydraulic capacity exists and where powerhouses and related structures can be built.

- River sites where small dams are built for flood control, navigation, irrigation or recreational purposes.

- Existing structures on irrigation or water supply canals (with particular reference to the installation of bulb-type turbines on the outlet valves of such canals and dams).

There is no area of Nigeria which does not have at least one of the above resources, judging from various irrigation schemes, but we have failed to harness them for hydro power generation. Small low-head or high-head hydro power facilities are available and turbines could be designed to match various water-flow conditions.

There are few constraints to the implementation of small hydro power generation in Nigeria, which may be summarized as follows:

- Lack of coordinating bodies for water resources. (A new water resources body was inaugurated recently.)

- Lack of technical manpower to carry out feasibility studies and to design, construct and operate small hydro power stations.

- Economic constraints.

It is hoped that the recent establishment of a National Council on Water Resources will go a long way to removing the constraints to the implementation of hydro power generation. It will be necessary to seek international cooperation to provide technical assistance, the development of manpower and finance in the form of long-term direct loans to finance development.

SOLAR ENERGY

Of the various new and renewable sources of energy, perhaps solar energy is the most promising for widespread application in Nigeria. Lying approximately between latitudes 4^{o}N and 13^{o}N as it does, there is hardly anywhere in Nigeria where the length of day is shorter than 11 hours. Although it is recognized that the lengths of actual sunshine hours are less because of cloud cover, there is definitely sufficient time all year for solar devices of some type to be put to use anywhere in Nigeria. On the average, the yearly total solar energy falling on a horizontal surface in Nigeria is about 2,300 KWh per square meter with an average of more than 2,000 hours of sunshine per year and relatively little seasonal variation, particularly in areas remote from the coast.

It should be mentioned that there have been a number of traditional uses of solar energy in Nigeria. Such applications include:

- Crop-drying by direct exposure to the sun.
- Drying of clothes and other wet materials.
- Drying of mud-blocks used in construction.

The above list is by no means exhaustive, but the uses are all attended by the same problem -- efficiency of operation. To improve the efficiency of utilization of solar energy, more modern methods will have to be employed.

Current Work on Solar Energy Development

Most of the work on solar energy utilization in Nigeria has been undertaken by individuals in the universities and polytechnics, and such research and development agencies as the Federal Institute of Industrial Research in Lagos and the Project Development Agency in Enugu. A number of experimental units have been built and tested, but the stage of commercial production of solar energy devices has not been reached in Nigeria. A few items have been imported and are working, but only as demonstration models. It is expected that the on-going developmental work and the attendant publicity soon will lead to some local manufacture on a commercial scale.

It is worth noting here that a Solar Energy Society of Nigeria has been formed recently. Such a body will increasingly provide a forum for sharing experiences among workers in the field of solar energy application.

It is necessary to identify solar energy applications suitable for Nigeria. In exploring these prospects, the following direct uses are relevant:

- Heating of water for domestic and industrial uses.
- Space heating.
- Cooking.
- Drying of agricultural and animal products.
- Refrigeration.
- Space cooling.
- Desalinization.
- Electricity generation -- thermal and photovoltaic.

The items in the above list have not been arranged in any particular order. An attempt will be made to expand on the above topics.

Water Heating

Solar water heating is perhaps one of the oldest and most developed of all applications. Hot water is widely used in homes for bathing and for washing clothes and dishes. There is little definitive data on the extent to which homes in Nigeria actually need hot water, but it is safe to say that given the hot climate in Nigeria, hot water requirements for bathing will be minimal although it is noted that modern homes, particularly in the urban areas, are frequently equipped with electric water heaters for this purpose. It is conceivable to expect a good market for solar water heaters in these areas, if only to reduce the pressure on the use of fossil fuels.

Perhaps a better use may be found for solar water heaters in Nigeria if the hot water is used for cooking and for washing and other sanitary functions. These duties will be particularly appreciated in rural areas where conventional forms of energy are not easily available.

Large-scale uses of solar water heaters also can be envisaged for hospitals, hotels, schools and industries. Industrial applications can extend to use of solar-generated hot water for processes or as feedwater for process water heaters.

The technology of solar water heaters already is well developed and the prime need in the Nigerian scene is for local adaptation that takes account of such constraints as inadequacies in the range of material available for construction, limitations in practicable fabrication techniques and the ready acceptability of such devices. Considering the fact that conventional fuels are relatively cheap in Nigeria, the aim must be to produce solar water heaters that are economically competitive with the present conventional alternatives.

Drying of Agricultural Products

The aim in crop drying is to achieve a low level of moisture content so the crop remains stable in storage and is easier to handle. The use of the sun to dry crops is an ancient practice and is widespread. Thus, in Nigeria, such crops as cocoa, groundnuts (peanuts), corn, yams and lumber are dried by spreading them out in the sun. The technique is simple, cheap to use and, to a large extent, effective. However, it has some serious limitations. When crops are directly exposed to the sun, they are open to infestation by insects, dust and vermin. They also are exposed to elements other than the sun, such as rain.

The use of solar dryers ensures that the drying takes place in protected surroundings and under controlled conditions, generally resulting in enhanced quality of the dried product. Solar drying can be extended to protein products, such as meat and fish, which would otherwise deteriorate rapidly in storage if attacked by flies during the exposed drying stage.

Perhaps the main constraint in the use of solar dryers is socio-economic in nature. Specifically, solar dryers are relatively expensive. Prices can only be brought down by the use of locally available materials of construction and the development of local fabrication expertise. Also, there is need for public education about the capabilities of solar dryers and, most importantly, an assurance that the quality of the dried product is not inferior to that obtained from traditional drying techniques. This is particularly necessary for cash crops such as cocoa and groundnuts. The farmer must be assured that the products are good and the end-users also must be assured that the finished products, such as chocolates, are in no way inferior to those obtained from the traditional drying techniques.

Distillation of Salt and Brackish Water

Although there are hardly any inland brine lakes in Nigeria, distillation of water can be useful in the coastal rural areas of Nigeria. These areas, particularly in the riverine areas of southern Nigeria, are not readily accessible and hence are mostly devoid of basic infrastructural facilities. Family- or village-size solar stills can be quite cost-effective. This is also true of several remote areas of Nigeria where dirty water is available.

Perhaps some byproducts of solar desalinization may be profitable. Notable among these is the production of distilled water for batteries. In Nigeria, in recent times, the cost of distilled water has risen sharply, coupled with a sharp decline in quality. Another byproduct, common salt, also may be feasible although more work needs to be done on this.

Space Heating

Although the weather in Nigeria is generally hot, some areas do require space heating, particularly in the Harmattan season. Some areas, such as Jos Plateau, are generally cool throughout the year. While there may be few active heating requirements, it will be most appropriate to develop techniques of passive heating for these areas.

Perhaps the constraints to the use of passive space heating have to do with the lack of the required technology. This will have to be overcome. Also builders and architects will need to be fully informed about how to integrate this system into modern as well as traditional architecture.

Space Cooling

There is a need for cheap cooling methods all over Nigeria. The popular vapor compression air conditioners are either too expensive or there is no electricity supply to drive them. As attractive as mechanical solar air conditioning appears to be, it is not likely to gain much favor in a developing country like Nigeria. Thermal systems are so capital intensive they are rather unattractive in economic terms.

Short of a drastic breakthrough, perhaps further developments in photovoltaic devices may put solar air conditioning within the reach of the rural dwellers. This is still several years hence.

However, passive cooling systems may go a long way to improving the comfort of Nigerians. The technology should be further developed locally.

Solar Refrigeration

Solar refrigerators are attractive for large-scale applications in long-term food preservation and for storage of various items, such as biological and medical materials. Considering the costs of solar refrigeration systems, farmers and other rural dwellers may have to form cooperative units for use of central refrigeration facilities.

Cooking with Solar Energy

Sociological considerations are likely to limit the widespread use of solar cookers in Nigeria.

Electric Power Generation

The technologies for electric power generation from solar energy are fairly well established. However, solar power plants are capital intensive and it may be many years before higher final costs and improvements in the pertinent solar technologies will make solar power generation economically viable.

In Nigeria, electric energy sells for about 6k (about 10¢) per kilowatt/hour. Any viable solar system will have to match this figure. Such a system necessarily will include storage devices and a distribution system.

However, there are several isolated areas of Nigeria not served by the grid system. They may use solar systems based on photovoltaic conversion profitably. Other uses in remote areas include railway signaling systems and telecommunication systems.

Industrial Applications

Although industrialization is in its infancy in Nigeria, some thought is being given to the conservation of depletable energy sources. To this end, and apart from the use of solar-generated heated water for washing and other domestic chores, hot water can be generated for process work or as the feed water for process water heaters.

Water Pumping

Perhaps the most noble use of any form of energy is for the provision of water for drinking and for irrigation. Large tracts of land are now not arable because water is not available. Governments have continued to spend large sums of money through the establishment of river basin authorities and other means mainly for the purpose of providing potable water for millions and irrigation water for the farmlands. As laudable as these ventures are, they are not really sufficient because of the vast expense involved. Solar energy is being thought of as a means of providing this essential service to the rural dwellers. While thermal systems may be rather expensive now, it is quite conceivable that systems based on photovoltaic conversion can be cost-effective. Some experimental pumping units have been installed in various parts of Nigeria with reasonable results. More work needs to be done in this all-important application.

BIOMASS

In the context of this energy source, consideration is given to fuel wood, charcoal and the organic fluids -- ethyl alcohol and biogas.

Fuel Wood

Fuel wood is not only the most popular biomass fuel in Nigeria. It is also the most widely used of all fuels, accounting for more than 40 percent of the total energy consumed. Annual consumption figures are not easy to come by, but an estimate of about 70 million cubic meters (about 38×10^9 kilograms) of wet wood is thought to be a minimum. Its use is not only confined to the rural areas, but also extends to the highly urbanized centers such as Lagos, Ibadan, Kano, Kaduna and Enugu. It is, without any doubt, the major fuel for large-scale domestic cooking and several small-scale industries (such as bakeries).

To supply the fuel requirements, fuel wood plantations have been established in Nigeria since about 1912. These are now supplementing the wood obtained from forests and assisting in fighting the environmental problems of deforestation and desertification. Unfortunately, however, the pressure on land utilization has tended to reduce the plantations.

Perhaps the main problem associated with the use of fuel wood is the fact that the fuel wood recovery appliances -- stoves and combustion chambers -- have remained crude. Conversion efficiencies are low (less than 8 percent) and pollution is intense. In spite of all these drawbacks, fuel wood is still the cheapest and naturally the most popular. Figures for Ibadan, a large town in Nigeria, indicate that fuel wood energy costs about 10.6k/MJ, while the corresponding figures for charcoal, bottled gas and kerosene are 29.73k, 30k and 49k/MJ, respectively.

Charcoal

Charcoal burning is a rural art, although its use is confined to the more urbanized areas because, in its best form, it is essentially smokeless. While its use is mostly confined to small-scale domestic cooking, some special charcoals are used by local blacksmiths and goldsmiths. Charcoal production is effected in earth kilns in the forests (particularly in the denied savanaahs) where it often constitutes a fire hazard. Recovery is very poor and some work in a Nigerian university has obtained only 11 percent of the over-dry weight of wood instead of the anticipated value of about 30 percent.

Unless there is more work in this line, it is unlikely that charcoal will contribute much to the energy growth of Nigeria.

Production of Ethyl Alcohol

This source of biomass energy has not been investigated thoroughly in Nigeria, although the country is rich in molasses, cereals and palm products, from which it frequently is derived. In 1972, more than 2 million cubic meters of raphia palmwine was produced in the delta area of Nigeria alone. It is quite conceivable that this figure has increased since. Some of this could be processed easily and converted to alcohol although tremendous competition should be expected from the numerous palmwine drinkers.

Bio-Methane

Some laboratory work has been reported in the area of anaerobic bacterial digestion of organic wastes for biogas production. Several plant and animal wastes and manures have been screened for their ability to generate methane gas, and some prototype plants have been built on a laboratory scale. A notable raw material for biogas production in Nigeria is siam weed (Eupatroium Odoratum), a powerful and ubiquitous weed which often threatens valuable vegetation because of its high competitive capacity. For example, siam weed has been found to generate about three times the amount of biogas produced from water hyacinth per kilogram dry weight per day.

Contribution to the Agricultural Sector

Fuel wood already is being used in crop processing. There is, however, an immediate need to develop biogas for the same purpose, particularly in the areas where livestock is available.

The development of the production of ethyl alcohol in rural areas and later methanol production is quite feasible. These would then be readily available to fuel some cultivation equipment. The use of alcohols, blended or unblended, may not be economical now, but with the rising cost of oil it eventually may become so. It will also confer independence in fuel resources to the rural areas and agricultural operations in particular.

Contribution to Domestic Energy Utilization Sector

Domestic energy requirements can be almost fully served by biomass products, especially in the rural areas. Already, firewood is being used for cooking. Biogas can satisfy basically all domestic energy needs. Liquid fuels, such as pyrolytic oil and alcohols, also can run various prime movers. There are mobile pyrolysis plants for wood and lignocelluloses.

Industrial and Commercial Sector

This is an energy-intensive area, and petroleum products will long remain the main source. Supplements, however, would be available from several sources, including biomass. Refuse-derived fuel is an essential development that will not only help to improve the urban environment, but also will provide energy for generating electricity or gas. In the long run, this is likely to remain the only viable method of waste disposal.

In agro-based industries, the utilization of wood wastes and agricultural residues has a good potential to raise process steam and steam for powering mobile plants. The greatest contribution will be the liquid fuels, particularly the alcohols. As a future alternative, the crude alcohol distilling technologies now practiced need to be refined to supplement energy needs, particularly for rural industries.

Associated Problems and Methods of Containing Them

Deforestation is a great danger in uncontrolled utilization of wood as fuel. This leads to desertification and soil erosion in the sahel and rain forest areas, respectively. The only national solution is to ensure a sustained reforestation program to supply not only fuel wood requirements (now standing at about 90 percent of total removal) but also other industrial wood requirements. Special efforts are required on raising the more potential tree species, including the Euphorbia species, which may be a basic raw material for liquid fuel production from biomass in the future.

