PERFORMED FOR: THE ADVISORY COMMITTEE FOR RECONSTRUCTION
MINISTRY OF DEVELOPMENT
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SINAI DEVELOPMENT STUDY

PHASE 1

DAMES & MOORE
IN ASSOCIATION WITH
INDUSTRIAL DEVELOPMENT PROGRAMMES SA

WORKING PAPER NO. 15

ENERGY RESOURCES ASSESSMENT AND EVALUATION OF ENERGY REQUIREMENTS

SEPTEMBER 1981

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PERFORMED FOR THE ADVISORY COMMITTEE FOR RECONSTRUCTION OF THE MINISTRY OF DEVELOPMENT

BY DAMES & MOORE
(IN ASSOCIATION WITH INDUSTRIAL DEVELOPMENT PROGRAMMES SA)

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LIST OF ACRONYMS AND ABBREVIATIONS

EGPC	Egyptian General Petroleum Company
CEDCO	Canal Electricity Distribution Company
SUCO	Suez Oil Company
GDP	Gross Domestic Product
GRP	Gross Regional Product
EEA	Egyptian Electrical Authority
LPG	Liquefied Petroleum Gas

* * *

Btu	British thermal unit
kWh	Kilowatt-hour
g	Gram
yr	Year
m	Meter
$stdft^3$	Standard cubic foot
$stdm^3$	Standard cubic meter
MWyr	Megawatt-year
LE	Egyptian pound
kV	Kilovolt
MW	Megawatt
l	Liter
bbl	Barrel
kcal	Kilocalorie
kg	Kilogram
J	Joule

W	Watt
km	Kilometer
sec	Second
GJ	Gigajoule

EXECUTIVE SUMMARY

The effective use of the energy resources of Sinai is a key element in determining the success of development over the next several decades. When compared with normal civil activities in more moderate environments, the harsh environment of Sinai will extract a heavy energy penalty in achieving development objectives. The successful blending of short-term energy requirements with energy-efficient, long-term goals and objectives will require the skill and dedication of energy experts in all aspects of Sinai development.

Sinai now exports energy in the form of petroleum, and projections indicate that this production will be sustained over the next 10 to 15 years. Natural gas associated with oil production is presently being flared, but steps are being taken by the Egyptian General Petroleum Company (EGPC) to collect and use this resource. The energy value of the flared gas is equivalent to 3 million barrels of oil per year, or 250 megawatts of electrical power if burned in an efficient power plant.

Proven reserves of coal at the Maghara mine exceed 35 million metric tons. Used in conjunction with natural gas in a combined-cycle plant, the coal reserves could provide 300 to 500 megawatts of electric power for 25 to 40 years. Other coal deposits at Wadi Thora and at Ayun Musa are not considered to be economical for exploitation at this time.

Annual solar radiation levels in Sinai are among the highest in the world, and certain regions--particularly along the Gulf of Suez and near the Red Sea--have consistently high wind velocities. These areas are therefore well suited for the implementation of renewable energy technologies, and many applications of solar and wind systems have been demonstrated in Egypt.

Under the first phase of a three-part program administered by the Canal Electricity Distribution Company (CEDCO), electricity is now being provided to all major population centers by means of diesel-electric generators and combustion gas turbines. The second interval of the CEDCO plan includes generation of power using flared gas; the third interval will generate 300 to 600 megawatts using coal from Maghara, with connection through the Hamdi Tunnel to the national electric grid.

Sinai is virtually virgin territory with respect to energy conservation since both the population and the per capita consumption of energy are low. If properly managed, Sinai can be developed in an efficient and orderly manner to attain maximum benefit from the expended energy resources.

Several factors essential to an effective energy program for Sinai are outlined below:

- Use of flared gas—Immediate steps should be taken to collect and use the gas associated with oil production. If used efficiently to produce electricity, this gas could generate in excess of 250 megawatts of electrical power. Alternatively, the gas could be used as a feedstock for fertilizer production or petrochemical industries.

- Use of Maghara coal—The Egyptian Geological Survey and the Ministry of Electricity and Energy have been evaluating proposals from international corporations for reactivation of the Maghara coal mine. Extraction at a rate of 600,000 tons/yr could generate in excess of 200 megawatts of electrical power. A high-efficiency, combined-cycle power plant of 450 to 500 megawatts could be located along the northern Gulf of Suez region to use coal from Maghara for supplementary firing of waste heat recovery boilers, while gas and oil could be used to power the gas turbines.

- Use of excess capacity of gas-turbine plants at oil company facilities on the Gulf of Suez—The single-cycle, gas-turbine plants of Petrobel and those soon to be operational at Suez Oil Company (SUCO) facilities will be operating at less than rated load, at a heat rate on the order of 400 grams of oil per kilowatt-hour (16,000 Btu/kWh) or higher. The plants would operate up to 20 percent more efficiently at full rated load, and the excess power could be sold to CEDCO at a small incremental cost. The addition of waste heat recovery boilers and steam-turbine generating equipment could lower the heat rate to 250 g/kWh (10,000 Btu/kWh) or less, providing significantly more power to CEDCO at an even lower cost.

- Conservation—Experience has shown that an aggressive conservation effort can result in significant savings. Although there is no apparent infrastructure in place to institute such a program, an effort should be made to at least identify energy alternatives and determine the total life-cycle costs for the various options.

- Alternative energy--Equipment has been developed and many practical demonstrations have been conducted in Egypt of solar, wind, and biomass devices to convert these renewable forms of energy for useful purposes. An alternative energy plan should be developed to define a specific program for selecting and applying practical, cost-effective, renewable energy systems in Sinai.

- Institutional changes--Control and management of energy and water resources to support the successful development of Sinai will require the cooperation and integrated support of numerous ministries and diverse organizations. A ministerial body is needed to develop policy guidelines and to coordinate the activities of the many individual organizations so that energy and water can be used most efficiently throughout Sinai.

The national goals of providing basic goods and services to all and of aiding and encouraging the rapid development of Sinai will tend to encourage waste and energy inefficiency. Artificially low prices must be accompanied by regulations and controls to prevent the development of high energy consumption patterns. A national program focusing on the rationalization of energy consumption and the efficiency of its application is clearly needed.

ENERGY RESOURCES ASSESSMENT
AND EVALUATION OF ENERGY REQUIREMENTS

1.0 INTRODUCTION

This paper is submitted in accordance with Task 8.3, Energy Resources Assessment, and Task 8.4, Evaluation of Energy Requirements, of the Sinai Development Study, Phase I. The information presented herein will also serve as input to Tasks 11 and 12, Preliminary Development Strategy and Investment Study and Semi-Detailed Physical Plans, respectively.

From January through July 1981, the Solar Engineering Group, under a subcontract to Dames & Moore, conducted an assessment of the energy resources in Sinai as a base for planning future energy requirements. Since firm projections of population and economic growth had not been established at the time of this writing and since the type and amount of industrial development had not been specified, the energy requirements were estimated on a per capita basis. Thus, the estimates can easily be adjusted to match the changing projections for Sinai.

An attempt was also made to determine the sectoral distribution of energy—that is, the distribution by use categories such as agricultural, fishing, transportation, electrical generation, industrial, residential, and commercial. Where data were available, per unit energy estimates were provided to facilitate future calculation of sectoral energy needs for various sectoral growth rates.

1.1 BACKGROUND

The energy resources of Egypt were extensively studied during 1978 by a joint Egyptian-U.S. team (U.S. Department of Energy, April 1979). The objectives of the study were to identify and characterize energy resources, present and projected energy requirements, and alternative scenarios that might be implemented to maximize the benefit to Egypt from the application of its energy resources. A more limited study was also made of various renewable energy options from the standpoint of Egypt's energy needs and its social and economic development (MITRE Corporation, July 1980).

With the return of Sinai to Egyptian control, there has been a recognition of the need to provide essential goods and services to the Sinai communities and to establish a program for growth and development of the region. The responsibility for providing essential electrical power to the Sinai and Canal Governorates was assigned to the Canal Electricity Distribution Company (CEDCO), an operating unit of the Ministry of Electricity and Energy. A plan for the electrical projects required for the development of Sinai and the canal region was released in August 1980, and an updated plan was prepared in August 1981 (CEDCO, August 1981). The first interval of the 6-year phase is well underway, with completion expected in mid-1982. The principal feature of the second interval, to be completed in 4 years, is the construction of combustion gas-turbine power plants to use the natural gas that is available along the Gulf of Suez. The third interval includes connection of north and south Sinai to the main electrical grid and construction of a thermal power plant, probably using coal from the Maghara mine.

Since electrical power in Sinai is generated by diesel-electric or combustion gas-turbine generators, all commercial energy in Sinai is ultimately derived from petroleum-based products. A primary purpose of this energy study is to recommend growth alternatives to achieve the required energy at minimum cost, commensurate with other development objectives for Sinai.

1.2 ENERGY RESOURCES IN SINAI

1.2.1 Petroleum

Sinai is endowed with energy resources far exceeding its anticipated energy needs and will thus be able to export energy to Egypt for at least the next several decades. Petroleum is the only energy resource being exploited at this time, though plans are in place for capture and use of the natural gas associated with oil production. Some exploratory work has been undertaken to determine the availability of natural gas not associated with oil, and there are indications that some Sinai gas fields may have commercial value. Present oil production is limited to onshore and marine fields in the Gulf of Suez, but leases have been sold in the Gulf of Aqabah, and exploratory drilling is taking place in the vicinity of El Arish.

At a crude oil production rate of 114,000 barrels per day (1980), the production-to-consumption ratio is estimated to be 225. Thus, the current demand for petroleum products in Sinai is much less than 1 percent of the production in the region.

1.2.2 Natural Gas

A significant energy resource which is presently being wasted is the roughly 1.4 million stdm^3/day of gas associated with petroleum production. This flared gas, with an energy content equivalent to 3 million barrels of oil per year, is 17 times the present energy demand for Sinai. The Egyptian General Petroleum Company (EGPC) is planning to capture this energy within the near term for commercial purposes. Its use for generation of electrical power in a highly efficient combined-cycle power plant could have a leverage of two or more in displacing oil consumed in less efficient thermal power plants in Egypt. In this application, the displacement of up to 6 million barrels of oil per year could have a positive impact on export income of $150 to $200 million per year.

Additionally, this natural gas could be used for electrical generation and desalination in support of activities at Abu Zenima once the ferromanganese facility is operational.*

1.2.3 Coal

The coal resources at the Maghara mine in north central Sinai are believed to be economically extractable. With 35.6 million metric tons of proven and probable reserves, the Maghara coal is being considered for use in a thermal power plant and

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* Immediately prior to the 1967 war, a ferromanganese facility was constructed at Abu Zenima, approximately 53 kilometers above the Belayim field. An electric furnace was planned for use in a duplex smelting of the ferromanganese ore--with a total processing capacity of 25,000 tons of ferromanganese per year. Electricity was to be generated onsite by three Brown Boveri Type TA 8007 gas-turbine generators (see Project Summary, Abu Zenima Electrical Generation and Desalination Facilities). Desalination facilities powered by waste heat boilers were designed to furnish 245,000 m^3/yr of desalinated water, though the anticipated requirement was only 191,000 m^3/yr.

The electrical generation-desalination plant had a projected requirement of 33 million cubic meters of natural gas per year, which was to be furnished from the Belayim field. Supply was to be transported through an 8-inch, spiral-weld steel pipe; though there are conflicting reports as to whether this pipeline was ever completed, at least part of it is still in place, but considerably damaged. The original compressor facilities at Belayim reportedly have been scrapped. The anticipated ferromanganese load requirements translated to approximately 3.2 million stdft^3/day of natural gas.

It appears that flared gas in the eastern Gulf of Suez area is approximately 15 times greater than the supply requirements for the ferromanganese facility at Abu Zenima, as originally designed. The projected supply will remain at more than 5 times the demand for such an industrial use until the year 1995.

also for blending with European coal to produce coke for use in Egyptian steel mills. If coal is used in conjunction with flared gas or oil in a combined-cycle power plant, each barrel-of-oil equivalent could displace two or more barrels of petroleum consumed in less efficient thermal power plants elsewhere in Egypt. The leverage in displacing petroleum consumption is directly related to the heat rates, or inversely proportional to the thermal efficiencies of the respective power plants. At a plant efficiency of 40 percent, the Maghara coal could produce 450 megawatts of electrical power for about 30 years. The equivalent electrical power from an oil-fired plant with a 20 percent thermal efficiency would require over 9 million barrels of oil per year, or about 275 million barrels over the life of the Maghara mine.

1.2.4 Alternative Energy

In addition to the proven recoverable deposits of nonrenewable energy in the form of crude oil, gas, and coal, Sinai is generously endowed with a relative abundance of solar energy resources. Peak solar insolation rates of 1,000 W/m^2 on a horizontal surface are readily achieved, and Sinai's favorable location and the lack of any significant cloud cover tend to support the application of conventional, ready-to-install, solar-powered facilities. Solar-powered domestic hot water heaters were used extensively in and around El Arish during the Israeli occupation, and a factory exists in El Arish with the capability of producing water heaters in conformance with the Israeli design.

Solar-powered water distillation and desalination systems have been demonstrated at the National Research Center's Solar Test Laboratory in Cairo. Similar units should be installed in demonstration solar facilities in Sinai. Solar photovoltaic panels have been used to support a variety of low-power applications which preclude the use of conventional electrical resources. Examples are remote site communication and data acquisition systems and refrigeration and cooling for medical supplies at remote clinics. Solar cookers and solar-powered water pumps have been demonstrated, and it is possible that variations of existing designs might be applicable in some locations. Some experimental or application engineering will undoubtedly be required to establish the applicability of many of the solar-powered devices.

Solar-powered salt ponds have proven to be operable in the Dead Sea area and in a few other sites. It is possible that a solar salt pond system could be economically operated in the Lake Bardawil area. Stored solar thermal energy in the salt pond could be used day or night to distill water, generate electricity, or provide mechanical power for pumping, air conditioning, or ice making.

Wind resources have been studied at various sites in Egypt. Numerous small wind machines have been set up to the west of Alexandria, and there are indications that larger machines might be appropriate for production of electrical power along the Red Sea coast. Although detailed wind data are not available at most locations in Sinai, some information exists for El Arish, El Tor, and Abu Rudeis.

For Sinai, the most promising applications of the mechanical energy output of a wind machine are water pumping and generation of electricity. Wind electric generators are available in sizes ranging from less than 100 watts to more than 1 megawatt. The smaller systems would be useful for remote sites far from the electric grid. The larger machines have not been extensively tested, and the reliability of different designs has not been well demonstrated. However, the use of wind energy for electrical generation has considerable potential to become a significant source of energy in an area such as south Sinai.

2.0 CONCLUSIONS AND RECOMMENDATIONS

The presentation of conclusions and recommendations on the future direction of energy matters in Sinai is indeed a significant responsibility in light of the almost complete lack of solid data with which to work. Although conclusions can be drawn at this time, it is quite probable that the availability of additional data could lead to other conclusions. These recommendations are, therefore, a first approximation of what might develop as a solid, well-defined energy program for Sinai. Sections 2.1 through 2.6 present these preliminary conclusions and recommendations.

2.1 PETROLEUM RESOURCES

Petroleum production is one of the dominant factors in Egyptian economic growth, accounting for more than 15 percent of the gross domestic product (GDP) in 1979. There are indications that a significant portion of new production will come from Sinai fields, since 64 percent of the 1 billion barrels added to the proven recoverable reserves of Egypt in 1980 were from the marine Belayim field and the Location 195 field off the coast of Sinai. New discoveries to the south of the Belayim field during 1981 could increase the proven recoverable reserves by a factor of two or three. An obvious conclusion is that petroleum production is the dominant industry in Sinai and a major contributor to the gross regional product (GRP) of Sinai.

RECOMMENDATION 1: Purchase excess electrical power from Sinai oil operations.

A strong effort should be made to cooperate with the Sinai petroleum companies to provide infrastructure that will help reduce their operating costs and provide a sound base for industrial development in the immediate area of oil company operations. As an initial step, arrangements should be made to purchase excess power from Petrobel and Suez Oil Company (SUCO), at the same price that power is purchased from the Egyptian Electrical Authority (EEA). This would provide about LE 80,000 per megawatt-year to the oil companies, without any significant increased expense and with no increase in investment since their power plants have both standby and spinning reserve capacity. The savings in gas oil used in the diesel-electric plants by substitution would be about 30,000 barrels/MWyr, with a world market value of about $900,000 per year; oil company operations in

Sinai should be able to provide 20 to 40 megawatts without adding capacity to their power plants.