The wood-burning stoves in use for domestic purposes are very inefficient and pollution-ridden. The level of technology required to improve on these is well within the reach of the country's human and material resources.

Large-scale production of methanol and ethyl alcohol may require the use of some basic food crops, such as cassava and cereals, as raw materials. This is likely to make these scarce food crops more expensive, and should be preceded by greater efforts at production of these crops. Efforts also could be directed towards the utilization as raw materials of other forest products that are not popular food crops.

Most of the appliances available are imported and are not specialized to utilize fuels other than petroleum products. It is known, however, that for several products, modifications can be made on the fuel injection/carburization systems of existing appliances to run on novel fuels.

General Recommendations

Biogas technology should be introduced immediately, and appliances to utilize these should be produced locally. This should be a viable commercial proposition.

Improvements in all wood-burning stoves should be effected and commercialized. Charcoal-burning kilns should be designed and commercialized. They should be capable of improving the percentage of charcoal recovery and the possible recovery of other fuels -- gas and oil. The design also should reduce the current serious forest fire risks in existing earth charcoal kilns.

The existing methods of fermentation and distilling of alcohols should be upgraded and newer raw materials should be examined.

Refuse-derived fuel should be introduced, especially into the urban areas. Reforestation is essential. Forest lands should not be unduly reduced. Plantation of special tree species and shrubs should be undertaken. Work also should commence on the technology of extracting liquid fuels from plants.

WAVE AND TIDAL ENERGY

Although a vast quantity of exploitable energy in the form of waves and tides abounds along the coastal areas of Nigeria, no attempt has been made to harness it for useful purposes. The situation is likely to remain so for the foreseeable future.

The constraints are generally as detailed for the other renewable sources of energy:

- Lack of detailed studies of waves and tides, and practically no data on basic parameters.
- Lack of information about the potential of waves and tides as viable sources of energy.
- High cost of power plants based on waves and tides.

The future use of wave and tidal energy in Nigeria will depend to a large extent on the formulation of an energy policy for Nigeria and the building up of a suitable data bank. Also, concerted efforts will have to be made at building up the technological manpower to design, build and operate the relevant systems and items of equipment and machinery. In this regard, the universities, colleges of technology and various research institutions will need to be properly funded with local and international participation to take on this assignment.

GEOTHERMAL ENERGY

Thus far, very little thought is being given to the development of geothermal energy in Nigeria. This is in spite of positive indications of several potential sources, particularly at Ikogosi in Ondo State, the Kerri Kerri Formation near Maiduguri in Borno State, Abakaliki in Anambra State and in the Niger Delta subsurface. In some of these sources, the surface temperature of the warm springs is 15^{o}C higher than for other surface waters in the relevant area, while temperatures of more than 80^{o}C have been recorded in some shallow boreholes. Nigeria's geothermal energy resource base is particularly large when one considers the existence of several thick highly pressurized aquifers with temperatures in excess of 120^{o}C in the Niger Delta subsurface. This is comparable to the setting in the Gulf Coast of the United States.

The successful exploitation of Nigeria's geothermal resources will have to await detailed studies aimed at providing the necessary data base as well as full feasibility studies of possible applications. Decision on the exploitation will have to await a comprehensive energy policy for Nigeria, although preliminary work must be done to obtain much-needed information.

WIND ENERGY

Nigeria is well-suited to the use of wind energy. Very little work has been done in this line, although isolated windmill-driven water pumping stations have been installed in some coastal areas of the south and in the northern parts of the country. Some of these installations, such as those in Badagry and some other coastal areas near Lagos, were installed more than 25 years ago. With the introduction of conventional electricity supplies, these units have gone into disuse and are now museum pieces.

Data on wind properties abound with the Meteorological Department. All that is needed is a collation and analysis of data for engineering purposes. Specific applications will be for water pumping for domestic, agricultural and industrial use, and for electricity generation.

Work has been done in some of the universities relating to windmills, particularly the Savonius Rotor using the normal oil drums.

MEASURES TO OVERCOME CONSTRAINTS

Institutional and Policy

Nigeria needs to define a comprehensive national energy policy that will include a policy on new and renewable sources of energy. To this end, the federal government of Nigeria recently instituted an Energy Commission of Nigeria, which shall be responsible for the strategic planning and coordination of national policies in the field of energy. It will:

- Serve as a center for gathering and disseminating information relating to national policy in the field of energy development.

- Serve as a center for solving any interrelated technical problems that may arise in the implementation of any policy relating to the field of energy.

- Advise the government of the federation or a state about questions relating to aspects of energy.

- Prepare, after consultation with government agencies in the field of energy development or supply, periodic master plans for the balanced and coordinated development of energy in Nigeria. The plans shall include recommendations for the exploitation of new sources of energy and other recommendations relating to its function.

- Lay down guidelines on the utilization of energy types for special purposes and in a prescribed sequence.

- Inquire into and advise the government of the federation or of a state on the financial needs of energy research, and ensure that adequate provision is made for this in relevant energy departments of the commission.

- Advise the government of the federation or of a state about grants and other financial disbursements to authorities charged with production and distribution of energy and similar institutions in Nigeria.

- Collate, analyze and publish information relating to energy from all sources, where such information is relevant to the discharge of its functions.

- Carry out other activities conducive to the discharge of its functions.

The commission is all-embracing and very powerful. When it becomes fully functional it is expected that most of the energy constraints listed would be adequately tackled.

It is pertinent here to mention other governmental institutions in the field of energy:

- The Federal Ministry of Mines and Power is charged with the overall policy aspects of solid fuel recovery and power generation.

- The Federal Ministry of Science and Technology is the ministry that oversees general research and development works in science and technology. One of the five divisions of the ministry looks after industrial and energy issues.

- The Nigerian National Petroleum Co. Ltd. is a public company charged with the exploration, exploitation and marketing of petroleum for domestic consumption.

- The National Electric Power Authority is a public corporation and the sole authority for the generation, transmission and distribution of electrical power.

- The Ministry of Water Resources is charged with policy aspects of water resources utilization.

- Nigerian Electricity Supply Co. is an old private company located in the Jos Plateau. This company has a history of efficient electricity supply using small-scale hydroelectric plants.

- In addition to the above, most of the 19 states have institutions charged with energy responsibilities.

Inadequate Data Base

One of the early activities of the Energy Commission will be establishment of data banks about new and renewable sources of energy. The data should include the energy demands of the people, the available energy sources and their distribution, and the social and economic acceptability of the resultant applications.

Financing

Government should commission feasibility studies for new and renewable source applications. Thereafter, government should consider various financial incentives, such as tax rebates and tax exemptions, which would make new and renewable sources of energy devices competitive with conventional means. Such incentives will induce the private sector into entering the new field.

Banks and other financial institutions should initiate new methodologies for financing new and renewable sources of energy projects, and the fiscal policy should be reassessed.

In view of the fact that applications of new and renewable sources are particularly suited to the rural areas, government should, as a matter of course, finance integrated new and renewable sources of energy schemes for rural communities. This way, the potential of the schemes can be demonstrated at the grass-roots level, while generating the required technology for constructing and operating the various devices.

Research and Development

Research and development efforts need to be stepped up and adequately financed. Efforts should be directed at organizing well-coordinated research and development, as well as demonstration programs.

Information Flow

The flow of relevant information needs to be improved considerably. There should be massive educational programs aimed at creating public awareness and employing all facets of the mass media. Information leaflets, pamphlets and brochures describing in nontechnical language the stories of new and renewable sources of energy appliances and plants should be distributed freely. To augment this, carefully planned and selected demonstration projects should be mounted all over the country, with care being taken to ensure the suitability of each project to the area where it is being mounted.

The relevant organs of government should prepare, for easy reference, technical feasibility and economic viability reports of various new and renewable sources of energy applications. These should be made available to planners and decision makers.

Government should encourage the organization of conferences, seminars and workshops as a means of creating avenues for discussion among specialists in the field. Educational institutions should include energy studies in their respective curricula.

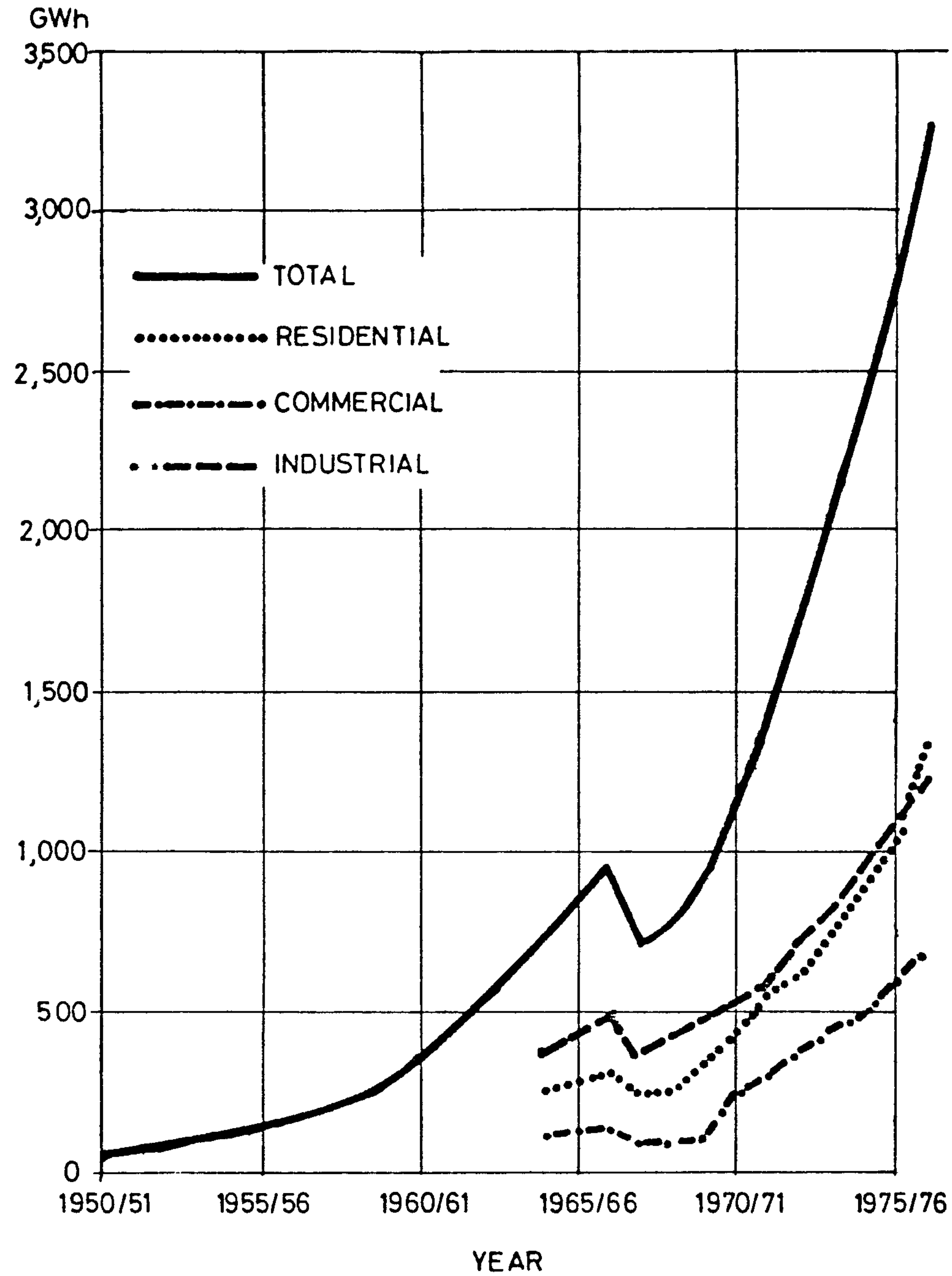
Education and Training

Training programs should be organized for managers, decision makers, architects, engineers, technicians and artisans. Special emphasis should be given to training in materials, sciences and technology.

Transfer of Technology

Emphasis now should be placed on cooperation rather than pure transfer of technology. Efforts should be directed at adaptive technology and the building up of the necessary design competence and fabrication infrastructure. Generally, very little technology is ever transferred. On the other hand, it can be acquired and adapted to suit local conditions.

FIGURE 1. HISTORICAL GROWTH OF ENERGY SALES



Pakistan

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INTRODUCTION

Pakistan is not as fortunate as the 28 developing nations that are net exporters of crude oil (such as China, Indonesia and Nigeria) but is better off than the 64 countries that have to rely on imports of petroleum crude and products for up to 75 percent of their energy requirements. Pakistan is 68 percent self-sufficient in its energy requirements, with about 40 percent contributed by natural gas. Total natural gas reserves are more than 10 trillion cubic feet. Five percent of total energy is in the form of indigenous production of petroleum crude, and there is the potential to become self-sufficient in the future. Coal, with proven reserves of more than 450 million tons, provides 6 percent of the indigenous sources with the balance from hydroelectric.

Pakistan has to import about 32 percent of total energy requirements as petroleum crude (20 percent) and deficit products (12 percent), namely high speed diesel, kerosene oil, 100 octane gasoline, light diesel oil, lube oils and some aviation spirit. Pakistan's energy needs, in terms of secondary source, are met up to 28 percent by electricity, which has 45 percent hydroelectric generation with the balance being thermal. The present capacity is 3,500 MW, with generation of about 30,000 million KWh. By the end of the current plan period -- 1983 -- the hydroelectric generation capacity is expected to increase by 84.8 percent, with an additional 250 MW generation capacity using coal as the primary energy source in the next plan period.

High speed diesel is consumed up to 65 percent in public road transport with 8 percent by railways, 15 percent in agriculture and the balance in other uses. The second largest consumption is of kerosene. Ninety-five percent of kerosene use is in the domestic sector, because it is the principal source of fuel, light, and operating oil for heaters in winter and refrigerators in areas where electricity is not available. The 100 octane gasoline is consumed in the transportation sector, and so are lubricants. Light diesel oil consumption varies with rainfall and is used principally in the agriculture sector.

Pakistan has connected more than 13,000 villages out of 45,000 villages and many thousands of settlements with the national grid. The villages connected generally have more than 1,000 houses and a population of more than 6,000, while the settlements contain 50 to more than 100 houses with an average of two or more cattle per family. The supply of energy to the rural areas always has been a priority with the government of Pakistan. Lack of energy availability contributes reasons for the rural population to migrate to cities, more in search of better environments and conveniences than incomes -- thus, energy has a strong bearing on rural life and its environment.

For the meager 32 percent of its energy need as oil imports, Pakistan paid $1.2 billion in Fiscal Year 1979-1980. The current bill will touch $1.5 billion or more. This constraint has to be reduced. Along with energy conservation measures, the development and deployment of new and renewable sources of energy plays a critical role in the future needs of the country more in the context of the domestic sector than industrial needs.

POTENTIAL FOR NEW AND RENEWABLE ENERGY

Pakistan has substantial resources for renewable energy systems. It has more than 2,500 hours of sunshine each year. The biogas production based on animal waste has a total potential of 150 billion cubic feet per year, which can yield biogas for cooking, produce 350 MW of electricity and provide 6 million tons of improved and enriched dry manure free from harmful microorganisms that otherwise cause plant diseases or become a source of insect breeding. Winds are inconsistent, having a velocity range of 5 knots to 16 knots across the country. The mean monthly average wind speed for coastal areas is in the range of 8 to 14 knots with an average of 4 knots in other areas. In these areas the wind storm is a frequent performance of changing weather in the country.

In view of the mentioned facts, new and renewable sources of energy, both for future energy and present energy needs, play a vital role in terms of compact energy systems to the rural population (which constitutes more than 70 percent of the country's people). The role of renewable energy in filling rural requirements would be:

- Fuel for domestic consumption, and energy for electricity to supply light and water for drinking and irrigation.
- Production of enriched manure, which could increase the present low yield per acre by 25 to 35 percent, particularly in rain-fed areas via anaerobic fermentation of animal waste and agricultural byproducts.
- Improve the environments and social conditions of villages to discourage migration to urban areas.
- Provide energy for cottage industries and appropriate the cottage industrial system.

ENERGY PROJECTS

To achieve the above objectives, Pakistan has developed the concept of Energy Centers. These are villages or settlements that have raw material for biogas production and wind for conversion to energy as a fuel for cooking, heat, electric generation and water pumping. In addition, Pakistan has undertaken cultivation of quick maturing firewood trees to supplement the fuel requirements of the villages. The deployment of new and renewable sources of energy achieves a greater significance when it is seen that biogas production potential alone can substitute the deficit imports of kerosene in the country. In addition, bio-electrification successfully achieved in Pakistan in June 1980 could further supplement the electricity requirement in the rural sector.

In the urban sector, renewable energy can play a vital role in domestic use, with deployment of solar water heaters and solar water cookers reducing consumption of natural gas and lowering household energy bills. Sewage treatment and anaerobic treatment of industrial wastes could produce large quantities of biogas, which could supplement the fuel generators of electric supply or meet the needs for fueling in the semi-urban areas. Also it would improve the environmental conditions of cities, and make the atmosphere free from pollution. Pakistan gives first priority to biogas production both from agriculture byproducts and animal waste. This concept is extended to production of biogas in cities from industrial waste and urban refuse. Pakistan's principal experience in biogas has been in research, development and deployment. After setting up more than 100 biogas units, starting with family biogas units with 40 cubic feet per day capacity, it has standardized the family biogas unit at 150 cubic feet per day. In the process of developing the family biogas unit to meet the requirements of one family with up to eight family members, it has designed its own community biogas system that uses thermophilic anaerobic process conditions with solar thermal heat generating higher process temperature. The first community biogas plant, with a capacity of 2,000 cubic feet per day, was commissioned in March 1980 and bio-electrification was achieved in June of the same year. This system, successfully deployed in a village having 52 houses and a population of 400, with more than 300 head of cattle, has been termed a Compact Biogas System (CBS). A project is underway to install Compact Biogas Systems in 160 villages in three years, by which time it is expected that the farmers would see and feel the benefit of the system and make their own investments. The government, having seen the success, has made liberal allocations for development and deployment of the Compact Biogas System.

Solar energy is the next vital source. Pakistan has just finalized, on a turn-key basis, establishment of its first solar village. The project calls for a capacity of 5 KWp, which shall provide light to 50 houses in a village with water-pumping and storage facilities for human and cattle consumption and for selected irrigation or vegetable cultivation. It also would provide energy to three communal television systems in the village to keep the villages abreast of the progress the nation is making and also to enable villagers to educate themselves by seeing the educational programs televised by the government. This system is complimented by a 5 KW bio-electrification system at the village.

Pakistan has a second project, under which a 20 KWp solar thermal system and 35 KWp photovoltaic systems will be set up in different ecological environments to provide compact energy supply, including water pumping for irrigation of project command areas. The third project would see installation of a 60 KWp photovoltaic system at four villages which shall deploy biogas production and wind as supplemental sources for generation of electricity. Both the above projects would start in 1981.

Wind potential also is being tapped, although Pakistan has the problems of inconsistent wind velocities. The development of wind energy is being done with greater emphasis on using wind for pumping water than for production of electricity.

Geothermal potential is being explored and some indications of such sources have been recorded in Pakistan. The likelihood of a geothermal source having potential to be used for electric generation presently is considered remote.

Tidal and ocean wave energy appears to have a very high cost-benefit ratio. Therefore, it is being pursued with last priority.

The possibilities of manufacturing photovoltaic cells through importing silica wafers could mature some time in 1981. Pakistan feels it essential that while it is developing and establishing the benefits of new and renewable sources of energy it should ensure self-reliance in technological systems and the equipment which converts the energy into usable forms.

Research alone for a developing country like Pakistan has no application unless it is practiced as applied. As these systems are being established in the villages, the related on-job training, the acceptance of a system, socio-economic gains and similar factors will be evaluated continuously. Decisions then will be made about when and how new and renewable sources of energy can become reliable and independent sources to be developed to supplement the national requirements -- initially, in the domestic sector. Pakistan does not see the renewable energy sources playing a crucial role in industrial consumption.

In view of the above, Pakistan has adopted the following strategy for development and deployment of renewable sources of energy:

Biogas

- Field research and development to continuously improve upon temperature, solid contents and similar factors that could optimize production of 1 cubic foot of gas per weight input from animal source in solids and for agriculture byproduct material such as wheat straw and rice husk.

- Develop plant designs and demonstrate benefits to achieve construction cost reductions.

- Design systems which are simple and need minimum maintenance to be operated by the rural population.

Solar

A photovoltaic system with low voltage (24 volts) would appear to resolve the energy supply situation in villages where animal waste either is not available or there is a waste collection problem.

- It would initially be limited to villages with fewer than 1,000 houses.

- It would be oriented towards providing light, irrigation, and energy for cottage wheat grinding mills, oil expellers and looms for the handicraft cottage industry.

- With local manufacturing facilities for photovoltaic cells and modules, the domestic package of a 250 to 500 watt photovoltaic system designed to meet a family's needs will be developed.

  It shall, after local manufacture, give a growing market for its annual use to reach beond 100 KWp per year in semi-urban areas and large villages.

Wind

Wind generators having a capacity of 20 KW each would be imported and tested in northern and coastal areas. Wind can make a substantial contribution, but presently it is more expensive than the solar photovoltaic system.

Wind for continuous water pumping and storage for controlled irrigation has a great potential, both in terms of costs per unit of energy and per liter of water output.

TEN-YEAR PROGRAM

The 10-year plan is shown in Table 1, and peak production costs in Table 2.

Pakistan is fortunate that it has no coordination problems at the national level because such work is coordinated by one agency, the Directorate General of Energy Resources in the Ministry of Petroleum and Natural Resources. This agency also has responsibilities of energy conservation and energy policy and planning, and is the secretariat of the inter-ministerial National Energy Policy Committee, with the federal finance minister and federal secretaries as its members. This creates a situation in which the role of renewable energy becomes acceptable to the government in a shorter time, compared with a national situation where there is duplication or overlapping of such work being shared by more than one institution in the country.

Pakistan feels that coordination and cooperation at the sub-regional and regional level is crucial if the countries are to gain expertise to develop new and renewable sources of energy most efficiently and economically. Sub-regional activity in energy is considered very vital and would include the following:

- Technical assistance on a regional and sub-regional level.

- Exchange of experts to work on on-going projects in other countries, and exchange of technical and similar information that could be of use to countries within the region.

- Financial assistance from world financing agencies, including the European Community to finance the foreign exchange costs of equipment and services on a grant basis.

- Provision of facilities such as on-job training for renewable energy engineers of member countries in developed countries which have established such systems.

- The transfer of technology should be made by developed economies to developing countries at a very low cost.

- Regional energy activities between countries having similar renewable resources and energy balances at the national level.

Developments of new sources to supplement the energy needs of Pakistan cannot be considered as a substitute for our need for nuclear generation or thermal generation of electricity, or as a substitute for liquid fossil fuel for the transport and agriculture sectors.

TABLE 1. RENEWABLE ENERGY PROGRAMS (1980-1990)

	Biogas MCFT/D by source			Solar (KWp)		Wind	
	Animal waste	Agriculture by product	Bio-electrification (KW)	Photo - voltaic	Thermal	Electric generat.	Mechanical energy HP
1980	26	--	5	5	--	--	--
1981	130	10	100	40	20	10	10
1982	250	20	200	65	20	20	20
1983	400	30	300	100	30	40	30
1984	700	40	400	120	50	50	40
1985	1000	55	600	170	90	60	80
1986	1500	70	900	220	130	80	120
1987	2000	85	1200	240	160	100	160
1988	2700	100	1500	280	190	120	200
1989	3400	120	2000	320	220	130	240
1990	4500	150	2500	350	250	150	300

Note: 1 - Each year is to be taken as fiscal year -- 1980 will mean July 1979 to June 1980, and 1981 shall mean July 1980 to June 1981.

2 - Other than government resource allocation, the foreign exchange component needed for purchase, service and equipment for a system on a turn-key basis is expected to be met by grants from world agencies and friendly countries on a bilateral basis.

TABLE 2. COST ESTIMATES OF COMPACT BIOGAS SYSTEMS

1 - Cost per cubic foot of biogas (assumed as costs payable for animal waste)

Family Biogas Unit (FBU)	=	0.91 paisa (with cost written off in one year)
Community Biogas Plant (CBP)	=	0.07 paisa (cost paid back in one year, excluding distribution cost)

2 - Cost factor in terms of kerosene oil replacement

Family Biogas Unit	=	1.94
Community Biogas Plant	=	0.025

(The kerosene price used is $485 per metric ton)

3 - Bio-electrification cost for 10 hours use/day = 1.82 paisa per KWh

Conversion: U.S. 10¢ = 1 Pak Rupee = 100 piasas

Sierra Leone

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INTRODUCTION

In Sierra Leone at present the main sources of energy are petroleum products, electricity (generated using oil) fuel wood and charcoal.

The 1980 imports of crude oil amounted to about 230,000 tons, which cost Le72 million and represented 20 percent of the estimated national income or 30 percent of the foreign exchange budget. Indications are that the prices of oil will continue to escalate and the effect on the national budget will become even more serious.

The installed capacity of electricity generating plants in Sierra Leone is 57.7 MW, of which 44.5 MW is in the Freetown area. From April 1979 to March 1980 the total electric power sold was 94,746,000 KWh.

Fuel wood and charcoal are the main sources of energy for cooking throughout the country. The total consumption for Sierra Leone has been estimated as 2.5 million cubic meters per year, of which 250,000 cubic meters is supplied to Freetown. The main sources are younger trees in protected forests and forest reserves, and this exploitation poses an ecological problem that also must be solved. However, the use of firewood will continue as the main energy source in rural areas for a considerable time.

Hydro power remains generally untapped with only one small plant of 2.4 MW at the Guma Water Supply Dam on the Freetown Peninsula. A second plant of 4 MW installed capacity is scheduled for construction at Goma, 20 miles north of Kenema.

Energy production from forest waste is being undertaken at the Forest Industries Corporation at Kenema where sawdust and wood waste are being utilized.

The generation of electricity, its distribution and sale come under the direction of the Ministry of Energy and Power through the agency of the Sierra Leone Electricity Corporation. However there are a number of generation plants throughout the country run by private or parastatal organizations primarily involved in mining operations. These come under the control of the Ministry of Mines.

The Ministry of Agriculture and Forestry controls the sources of fuel wood.

PROPOSED ACTION ON NEW AND RENEWABLE ENERGY

A national energy committee has been formed. The first actions required in Sierra Leone are to define national energy, to determine national energy policy, to coordinate activities within this sector and to create a controlling body to implement the policy decisions.

Policy will be laid down to cover matters such as:

- Conservation of energy.
- Control of basic sources.
- Priorities in use of basic sources.
- Size of development expenditure.
- Cooperation regionally and nationally.

ROLE OF PRESENT, NEW AND RENEWABLE SOURCES

The role of various energy sources and their foreseen future direction is given below.

Oil and Petroleum Products

At the moment, oil dominates the energy scene in Sierra Leone and plays a controlling part in the economy.

Oil is the energy base for electricity production and transportation. The main effort to improving the economy of the country will be directed toward developing alternative means of producing electricity (hydro power) and making economies in the use of petroleum products as a fuel for transportation.

Economies in transportation can be achieved by the following means:

- Improved road alignments and surfaces.
- More economical vehicles.
- A change to more fuel efficient means of transport.

A further avenue that could make economies in bulk transportation is greater use of rivers, estuaries and coastal waters for water transportation. This highly efficient method of moving heavy loads is not properly exploited at present and deserves closer investigation.

Hydro Power

The total hydroelectric potential of Sierra Leone rivers has been estimated at abut 2,000 MW. This is approximately 100 times the present installed capacity of oil-powered generating units.

While it is doubtful that the above potential ever could be realized, it is conceivable that a figure of 1,100 MW could be harnessed.

As a first step toward the development of hydro power in Sierra Leone, the construction of Bumbuna Scheme on the Seli River will commence in 1982 and the first phase, with an installed capacity of 60 MW, will come on stream in 1986.