2.2 NATURAL GAS

Natural gas associated with oil production operations in the eastern Gulf of Suez area amounted to about 1.4 million m^3/day in 1980 (50 million $stdft^3$/day). Present projections are that the level of production will be maintained through 1985, dropping to one-half by 1990, and to one-third the above value by 1995. Production from newly discovered fields could add to the present reserves, as could exploratory drilling in north Sinai and in offshore areas in the Mediterranean Sea.

The energy content of the natural gas associated with oil production in the eastern Gulf of Suez area is approximately 5×10^{10} Btu/day. Converted to electricity with efficient, combined-cycle, gas/steam turbine generators, this energy would produce 240 megawatts of power—with an annual value of LE 32 million (based on 1.6 piasters per kilowatt-hour).

RECOMMENDATION 2: Build an electrical power generating plant in Sinai to use flared gas from the Belayim field.

The energy content of the flared gas in Sinai is equivalent to more than 1 percent of the total oil production in all of Egypt; flaring of the gas is equivalent to wasting over 7,000 barrels of oil per day or 3 million barrels per year. Unless a more attractive alternative can be found for use of the gas, construction should be started immediately on the first phase of a 500-megawatt, combined-cycle power plant. The first phase should include procurement of up to 180 megawatts of dual fuel (liquid gas) gas turbines, with provision for later additions of waste heat recovery boilers and steam-turbine generators. The first phase should also include the construction of a 220-kilovolt transmission line to Suez City and 220-kilovolt power cables through the Ahmed Hamdi Tunnel. Since it is planned that Sinai will eventually be connected to the national power grid, and since the flared gas is equivalent to 3 million barrels of oil wasted per year, the national economy will benefit from an accelerated construction schedule as recommended herein. The direct benefit to the region will be an adequate electrical power system to support an aggressive industrial development program in the Abu Rudeis area.

2.3 COAL

There are 35.6 million metric tons of proven recoverable reserves of coal at Maghara. Although consideration is being given to blending Maghara coal with European coal to provide coke for steelmaking, it is possible that greater benefit can be achieved by using it in an efficient, combined-cycle power plant to offset or replace electric power now being generated in less efficient oil-burning thermal plants. Although natural gas or oil should be used to power the combustion gas turbines, coal can easily be used in the fully fired waste heat recovery boilers to drive the steam-turbine generator portion of the plant. A combined-cycle plant operating at 40 percent efficiency will replace 1.6 units of oil burned in a thermal plant with 25 percent efficiency and 2 units of oil burned in a thermal plant with 20 percent efficiency.

Since mining was considered to be worthwhile prior to 1967, and since the Israelis considered coal removal to be only marginally economic under temporary (occupation) conditions, it is reasonable to believe that the increased value of energy today should make the operation of the Maghara mine economically attractive. The combination of Maghara coal with the natural gas currently being flared from the Belayim field could provide a viable energy source for producing 400 to 500 megawatts of electrical power in a combined-cycle power plant.

RECOMMENDATION 3: Mine coal at Maghara for use with natural gas from the Belayim field to generate electricity.

Unless blending Maghara coal with European coal is found to be more attractive than its use in an efficient, combined-cycle power plant, it is recommended that the mine be activated and a second phase be initiated to expand the power plant proposed in Recommendation 2. The expansion plans should include the addition of waste heat recovery boilers to capture the energy in the turbine exhaust and steam-turbine-powered electric generators to produce 300 to 450 megawatts of additional electrical power. The coal can provide supplementary firing in the waste heat boilers to consume the high oxygen content that remains in the turbine exhaust gases.

2.4 CONSERVATION

There is a commitment on the part of the Government of Egypt to provide energy resources to the people at reasonable prices, frequently far below the world market levels for energy in other countries. The low costs of energy to the user tend to remove any incentive to save, since the pay-back period for investments in conservation will be long. Furthermore, though government agencies are charged with making energy available, there are no agencies charged with seeing that energy is used efficiently. The poor maintenance on most of the nation's buses and trucks can be directly tied to the low cost of liquid fuels. The rapid expansion of the use of electricity is a direct result of its availability at low prices. Electric power generation is the least economical of all the available energy alternatives in Sinai.

It is easy to conclude, even on the basis of limited observations, that there is a tremendous waste of energy in many forms. The diverse responsibilities for various aspects of energy supply and distribution preclude the possibility of coordinated action for energy conservation.

RECOMMENDATION 4: Develop an energy conservation program.

An effective energy conservation program must be developed for Sinai. To be effective, the program must be able to command the attention and cooperation of all the many governmental agencies and semigovernmental organizations.

A detailed study is recommended to develop a comprehensive energy conservation program for Sinai. The program should incorporate all aspects of energy resources, energy production, and energy use so that maximum benefit can be obtained from capital and resources expended for energy. The conservation program should consider:

- The use of centralized production of electric power at efficient plants versus distributed use of diesel-electric generators.
- The use of solar domestic hot water heaters versus gas- or electric-powered hot water systems.
- Desalination, distillation, pumping, or shipboard transport of potable water and water for agriculture and other purposes.
- The use of all types of renewable energy as alternatives to nonrenewable energy resources.

2.5 ALTERNATIVE ENERGY

The Sinai Peninsula appears to be an ideal location for the application of various forms of renewable energy as an alternative to the consumption of oil, gas, and other scarce or expensive energy sources. Solar domestic hot water systems have been shown to be practical in Sinai, and an existing factory in El Arish could eventually manufacture 35 systems per day (10,500 systems per year), at a total value of more than LE 2 million per year. Solar water distillation systems, demonstrated at the National Research Center in Cairo, are practical for the production of small-to-medium amounts of potable water from brackish or saline water sources. Wind power appears to be adequate for pumping water or generating electricity at certain remote locations. Biogas can be produced from animal dung, night soil, and agricultural waste to provide for cooking and gas lighting. And solar salt ponds have been demonstrated to be a potentially practical method for generating multimegawatt levels of electrical power; the Lake Bardawil area could prove to be an economical site for a 10- to 100-megawatt power plant operating on solar energy via a solar salt pond.

RECOMMENDATION 5: Develop a plan for an alternative energy program in Sinai.

The objective of this plan should be threefold--to ensure the rapid deployment of proven alternative energy systems that are economically viable; to initiate the implementation of appropriate technology for essential remote site applications; and to establish a research and development program to test the feasibility of large multimegawatt power systems, such as solar salt ponds, solar power towers, and large wind-powered machines.

The alternative energy program should provide for an early field data collection task to establish wind and solar energy profiles throughout Sinai. It should develop detailed definitions of alternative energy demonstration and training sites in the vicinity of El Arish, El Tor, and New Mit Abu El Kom. The program should include an implementation plan for rapid deployment of proven alternative energy systems that are economically competitive with conventional energy systems and remote site applications. The determination of sources of capital funding should be addressed by the implementation plan, since a major portion of the savings will accrue to the Government under highly subsidized energy systems. Finally, the alternative energy program plan should define engineering analysis and economic evaluation tasks to study the technical and economical feasibility of large-scale, multimegawatt, solar- and wind-powered systems in appropriate regions of Sinai. For those multimegawatt systems that appear to be technically and economically promising, the program plan should set up a task for experimental verification of feasibility for establishing design definition of a pilot demonstration plant.

2.6 INSTITUTIONAL REQUIREMENT

Control and management of all aspects of energy and water are crucial to the successful development of Sinai. The harsh environment, remoteness, and marginal economics of many of the potential projects in Sinai will tend to increase energy needs. Conservation, cooperation, and innovative applications of energy options will be key elements of a successful development program. The control and management of energy and water in Sinai will require one operating official to maintain cooperation and integration among the many ministries and other organizational units functioning in Sinai.

RECOMMENDATION 6: Establish an energy and water management body within the Supreme Council for Energy.

A higher ministerial body should be created to provide policy guidelines and to coordinate the activities of the agencies in charge of production, distribution, and consumption of energy and water resources in Sinai.

3.0 CURRENT ENERGY DEMAND IN SINAI

3.1 PETROLEUM PRODUCTS

Data on the consumption of petroleum products in Sinai illustrate the rapidly changing energy situation in the region. Table 3-1 is a summary of the 1979 and 1980 figures for consumption of the major petroleum products. Since different fuels are used for different purposes, a preliminary estimate can be made of consumption by sector and, to some extent, of activities within sectors. Table 3-2 presents 1980 data on petroleum product consumption by region.

Butagas is used primarily in residential and commercial buildings in urban areas. Since such areas are often electrified, the primary use of butagas is for cooking, though it is also used for lighting and hot water heating.

In urban residences, kerosene is used for both cooking and lighting. In rural residences, it is used almost entirely for lighting since dried dung or other biomass materials are used for cooking.

Gas oil is used for transportation (in trucks, buses, and boats), as well as for electrical generation. By estimating the volume of electrical usage in Sinai in 1981 (16 megawatt-hours, from Section 3.2), and making an assumption for the conversion efficiency from gas oil to electricity (500 to 600 g/kWh), gas oil consumption for electrical generation (in 1981) is estimated to be on the order of 10,000 tons/yr, or somewhat more than 50 percent of the total gas oil consumption.

3.2 ELECTRICITY

The authority for governmental policy and planning for electrical power for all of Egypt rests with the Ministry of Electricity and Energy; the responsibility for electrical generation and transmission on a nationwide basis is delegated to the Egyptian Electrical Authority (EEA). The EEA generation facilities consist of two hydroelectric power stations at Aswan, with a total generating capacity of 2,445 megawatts. An additional 1,444 megawatts of steam-generating units and 523 megawatts of gas-turbine installations provide a total capacity of 4,412 megawatts. During 1979, the latest year for which statistics are available, the peak generated load was 2,752 megawatts, and total electricity generated was 16,338 terrawatt hours (16×10^9 kilowatt-hours). Averaged over the period from 1975 to 1979, both peak load and total electricity generated have grown at a rate of 12 percent per year.

TABLE 3-1

Annual Consumption of Petroleum Products in Sinai
(in tons)

Product	Usage	1979	1980
LPG (butagas)	Cooking/lighting	184	582
Motor fuel (benzene)	Automobiles	2,390	4,072
Kerosene	Cooking/lighting	739	1,454
Gas oil (sular)	Transportation (excluding automobile/electricity)	6,152	18,408
Luboils/greases	Transportation	154	323
TOTAL		9,616	24,839

SOURCE: The General Petroleum Authority, Statistical Department, April 1981.

TABLE 3-2

Consumption of Petroleum Products
in Selected Regions (1980)
(in metric tons)

Product	El Shatt	Qantara	El Tor	El Arish
Super benzene	--	90	2,190	1,387
Regular benzene	--	16	233	167
Kerosene	--	116	636	1,449
Gas oil (sular)	448	719	12,722	8,501
Fuel oil (mazout)	--	--	--	26

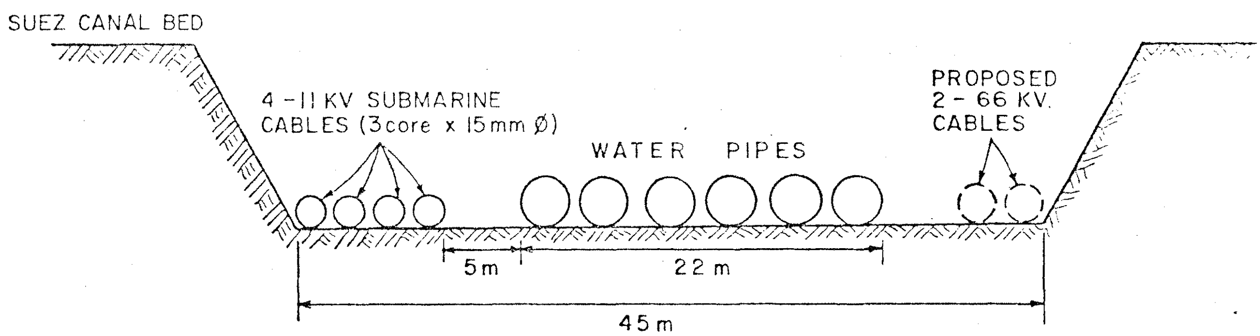
SOURCE: Egyptian General Petroleum Company, August 1981.

Electricity is sold by EEA to major industries, governmental authorities, and electrical distribution companies for distribution and resale to individual consumers. The Canal Electricity Distribution Company (CEDCO) is responsible for providing electricity in the Governorates of Port Said, Ismailia, Suez, Sharkla, Red Sea, North Sinai, and South Sinai. In 1979, CEDCO sold 556.2 million kilowatt-hours, with a value of LE 6.8 million. Currently, no electricity is transmitted from the national grid to either of the Sinai Governorates, but four 11-kilovolt, three-phase submarine cables have been placed under the Suez Canal in parallel with the six Nile water siphons at Ismailia. Two 66-kilovolt submarine cables are also being installed and should be available for use before the end of 1981. A schematic configuration of the submarine cables and the water siphons is shown in Figure 3-1.

Space has been provided in the utility section of the tunnel, under the canal at Suez City, for two 220-kilovolt, 500-ampere, three-phase cables, each with a capacity of 150 megawatts. Additionally, 11-kilovolt cables provide electrical power for the tunnel facilities.

Since the return of control of Sinai to Egypt, CEDCO has been primarily concerned with establishing small generating stations in most population centers, which are used mainly for public buildings and municipal operations. Efforts were made to restore an adequate electrical supply to El Arish after the connection to the Israeli grid was severed. Most of the electric power is provided throughout the rest of Sinai by about 50 small diesel generators (50 to 250 kilowatts). The existing power station in El Arish has a number of turbine generators, and a 7.5-megawatt turbine is currently being installed at a new generating station. Figure 3-2 shows the existing power generation and distribution network at El Arish, including the new El Masaid power station, now under construction, and the 22-kilovolt transmission line from Israel that was disconnected (on May 25, 1979) after installation of two 3,200-kilowatt combustion gas-turbine units. Also shown are three 460-kilovolt-ampere (actual capacity is 300 kilowatts) emergency power units connected to the 3.3-kilovolt distribution network.

Details on locations of existing generators in north Sinai were provided by the Technical Office of the North Sinai Governorate and are included in Table 3-3. South Sinai has 22 generators operated by CEDCO--in Ras Sudr, Abu Rudeis, El Tor, and St. Catherine. Electric power for Abu Zenima is provided by two 50-kilowatt electrical generators belonging to the ferromanganese plant. Although details were not available on generating facilities in all of the south Sinai towns,



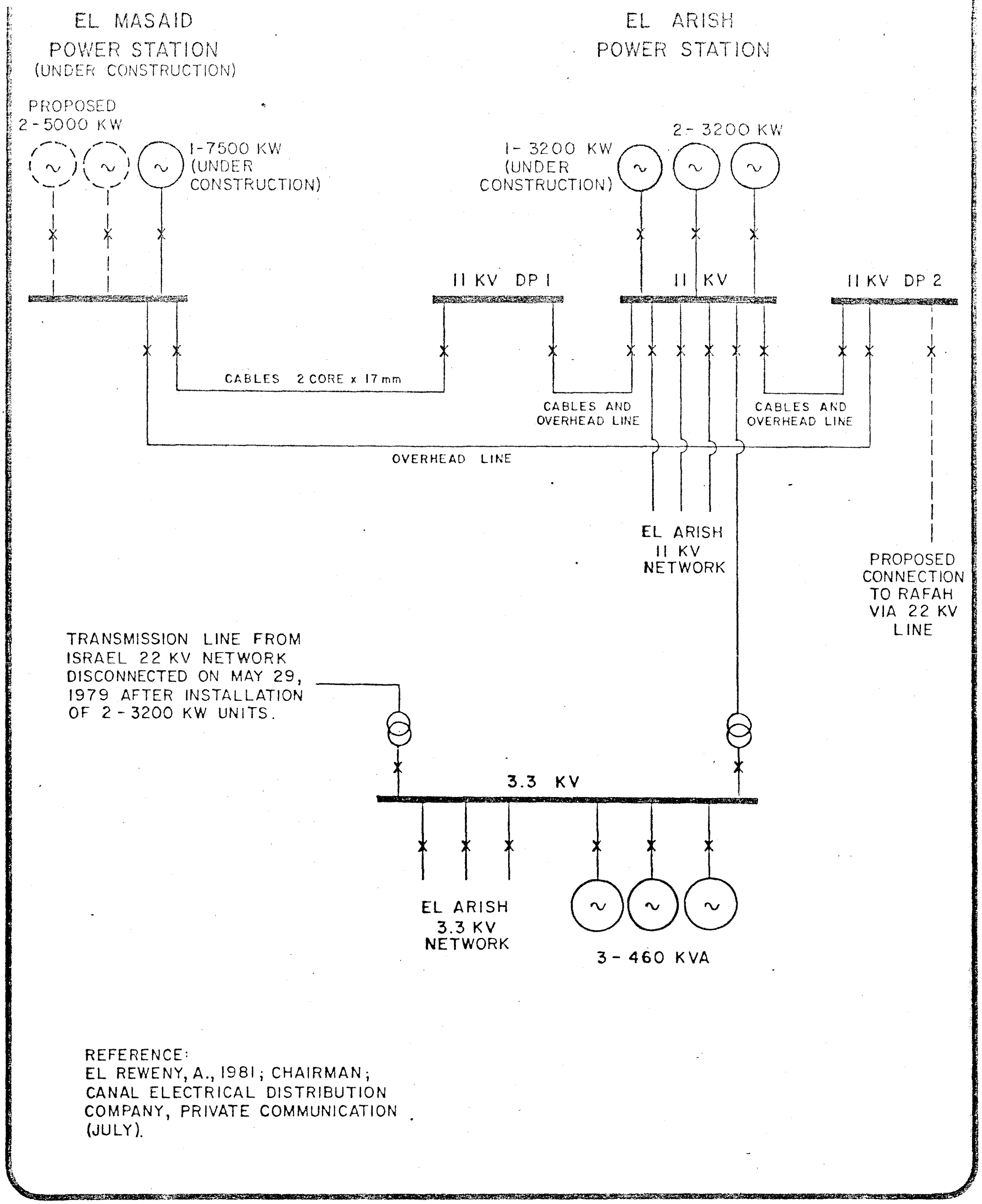
REFERENCE:
EL REWENY, A., 1981; CHAIRMAN, CANAL ELECTRICAL DISTRIBUTION COMPANY, PRIVATE COMMUNICATION (JULY).