Further phases in this scheme will be constructed as required and will have a total installed capacity of 305 MW. This finalized scheme has been planned to supply the majority of the country's needs up to 2030.

In addition to this scheme, the Kongo Scheme on the Mano River now is being designed. This could supply 75 MW of power to Sierra Leone when completed.

To supply power efficiently to the rural areas where the cost of transmission from the major schemes would be too high, it is proposed to develop small scale hydro schemes at Kabala, Dodo, Gandorhun and Moyamba.

The major and small-scale schemes will be progressively connected so that a national electric power grid is developed and distribution can be effected to all large villages in the country.

Biomass

In Sierra Leone, as in most other developing countries in Africa, fuel wood and charcoal are the main source of energy for the majority of the population. This source of energy will continue to be dominant for a long time.

Efforts being made by the government to maintain and control the source are centered primarily in forestry projects supported by bilateral and multilateral aid.

These projects will concentrate on reforestation, production of fuel wood and charcoal, manufacture and distribution of efficient stoves, training of forestry and wood industry personnel, reorganizing forest policy and organization.

In addition, effects will be made in the various Integrated Agricultural Development Projects to establish village woodlots where quick-growing trees will be planted to provide fuel wood for the immediately adjacent areas.

More efficient charcoal manufacture will be developed to maximize the energy obtained from this source.

Little use is being made of agricultural wastes to produce energy in Sierra Leone, although sawdust and wood waste is being used to fuel the Forest Industries Corporation's factory in Kenema, and palm kernel shells have been used to fuel boilers in some oil palm factories.

The use of agricultural wastes needs to be developed further, especially using rice husks, palm kernel shells, cocoa pods and bagasse.

A new sugar cane project has been started with bilateral assistance and there will be an output of alcohol from this project which could be directed toward use as a fuel supplement. Further research is required into the production of alcohol from special crops, such as sugar cane and cassava. Development of such cash crops would have the double benefit of energy substitution and income for rural producers.

When consideration is given to the use of agricultural wastes it must be remembered that transport costs can make proposals uneconomical. Schemes, therefore, should aim at using wastes where they are produced.

Biogas

The production of biogas in Sierra Leone appears to have limited application. In countries where biogas is well developed the main ingredient is animal manure, and in Sierra Leone the raising of animals is not widespread. In areas where animals are raised the herders head a semi-nomadic life -- once again, this mitigates against the establishment of biogas generators. It is possible that customs may be changed by the production of biogas energy and the fertilizer by-product, but a long time would be required for such a change.

Studies should be made, preferably by local universities and consultants, to determine what biomass sources are available for biogas production. These studies also should determine how receptive rural communities would be to the production and use of biogas.

Solar Energy

This source of energy is being developed. Future uses are envisaged as water heating in domestic and commercial (hotels) environments and drying of some crops, fish and meat. These uses require studies and are likely to be applicable only in outlets that have adequate finance, because of the high initial cost.

The use of solar power could be limited in Sierra Leone by adverse atmospheric conditions during a large part of the year (cloud and harmattan dust).

One application that will bear further studies is the use of photovoltaic methods to power isolated communications installations. This could be in marine and inland locations where access is limited.

The university is carrying out research into the use of solar energy and the work being carried out could well be intensified by government and multilateral assistance.

Wind

Wind energy is not exploited at the moment, Some areas of Sierra Leone could well use this form of energy, however, especially for duties such as pumping water and providing electricity for charging batteries for lighting.

The production of salt in ponds adjacent to the sea is under consideration and in these areas wind power for elevating the water beyond the tidal range could prove most applicable.

A detailed study is required to determine the potential of wind power throughout the country.

Lignite

Deposits of lignite were discovered near Freetown and are overlain with clay, and in the past clay bricks have been manufactured using the clay as the brick material and the underlying lignite as the fuel for burning.

Investigations are being carried out to determine whether the lignite could be mined successfully and used as a fuel to produce electricity in a steam-powered generating station to reduce dependency on oil.

CONCLUSION

The government of Sierra Leone recognizes the importance of controlling the use of energy. It realizes that renewable energy sources are of paramount importance to its future economy and is interested in the development of new and renewable energy forms. It intends to participate in regional and international efforts to develop new sources of energy, and is seeking assistance in the development first of hydroelectric power, because this is its most abundant source of energy. It has embarked on a major forestry project that would develop the production of firewood for fuel. Investigations are being carried out into other forms of energy applicable to Sierra Leone.

TABLE 1. CONSTRAINTS AND REMEDIES

The constraints to the development of new and alternative sources of energy with suggested action to remove them are:

Constraints	Remedies
Lack of national energy policy.	Formulation of national energy policy with due consideration to sectoral priorities.
Lack of data on various energy sources.	Commission existing personnel in ministries, universities and other bodies to gather information.
Lack of studies to guide decision makers on costs and benefits of various energy sources.	Commission consultants to prepare studies. Local university and consulting personnel are competent for most studies.
Lack of funds for studies and pilot schemes.	Request funds from bilateral and multilateral sources.
Lack of technical skill and experience at certain levels.	Include study of energy conservation and development in technical education courses at all levels.
Lack of energy management skills.	Training and exposure to energy management, both locally and foreign.
Lack of general knowledge on energy conservation and use.	Use television and radio to spread knowledge to general public.

Sudan

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INTRODUCTION

Sudan is the largest country in Africa, with an area of 2.5 million square kilometers, and a population just less than 18 million with growth rate of 2.7 percent. Nearly 85 percent of the population lives in rural areas, but the rate of urbanization is increasing.

The labor force is estimated at 5 million persons and at least 70 percent of this force is engaged in agriculture. The country is rich in water, animal and land resources.

Cultivable land is estimated to equal 80 million hectares, but only 31 million hectares are utilized so far for crop production and grazing. The animal wealth is about 51.3 million head. As for mineral and energy resources, the Sudan has an important potential which remains untapped for a number of economic reasons -- the shortage of foreign exchange and lack of infrastructure being the main ones.

Industry in Sudan is in its infancy and there is a gradual move toward industrialization. Integration of agriculture and industry is emphasized in the national development plans, particularly in agricultural and livestock processing.

Also, promotion of the mining and mineral industries, tapping the vast mineral resources of the Sudan, is a high priority policy for the government. Industry now consumes about 18.4 percent of the total commercial energy produced.

Natural gas has been found in the Red Sea area, and gypsum and asbestos are targeted for future investment. Recent discoveries of light crude oil have been made in Sudan, and a small refinery of 5,000 to 6,000 barrels per day is scheduled to be erected soon.

The transportation sector is the major user of commercial energy, and the percentage consumed by it in 1979-1980 reached 54.5 percent. The existing railway system is incapable of meeting transport requirement for export and import products that need to be moved more than 1,000 miles to and from Port Sudan. This situation has led to an enormous growth of road traffic, aggravating the energy intensity of transportation. The road linking Khartoum to Port Sudan and passing through the agriculturally and minerally rich regions of Gezira, Blue Nile, Kassala and Red Sea provinces is now completed. The roads linking Khartoum to Damazine and Kosti via Sennar are underway. Plans are in progress to revitalize the railways by icreasing capacity through track improvement. The harbor at Port Sudan is receiving special attention to improve all services, and Suakin old harbor is under rejuvenation.

THE PRESENT ENERGY SITUATION IN SUDAN

The main present sources of energy in Sudan are imported oil, locally produced wood fuel and, to a much lesser extent, hydroelectric power. The quantity of crude oil imported during 1979-1980 and processed in the Port Sudan refinery amounted to 1 million tons. In addition, about 200,000 tons of processed oil also was imported. Oil products and electricity generated thermally and hydroelectrically constitute the only commercial source of energy, which amounts to 22.66 percent of the estimated total energy consumption in the country for the fiscal year 1979-1980. Non-commercial energy in the form of firewood, charcoal, agricultural crop residues and animate power contributed 77.34 percent of the total energy consumed in 1979-1980.

Petroleum Products

Petroleum products are the principal commercial fuels in the country. They constitute 98 percent of the total commercial energy used. With the exception of hydro power used for a portion of electricity generation and a small amount of bagasse, petroleum products supply virtually all modern sectors with their energy requirements, including that used in transport, modern industry and processing and mechanized agriculture. For the past five years, there was an annual increase in petroleum products consumption averaging 6.3 percent. In industry, the annual growth of petroleum products consumption averaged 9.6 percent and it ranged between 4.9 percent and 6.7 percent in other commercial sectors.

Electric Power

Electric power contributed 2 percent of the total commercial energy used in 1979-1980. Of the total 892 GWh generated, 233 GWh, or 26.1 percent, was thermally produced from 17 isolated stations, and 659 GWh, or 73.9 percent, was produced hydroelectrically from three stations.

Two national grids exist in the country. The Blue Nile Grid links Roseris hydroelectric power station via Sennar hydro station with the major load centers of Khartoum, and connects Sennar station to Gezira and White Nile provinces. The Eastern Grid links Khashm El Girba hydroelectric station with the major load centers of Kassala province.

The installed capacity of electric power is inadequate for current needs and is one of the major constraints on industrial sector productivity and growth. It also is responsible for the low foreign investment and the slow expansion of industry.

Production figures for the past five years show an average annual growth of 10.5 percent in overall electricity generation. Growth in consumption has risen in the same period by 13.5 percent in industry, 5.7 percent in the residential and services sector and 2 percent in agriculture. Development of electricity generation passed through two stages. The third stage, which is under development, is the Power III project to double electricity capacity by the year 1983.

Table 1 shows national grids, thermal and hydroelectric energy generated in 1979-1980.

Non-commercial energy, in the form of wood fuel, agricultural crops residues and animate power, contributed 77.34 percent of the total estimated energy consumed in the country during 1979-1980. The share of each source was estimated as follows:

Wood Fuel		
Firewood	69.13%	
Charcoal	5.99%	75.12%
Agricultural Residue		
Crop residue	0.78%	
Animal refuse	0.59%	1.37%
Animate Power		0.85%
Total		77.34%

Firewood

The total amount of firewood consumed in 1979-1980 was estimated to be 10.65 million tons. Nearly 98 percent was utilized as household fuels and in domestic services and bakeries, mostly in rural areas. About 2 percent of the total firewood consumed was the only available fuel for the rural industries, including brick burning, pottery, tobacco curing and production of steam for the processing of vegetable oils.

Almost all the firewood produced was obtained from the natural forests and the desert scrub. The contribution from wood fuel plantations was about 1.3 percent. Firewood is obtained for household consumption either free or at very low cost, but royalties are collected against the amounts used in bakeries and rural industries. A considerable amount of firewood is railed and road-transported to the big population centers from distances reaching more than 500 kilometers, to be used mainly as fuel in bakeries and in brick burning. Cost of transported firewood is very high.

Charcoal

The main household and domestic fuel in urban areas of Sudan is charcoal. In 1979-1980, the amount produced and consumed totaled approximately 550,000 tons. Like firewood, charcoal is obtained from natural forests. It is produced by the primitive local earth kilns, where quality is poor and recovery percentage very low, not exceeding 15 percent. Unlike firewood, charcoal is costly. It is railed and transported by road and river from great distances.

The total amount of wood fuel in the form of firewood and charcoal removed from the forests annually exceeds 13 million tons. The annual rate of increase of consumption is 2.2 percent. This sort of utilization of wood fuel already has its bad effects, shown in the desert creep, soil degradation and increased aridity in many parts of northern, central and western Sudan. Meanwhile, the expansion in agriculture strips more land annually of its forest cover. The reforestation program is meager and inadequate to curb the adverse change in environment. This situation, besides its harmful effects on agriculture (the major economic sector of the country), also will affect seriously firewood supply and demand balances in the near future.

Agricultural Residues

Sudan, being an agricultural country, has a great potential of crop residue to be utilized as energy. The quantity of crop residue so far estimated exceeds 3 million MT annually. At present, only a small portion is used in the rural areas as household and domestic fuels. Bagasse is utilized in the sugar factories for the generation of electricity, where the amount generated is estimated to be 20 GWh.

The use of animal refuse is negligible and is only practiced in some parts of the northern province.

Animate Power

As for animate power, the contribution in total energy consumption is considerable and is estimated to be .87 percent of the total energy. Animate power is used mainly in irrigation, agriculture, transport and household and domestic services.

NEW AND RENEWABLE RESOURCES IN THE COUNTRY'S FUTURE

As stated earlier in this paper, the two main fuel sources for Sudan are, at present, imported oil fuels and locally produced wood fuels. The present rise in the prices of oil fuels has serious effect on the country's balance of payments and the country's development in general, making consideration of new and renewable sources of energy pertinent. The present pattern of utilization of wood fuel is both wasteful and harmful to the country's economy. The need to develop the use of wood fuel more efficiently and economically is urgent and should go hand-in-hand with the development of other new and renewable resources.

The Development of Biomass

Firewood: Despite the fact that huge amounts of firewood, to the extent of more than 10 million MT, are burned directly as fuel with heat recovery not exceeding 6 percent, it is not easy to convert this type of fuel into the modern forms of energy like methanol or gaseous energy. The main reasons are the scattering of the resource, the costly operation of collection, and particularly the difficulties of introduction of modern technologies that entail financing, expertise and the social problems. For these reasons, firewood is going to be used in the same pattern, perhaps for the next two decades. There is, however, small hope of increasing the efficiency of use to raise the percentage of efficiency by 2 or 3 percent where firewood is used in such industries and services as brick burning, lime production and steam production.

Charcoal: As for this type of fuel there is a wide scope to develop both production and consumption methods to reduce waste enormously and to render more volume, available with the same volume of raw materials. The Forest Department in Sudan is planning to improve on charcoal production and to raise quality and production recovery through the introduction of modern types of kilns.