Sinai Development Study Phase 1
Ministry of Development

Dames & Moore

ELECTRICAL CABLES IN ISMAILIA SIPHON TRENCH

FIGURE 3-1



Sinai Development Study Phase 1
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EL ARISH POWER STATIONS DISTRIBUTION NETWORK

FIGURE 3-2

TABLE 3-3

Electrical Generating System--North Sinai

Location	Rated Capacity (kilowatts)	Actual Capacity (kilowatts)
El Arish	2 x 3,200	5,000
	3 x 460	900
	500	400
	25	20
SUBTOTAL (El Arish)	8,305	6,320
El Hasana	50	30
Nakhl	50	30
Bir El Abd Region		
Bir El Abd	145	110
El Hezba	58	35
	91	91
Negila	58	40
Rabaa	90	72
Qatia	33	33
New Romana	2 x 120	240
Old Romana	90	70
Baluza	91	91
	58	45
Other sites	58	90
	91	91
	64	50
SUBTOTAL (Bir El Abd region)	1,167	1,058
TOTAL	9,572	7,438

Abu Rudeis has two generators and El Tor has six. The El Tor generating equipment consists of four 75-kilowatt and two 515-kilowatt generators.

Electric power for oil production is the responsibility of the individual oil companies, each of which operates its own plant.

On May 25, 1976, the peak load at El Arish was 800 kilowatts, and on May 25, 1981, it was 3,100 kilowatts (El Reweny, July 1981). A survey of communities in north and south Sinai provided estimated consumption figures as follows:

- Average daily consumption in north Sinai, 40,800 kilowatt-hours (35,000 kWh/day in El Arish alone).
- Average daily consumption in south Sinai, 3,200 kilowatt-hours.

At the time of this survey, most small communities--accounting for about 15 percent of the demand--used the generating equipment only in the evening, for approximately 6 hours a day.

3.3 NONCOMMERCIAL FUELS

Noncommercial energy--primarily in the form of biomass and animal wastes burned for cooking and, to a much lesser extent, for space heating--represents a significant portion of energy consumption in Egypt (U.S. Department of Energy, April 1979). No accurate determinations have been made of the quantities of noncommercial fuel used in Sinai. However, based on some very limited information available for Egypt as a whole, and considering figures for petroleum product consumption in Sinai, some general observations are possible. Most noncommercial energy is in the form of biomass (e.g., vegetation, agricultural residues), and most of the remainder is provided by dried animal dung. Probably 50 to 75 percent of the rural households in Sinai use noncommercial fuels for at least some of their cooking requirements. Due to the increasing availability of kerosene and butagas in Sinai, and because of the value of biomass and dung for a variety of other uses, the total quantity of noncommercial fuels used in Sinai is not expected to increase significantly in the future, and per capita levels will decline as more areas are settled.

Yields from solar stills at the National Research Center are between 2 and 4 l/m^2/day, depending on the season. Average annual yields are 1,000 to 1,100 l/m^2. The stills constructed at the National Research Center cost LE 44.5 per square meter in 1979. Approximately 30 percent of this cost was for labor, and the foundation, glass cover, and insulation accounted for about 15 percent each. Maintenance costs were estimated at LE 1 per square meter, in 1979 currency. Based on these costs and a life of 15 years, distilled water costs were calculated to be LE 3.64 per cubic meter (Helwan, 1980). At this rate, solar stills will not be economical in most regions of Sinai.

However, some areas of south Sinai are currently paying more than LE 4 per cubic meter for water. Since solar stills are low-temperature devices, cheaper materials could be used, which might significantly lower the capital investment required. Additional research should be conducted to improve yields from stills and to lower construction costs. In areas of Sinai far from any sources of freshwater, solar stills could be used to provide potable water to small communities.

3.4 RATIONALIZING ENERGY DEMAND

One of the significant measures of a high standard of living or high GDP is the per capita consumption of energy. The use of power-operated equipment can greatly multiply the output of human labor to bring about growth and development. However, with the substantial increases in world prices for energy since 1973, and with the possibility of energy shortages in future years, it is important that energy be used efficiently in all aspects of development.

3.4.1 Petroleum Energy

From a supply-demand point of view, Sinai is abundantly endowed with both fossil fuels and renewable energy resources. Energy will continue to be a significant regional export commodity for at least the next several decades. The statistics in Table 3-4, provided by the Ministry of Petroleum, show this comparison; in 1980, petroleum production was 225 times greater than petroleum consumption.

TABLE 3-4

Supply-Demand Comparison of Petroleum Products in Sinai (1980)[a]

Product	Quantity Produced (thousand tons)	Quantity Produced (10^{12} Btu)	Demand (thousand tons)	Demand (10^{12} Btu)
Benzene	4.07	0.178	4.15	18.2
Kerosene	1.45	0.061	1.45	6.1
Sular	18.41	0.779	18.42	78.0
Butagas	0.58	0.026	0.58	2.6
TOTAL	24.51	1.044	24.60	104.9

$$\frac{\text{Production}}{\text{Consumption}} = \frac{365 \times 6.46 \times 10^{11}}{104.9 \times 10^{10}} = 225$$

[a]Daily crude production = 114,000 barrels or 6.46×10^{11} Btu.

The natural gas associated with oil production is presently being flared, though the Egyptian General Petroleum Company (EGPC) is initiating steps to capture the 1.4 million m^3/day, equivalent to 8,500 barrels of oil per day or 3.1 million barrels per year. The heat value of the flared gas is:

$$\frac{3.1 \times 10^6 \text{bbl/yr} \times 42 \times 135{,}000 \text{ Btu/gal}}{104.9 \times 10^{10}} = 17.58 \times 10^{12} \text{ Btu/yr.}$$

The ratio of the flared gas in the Sinai coastal fields to the energy consumption in Sinai is:

$$\frac{17.58 \times 10^{12}}{1.049 \times 10^{12}} = 16.8.$$

Thus, oil production in Sinai is 225 times greater than oil consumption, and the energy content of the flared gas is over 16 times greater than the oil consumption rate.

During the occupation years, a "stripping" refinery was built south of Abu Rudeis to extract fuel oil for use in tanks, returning the other distillates to the residual crude. Recent studies have shown that the plant can be returned to service with minimal expense in comparison to its worth. With some upgrading, the facility can be made to produce a range of fuels suitable for consumption in Sinai. This would add to the petroleum operations, providing an added industrial base in the area.

3.4.2 Electrical Energy

The electrical demand in Sinai is not easy to define. Much of the electrical power is being installed for the first time, and there is no historical base on which to make projections. In some locations, particularly in El Arish, electrical power was provided during the occupation, and replacement power was provided by CEDCO.

Load demand records of CEDCO show an extremely high rate of demand growth for the Canal Governorates, which were generally without power until after 1973. Although conditions in the North and South Sinai Governorates are somewhat different, it is reasonable to believe that their growth rate over the next decade will greatly exceed the growth rate for the rest of Egypt.

It has been recognized by CEDCO that the installation of diesel-electric generators in isolated networks is a very high-cost approach and cannot be expected to continue over a long period of time. As soon as possible, transmission lines should be installed in the Abu Rudeis-Suez City area and be connected through the Hamdi Tunnel to the national electric grid. This will permit the establishment of a strong electrical network to support industrial growth in the Abu Rudeis area. The generation of up to 500 megawatts of low-cost electrical power (using flared gas and coal from Maghara) can support the electrical needs of all of Sinai and also provide for export to the rest of Egypt.

3.4.3 Water

Water is easily the most critical element constraining the development of Sinai. The nomadic lifestyle of the Bedouin tribes is dictated by seasonal changes in water conditions. Recent experience has shown that an assured supply of water will encourage more permanent settlements. Although not, of itself, an energy resource, water production, processing, and distribution can consume large blocks of energy.

The cost of water is determined, to a great extent, by the energy needed to move and process it from a source to a point of use. Both the required quantity and quality are dictated by the end use, and alternative techniques are frequently available to develop a source of supply. Alternative techniques for developing water sources are to be evaluated under a separate water resources study. Energy requirements for various pumping functions are reported in Section 6.2 of this report.

4.0 CONVENTIONAL ENERGY RESOURCES

4.1 PETROLEUM

Petroleum production has become one of the most dominant factors in the economic growth of Egypt, accounting for more than 15 percent of GDP in 1979. Total crude output increased from about 21 million metric tons in 1977 to an estimated 30 million metric tons in 1980, and is expected to increase to 31 million metric tons by 1985. The Egyptian petroleum export price increased from $12 per barrel in 1978 to $30 per barrel in 1980.

Export earnings from petroleum amounted to approximately $2.8 billion in 1980. An increase in domestic consumption has cut into potential net exports, which rose by 4.2 million metric tons in the 1977 to 1980 period (out of a potential increase in the exportable surplus of 9.5 million metric tons).

Although petroleum exports account for more than half of Egypt's export earnings, the current export account deficit is close to 10 percent. A modest improvement in petroleum or natural gas export would contribute significantly to Egypt's export trade balance.

4.2 NATURAL GAS

The capture and use of associated natural gas that is currently flared in the central and western Gulf of Suez fields has been the subject of a thorough project evaluation by the World Bank, in cooperation with the Egyptian General Petroleum Company (EGPC). Although details of this project have not been released, it appears to be going forward, and a general outline was derived from interviews with knowledgeable sources.

At present, only minor quantities of associated natural gas are captured for internal use in the petroleum production operation. The fields from which gas recovery is being considered in the western Suez project are Ramadan, July, and Location 382, as well as the Amal field, which produced nonassociated gas. Additionally, gas from some single-well fields, including Location 195, may be dedicated to this project. Of these fields, only the Ramadan and July fields are currently producing; a major uncertainty facing the gas recovery project is the volume of gas production attainable from Location 382 and Amal.

Petroleum production in Egypt is concentrated in the Gulf of Suez area, with more than 90 percent of the national output coming from fields that are primarily offshore. Although past production has been greater from fields identified with the western side of the gulf, the additions to new reserves over recent years have been primarily in that portion of the Suez identified as Sinai production.

For example, in 1980, 1 billion barrels of petroleum were added to the proved recoverable reserves in Egypt as a whole—a figure that represents all newly discovered fields and all new discoveries in previously identified fields. Of this amount, 450 million barrels of new recoverable reserves were identified in the marine Belayim field, and 190 million barrels of new reserve were found at Location 195, which is also in the Abu Rudeis area. Thus, approximately 64 percent of the additional proven recoverable national reserves were in the Sinai area.

Two companies are currently involved in petroleum production in Sinai. The major producer is Petrobel, with wells near Abu Rudeis, Belayim, and Wadi Feiran. Current production from these wells amounts to 114,000 barrels a day, and the reserves are estimated at 1,112 million barrels. Petrobel is now improving its fields in Abu Rudeis and Wadi Feiran to increase production. The EGPC operations are much smaller, producing 3,000 barrels a day, with estimated reserves of 3 million barrels, near Ras Sudr, Ras Misalla, and Ras Matarma. The Suez Oil Company (SUCO) is currently building facilities in Ras Budran, north of Abu Rudeis, in preparation for drawing on estimated reserves of 234 million barrels beginning in 1982 or 1983.

Licenses have been issued to various companies to initiate exploration activities, primarily in north Sinai. These include licenses for Mobil Oil (in Ras Sudr), Conoco (near Lake Bardawil), Gulf Oil (in northwest Sinai), and British Petroleum and International Egyptian Oil Co. (elsewhere in north Sinai). These explorations are expected to result in some additional discoveries of natural gas.

The western Suez project involves the capture of currently flared gas and transport to a compressor location at Ras Shukeir, where liquefied petroleum gas (LPG) and natural gas liquids will be stripped, and the dry gas transported by pipeline to Suez City. In Suez, the gas is assigned to industrial use, primarily by an extant fertilizer plant, a 30-megawatt electrical generation station, and a proposed cement plant. Excess gas will be transmitted to Cairo by existing pipeline facilities.

The use of gas from these fields is important to Sinai energy planning. If the western Suez project is not successful, it may be desirable to designate gas production in certain fields for use in Sinai gas capture projects. Specifically, gas from Amal, Location 382, and Location 195 might equally well be transported to the eastern side of the Suez for treatment and use in Sinai.

Unpublished information on the current and projected availability of natural gas in the eastern Gulf of Suez is shown in Table 4-1. It is estimated that 50 million ft^3/day were available in 1980 but not captured. Production is expected to rise to 54 million ft^3/day by 1985 and then decrease to 29 million ft^3/day by 1990.

TABLE 4-1

Natural Gas Availability in the Eastern Gulf of Suez Area (1980 - 2000)[a]

	Production (millions of standard cubic feet/day)			
Field	1980	1985	1990	1995
Belayim area Petrobel marine field	31	25	21	17
Abu Rudeis area Locations 195, 185, 173	9	20	7	0
Shoab Ali area Alma field	10	9	1	0
TOTAL	50	54	29	17

[a]These data were presented to the Supreme Council for Energy in February 1981.

The significant feature of this projection is the dominance of production from the Petrobel Belayim field. Only this field furnishes a major quantity of gas over a sufficiently long period for serious consideration in planning Sinai development. Recent additions to the reserves to the south of the Belayim area are two to three times the present Belayim reserves.

A major uncertainty regarding gas from the Belayim field is the possible existence of absorbed hydrogen sulfide (H_2S). Some initial studies indicate that this gas, which is potentially corrosive to stripping and compression equipment, has been found to exist in 300 to 400 parts per million in recent tests of associated gas from the Location 382 field. Pretreatment to remove hydrogen sulfide would be required if it was found to exist at these levels.

4.3 COAL RESOURCES

Although coal resources are known to occur at several locations in Egypt, only those in the Sinai region are believed to be economically extractable. The largest deposits are at Maghara, where proven and probable net metric tonnage is estimated to be 35.6 million (Powell Duffryn, May 1966). Of this, approximately 2 million metric tons are in an upper seam that possibly could be extracted economically at a rate of 600,000 tons/yr (Ben Gurion University, August 1976). The overburden ratio is approximately 29 m^3/m^3 of coal.

During the occupation years, Israel considered extraction at two rates of production, but reserve was not developed because it would have provided slightly submarginal economic returns. Also, there was a question concerning the length of time available to recover the investment at a higher rate. The more economical seam at Maghara is mineable by underground shaft techniques. Characteristics of this coal are given in Table 4-2. It is a subbituminous coal with a gross heating value of 7,215 kcal/kg (12,990 Btu/lb) and a relatively high, though washable, sulfur content.

There are two other known coal deposits in Sinai, one of which contains 60 million metric tons and is located at Wadi Thora. Although extraction is not now considered economical, it may prove to be such if gasification or liquefaction is feasible. Coal also occurs in lenticular beds at Ayun Musa, approximately 400 to 600 meters beneath the surface. Exploitation of this deposit is complicated by high rates of water flow from an artesian aquifer, and economic extraction is not possible at present (U.S. Department of Energy, Vol. 2, Annex 1, April 1979).