Some types of French metallic kilns were introduced in the country. The expansion of their use was limited by certain factors, such as transportation from place to place and small production capacity. All charcoal is produced now from natural forests, which are characterized as scattered. Mechanized agriculture is expanding among the natural forests, pushing this resource farther away from consumption areas. The installation of modern kilns in these natural forests will not be economically feasible. Stationed modern types of kilns can be used economically with wood fuel plantations where the resources and the raw materials can be renewed annually through the managed growth. So, for the development of wood fuel as a major source of energy in the Sudan, the establishment of wood fuel plantations is very important, and is expected in the range of 120,000 hectares annually. The present rate of reforestation does not exceed 7,000 hectares, or only 6 percent of what should be planted per annum, which can result in deficiency of wood fuel production just after 1985. The reason for this meager reforestation program is mainly financial, because at least LS.250 is required to establish 1 hectare of plantation, including tending and protecting operations for the first five years. This cost can be reduced greatly if the concerned population can be attracted to participate in all or some of the plantation operations. Such measures require public alertness through a vast and detailed program of education and social culture. Recently, Sudan has been aided by some of the international agencies. The International Council of Churches, for example, is working on a reforestation program in the Nile Province and farmers are taking an active part in it.

The second important activity is to improve on charcoal consumption efficiency. This is taken over by the Energy Institute in the Sudan, where work is underway for the development of local stoves using charcoal.

Agricultural Crops and Crop Residues: There is a great potential in Sudan to use crops and crop residues as sources of fuel. It is not likely for the coming 10 years that any of the energy-rich crops such as sugar cane, sweet sorghum and cassava will be used for fuels because food production is the priority. But after that they surely will contribute considerably to energy. In the case of agricultural crop residues, the potential is already big. At least 3,089,000 MT of crop residue is available now to be utilized as energy. This amount is estimated to give 1.58 million tons of oil equivalent (Mtoe) if directly combusted, 120 million gallons of alcohol if distilled, 3,700 million cubic feet of biogas and 37,000 million cubic feet of low Btu gas if it is gasified. The main difficulties in utilizing residual crops now are collection and transport costs, because these residues are scattered across enormous areas of the country. It is in the plans of the government to undertake feasibility studies at least for production of ethanol from molasses now produced in large quantities by the sugar industry for the purpose of blending with gasoline. Meanwhile, bagasse is being used to generate electricity in the sugar factories. The quantity of electricity generated in 1979-1980 by burning bagasse was estimated to be 20 GWh.

Hydroelectric Power: Hydro energy is by far the best-studied resource in the country, and it accounts for more than 78 percent of the entire development of electrical energy. The potential hydro energy sets cover all the reaches of the Nile, from southern borders to the northern borders. This can suffice for the high population densities along the Nile. This potential, as estimated, can allow for an installed power capacity of 3,370 MW, generating annually 21,217 GWh.

When comparing this to the present utilization of hydroelectric power, where only 249.7 MW is installed and generating 892 GWh, the remaining potential is enormous.

The cost of installation of 80 percent hydroelectric power to utilize this potential in 1978 is LS.3587.5 million -- too much for the country to undertake in its present financial situation.

Because the development of hydroelectric power will benefit by exploiting of surface water resources on a national level, this program will have its due consideration as soon as the financial position improves.

Solar Energy

The earth receives daily from the sun an amount of energy equivalent to 2.4 x 10^{12} barrels of oil, which is equal to the known world reserves of oil. About 30 percent of this energy is reflected and scattered by the upper layers of the atmosphere. Seventeen percent is absorbed by clouds and atmospheric constituents and emitted also to outer space as infrared rays. Twenty-two percent reaches the surface as diffuse sky radiation. Only 31 percent reaches the earth's surface as direct-beam solar radiation.

Part of the incoming sunshine is absorbed during the photosynthesis process by green plants for the growth of organic matter. Although plants convert only 1 percent of the energy they receive, this energy converted annually is equivalent to about eight times the current oil consumption. Another part is absorbed by the atmosphere and earth's surface and converted into wind. Also, evaporation of water absorbs some solar energy. The remainder of solar radiation disperses into the heating of land and water masses resulting in low concentrations. Technical difficulties hinder the full utilization of solar energy on a commercial basis. One problem has been collecting and concentrating the sun's energy due to its lower intensity. Another has been finding a means of storing the energy during sunny hours so that the power is available at night and during cloudy spells. Nevertheless, worldwide research and development efforts are striving to overcome these difficulties.

Sudan is one of the most solar radiation-rich countries of the world. Geographically, it is located between latitudes 4^{o} and 22^{o} north of the Equator. Thus it is a suitable place for utilizing such an important source of everlasting energy. Utilization of solar energy is not a new subject in Sudan. It has been used during many ages for the drying of agricultural products, timber, mud and bricks. These applications of solar power, although primitive in nature, were the first steps to enter the solar era. Scientific research of solar energy in Sudan started in 1955 at the University of Khartoum, where the Department of Physics engaged in power generation and measurements of solar energy. In 1958, the Department of Mechanical Engineering began to conduct research on solar desalinization, power generation, water heating and dehydration. The Institute of Solar Energy was established in 1970. In 1977 it was renamed the Institute of Energy Research (IER). The activities of this institute in solar energy research include the following:

- Development of solar stills for large-scale application.
- Low-cost water heaters.
- Flat plate steam generators.
- Solar cooling systems.
- Solar drying.

In May 1980, the National Energy Administration was created as an organ of the Ministry of Energy and Mining. Its major role is to control, coordinate, utilize and rationalize the energy sources in Sudan. Solar power research and development lie within the scope of its activities. The National Energy Administration will enable, through intensive research work, solar energy to participate in the total share of energy needed in Sudan by the first quarter of the 21st century. The National Council for Research is undertaking the development of different solar power projects. A brief summary of these projects follows:

- Solar water heaters: Five units are installed at the Faculty of Engineering (University of Khartoum). Each unit is inclined 15^{o} to the south and comprises galvanized steel tubes seated on galvanized corrugated steel plates or mesh wires. The tubes are covered by glass plates. Outlet temperatures up to $75^{o}C$ are reached, depending upon water flow rates inside the tubes. Such units may prove suitable in residential areas, hostels and hospitals.

- Solar stills: These units produce distilled water from tap water or well water. Each unit consists of a flat glass mounted on a basin. This basin is filled with water, and by the "greenhouse" effect, water evaporates and then condenses on the glass surface and the droplets are gathered on troughs. One gallon of distilled water is produced per square meter flat plate per day. Four units are installed near Khartoum:

Place	gal/day
University of Khartoum (Institute of Energy Research)	20
Suba (Institute of Energy Research)	40
Shambat (Food Research Center)	16
Medani (Agricultural Research Corporation)	20

  Petrol stations can utilize such units to produce distilled water for car accumulators.

- Solar cooling unit: This unit is a donation from the Netherlands, and is installed at the Faculty of Engineering (University of Khartoum). It is composed of steel tubes filled with solid calcium chloride. Ammonia is absorbed by $cacl_2$ during the night and ejected during day. As a result of this process, cooling occurs. This unit now produces about 16 kilograms of ice per day.

- Solar drying: Air is forced, by means of fans, to pass a series of cascades toward a cabinet where drying takes place. The cascades are composed of black tubes with flat glass plates mounted over them. Air absorbs heat as it passes through the cascades and the outlet temperature reaches up to $70^{o}C$ ($158^{o}F$). Bricks are tested in the cabinet for drying and good results are obtained.

- Photovoltaic solar pumps: One type of such pumps is positioned at Butri (25 kilometers south of Khartoum). It is composed of a panel of solar silicon cells which converts solar energy directly into electrical energy (direct current). The panel has a design peak power of 660 watts with an average output of 400 to 500 watts. A direct current motor drives a centrifugal pump to force water from a surface well with a capacity of 18 to 23 cubic meters per day. Although the capital installed cost is comparatively high, the operating condition of the pump is now under investigation.

- Solar thermal pump: This unit is under erection now at Suba (15 kilometers south of Khartoum). It consists of flat plate collectors which contain freon 13. An engine is pressed by heating freon and a reciprocating motion is created and transmitted to a hydraulic press, which delivers water from an artesian well.

The potentials of harnessing solar energy in Sudan have good prospects due to several reasons:

- Sudan's climate is very suitable for solar utilization, especially in the central and northern areas. The average sunshine duration is more than 10 hours, and the solar flux is about 80 calories per hour per square centimeter.

- The majority of the population resides in rural areas lacking conventional sources of energy. Solar energy can be utilized at reasonable cost to promote the development in these remote areas. Water pumping, irrigation and cooking are suitable fields of solar applications.

- Needless to say, solar energy is the cleanest source of energy, and needs less operating and maintenance expense once the equipment is erected.

In fact, Sudan lacks the technology of solar energy (like many other developing countries), but would like to step forward through research and the help of other developed nations.

Wind Energy

The application of wind energy in Sudan as a source of power dates back to 1950, when windmills were erected in Gazira Province to deliver water for drinking from artesian wells for the scattered small communities which inhabited that area.

About 250 units brought from Australia were installed throughout the province during 1950-1952. At that time, the 900 gallon per hour discharge rate of windmills served these small (500 people each) communities satisfactorily. As time progressed, diesel-driven engines, and later electrically driven motors, began to replace windmills. In 1965, the last windmill had been dismantled. Three main reasons led to the shift from windmill operations:

- The increase in population of the small communities, from 500 to 2,500 people, required a corresponding increase in water off-take, making the output of windmills lag behind. Also, urbanization increased the consumption of water per capita. The current consumption now has reached 10 gallons per day per capita.

- The scarcity of spare parts led to the local manufacture of these parts. The local parts were not precise, decreasing the lifetime of the windmills. The improper repairing deviated the dynamic balance of the shaft, thus increasing its fatigue and decreasing the life span of windmills.

- During the period from March to May, annually, people usually suffered from acute water shortages due to the windless period that occurs within these months. These communities complained to authorities accordingly.

Windmills were replaced first by force pumps with capacity of 1,200 gallons per hour, and later with centrifugal pumps with capacity of 5,000 gallons per hour. In fact, poor design and bad maintenance and repair of windmills contributed vigorously to the replacement.

The emergence of the energy crisis in early 1970s put windmills again to the surface as a means to conserve energy.

An Australian team from the Australian Development Assistance Bureau (ADAB) visited Sudan last year and went to western Sudan to investigate the possibility of installing new windmills there.

According to the team, the project was justified on the basis of:

- Apparently adequate wind.
- Fuel, cost and transport savings.
- Minimal maintenance costs.

The total cost of the project amounted to about 100,000 Australian dollars to provide installed costs of three windmills. The equipment is expected to arrive by the end of this year. The potential of wind energy in Sudan seems to be promising due to the favorable climate conditions and the shortage in petroleum fuels to operate diesel engines. Although the capital cost of windmills is comparatively high, the running costs are almost negligible.

Geothermal Energy

Geothermal energy is one of the renewable energy resources now receiving some attention in Sudan. There are indications of available resources in the volcanic areas of Sudan, such as Gabal Mara, Rejaf, Meidob, Gadarif and along the Rift Valley. Because the primary cost of utilizing this resource is considered to be low, compared with other resources, its development will be encouraged. The NEA is planning to identify geothermal sites in the near future.

OBSTACLES TO NEW AND RENEWABLE RESOURCES

According to the present trend of consumption of commercial energy at an annual rate of increase of 6.3 percent of petroleum products and 10.5 percent of electricity, coupled with .5 percent decrease in non-commercial energy use, the country's requirement of commercial energy will be double the present requirement by 1995. Until the development of new and renewable energies, we have to use petroleum products with the difficulties of shortages and rising prices. As the petroleum products prices keep rising, the balance of payments will be worsened further, and an unstable world economy will aggravate our financial position and hinder any appreciable development.

This situation reflects the considerable magnitude of the energy problem, and calls for urgent viable solutions. The development of all new and renewable energy resources should go together to achieve the overall social goals of national income growth, better balanced income distribution, environmental quality, institutional stability, public health and regional development. Our planning should focus on more than one energy resource, on a long-term rather than short-term policy, on covering larger areas and including broader technical aspects, and should allow for multisectoral development. As we embark on the development of new and renewable energy resources we face numerous obstacles.

Financing

The activities to be financed have been summarized as follows:

- Research on biomass, wind, solar and hydro energies.
- Development of alcohol and gaseous energy from sugar residues and other agricultural crop residues.
- Improvement of charcoal production techniques and on stoves using charcoal.
- Establishment of wood fuel plantations.

- Combination of wind and solar energy for water pumping in rural areas.

- Development of hydroelectric power -- larger, medium and mini-technologies.

Great and cost intensive effort has to be made to develop these activities, which require large capital and take many years to come into production. This accelerates the capital interest rate, and ties up the capital for a long time without any pay-back dividends. As our foreign currency situation does not allow us at present to undertake all of these projects, we depend partly on bilateral aids and some help from the international financial institutions for a small share of the capital needed. The problem of procuring more funds for bigger investments still exists.

Transfer of Technology

There are certain difficulties hindering the transfer of the appropriate technology which can be suited to our conditions. In the first place, we depend on imported technology whether in the form of machinery, equipment or expertise. Important infrastructures are lacking in the country, such as consultancy in development and planning, contracting enterprises, engineering, metallurgical and chemical industries. Difficulties are encountered in the selection of suitable technology, particularly medium and small types which are not easily available in the market. In addition, suppliers' attitudes frequently tend to impose both type and place of machinery to be provided. Moreover, no evaluation or appraisal of the existing technology in the country has been made to ascertain the best methodology to be adapted in the future.

Research, Education and Training

In this field, the institutions of education, research and training are inadequate and lack the most important infrastructures of equipment, personnel and needed funds to achieve their goals. There is no planning for the priorities of research regarding basic applied research, particularly in connection with the rural area need of clean water supply and electricity. In the field of education and training, there is a need to improve on the present means to the effect that technology adaptation can be feasible. Construction of prototypes, pilot plants and demonstrating systems of the new and renewable technologies surely will help the promotion of education and training.

Information Flow

In this field the obstacles are very clear. First, the important data regarding energy use in all economical sectors is not easily available. There is no system in the country to guarantee access to, and use of, information. Public information to promote awareness, and alert the public to energy problems, does not exist. There is a need to establish an effective information system in the country. Although highly advanced technology information flows to the country from the industrialized areas, the information from neighboring countries or from countries which have difficulties like ours is very scarce.