TABLE 4-2

Characteristics of Coal from the Maghara Mine

	As Received	Dry	Dry, Ash Free
Proximate Analysis (%)			
Moisture	4.9		
Ash	6.5	6.8	
Volatiles	50.7	53.3	57.2
Fixed carbon	37.9	39.9	42.8
Ultimate Analysis (%)			
Moisture	4.90		
Ash	6.50	6.84	
Carbon	70.66	74.33	81.98
Hydrogen	5.67	5.96	6.58
Nitrogen	1.04	1.09	1.21
Combustible sulfur	2.97	3.12	0.65
Oxygen (by difference)	8.26	8.69	9.58
Kilocalories per Kilogram			
Gross	7,215	7,610	8,476
Net	6,890	7,292	8,082

SOURCE: Powell Duffryn, May 1966.

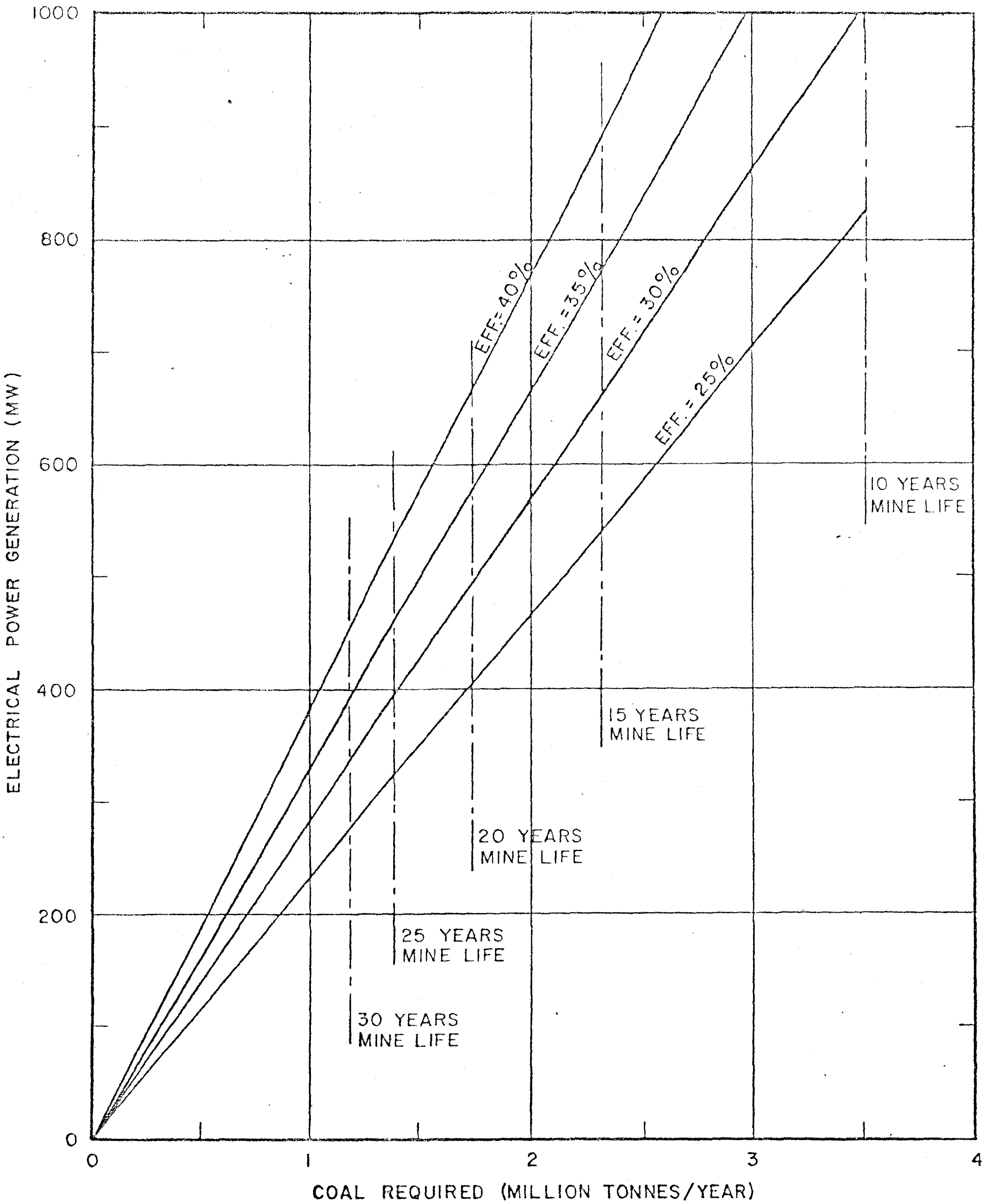
The Egyptian Geological Survey has moved forward with plans for reactivation of the Maghara coal mine, and a request for proposals for this project was issued last year, with a closing date of December 10, 1980. There are indications that 10 proposals were submitted and reviewed, but no final determination had been made as of July 1981. The alternatives under consideration are to use the coal in coking, to blend it with better European coking coals, or to use it for electrical power generation.

If used exclusively for generation of electricity, the life of the Maghara mine will be a function of the megawatt-hours per year and the overall efficiency of the power plant. Figure 4-1 shows the mine life at various rates of extraction and the average power output of the plant at efficiencies from 25 to 40 percent. Table 4-3 shows the yearly coal consumption for various sized electrical power generating plants operating at efficiencies of 25 to 40 percent. The heat rate (Btu's per pound) for various operating efficiencies was determined by dividing 3,413 Btu/kWh by the efficiency. Appropriate heat rates for a range of efficiencies are as follows:

- 0.9×10^6 J/kWh (13,652 Btu/kWh) at 25 percent efficiency.
- 1.1×10^6 J/kWh (11,377 Btu/kWh) at 30 percent efficiency.
- 1.3×10^6 J/kWh (9,751 Btu/kWh) at 35 percent efficiency.
- 1.4×10^6 J/kWh (8,533 Btu/kWh) at 40 percent efficiency.

The average megawatt output of a generating plant was calculated on the basis of tons per year of coal and heat rate according to the following formula:

$$\text{Megawatt output} = \frac{\text{tons/yr} \times 2.9 \times 10^{10} \text{ J/ton} \times \text{efficiency}}{8{,}760 \text{ hr/yr} \times 3.6 \times 10^{9} \text{ J/MWh}}.$$



REFERENCE:
POWELL DUFFRYN TECHNICAL SERVICES FOR THE GENERAL ORGANIZATION FOR INDUSTRALIZATION, MAY 1966; (35.6 METRIC TONS MAGHARA RESERVE).

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POWER GENERATION CAPACITY
MAGHARA COAL RESERVE

FIGURE 4-1

TABLE 4-3

Annual Coal Consumption of Electrical Generating Stations at Various Operating Efficiencies

	Efficiency (thousands of metric tons per year)			
Megawatts	25%	30%	35%	40%
1,000	4,184	3,484	2,987	2,613
900	3,766	3,136	2,688	2,352
800	3,347	2,787	2,389	2,090
700	2,929	2,439	2,091	1,829
600	2,510	2,091	1,792	1,568
500	2,092	1,742	1,493	1,307
400	1,674	1,394	1,195	1,045
300	1,255	1,045	896	784
200	836	697	597	523
100	418	348	299	261

4.4 ELECTRICITY

CEDCO has projected power requirements by querying both the North and South Sinai Governorates as to their anticipated demands in 1981, 1985, and 1990. Based on this survey, a total demand of 18,650 kilowatts is projected in 1981, 56,450 kilowatts in 1985, and 169,550 kilowatts in 1990. Additionally, a 20,000-kilowatt demand is projected in 1985 and 1990 for the ferromanganese facility at Abu Zenima, if the facility is reopened.

A breakdown of projected demand by load category is given for north Sinai in Table 4-4, and for south Sinai in Table 4-5 (CEDCO, August 1981). Figure 4-2 is a graphical representation of these data. Demand in north Sinai is expected to grow to 110 megawatts by 1990, dominated by tourism, land reclamation, and housing. Electrical load in south Sinai, exclusive of oil company load requirements, is projected to be 60 megawatts in 1990, with the primary demand from housing and land reclamation. The oil company load requirements are expected to exceed all other electrical loads in Sinai.

Over the near-to-medium term (6 years), electricity planning for Sinai will be conducted in three intervals. The first interval, which is regarded as the most

TABLE 4-4

Anticipated Loads for North Sinai
(in kilowatts)

Projected Power Requirement by Load Category	Through the Year 1982	1985	1990
Tourism and hotels (letter from Deputy Minister of Tourism)	3,000	30,000	42,000
Ministry of Health	150	300	400
Military and other national security	1,500	1,900	1,900[a]
Ministry of Industry (Maghara project)	400	2,000	2,000[a]
Training centers	200	400	400[a]
Private sector projects	1,500	2,000	6,000
Ministry of Irrigation (poultry, canning, livestock at El Arish)	1,500	1,500	3,000
Town of Bir El Abd	300	500	800
Industrial schools at El Arish	200	300	300[a]
Ministry of Supply (corn grinding and bakery at El Arish)	400	600	600[a]
Ice production units at El Arish	500	1,000	2,000
Other ice production units and governmental food shops	300	300	300
Ministry of Development--Housing	1,500	2,500	20,000
Ministry of Development--Land reclamation	2,000	4,400	30,000
TOTAL	13,450	47,700	109,700

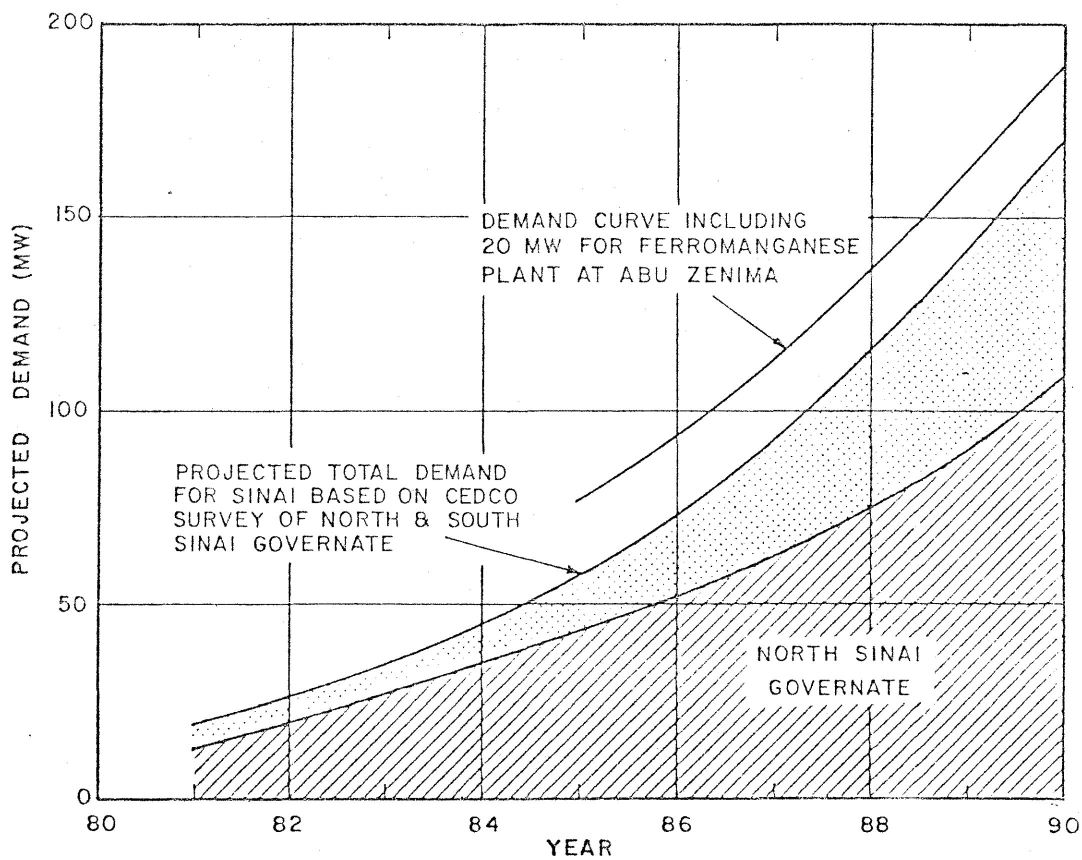
[a] Assumed values, no estimate provided.

TABLE 4-5

Anticipated Loads for South Sinai
(in kilowatts)

Projected Power Requirement by Load Category	Through the Year 1982	1985	1990
Tourism and hotels (letter from Deputy Minister of Tourism)	1,000	2,000	2,000
Ministry of Health	100	150	150
Training centers (Ministry of Industry)	100	200	200[a]
Private sector projects	800	1,250	4,500
Ministry of Higher Education	200	200[a]	200[a]
Ministry of Supply (corn grinding and bakery)	200	300	300[a]
Ice making and governmental food shops	300	600	2,500
Ministry of Development--Housing	1,500	2,500	20,000
Ministry of Development--Land reclamation	2,000	5,600	30,000
TOTAL	6,200	12,800	59,850
Power requirements for Sinai ferromanganese facility	--	20,000	20,000[a]

[a]Assumed values, no estimate provided.



REFERENCE:
CANAL ELECTRICAL DISTRIBUTION
COMPANY, 1980; SINAI ELECTRICAL
PROJECTS REPORT.

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PROJECTED ELECTRICAL DEMAND FOR SINAI

FIGURE 4-2

important, will last 2 years--until mid-1982. During this period, the main objective is the installation of generating stations and the low- and medium-voltage transmission and distribution system. This electrical network will be installed in coastal areas to meet the needs of tourism, industry, and land reclamation. Figure 4-3 shows the capacities of generating units and their proposed locations in Sinai.

4.4.1 First-Interval Network Planning

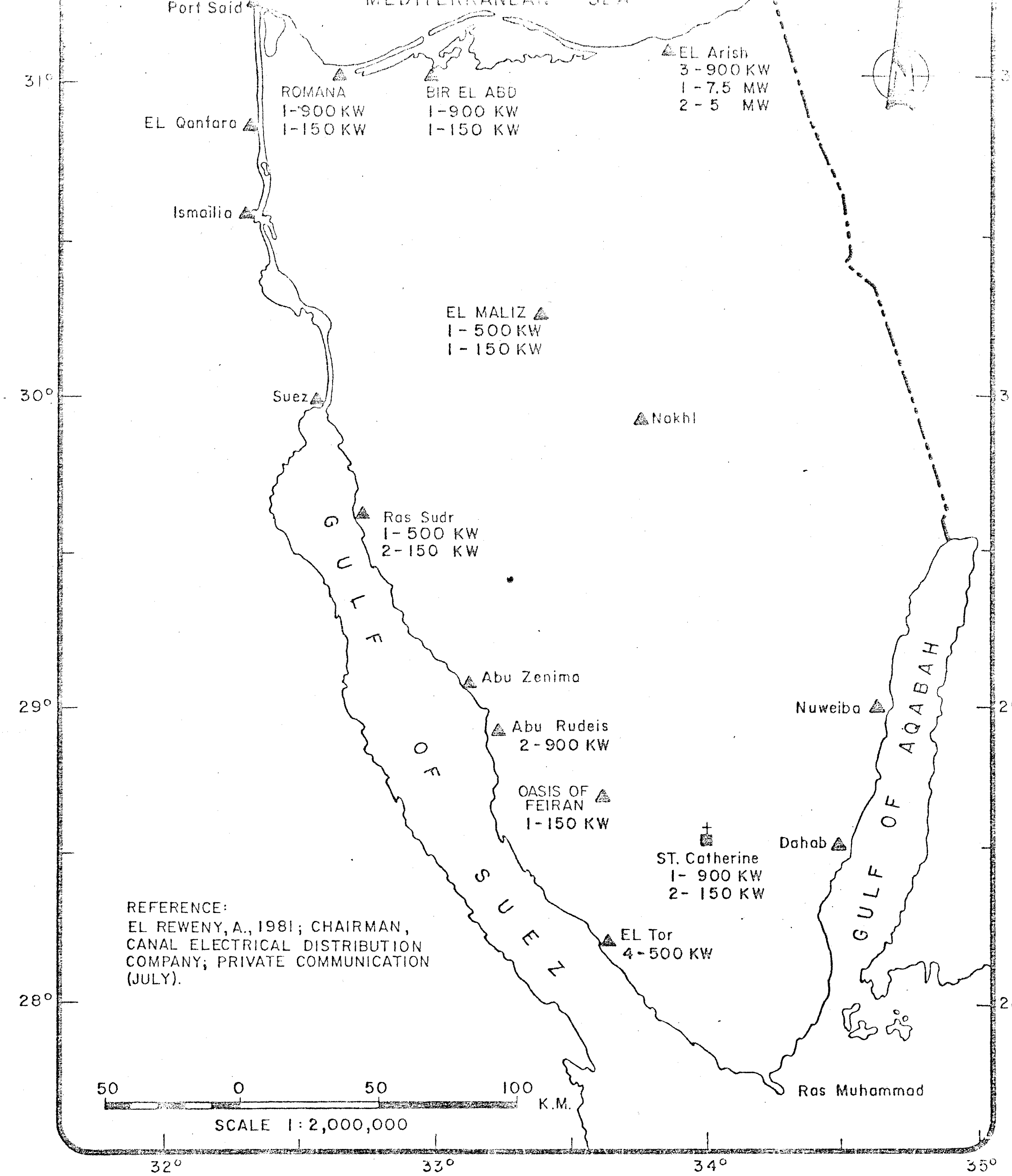
Information made available by CEDCO in January 1981 indicates that nine major projects are planned in north Sinai for the period from November 1980 to December 1981 (Table 4-6). These include installation of generating stations and associated distribution networks at Romana, Bir El Abd, El Arish, and El Maliz. The peak load at El Arish on May 25, 1976, was 800 kilowatts, and on May 25, 1981, it was 3,100 kilowatts. CEDCO has estimated that the power demand for El Arish and the surrounding area will increase to 16 megawatts over the next 3 years. Total cost is expected to be LE 17.5 million.