HOW TO OVERCOME THE OBSTACLES

To develop new and renewable energy resources, overcome difficulties in this respect and enhance development to ease the energy crisis at present and prepare for the near and far future needs of energy, Sudan's government is undertaking the following measures:

Organization of Energy Sector

With a view toward identifying energy problems, the government created a new ministry in 1977, the Ministry of Energy and Mining. Under the umbrella of this ministry are almost all energy institutions, including General Petroleum Corporation, Sudan Pipe Line and the Nile Import and Trading Company for petroleum products distribution. In May 1980, the National Energy Administration was created within the Ministry of Energy and Mining to undertake the tasks of the assessments of energy resources, current energy production and consumption, identification of suitable energy projects and the overall planning and policy making for the energy sector in the country. The NEA has to work in coordination, cooperation and harmony with all the institutions of energy and energy-using sectors in the country.

Energy Strategies and Planning

To develop sound energy strategies and planning, integrated with the development of different economical sectors, Sudan is embarking now on a project for the assessment of the energy situation in the country. The United States and Sudan have agreed on aid to Sudan from the U.S. Agency for International Development (AID) to undertake this assessment for a period of two years ending in September 1982. Based on results of this assessment, the country will formulate the plans and strategies that will focus on the development of the energy sector, including new and renewable energies.

Energy Conservation

Different measures to secure rational utilization of the various energy resources are being studied. In the field of wood fuel, improvement of charcoal stoves is being worked on by the Energy Institute. The Forest Administration is preparing plans to improve on charcoal production and to secure future demands of firewood for rural areas through reforestation programs and protection of the natural forests. The development of molasses as a substitute source of energy is being thought of seriously. In the case of petroleum products, improvement in the transportation sector is being worked on to increase efficiency, particularly the improvements of roads and railways. The establishment of the pipeline between Port Sudan and Khartoum is a step forward in energy conservation. Continuous efforts are going on to improve on electricity generation, transmission and consumption. The Power III project is the latest of these efforts.

TABLE 1. NATIONAL GRIDS AND THERMAL AND HYDRO STATIONS (1979-1980)

National Grids and Electricity Stations	Installed Capacity MW	Energy Generated 1979-1980 GWh		
		Hydro	Thermal	Total
Blue Nile Grid	229.3	637.5	110.7	748.2
Eastern Grid	20.4	21.3	--	21.3
Dueim	0.9	--	3.7	3.7
Kassalla	5.1	--	5.6	5.6
Atbarra	13.0	--	21.4	21.4
Dongolla	0.4	--	1.2	1.2
Shendi	1.2	--	4.3	4.3
Port Sudan	14.1	--	32.9	32.9
Malakal	0.9	--	1.0	1.0
Wau	0.9	--	1.0	1.0
Juba	6.0	--	36.8	36.8
El Obied	5.1	--	5.3	5.3
Umroaba	1.3	--	2.8	2.8
El Fashir	1.3	--	2.5	2.5
Nyala	0.9	--	3.9	3.9
TOTAL	300.9	658.8	233.2	892.0

TABLE 2. HYDROELECTRIC POTENTIAL

Proposed dam site	Location	Proposed power (MW)	Average energy (GWh)	Capital cost (LS million)
Sabaloka	6th Chatarat	100	650	165
Sherick	5th Chatarat	240	1400	317.5
Shirri Island	4th Chatarat	450	2600	535
Low Merowe	4th Chatarat	600	4800	668.75
High Merowe	4th Chatarat	750	3500	797.5
Dal	Dal	600	67	728.75
Rumela	Atbara River	30	2000	375
Bedin	Bedin Papids	300	1600	n.a.
Fola	Fola	300		n.a.
TOTAL		3370	21217	

Prices as at January 1978 exchange rate: $ U.S. 2 = LS.1.0 (excludes import duties)

TABLE 3. AVERAGE WIND SPEED IN GEZIRA PROVINCE (1960 to 1970)

MONTH	AVERAGE OF WIND SPEED IN MILES PER HOUR
January	8
February	9
March	8
April	7
May	8
June	10
July	10
August	9
September	7
October	5
November	7
December	8

Turkey

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INTRODUCTION

Turkey, in the throes of a major industrialization effort, is in need of secure and reliable energy supply and of adequate energy technology to establish industry, and to improve the economic status and living standards of the country.

The total primary energy consumption is estimated to be 1,410 PJ in 1980, representing a per capita energy consumption of 31 GJ, which is well below the world average of 60 to 65 GJ per capita. Energy requirements are increasing at a far greater rate than production and importing is the only way to cover the growing shortfall. At present, nearly half of the national energy requirement is being imported in the form of oil.

The overall objective of the National Energy Policy is therefore aimed at reducing dependence on imported oil and avoiding its impact on any further increases in the balance of payments deficit. In this regard, the Turkish government is focusing its efforts on accelerated development of alternative energy sources and on promotion of energy conservation without hampering the process of economic development.

To ensure these policy objectives, the Five-Year Development Plan calls for a strategy consisting of the following means:

- To expand the indigenous oil production through enhanced recovery techniques while exploring for new resources in the promising fields.

- To promote the development of the coal resources possessing high potential utilization.

- Optimum utilization of hydraulic resources.

- Deliberate energy conservation through increased efficiencies and rational use of energy in all sectors of the national energy economy.

- Development of new and renewable sources of energy.

In this context, much relative importance has been assigned upon all pertinent forms of new and renewable sources of energy with a view to determine the potential they could represent in meeting the present and future domestic energy needs.

Hydraulic, solar, geothermal and biomass are the most substantial new and renewable sources of energy in Turkey, with a potential adequate to supply a considerable portion of the energy requirements in the coming years.

Hydro power already is being exploited. Research and development programs in solar, geothermal and biogas are in operation.

INSTITUTIONAL STRUCTURE: NEW AND RENEWABLE SOURCES

Energy management and supply is carried out by the state through development plans of five-year periods, while the energy demand is controlled by means of price and tax regulations and industrial investment incentives.

The State Planning Organization plays the key role in decision-making in energy as well as in other sectors of the national economy.

A simplified diagram of the present energy management infrastructure for establishment and implementation of the national energy policies in the field of new and renewable sources of energy is illustrated in Figure 1.

The corresponding responsibilities of the related governmental organizations concerning the evolving and monitoring of the strategies and national research, development and demonstration programs are summarized in Annex 1.

ROLE OF NEW AND RENEWABLE SOURCES

Conventional Energy Sources

Primary Energy Reserves and Resources: Practically all conventional sources of energy exist in Turkey. Estimates of primary energy reserves and resources are presented in Table 1.

The general outlook is that Turkey is endowed with a sufficient quantity of fuels. Nevertheless, the present fossil fuel resource base does not seem to be encouraging to ensure the intensive industrial and socio-economic development in the long run, mainly due to its low-grade nature and to the formidable obstacles encountered in the extraction of these resources.

Petroleum is extracted with great difficulty, owing to the depth of the wells and its viscous nature. The sulfur content of Turkish petroleum also is considerably high.

Similarly, coal mines are at great depths and the layers are quite thin. The lignite reserves are rather abundant, particularly in the eastern part of the country, but consist mostly (about 85 percent) of low-grade (less than 3000 kcal per kilogram) and high sulfur deposits.

It is, however, worth emphasizing that great uncertainties exist in coal, particularly in lignite reserve estimates, and exploration for additional reserves has been foreseen.

Energy Supply and Consumption Patterns: Turkey's main indigenous energy resource base has been solid fuels (lignite, coal and non-commercial energy sources) and hydro power.

Primary energy production and consumption patterns over the period 1960-1990 are presented in Tables 2 and 3, respectively.

Of the 57 percent of total primary energy (TPE) consumption produced domestically in 1980, 72 percent was from solid fuels, 15 percent from hydroelectricity and 13 percent from oil.

In pace with the growth of the national economy, TPE consumption rises much higher than the TPE production, which in turn increases the gap between the national energy demand and supply.

The energy consumption structure for the period of 1950-1990 is plotted in Figure 2. The figure shows three distinct characteristics:

- The fastest rate and quantity of increase is in petroleum use.
- Utilization of lignite and hydraulic resources is growing at a slow pace.
- The increase in coal, wood and animal wastes in terms of quantity has almost remained the same.

Figure 3 gives the breakdown of energy consumption in 1980 on sectoral and fuel bases, together with the domestic and imported energy ratio.

Regarding future projections, it should be noted that Turkey plans in the ongoing decade a quick increase in domestic energy production from 797 PJ in 1980 to 1,562 PJ in 1985 and to 2,111 PJ in 1990. Nevertheless, in the same period oil imports are projected to rise 2.7 times to 1,555 PJ (37.1 Mtoe).

Potential Role of New and Renewable Sources of Energy

The new and renewable sources of energy with existing and potential use expected to have significant contributions to the national energy balance are:

- Hydraulic energy.
- Solar energy.
- Geothermal energy.
- Biomass energy.
- Wind energy.

Among them, only solar energy and biomass are available at the national level.

Although Turkey is surrounded by water on three sides, the plausible contribution from tidal and wave energy is envisaged to be minimal and consequently is not taken into consideration.

Hydraulic Energy: As is evident from the mountainous character of the eastern Anatolia and the Central Plateau regions, Turkey possesses a tremendous hydraulic potential. Of the total of 430 TWh gross theoretical hydroelectric potential, nearly 100 TWh is estimated to be economically feasible.

Continuous efforts are underway for the purpose of considerable expansion of the national hydroelectric potential, of which only 10 percent has been developed to date.

It is estimated that this potential, if fully exploited, could suffice in meeting half of Turkey's electricity demand well into 2000.

At present, the installed capacity of the main 44 hydroelectric power stations in operation amounts to 2,131 MW, and approximately 11,325 GWh of electricity is generated annually. Through realization of the big and medium-sized hydroelectric power plant projects with a total of 23,885 MW installed capacity to be commissioned in the period 1980-1997, it is planned to utilize 65 percent of the existing economically exploitable potential by 1997.

The utilization of small-scale hydroelectric capacity has been minimal to date and much relative importance has been assigned to the full appraisal of large-scale projects. Nevertheless, the related studies with regard to optimum assessment of small-scale hydro power plants have gained momentum in parallel with the national objectives to attain increased contribution from the indigenous small-scale hydroelectric potential amounting nearly to 20 to 30 TWh per annum.

At present, 150 small hydro plants are in operation, representing a total installed capacity of 25 MW.

On the other hand, relevant studies are in the planning stage concerning design, construction and operation of mini-hydro plants within the range of 50 KW to 1 MW for harnessing the exploitable potential of mini-hydro power in meeting the electricity needs of the remote rural areas.

Solar Energy: Among the new and renewable sources of energy currently under investigation, solar energy seems one of the most promising fields, and promoting the utilization of practical applications of solar energy has become a matter of growing national concern due to the attractive geographic climatology of the country.

Turkey has, on the average, 2,500 hours of sunshine per annum while the yearly average solar flux exceeds 1,800 KWh. In this regard, the average yearly solar energy potential which could be assessed as low-temperature heat is estimated at about 36.10^6 tons of hard coal equivalent, and the duration of solar radiation intensity over the country is highly appropriate for all kinds of applications.

Figure 4 shows the annual average total radiation on a horizontal surface in Turkey.

In the Fourth Five-Year Plan, the total solar energy utilization was predicted to be .06 percent of the total energy production in 1980. However, this figure excludes the natural solar drying of various agricultural products, which is widely used throughout the country, and a realistic assessment of the extent of its plausible contribution is difficult to estimate.

Geothermal Energy: Turkey can be regarded as having considerable geothermal energy potential due to its appropriate geographic structure for formation of rich geothermal reservoirs. It is located on the Mediterranean volcanic belt where volcanic and tectonic activities are observed frequently. The most promising geothermal fields are mainly concentrated in the western Anatolia.

A variety of surveys through exploration and drilling activities are being conducted throughout the country for drawing up an inventory of the total geothermal potential. Although a realistic assessment cannot be made of the extent of its contribution, tentative estimates indicate that a potential of 4,500 MWe could be utilized for electricity generation.

On the other hand, it is anticipated that the total potential of low-enthalpy geothermal fields, not suitable for electricity generation but which could be utilized for heating purposes, was much more substantial, amounting nearly to 31,500 MW_{th}.

Biomass Energy: Wood, animal dung and plant wastes, still constituting the staple and non-commercial energy sources of most of the rural areas in Turkey, are used mainly for heating and cooking purposes.

The total area of domestic woodlands amounts to approximately 20.10^6 hectares, and according to the latest figures the rate of useful and renewable product per hectare is about 1.5 cubic meters, which is well below the 5 cubic meters per hectare realized in western countries.

The amount of firewood consumption in 1980 reached 14.10^6 tons, constituting nearly 12.5 percent of the total energy consumption.

Utilization of wood as fuel leads to deforestation and abolishing forest areas in the country, due to the excessive firewood consumption. In this respect, harnessing of wood for industrial purposes should be considered from an economic viewpoint.

If the useful product output is to be increased to the 5 cubic meters per hectare level, then wood energy can contribute significantly to Turkish energy demand.

According to 1980 statistics, the cattle population is about 15.10^6, yielding 75.10^6 tons of manure per year.

Animal wastes constitute very rich input from the agricultural viewpoint, and therefore the basic policy of the Turkish government is focused on multipurpose utilization of agricultural wastes, namely as biogas and organic fertilizer.

A theoretical estimate of the biogas potential in Turkey reveals that an equivalent of 9.9 TWh energy (2.5 x 10^6 tons of petroleum equivalent) could be provided if the total production of cattle manure in 1980 were exclusively used in biogas production.

With agricultural wastes included, the total biomass energy potential is estimated to be 3.4 x 10^5 TJ per year (8.10^6 tons of petroleum equivalent.)

Wind Energy: Turkish conditions are considered to be scarcely profitable in comparison with those countries already utilizing wind power.

Most of the wind energy utilization potential is at the north, along the Black Sea Coastland and in the Aegean region, where the yearly average wind velocities are assumed to be 5 meters per second, very rarely exceeding the economic utilization limit. However, there is still the possibility for use in irrigation and small-scale electricity production.

RESEARCH, DEVELOPMENT AND DEMONSTRATION ACTIVITIES AND COOPERATIVE PROGRAMS

The economic crisis and the bleak future in the energy situation have aroused a nationwide continuous interest in new and renewable energy sources, with particular reference to solar energy and energy conservation.