Table 4-7 shows a more limited expansion program for south Sinai, where major population centers have already been furnished with electrical generation and distribution networks. The total cost for the first interval is estimated to be LE 13.8 million. Additionally, essential power requirements for those portions of the Canal Governorates that lie geographically in the Sinai Peninsula are shown in Table 4-8, at a total cost of LE 12.7 million. The total anticipated development cost for the first-interval electrical system for Sinai is thus LE 44 million.

CEDCO has ordered 24 turbine generators to be located throughout Sinai. The anticipated installation schedule is as follows (El Reweny, 1981):

- Two 500- and two 900-kilowatt units by October 1981.
- Two 500- and two 900-kilowatt units by November 1981.
- Two 500- and two 900-kilowatt units by December 1981.
- Two 500- and two 900-kilowatt units by May 1982.

The delivery and installation dates for eight 150-kilowatt generators have not yet been determined.



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PROPOSED LOCATIONS OF TURBINE GENERATORS

FIGURE 4-3

TABLE 4-6

Essential Distribution Network Requirements--
North Sinai (October 1980-June 1982)

Project	Cost (1,000 LE)
Installation of a generating station (two 900-kilowatt diesels) at Romana Village, including step-up transformer and 11-kilovolt distribution network	950
Installation of 11-kilovolt transmission line from east to south of Romana (42 kilometers), including pole transformers and cabinets	900
Installation of electric generating station (three 900-kilowatt diesels, two 150-kilowatt diesels) at Bir El Abd, with step-up transformers and distribution network	1,950
Installation of 11-kilovolt transmission line, from east to west of Bir El Abd (50 kilometers), including pole transformers and cabinets	1,000
Construction of a new El Arish generating station, temporarily with one 7.5-megawatt and one 5-megawatt gas turbine with distribution network	5,000
Installation of 11-kilovolt transmission line plus cables (75 kilometers) and transformers in El Arish	1,500
Installation of four small generating stations at El Maliz, Gifgafa, Nakhl, and Hassana (two 75-kilowatt and two 150-kilowatt units), including switchboard and step-up transformers	200
Installation of low-voltage electric network in various villages and towns (750 kilometers), including internal network and street lighting	6,000
TOTAL	17,500

SOURCE: CEDCO, August 1981.

TABLE 4-7

Essential Distribution Network Requirements--
South Sinai (October 1980-June 1982)

Project	Cost (1,000 LE)
Improvements to present electric generation station at St. Catherine (two 900-kilowatt and two 150-kilowatt units), complete with step-up transformer	1,050
Development of generation station in Oasis of Feiran (two 150-kilowatt units) and switchboard	100
Development of present generating station at Ras Sudr (three 500-kilowatt units)	900
Installation of two 900-kilowatt units in Abu Rudeis, including transformers and switchboard	950
Installation of four 500-kilowatt units in El Tor, including transformers and switchboard	1,200
Installation of 11-kilovolt transmission line from generating stations, for 200-kilometer total length, including transformers and cabinets	4,000
Installation of low-voltage electric transmission lines for street lighting and internal network	5,600
TOTAL	13,800

SOURCE: CEDCO, August 1981.

TABLE 4-8

Essential Distribution Network Requirements--
Canal Governorates (1981-1982)

Project	Cost (1,000 LE)
60-kilometer reinforced electric cables, 11-kilovolt, type XLPE, three-phase, 240-square-millimeter section	2,000
60-kilometer reinforced electric cables, 11-kilovolt, type XLPE, three-phase, 50-square-millimeter section	1,500
40-kilometer reinforced electric cables, 11-kilovolt, type XLPE, three-phase, 70-square-millimeter section	600
150 cabinets and transformers, 500 kilovolt-amperes, and extra material for medium and low voltage	2,250
250 tons of conductors, variable sections	500
6,000 light poles, various makes, 8 to 10 meters in length	600
20 distribution boards, medium voltage	1,700
100-kilometer, low-voltage cables, various sections	1,500
Cable connection boxes and insulators of low voltage, various iron parts	500
Electric switches, medium voltage, indoor and outdoor types	1,000
2,000 poles, metal structure, 11 kilovolt, 12 to 15 meters in length	600
TOTAL	12,750

4.4.2 Second- and Third-Interval Network Planning

The second interval, to be conducted from mid-1982 to mid-1984, will consist primarily of establishing combustion gas-turbine generating stations using natural gas, to be connected by a 66-kilovolt grid. The third interval, planned for mid-1984 to mid-1986, will include connection of both north Sinai and south Sinai to the national grid, construction of the thermal generating stations (using Maghara coal), and extension of the 66- and 220-kilovolt networks.

The Maghara facility is slated to contain two 300-megawatt generators, and the estimated total investment is $80 million local currency equivalent and $300 million foreign currency (Strategy of the Ministry of Electricity and Energy for the Period 1980-2000, February 3, 1981). Facility size and location have not been established, but locations at mine mouth, at El Arish, and along the canal are being considered. Also, the decision to use Maghara coal both for coking and for electrical generation could dictate that only the smaller plant be constructed.

Plans for the second and third intervals will not be finalized until funds become available in the next 5-year plan. However, first-interval activities are underway, and total investment is expected to be LE 41.6 million ($20 million equivalent foreign currency).

5.0 RENEWABLE ENERGY

The economic value of petroleum resources on the world market is a strong impetus for the extensive use of solar, wind, and biomass energy resources in Sinai. Displacement of petroleum use by alternative energy resources will directly benefit Egypt's export trade balance since all petroleum production in excess of national needs is sold at world market prices. The high capital cost of providing conventional electrical power to remote locations with low population densities is an additional incentive to use alternative energy sources.

The development of various renewable energy resources may be the key to long-term economic growth and stability for the remote regions of Sinai. Estimated costs for renewable energy technologies are summarized in Appendix F, together with costs for conventional forms of energy.

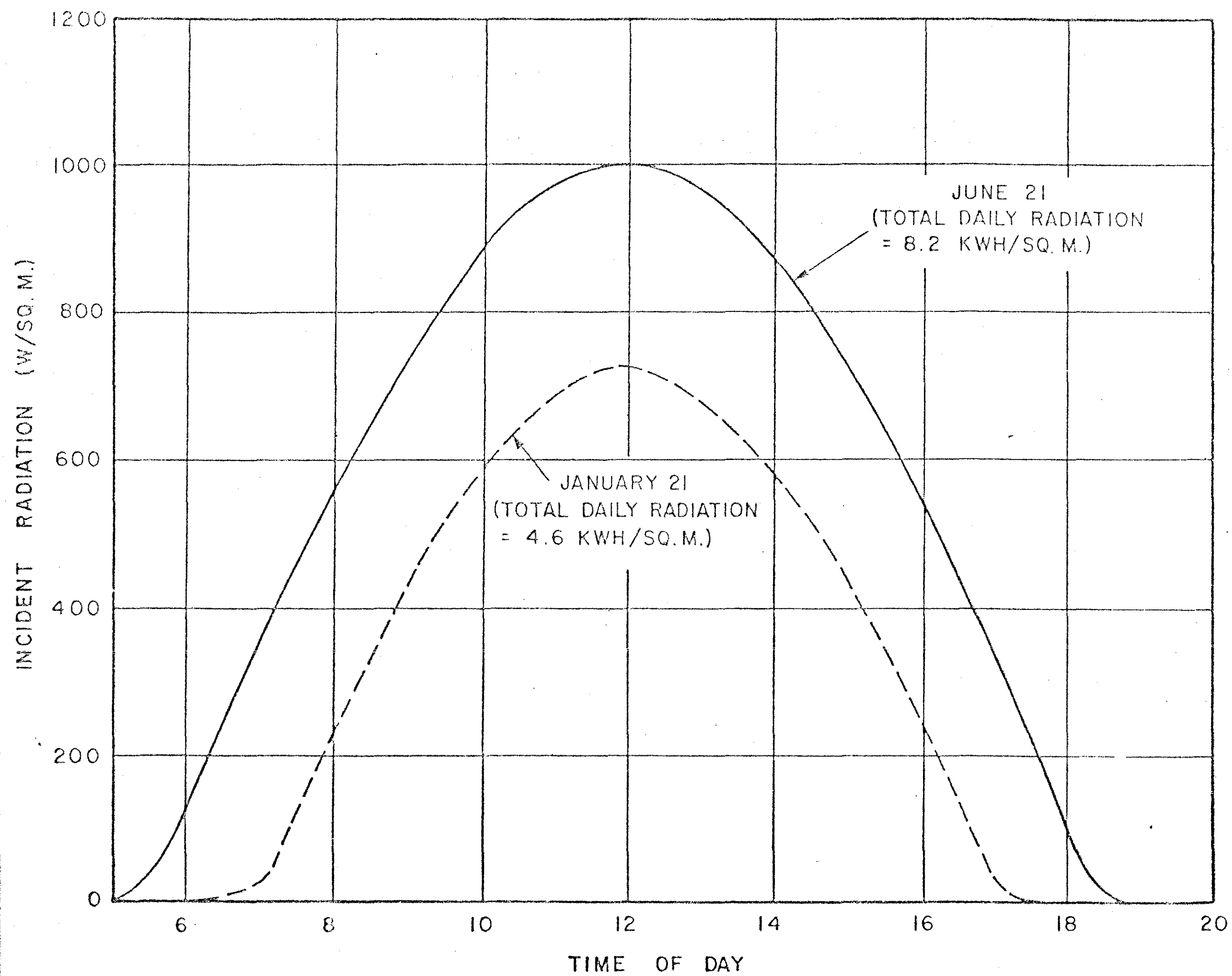
5.1 SOLAR ENERGY

5.1.1 Resource Potential

Due to its favorable location and the lack of any significant cloud cover throughout most of the year, Sinai has a relative abundance of solar energy. Peak insolation rates are around 1,000 W/m^2 on a horizontal surface. Figures 5-1 and 5-2 illustrate typical values for incident solar radiation throughout the day. Factors that reduce insolation levels include sand and dust storms and fog, but these probably account for less than a 5 percent reduction in total radiation levels in Sinai.

5.1.2 Solar Water Heating

The use of flat plate solar collectors to provide domestic hot water is a technology that has proven effective in numerous locations throughout the world. Hot water heating is an ideal application of solar energy for a number of reasons—operating temperatures are low, which results in relatively high energy conversion efficiency; there is an essentially constant year-round demand for hot water, thereby making maximum use of equipment; and domestic hot water heating systems require only simple construction. Thermosiphon systems are the most common in warmer climates, and in a location such as Sinai these have the advantages of not requiring anti-freeze or other chemicals, and not having any moving parts. Many of the existing houses in El Arish have solar hot water



REFERENCE:
KREITH, FRANK; KREIDER, JAN F., 1978,
PRINCIPLES OF SOLAR ENGINEERING,
WASHINGTON.

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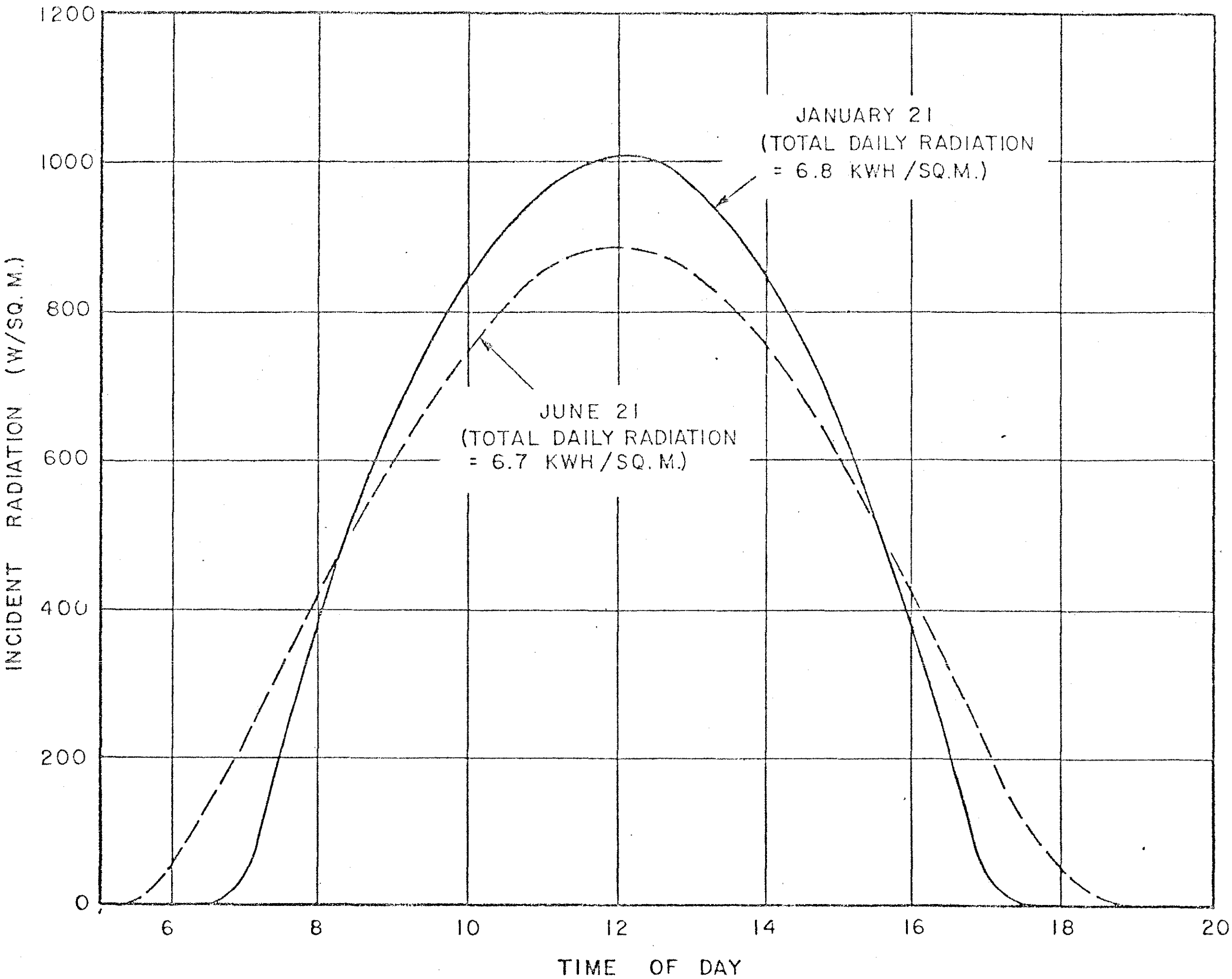
TYPICAL INCIDENT SOLAR RADIATION
ON A HORIZONTAL SURFACE

FIGURE 5-1



REFERENCE:
KREITH, FRANK; KREIDER, JAN F., 1978,
PRINCIPLES OF SOLAR ENGINEERING,
WASHINGTON.

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TYPICAL INCIDENT SOLAR RADIATION ON A SOUTH FACING SURFACE TILTED 35° FROM HORIZONTAL

FIGURE 5-2

systems, and a small metal-working factory in El Arish has the capability of manufacturing solar hot water systems of a similar design.

The economics of solar hot water heating are affected by the amount and temperature of water used, the type of fuel that would normally be used for hot water heating, and the specific characteristics of the solar system. In general, solar hot water systems cost between LE 120 and 170 per square meter of collector surface. The total energy provided annually by such a system would vary from 700 to 1,250 kWh/m^2 of collectors, and most systems have a useful life of at least 10 to 15 years.