The efficiency of the present energy utilization pattern in the main sectors of the national economy is considerably poor in Turkey. Consequently, research on national use of energy is a necessity in the industrial and domestic sectors -- comprising almost 79 percent of the final energy consumption. Research and development work toward energy conservation has enjoyed nationwide attention, and currently is being pursued by various research groups.

Present research and development activities in solar energy are concentrated primarily on flat plate collectors and solar architecture.

Geothermal, biomass and wind energy also are receiving considerable attention. Several prototypes were built and related demonstration projects have been completed in applications of geothermal energy and biogas.

Major government energy research and development programs regarding the promotion of the practical utilization of new and renewable sources of energy are currently centered on:

- Solar heating and other low-temperature applications.
- Utilization of geothermal energy in electricity generation, space heating and the heating of greenhouses.
- Utilization of mini-hydro power.
- Biomass (biogas production from organic agricultural residues) as an alternate fuel.
- Assessment of wind energy for small-scale electricity generation within the scope of combined utilization of renewable energy sources (such as solar and biogas), particularly in remote rural areas.

Research and development work on solar and geothermal energy and biogas are already in operation, while programs in wind energy and mini-hydro power are in the planning phase.

Solar Energy

Activities aimed at making more effective contribution of solar energy to the national energy balance are pursued under the coordinative responsibility and supervision of the Ministry of Energy and Natural Resources. In order to reach the planned targets, Marmaris Solar Energy Research Centre was established in 1977.

In this respect, the Mineral Research and Exploration Institute was entrusted with the task of formulating a national solar energy working program, to be organized on the basis of establishing and maintaining a close collaboration with all the interested universities in order to conduct the proposed activities in a cooperative manner.

On the other hand, the Scientific and Technical Research Council of Turkey and various universities, particularly Ege University, also are engaged in active research work in the field of solar energy.

At the present stage of development, the main features of the activities, comprising merely low-temperature applications, in progress at the above-mentioned institutions cover the following areas:

- Solarimetry studies and development of a solar map of Turkey.
- Design, construction and performance-testing of various solar collectors.
- Water heating.
- House heating (passive and active methods).
- Drying of various agricultural and industrial products.
- Heating of greenhouses.
- Solar distillation of sea water.
- Architectural aspects of solar energy use for energy conservation in buildings.

In addition to the activities described above, the following research and development programs are planned to be put forward in the near future:

- Determination of the feasibility of combined utilization of solar, biogas and wind energy in meeting the various specific needs of isolated rural areas not yet connected to the national grid.
- Development of concentrating collectors for process heat production in industry.
- Solar distillation of brackish water for sodium sulfate and magnesium sulfate production.

- Energy storage.
- Solar absorption cooling.
- Solar ponds.

Moreover, several commercial firms in the private sector are engaged in manufacturing and marketing various domestic solar water heaters, and have been for more than three years.

The solar water heaters are installed in residential and commercial buildings and tourist places generally in locations where insolation is high and fairly uniform throughout the year.

Geothermal Energy

The activities regarding the assessment of geothermal energy potential have been going on systematically since 1961 under the administration and sponsorship of the Mineral Research and Exploration Institute.

As a consequence of detailed surveys in certain regions having suitable reservoir and hydro-chemical conditions, energy generation possibilities have been determined, especially in the western and central parts of Anatolia. At present, 13 promising fields are considered to be primarily important and planned projects regarding the assessment of exploitable geothermal potential are focused on electricity generation and heating.

In the Denizli-Kizildere geothermal field, which is the most progressive one at present, an experimental pilot plant of .5 MW installed capacity, established in 1975, has been operated successfully. Implementation of a power plant of 20 MW installed capacity (120 GWh per year) has been planned and commercial operation was foreseen for 1982.

In addition to the electricity generation, waste geothermal fluid will be harnessed for the purpose of heating greenhouses. At present, a pilot project is in operation for heating greenhouses 3,000 square meters in area. Favorable results have been obtained and the possibility of further heating of greenhouses, of 500,000 square meters in area, has been identified. Heating of the nearby towns offers another possibility.

Upon realization of the commercial operation of the power plant to be implemented in the Denizli-Kizildere field, relevant studies for power production from other promising geothermal fields would be accelerated. In this connection, a large-scale demonstration project is underway, aiming at construction of a domestic-designed turbine generator of 5 MW capacity.

On the other hand, preparatory activities for appraisal of low-enthalpy geothermal fields were commenced.

Biogas

Research and development activities on the promotion and utilization of biogas in Turkey are being conducted by the Mineral Research and Exploration Institute under the coordination and sponsorship of the Ministry of Energy and Natural Resources.

The work program has been put forward in three phases, and in light of the results achieved from the laboratory and pilot stages research work, a joint research and development project has been implemented with UNICEF for demonstration and propogation of biogas technology in Turkey on a national scale under cold climatic conditions. A large-scale biogas plant, of 35 cubic meters in capacity, was designed and constructed in one of the eastern provinces of the country, where biogas definitely is deemed an important source of energy and agricultural-economic input.

The project is in progress under the coordinative responsibility of the State Planning Organization in cooperation with the Ministry of Energy and Natural Resources and the Ministry of Agriculture and Forestry.

Testing activities are underway to determine the necessary economic and operational criteria. In the future course of activities, propagation of the prototype digestors throughout the country will be taken into consideration, subject to economic reliability of the first stage of demonstration work.

MAIN CONSTRAINTS

The national energy budget for the Fiscal Year 1980 amounted to about 1.6 percent of the GNP. Heavy reliance on petroleum has affected the Turkish economy severely.

The heavy burden inflicted on the national economy by the petroleum imports bill has prolonged several major energy projects, which in turn has forced a national blackout program and even importation of electrical energy.

It is also worth emphasizing that industry, the largest energy consumer, is presently based mostly on inefficient technologies due mainly to the transfer of outdated and least expensive technologies and know-how from developed countries, with minimum energy conservation considerations.

Turkey foresees certain problems for the expansion of its basic national programs, as far as industrial capabilities and technical experience are concerned, for certain large-scale applications. In this connection, process heat production, seasonal energy storage and small-scale electricity generation in the field of solar energy could be cited.

There is a considerable imbalance between the locations of resources and consumption centers. The major deposits of petroleum, lignite and peat, as well as the main hydraulic sites, are located in the southeastern part of the country, while most of the industrial and agricultural activities and the population are concentrated in the western and northern regions.

It can therefore be concluded that an optimum balance between regional energy production and consumption patterns should be established and, in this regard, effective assessment and beneficial utilization of the new and renewable sources of energy potential, as dispersed energy forms for local use, deserve adequate attention.

FACILITATING NEW AND RENEWABLE SOURCES

To overcome the impediments encountered in further expanding the utilization of new and renewable sources of energy, the main lines of action concentrate on the following issues:

- Promotion of the supporting of research and development activities.

- Allocating adequate financial resources to the related projects in the public sector.

- Establishment of incentives for commercial applications.

Many research groups in governmental and private and academic institutions have been engaged in concerted research activities in the field of energy with due consideration to energy conservation, process optimization, new and renewable sources of energy and technology development.

Although the contribution of domestic industry to the energy sector is limited to production of small-scale mechanical equipment and construction work, development of a national energy industry is expected and envisaged in the present National Development Plan. On the other hand, the technical infrastructure and industrial capability (know-how, engineering services and labor force) are quite sufficient for building and constructing energy producing plants subject to importation of the major equipment.

In the field of new and renewable sources of energy, the program for local manufacture of equipment is aimed at developing appropriate prototypes within the framework of economical, technical and social patterns prevailing in the country.

At the present stage of development, main industrial attention is focused on solar energy equipment manufacturing, particularly flat plate solar collectors and complete systems for water and space heating. Solar water heating is clearly the most promising application at present and the technological capability of the country is good enough to allow the development of such technology on a national basis.

Special subcommittees have been formed within the Ministry of Energy and Natural Resources to handle and coordinate the development of ongoing national activities in the field of new and renewable energy sources in an effective manner. The preparatory activities are underway for further assessment of the economical, administrative and technical aspects of the relevant research and development activities.

Furthermore, close cooperation with international organizations (mainly with the United Nations) and foreign countries are being carried out in conformity with the programatic goals of the related national activities in order to overcome constraints encountered in the execution of the present research and development projects, stemming particularly from lack of foreign financing and equipment.

CONCLUSION AND RECOMMENDATIONS

The prospects for potential use of new and renewable sources of energy is highly promising in Turkey. Substantial attention in national energy planning now is being assigned to harnessing their beneficial utilization, and investments are encouraged with the aim to realize the planned targets on the practical applications of pertinent forms of new and renewable sources of energy.

The immediate fields of application comprise such domestic and agricultural uses in rural areas as heating, cooking, greenhouse heating, drying and irrigation.

Among the new and renewable sources of energy presently under investigation, solar energy plays the most prominent role. The passive utilization of solar energy in the residential sector seems very promising. The existing building codes offer scope for meeting a considerable fraction of the heating requirements of dwellings and industrial plants by solar energy. Moreover, the temperature level of energy use by industry is very encouraging for solar process heat production.

ANNEX 1. ORGANIZATIONAL STRUCTURE IN THE AREA OF NEW AND RENEWABLE SOURCES OF ENERGY

Government Agencies Responsible for Evolving Strategies

The State Planning Organization, established in 1960, has comprehensive authority over the preparation of national development plans, programs and investment programs, as well as approval of related decisions with respect to implementation of plans and programs.

In this connection, it has the statutory responsibility for determination of main energy policies, annual and long-term targets and for evaluation of the investment programs within the perspectives of national economic strategies adopted in five-year national development plans.

The Ministry of Energy and Natural Resources, set up in 1964, is responsible for implementing and coordinating national energy policies for the exploration, development, production, supply, distribution and use of energy, and the total natural energy resources of Turkey.

It is, in this respect, in charge of preparing investment proposals and of their implementation to ensure the realization of the planned strategies and program targets in conformity with the envisaged national policies adapted in the development plans.

The Scientific and Technical Research Council of Turkey was formed in 1963, to develop, carry out, promote and encourage basic and applied research in accordance with the objectives stated in the national development plans and programs.

In the framework of the above-mentioned objectives, it assists in facilitating adaptation and implementation of new technologies by means of technical and financial support to relevant organizations.

Government Institutions Responsible for the Execution of National Programs

Within the Prime Ministry: The Under-Secretary for Environmental Affairs is responsible for overall coordination of the activities with regard to environmental protection issues on the basis of the national environmental policies.

The Ministry of Finance is responsible for financing the investment projects.

The Ministry of Industry and Technology is responsible for technology transfer within the energy, research, development and demonstration programs, as well as for guiding the private sector in commercial applications.

The Ministry of Agriculture and Forestry is responsible for policy and implementation of the energy research, development and demonstration programs dealing with biomass.

The State Meteorological Institution is in charge of meteorological forecasts, and provides advice and background information to relevant organizations for promoting meteorological and heliometric data in the field of new and renewable sources of energy.

Under the Ministry of Energy and Natural Resources: The Mineral Research and Exploration Institute (MTA) is in charge of conducting the national research, development and demonstration programs dealing with solar, geothermal, biomass and wind energy.

The State Hydraulic Works (DSI) is responsible for assessment and utilization of hydraulic resources.

The Electric Power Survey Administration (EiEi) is in charge of preparing surveys on hydraulic resources in order to supplement the above-mentioned activities pursued by DSI as well as of investigations in the field of energy conservation.

In addition to the government agencies: Ege University is responsible for executing part of the research and development activities concerning solar energy.

Private firms are engaged in commercial applications mainly in the field of solar energy and energy conservation.

TABLE 1. PRIMARY ENERGY RESERVES AND RESOURCES

(10^6 tons)

	Proven	Proven + Probable	Probable	Possible	TOTAL
Hard Coal	187.2	71.4	287.2	906.2	1452.0
Lignite	4140.0	1016.8	1724.0	461.7	7342.0
Crude Petroleum	57.0	-	-	-	57.0
Asphaltites	-	36.0	-	16.0	52.0
Bituminous Schists	340.0	-	-	4856.0	5196.0
Natural Uranium	4.0	-	-	0.6	4.6
Thorium	380.0	-	-	-	380.0

TABLE 2. PRIMARY ENERGY PRODUCTION IN THE PERIOD 1960-1990

(10^{15} J)

Years	Hardcoal	Lignite[1]	Petroleum	Hydro	Geothermal	Nuclear	Wood	Animal and Plant Wastes	TOTAL
1960	93	36	16	10	-	-	163	87	405
1965	112	56	67	23	-	-	162	91	511
1970	117	75	156	32	-	-	161	97	638
1975	123	130	136	62	-	-	183	103	737
1980	92	210	102	118	-	-	176	99	797
1985	117	701	140	227	0.96	-	216	159	1561
1990	132	922	140	491	0.96	38	236	153	2113

PRIMARY ENERGY PRODUCTION STRUCTURE

(%)

1960	23.0	8.9	4.0	2.5	-	-	40.2	21.4
1965	21.9	11.0	13.1	4.5	-	-	31.7	17.8
1970	18.3	11.8	24.5	5.0	-	-	25.2	15.2
1975	16.7	17.6	18.5	8.4	-	-	24.8	14.0
1980	11.6	26.3	12.8	14.8	-	-	22.1	12.4
1985	7.5	44.9	9.0	14.5	0.06	-	13.8	10.3
1990	6.3	43.6	6.6	23.3	0.04	1.8	11.2	7.2

(1) including asphaltities

TABLE 3. PRIMARY ENERGY CONSUMPTION IN THE PERIOD 1960-1990

(10^{15} J)

Years	Hardcoal	Lignite [1]	Petroleum	Hydro	Geothermal	Nuclear	Wood	Animal and Plant Wastes	TOTAL [2]
1960	99	34	85	11	-	-	163	87	479
1965	115	55	174	23	-	-	162	91	620
1970	119	73	337	32	-	-	161	97	819
1975	121	130	613	62	-	-	183	103	1213
1980	107	210	684	119	-	-	176	99	1409
1985	375	772	1177	227	0.96	-	216	159	2927
1990	656	1114	1695	491	0.96	38	236	152	4383