5.1.3 Space Conditioning

Housing for desert climates can be designed so as to be comfortable throughout the year with minimal energy requirements. Such structures incorporate high thermal mass to dampen fluctuations in outside ambient temperatures, to provide protection from summer sun, and to provide adequate ventilation. In addition to reducing heating requirements, or alternatively to make dwellings more comfortable in cold weather, buildings can be sited and designed to make use of solar radiation for passive heating and can be insulated to reduce heat losses.

Much of the existing construction in Sinai incorporates several of these features. Concrete block buildings, with interior masonry walls, are often constructed with overhangs to provide shading and with an air space below the roof to reduce the transfer of heat from the roof into the living space. The continued use of these and other appropriate construction techniques is very important in ensuring that demands for electricity and other forms of energy do not increase any more rapidly than necessary.

Residential cooling can be enhanced by a number of proven methods that require simple technologies and little or no energy. Ventilation rates can be increased with chimneys that use the heat of the sun or the existing winds to create pressure differences that force air through buildings; this has been a common construction technique in the Middle East for thousands of years.

A number of systems have been devised that use the heat of evaporation to cool air. Some passive ventilation systems have included fountains or damp surfaces in the air flow path to increase the cooling effect.

A number of commercially available packaged units incorporate a fan that draws air through a wetted pad, usually made from a fibrous material. These evaporative cooling systems have drawbacks in certain environments. In areas where water is scarce, evaporative coolers may not be appropriate since they are significant water consumers, though saline or brackish water can be used where it is available. Also, most evaporative coolers require electrical energy to drive the necessary pumps and fans. Furthermore, during warm weather, evaporative cooling is of little or no benefit in areas of high relative humidity. In spite of these disadvantages, evaporative cooling can often be an economic and energy-efficient replacement for air conditioning.

5.1.4 Desalination

The scarcity of freshwater in many areas of Sinai may dictate the use of desalination units to provide potable water. Desalination using reverse osmosis, vapor decompression, and flash distillation can be accomplished using solar energy as a source of power, but since these systems are not dependent on a unique source of energy (i.e., electricity, natural gas, or other fossil fuels can be used), they are not discussed herein. Solar stills represent a means of providing freshwater using simple technology and readily available materials. A number of designs for solar stills are shown in Figure 5-3.

In general, the process of desalination in a solar still consists of water in a shallow container with a dark bottom being heated by the sun, evaporating, and thereby saturating the surrounding air, which is enclosed in a transparent roof. Because the glazing in the roof is cooler than the air, freshwater will condense on the glazing, which is sloped, and run into a collection basin.

Yields from stills at the National Research Center are between 2 and 4 l/m^2/day, depending on the season. Average annual yields are 1,000 to 1,100 l/m^2. The simplest stills constructed at the National Research Center cost LE 44.5 per square meter in 1979. Approximately 30 percent of this cost was for labor, and the foundation, glass cover, and insulation accounted for about 15 percent each. Maintenance costs were estimated at LE 1 per square meter in 1979 currency. Based on these costs and a life of 15 years, distilled water costs were calculated to be LE 3.64 per cubic meter (Helwa, 1981). At this rate, solar stills would not be economical in most regions of Sinai. However, some areas of south Sinai are currently paying more than LE 4 per cubic meter of water. Since solar

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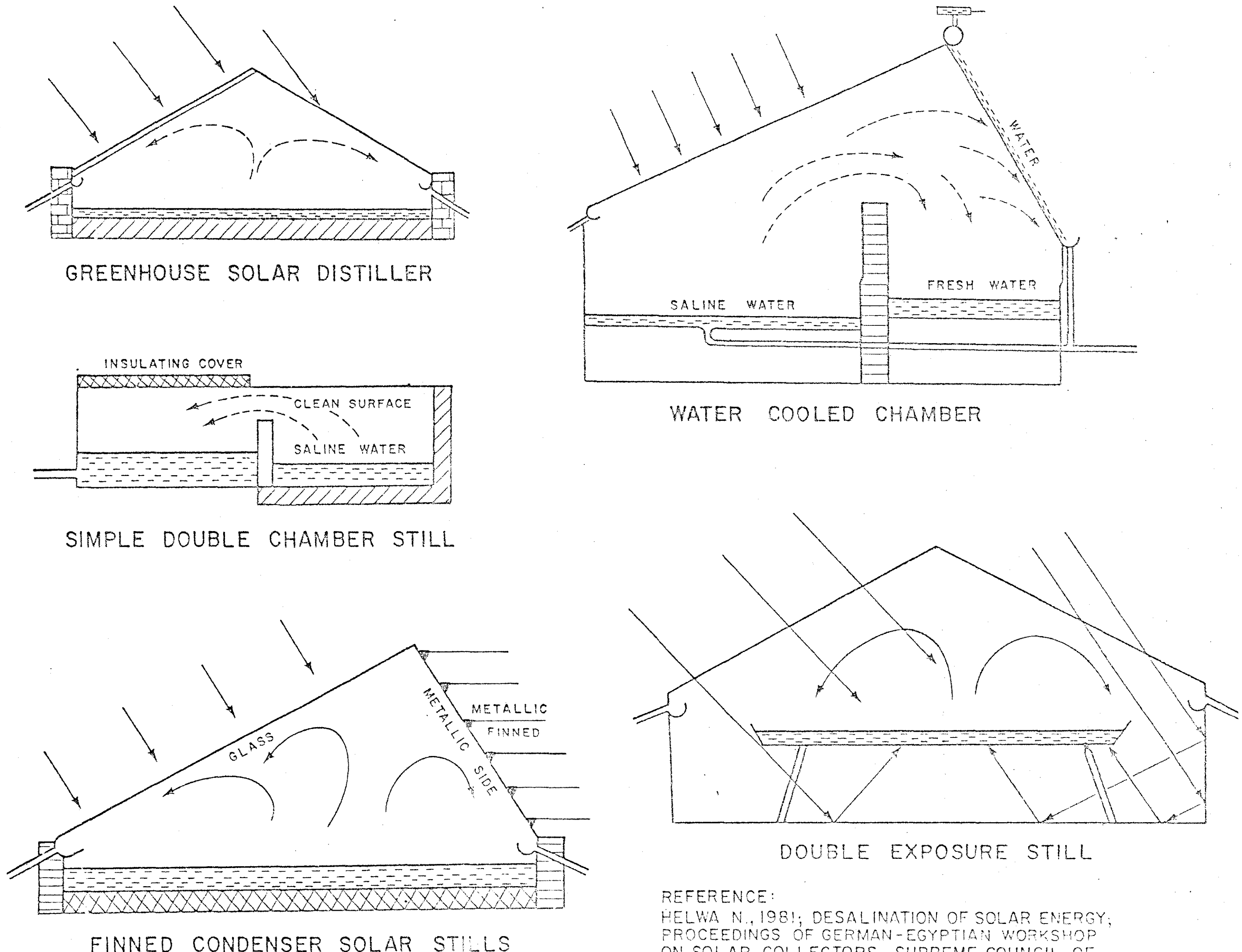
SOLAR WATER STILLS



REFERENCE:
HELWA N., 1981; DESALINATION OF SOLAR ENERGY; PROCEEDINGS OF GERMAN-EGYPTIAN WORKSHOP ON SOLAR COLLECTORS; SUPREME COUNCIL OF NEW AND RENEWABLE ENERGY; CAIRO, EGYPT.

Dames & Moore

FIGURE 5-3

stills are low-temperature devices, cheaper materials could be used that might significantly lower the capital investment required. Additional research should be conducted to improve yields from stills and to lower construction costs. In areas of Sinai far from any sources of freshwater, solar stills could be used to provide potable water to small communities.

5.1.5 Food and Crop Drying

Food and crop drying are some of the oldest uses of solar energy. However, some traditional drying methods have drawbacks, including loss of nutritional value due to spoilage or breakage and the long periods of time required for drying. Many foods are dried commercially using natural gas or other fossil fuels, but this is not likely to be particularly applicable for most of Sinai agriculture due to the high capital and operating costs.

Numerous solar drying systems have been developed, usually consisting of very simple air collectors in conjunction with a drying chamber, or drying chambers designed to admit solar radiation and retain heat. Compared with conventionally fueled dryers, most solar drying systems have the disadvantages of requiring longer drying times and operating cycles consistent with periods of sunshine or, alternatively, requiring thermal storage. Although costs are higher for solar food drying relative to traditional methods, where fossil fuel-fired dryers are being considered, or where traditional drying methods result in severe reductions in the value of the product--solar drying is a potentially viable option and should be evaluated.

5.1.6 Solar Photovoltaic Applications

Photovoltaic cells provide a means for direct conversion of solar energy to direct current electricity. Cell efficiency is on the order of 10 percent, providing 100 W/m^2 of surface normal to the direct insolation. For large photovoltaic installations, tracking systems and concentrating optics can be used to maintain a high level of solar insolation and thus a higher than normal output per solar cell.

Electric storage batteries are normally used to provide electric power during periods when the sun is not shining, and solar cells are used to charge the batteries during sun periods. Some applications--principally water pumping for irrigation--can be accomplished as the sun shines, with a resulting reduction in cost of the (storage) system. The cost of photovoltaic systems is expected to drop over the next few years because of major cost reduction programs instituted by the U.S. Department of Energy.

Due to the high costs of photovoltaic systems at present, applications for solar cell-based systems in Sinai will most likely be in remote locations where small amounts of electrical energy are required for refrigeration, communications systems, water pumping, etc.

5.1.7 High-Temperature Solar Applications

Solar concentrating reflectors, including trough-type (line focus) and paraboloidal (point focus) optical systems, can be used to provide high-temperature water or process steam. Applications of high-temperature process steam range from hot water or steam for food processing or other industries to pressurized steam for electrical generation. Most air conditioning systems using solar energy are based on medium- or high-temperature cycles, using fluids heated in concentrating collectors.

Concentrating systems have several disadvantages in most applications. The use of higher temperatures usually limits system efficiencies, tracking requirements add to the initial and operating and maintenance costs, and the periodic availability of sunshine may dictate the need for storage systems for high quality energy, which are usually fairly expensive. Furthermore, the dust and sand in areas such as Sinai could seriously increase operating and maintenance costs and cause increased capital costs due to the need for special materials and enclosures.

Concentrating collector systems may be most appropriate for consideration in large air conditioning systems, where appropriate design allows the use of lower temperature fluids and coefficients of performance greater than one can be obtained, and the peak demand usually corresponds roughly to the period of peak insolation. As larger paraboloidal concentrating systems become more reliable and more efficient, the use of solar "power towers" for electrical production in Sinai should be evaluated over the long term.

5.1.8 Solar Ponds

The solar gradient salt pond is an emerging technology that appears to have near-term application for Sinai. Solar gradient salt ponds can be a source of solar thermal energy of sufficient quality (i.e., temperature) to be useful for the generation of electrical energy or for a variety of applications that use mechanical shaft power.

The salt gradient pond has high concentrations of salt near the bottom, decreasing to low concentrations near the surface. Salts most commonly used are NaCl and $MgCl_2$, though there are numerous other possibilities. Solar radiation enters the pond, and though some is absorbed in the water, the majority is absorbed on the dark bottom (which may be an artificially blackened liner). As a result of this heat collection at the bottom, the deeper waters become warm. Because of the higher concentrations of salt in the lower pond regions, the warmer, deep waters have a higher density than the cooler waters near the surface. Pure water becomes less dense when heated, and if there was no salt gradient in the pond, there would be a continuous convection of the warmed water from the bottom of the pond to the cooler layers near the top. The increased density caused by the salt prevents this natural convection and traps the heat in the bottom of the pond. Heat transfer to the surface of the pond, which normally occurs by convection, is broken up to enable the lower regions of the pond to maintain a high temperature ($100^{\circ}C$ has been measured in actual ponds).

In practice, the salt gradient pond has three layers. Vertical convection takes place in the top layer due to the effects of wind and evaporation; this layer is kept as thin as practically possible. The next layer, which may be 1 meter thick, contains an increasing concentration of salt with increasing depth and is nonconvecting. The bottom layer is a high-density convecting layer that provides most of the thermal storage and facilitates heat extraction.

Solar gradient salt ponds have operated in Israel, in Canada, and in Ohio and New Mexico in the United States. The largest unit in operation at present has been producing 150 kilowatts of electrical power since 1980. It is reported that solar ponds can produce electrical power at a total cost of $0.12 to $0.13 per kilowatt-hour, and much larger units are under study.

One possible application of solar ponds in Sinai is to generate electrical power and manufacture ice for the fishing industry at Lake Bardawil. The high salt concentration in Lake Bardawil and the existing terrain, which could minimize the cost of excavation, are two factors that could be significant in the economics of building and operating the facility. Further study is suggested to determine the significance of these factors and to establish the practicality of salt gradient pond technology.

5.2 WIND

5.2.1 Resource Potential

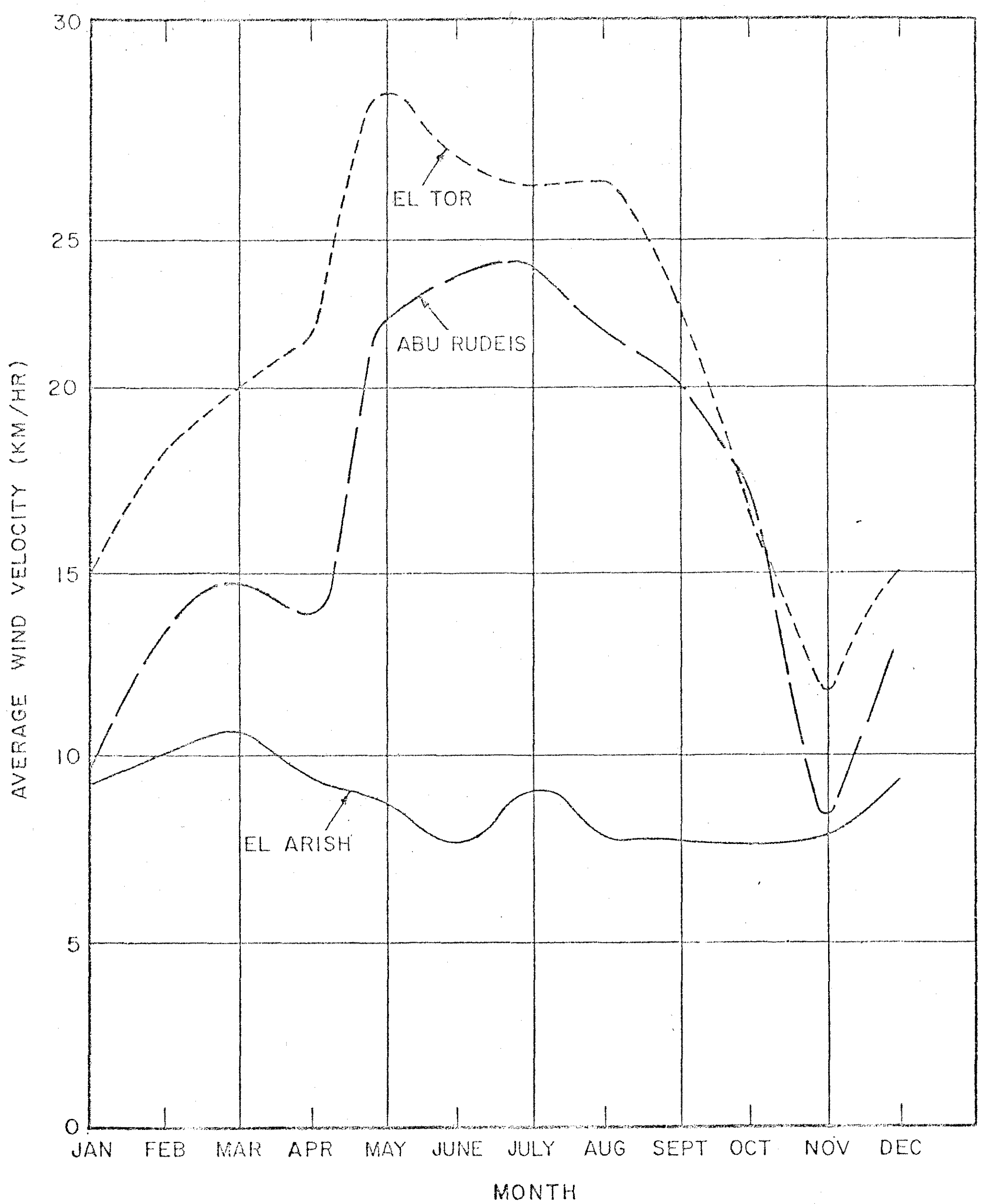
High wind velocities are common in several areas in Sinai, particularly along the coast of the Gulf of Suez. Although detailed data are not available for most locations in Sinai, some information exists for El Arish, El Tor, and Abu Rudeis. Average wind speeds of 20 km/hr (5.7 m/sec) in El Tor and 17 km/hr (5 m/sec) in Abu Rudeis indicate considerable potential for wind energy use, and the seasonal variations in wind velocity indicated in Figure 5-4 suggest that the periods of peak supply may be well matched to periods of peak demand for irrigation or other applications. Average wind speeds for El Arish are 9 km/hr (2.5 m/sec); the relatively constant velocities year-round and the lack of significant periods of high wind velocity, indicated in Figures 5-4 and 5-5, suggest that El Arish is not well suited for major development of wind systems.

Planning for a major wind conversion system requires detailed wind velocity information for the specific location. Wind monitoring at various sites in Sinai, particularly along the Red Sea coast, is an important first step in assessing the potential for use of wind energy, and in evaluating the potential effects of seasonal and daily variations in wind velocity.

5.2.2 Applications

An important attribute of wind energy is that conversion systems produce mechanical energy directly, which is more valuable than thermal energy for most applications. Wind energy has been used for many purposes, including milling and grinding, water pumping, electrical generation, sawmill operations, and heating. The most promising applications in Sinai are for water pumping and production of electricity.

Wind pumps in a variety of designs have been used for hundreds of years. Multibladed horizontal-axis windmills, such as those used extensively in the American Midwest in the 1800's and early 1900's, provide high torque, which allows for the use of direct-drive systems for pumping--reducing capital and maintenance costs and the complexity of construction. The simplicity of design and the use of common materials for construction favor local production of wind pumps. A multibladed pumping system is currently being assembled in Egypt for a demonstration unit to be installed and tested by the National Research Center (El Mallah, 1981). The fact that the water in Sinai is often relatively deep means that the use



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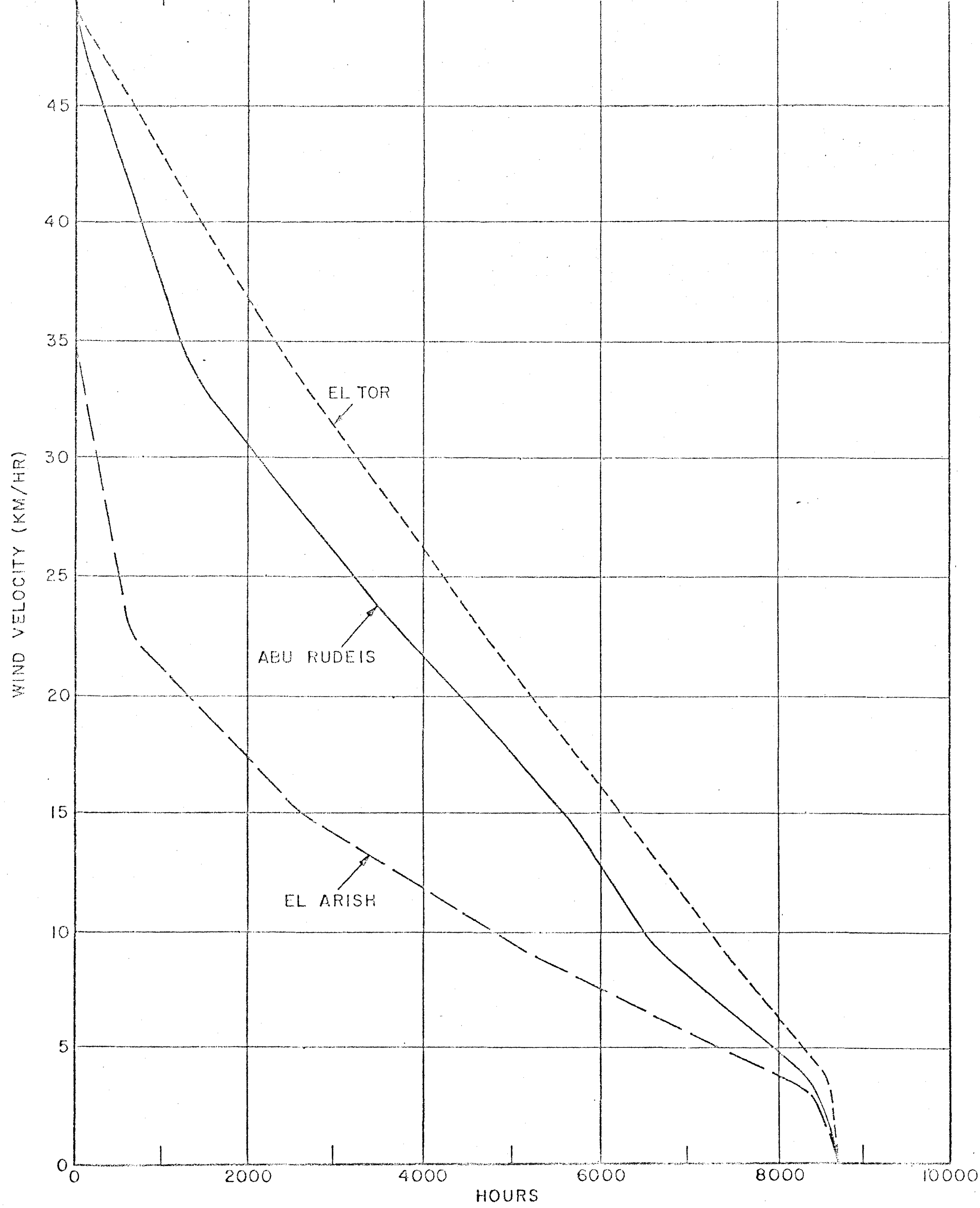
ESTIMATED SEASONAL WIND VELOCITY VARIATIONS

FIGURE 5-4



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WIND VELOCITY DURATION CURVES

FIGURE 5-5

of wind energy may be developed to the greatest advantage by designing simple wind equipment, or by modifying existing designs specifically for use in certain regions.

Wind electric generators are in operation in sizes ranging from 100 watts to more than 1 megawatt. Smaller systems are usually significantly more expensive per watt, and would be most applicable in areas far from the electric grid. Larger wind generators (40 kilowatts and greater) have not been extensively tested, and the reliability of different designs has not been well determined. However, the use of wind energy for electrical generation has considerable potential to become a significant source of energy in an area such as south Sinai, and research and development efforts are important to determine potential sites and to initiate the design and installation of prototype units.

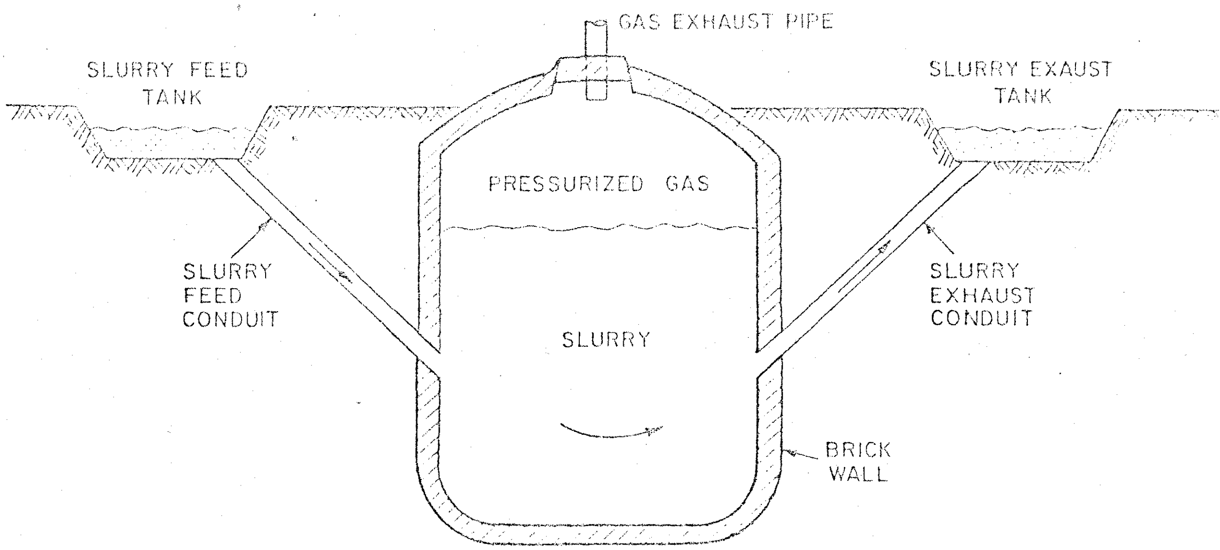
5.3 BIOGAS GENERATION

Agricultural byproducts and animal wastes generally contain significant amounts of energy, and these and other forms of biomass are the primary fuels in many parts of the world. Direct combustion of biomass is usually an inefficient process that often leads to depletion of raw materials that can be valuable for other uses.

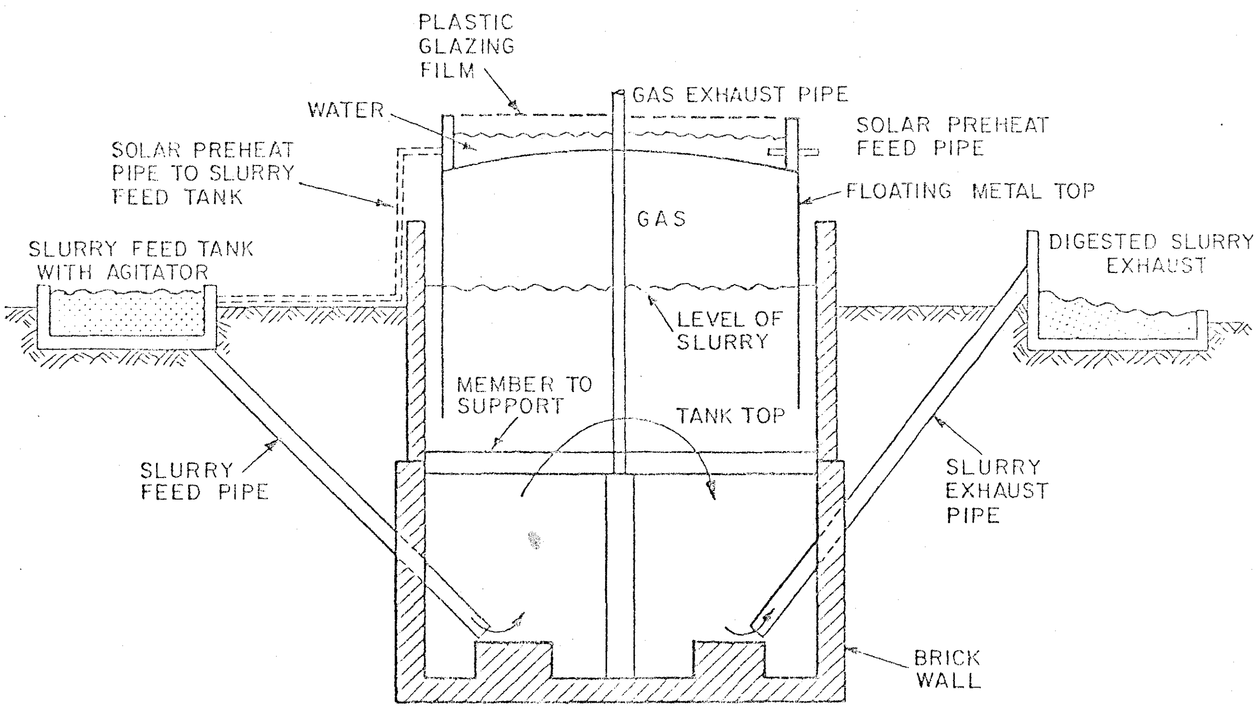
Ethanol and methane (biogas) production from biomass are two processes that produce a fuel with relatively high energy content and allow the raw materials to be reused for fertilizer, soil conditioners, or animal feeds. Ethanol production is a complex process that usually requires relatively high-value biomass as a feedstock. Biogas, on the other hand, can be produced from most animal wastes using simple equipment that can often be locally constructed.

Biogas generation using a variety of animal wastes as feedstocks has been successfully demonstrated in India, China, and other parts of the world. The National Research Center has recently assisted in the construction of two demonstration biogas generators in the town of Manawat, south of Cairo (Abdel-Dayem, 1981). These digesters were based on Indian and Chinese designs, modified to accommodate high water tables common in the Nile Valley. Schematic drawings of these two types of digesters are shown in Figure 5-6.

The most important requirements of biogas generation are the availability of at least 60 kilograms of human and animal wastes per day (excluding camel dung), as well as an equal volume of water. The integration of a digester with animal and



MODIFIED CHINESE DESIGN



MODIFIED INDIAN DESIGN

REFERENCE:
ABED ABDEL-DAYEM, 1981;
NATIONAL RESEARCH CENTER;
PRIVATE COMMUNICATION (JULY).

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BIOGAS DIGESTER DESIGN

FIGURE 5-6

human housing structures, in a manner compatible with existing agricultural practices and social customs, is important to minimize the labor involved in operating a biogas generator.

Biogas generation is not a practical solution for most of the existing livestock owners in Sinai. Current grazing and herding practices and the predominance of small animals (goats and sheep) make the collection of sufficient quantities of animal waste very difficult. Furthermore, the traditional digester designs do not function well with camel manure. However, where cows are raised in conjunction with other animals, or in commercial poultry operations, biogas production is quite feasible.

The major reason for using biogas digesters is the resulting improvement in sanitation. The digestion process destroys most of the pathogens in the wastes, without affecting nutrient qualities. The need to flush materials into the digester at least once a week results in cleaner housing for humans and animals, and reduces pest populations in and around residences. The major economic incentive for biogas generators is reduction in the considerable labor associated with moving soil and manures between animal shelters and fields. The value of the gas is secondary to these labor savings.

Several problems are associated with the management and operation of digesters. Failure to feed and agitate the digester at regular intervals may halt the digestive process. Some minor maintenance and inspection are required to ensure proper performance.

Cooking equipment must be modified to accommodate gas with lower energy content, and ovens using biogas are more expensive than traditional ovens. Although community-size digesters are technically feasible, allocation of the gas and spent slurry is troublesome, and ensuring proper maintenance is difficult in the absence of clear personal incentives.

Appendix G contains detailed technical information concerning the Indian and Chinese biogas digester designs. Based on experience in the Nile Valley, total construction costs in 1981 for the modified Indian design were LE 550 for a 10-cubic-meter digester, and LE 350 for a modified Chinese digester of the same size. The modifications to the residence and animal shed to facilitate the collection of wastes and the use of the gas cost approximately LE 200. A 10-cubic-meter digester can be expected to yield around 2 cubic meters of gas per day, with an energy content of 5,600 kcal/m^3 (630 Btu/ft^3), and will provide for all the cooking and lighting energy requirements for a family.

In households in Sinai where several large animals are kept and livestock shelter is provided, biogas generation is a simple process that can be used to improve sanitation and reduce disease and parasites, and provide for all household energy needs. In commercial livestock and poultry facilities, larger traditional digesters or other digester designs can be used to provide fuel for hot water heating, electrical generation, or other small-scale uses, while at the same time destroying most of the pathogens in animal wastes before they are spread on the fields.

5.4 GEOTHERMAL

There has been limited systematic evaluation of possible sources of geothermal energy in Egypt. Of the known hot springs, two are located in Sinai--at Hammam Faraun and Hammam Saidna Musa. As shown below (Ramly, 1969), the measured temperature of the Hammam Faraun spring is about 75°C; its volumetric flow rate exceeds that of all other Egyptian sources:

- Ain Hammam Faraun: 75°C, 880 m^3/day
- Ain Hammam Saidna Musa: 34°C, flow rate unknown.

These volumetric flow data were collected in 1961.

Sinai may prove to be well suited for the development of geothermal resources. Due to the considerable petroleum exploration and production activities in Sinai and in the Gulf of Suez, a large amount of data has been collected concerning the geological characteristics of the area. The General Petroleum Corporation is currently preparing to assess the geothermal potential in Egypt, including Sinai. The first step in this evaluation will be the revision of well logs from petroleum operations to map the most probable areas for geothermal exploitation and to assess the energy potential and quality of these areas.

Due to the high costs of developing geothermal resources, the time required to evaluate regional potential, and the low number of applications for geothermal energy in the immediate future, from the perspective of Sinai development, geothermal resources may represent a significant energy source that could become available toward the year 2000. To expedite the development of this resource, the study of existing drilling logs and existing wells should be undertaken immediately.

At the same time, in light of their low energy flow and isolation, the hot springs at Hammam Faraun should be evaluated for potential as a touristic attraction.