PRIMARY ENERGY CONSUMPTION STRUCTURE

(%)

Years	Hardcoal	Lignite	Petroleum	Hydro	Geothermal	Nuclear	Wood	Animal and Plant Wastes
1960	20.7	7.1	17.7	2.3	-	-	34.0	18.2
1965	18.5	8.9	28.1	3.7	-	-	26.1	14.7
1970	14.5	8.9	41.1	3.9	-	-	19.7	11.9
1975	10.0	10.7	50.6	5.1	-	-	15.1	8.5
1980	7.6	14.9	48.6	8.4	-	-	12.5	7.0
1985	12.8	26.4	40.2	7.8	0.03	-	7.4	5.4
1990	15.0	25.4	38.7	11.2	0.02	0.9	5.4	3.4

(1) including asphaltites
(2) includes electricity imports

FIGURE 1. ENERGY MANAGEMENT INFRASTRUCTURE IN THE FIELD OF NEW AND RENEWABLE SOURCES OF ENERGY

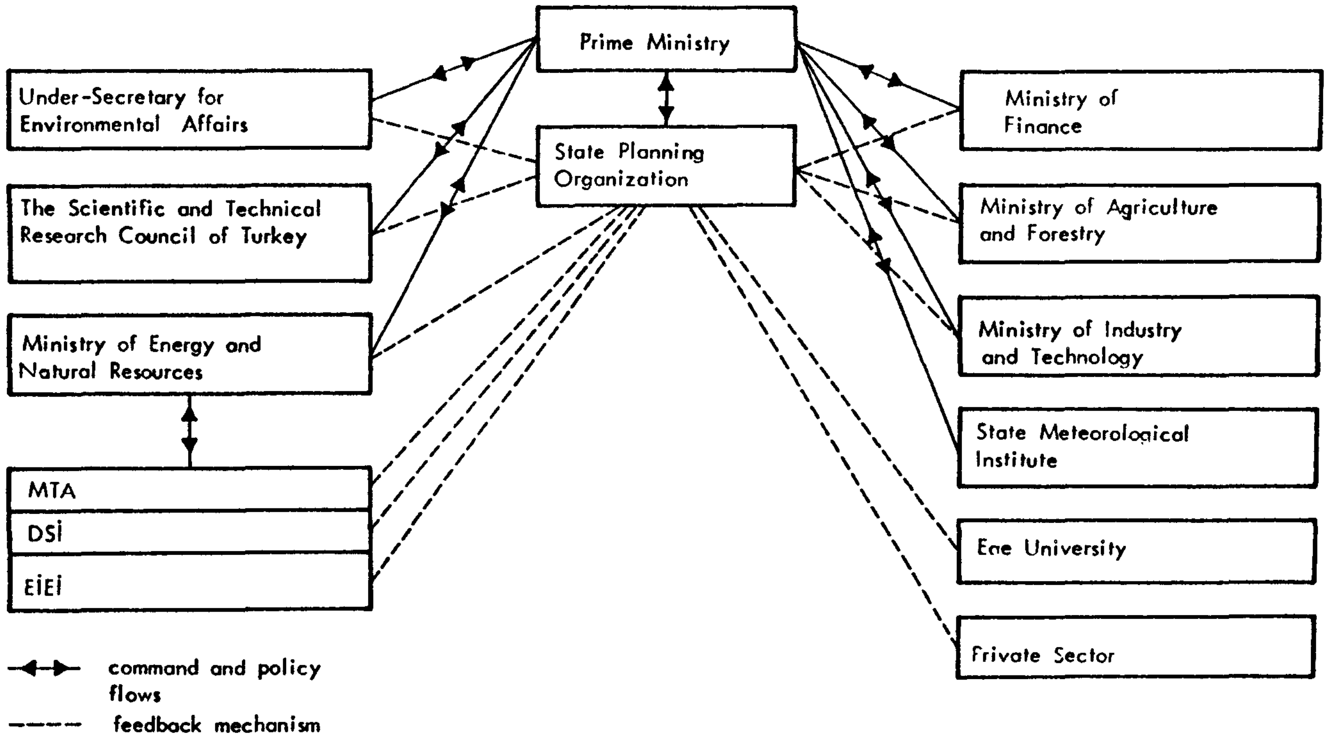


FIGURE 2. ENERGY CONSUMPTION BY PRIMARY ENERGY SOURCES

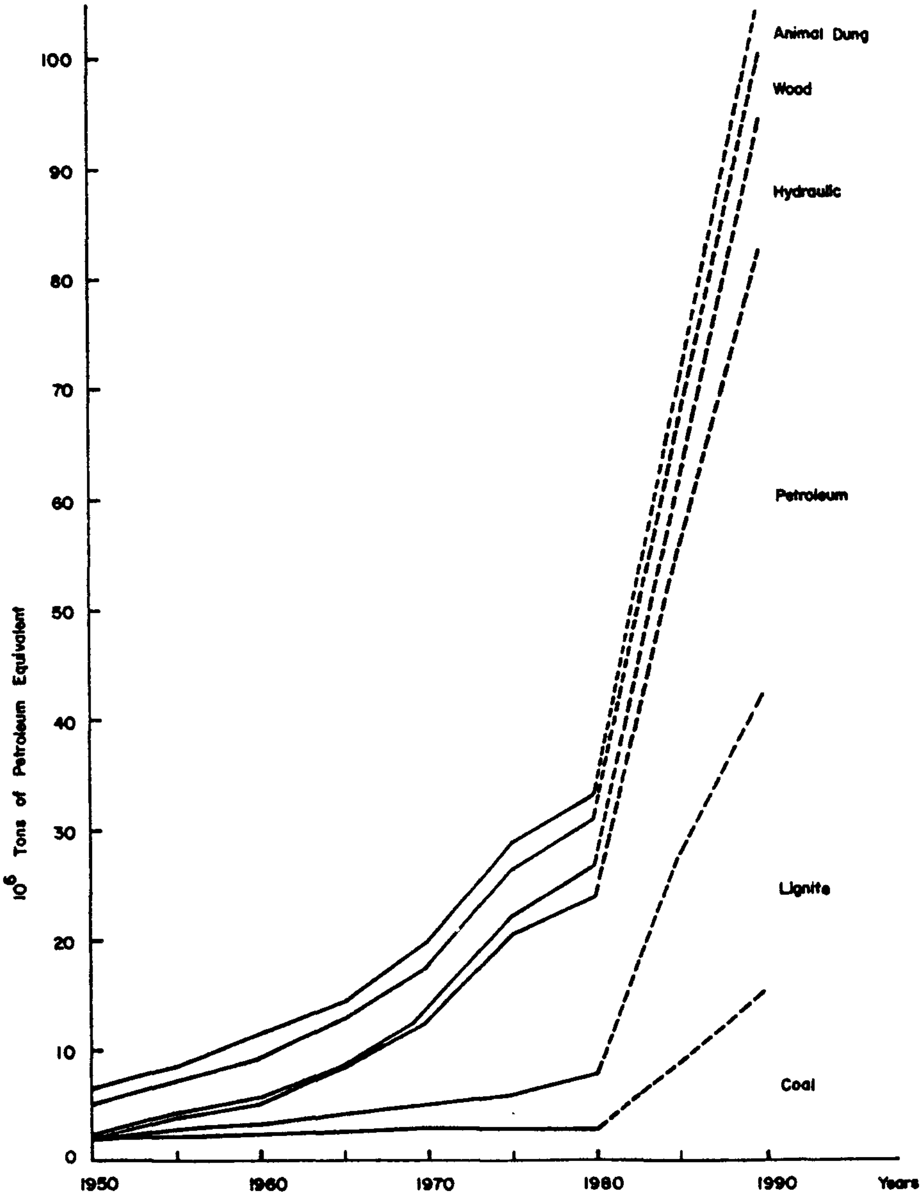


FIGURE 3. THE DISTRIBUTION OF ENERGY CONSUMPTION IN 1980

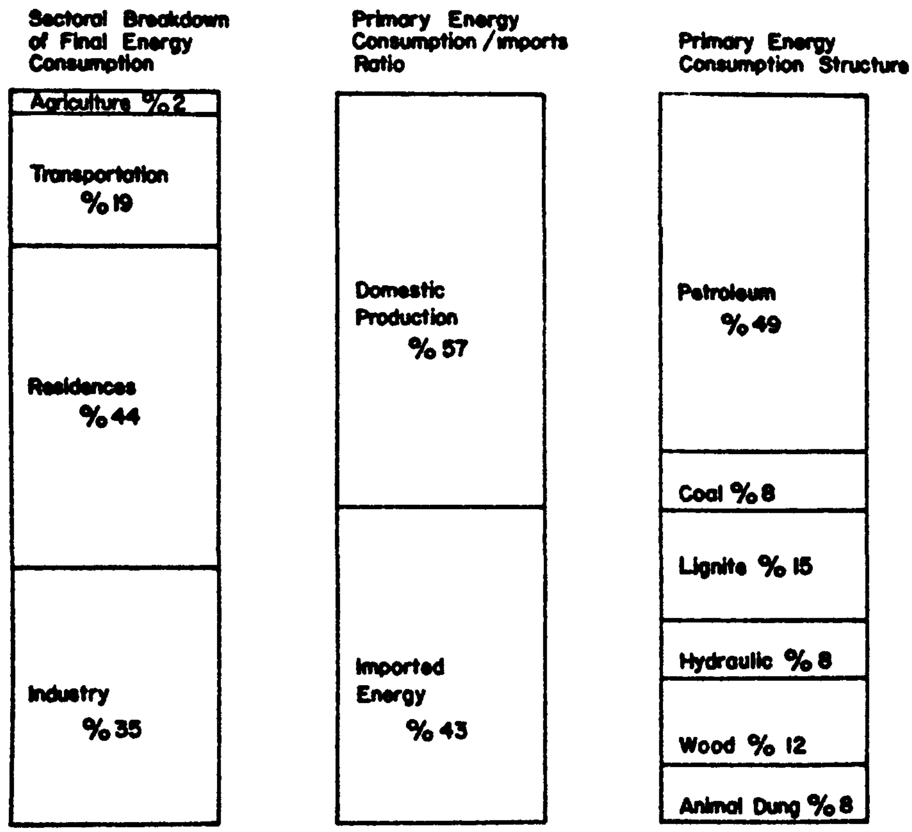
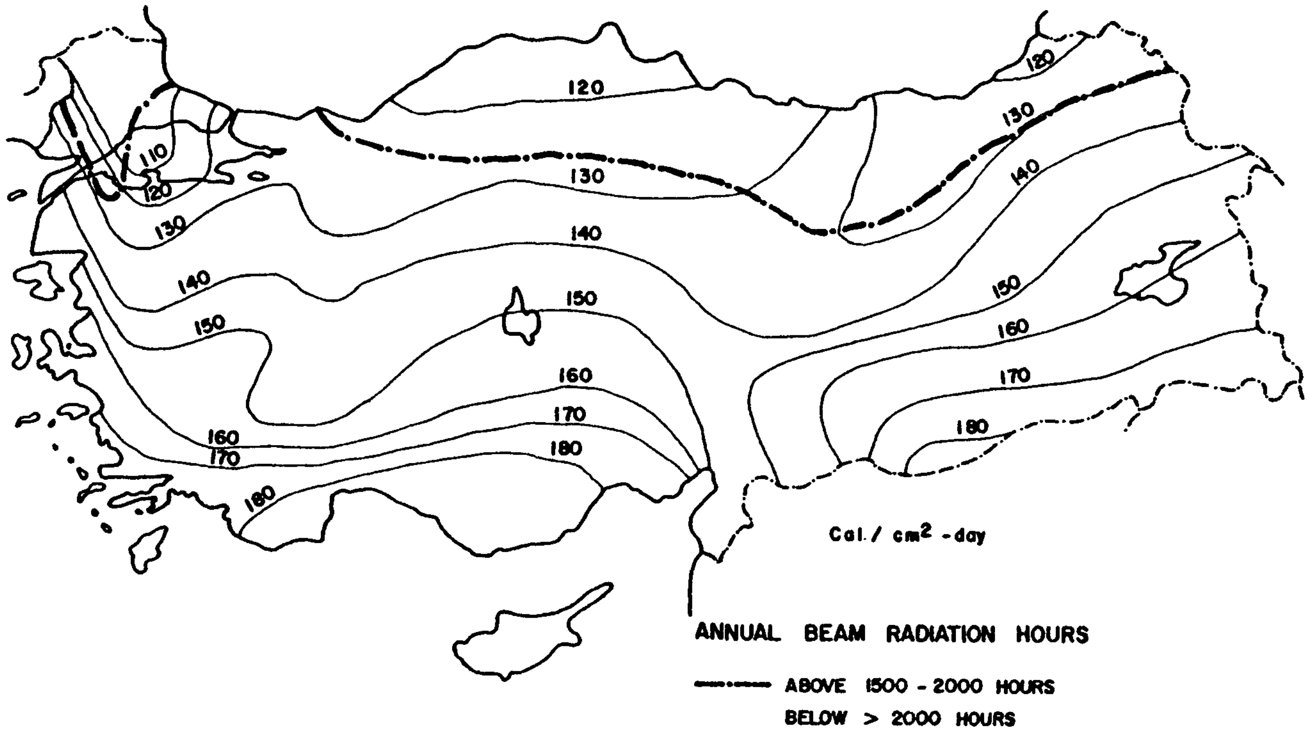


FIGURE 4. SOLAR MAP OF TURKEY
(Annual total solar radiation on horizontal surface)



DOCUMENT NUMBERS FOR ORIGINAL U.N. REPORTS

The reports in the *Future Energy Sources: National Development Strategies* series are edited and abridged versions of documents prepared by national governments for the United Nations Conference on New and Renewable Sources of Energy, held in Nairobi, Kenya in August 1981. All editing and abridging was done by McGraw-Hill.

The following are document numbers for the original, unedited U.N. papers. All numbers are preceded by the prefix A/CONF.100/NR/. The number for Egypt, for example, would read A/CONF.100/NR/41.

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