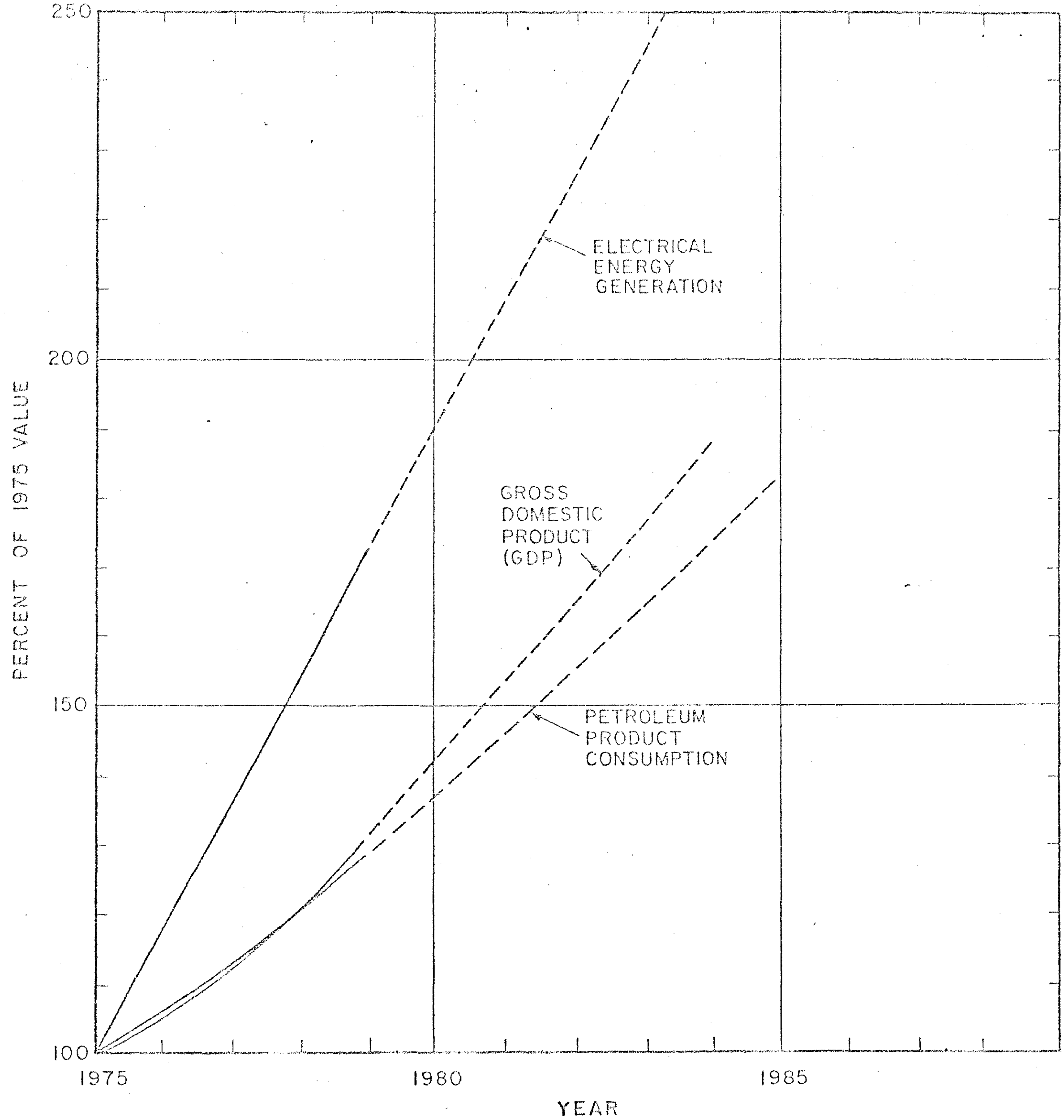
6.0 PROJECTED ENERGY DEMAND

The prediction of energy demand for Sinai is severely complicated by the scarcity of data and the rapid rates of change in energy consumption in recent years. Additionally, the available information is of limited use as a basis for projections since it is--to a large extent--the result of policies and conditions associated with the reconstruction and development of Sinai since 1979. Figure 6-1 shows projections of energy consumption and GDP growth for all of Egypt to the year 1990 (see Section 6.1).

Electrical consumption is currently dominated by use in public and municipal buildings, due in part to the lack of infrastructure to distribute electricity for residential use. Where commercial operations and residences are using electricity, low or nonexistent charges for power encourage high usage. The inefficiency of current generating facilities and the lack of a grid connecting generating stations create a high rate of fuel consumption per kilowatt-hour generated, but this can be expected to decrease as facilities are improved and tied to a network. Figures 6-2 and 6-3 show slow growth and rapid growth projections, respectively, for per capita energy consumption in Sinai (see Section 6.1).

The use of petroleum products for activities other than electrical generation is also affected by some temporary conditions. The traffic across the canal--which provides much of the food and construction materials, and some of the water for Sinai--uses fuel that, in light of the relatively small number of fuel stations in Sinai, probably comes primarily from the western side of the canal. In any event, as water from local sources and produce from currently occupied territories become available, and as tourism activities increase, fuel consumption patterns will change significantly.

In light of this situation, projections for future energy requirements are based on two approaches. First, information on energy consumption and projections for future demand for Egypt as a whole are considered in relation to per capita GDP. The resulting figures are evaluated and adjusted in accordance with the existing and planned infrastructure in Sinai. Second, energy requirements in Sinai are based on projections of estimated requirements for activities in different sectors. Power requirements for major industrial projects, irrigation and land reclamation projects, vehicular traffic, etc., are estimated on a per unit basis.



REFERENCE:
US DEPARTMENT OF ENERGY, 1979; JOINT EGYPT/UNITED STATES REPORT ON EGYPT/UNITED STATES COOPERATIVE ENERGY ASSESMENT, VOLUME 4.

NOR EL-DIN, A., 1980; PREDICTION OF ENERGY CONSUMPTION DURING THE YEARS 1985-1990-1995-2000. EGYPTIAN SUPREME COUNCIL FOR ENERGY.

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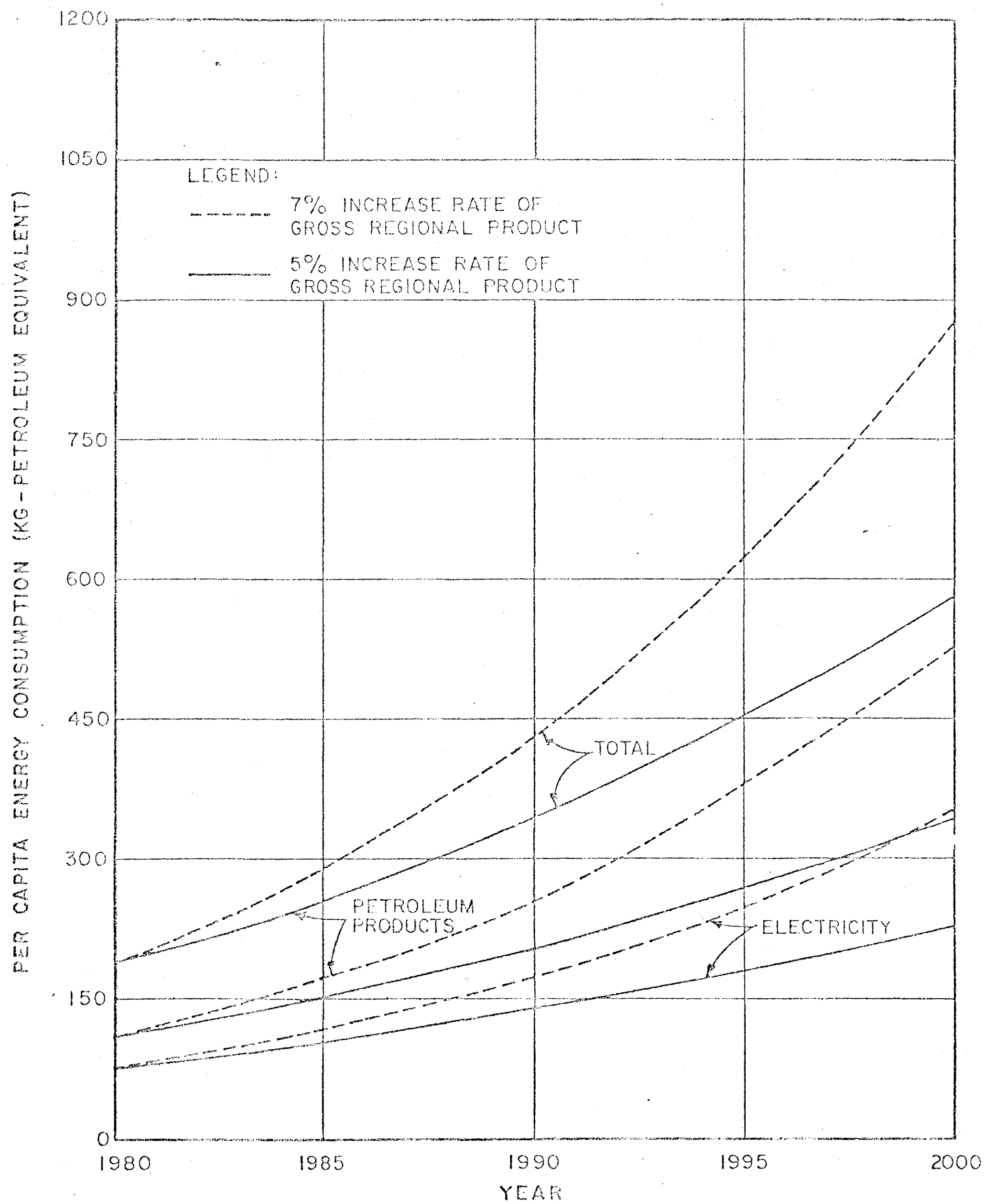
PROJECTED ENERGY CONSUMPTION AND GDP GROWTH OF EGYPT

FIGURE 6-1



REFERENCE:
NOR EL-DIN, A., 1981; EGYPT GENERAL PETROLEUM COMPANY; PRIVATE COMMUNICATION (APRIL)

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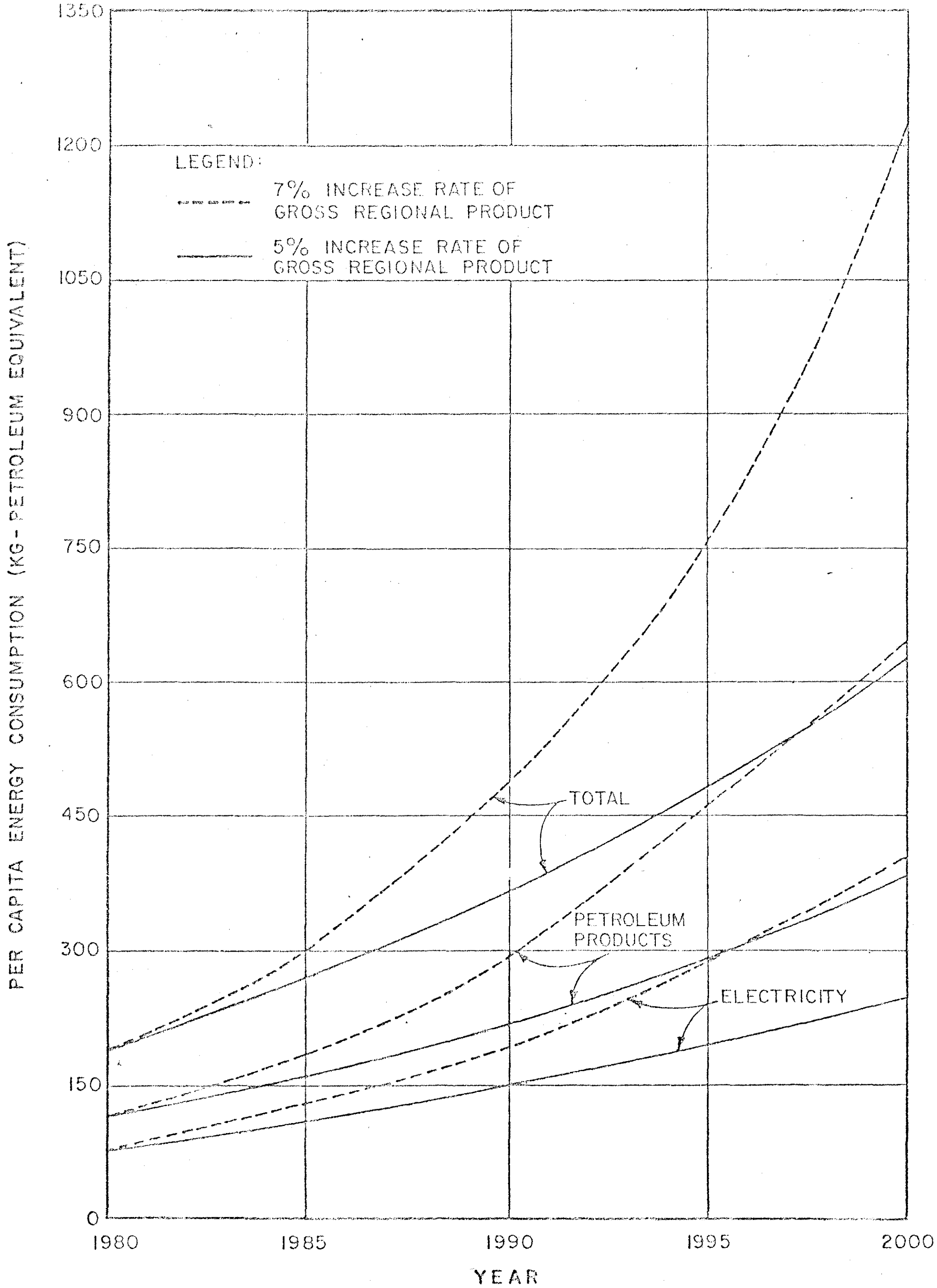
PROJECTED PER CAPITA ENERGY CONSUMPTION IN SINAI (SLOW GROWTH)

FIGURE 6-2



REFERENCE:
NOR EL-DIN, A., 1981; EGYPT GENERAL PETROLEUM COMPANY; PRIVATE COMMUNICATION (APRIL)

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PROJECTED PER CAPITA ENERGY CONSUMPTION IN SINAI (RAPID GROWTH)

FIGURE 6-3

6.1 PER CAPITA PROJECTIONS

Energy consumption will grow as a function of population and economic growth. The rate of energy use increase per capita can be correlated to economic growth, expressed in terms of GDP or GRP, by means of an index of elasticity. This index (IG), as used herein, is defined by the relationship:

$$IG = \frac{GDP_o}{GDP_t} \times \frac{E_t}{E_o}$$

where E_t and E_o are energy consumptions for the subject year and a starting year, respectively, and GDP_o and GDP_t are the GDP, or regional equivalent, for the same years (U.S. Department of Energy, April 1979). Figure 6-1 indicates that from 1975 to 1979, for Egypt as a whole, the average index of elasticity for petroleum products was 1.0, and the index for electrical usage was approximately 1.3. In general, the index of elasticity in developing countries varies from 1.3 to 1.0.

The commitment to develop Sinai and the availability of some funds for development of energy resources suggest that, in the near term (until 1990), energy growth rates will be considerably greater than GRP growth. Attempts to stimulate economic growth by providing low-cost energy will also result in high indices of elasticity. Figure 6-2 is a projection of electricity and petroleum product consumption growth based on an index of elasticity for electricity decreasing from 1.8 to 1.1 in the years 1980 to 2000, and for a petroleum index from 1.4 to 1.1 during the same years. Figure 6-3 assumes an index of elasticity declining from 1.4 to 1.0 for electricity, and from 1.3 to 1.0 for petroleum products.

The present consumption of electricity used in these projections—75 kilograms of petroleum equivalent per capita per year—was estimated on the basis of the petroleum consumption figures in Section 3.1, the current installed generating capacity as described in Section 3.2, results of surveys conducted by Dames & Moore, and a population estimate of 130,000 for 1981. The conversion efficiency of the existing generating stations was assumed to be 500 kilograms of petroleum equivalent per kilowatt-hour. Energy consumption for the existing and projected petroleum facilities in Sinai has not been included in these projections, since the requirements for these operations greatly overshadow other projected energy needs through 1990.

In spite of the relatively high indices of elasticity for the projections in Figures 6-1 and 6-2, these are probably low estimates corresponding to a slow growth scenario, such as one in which growth is primarily based on the use of existing Sinai resources (local resource-based development strategy). In fact, if CEDCO's plans for expansion of the electrical network proceed according to schedule, Figure 6-2 probably represents a low estimate of energy growth even in the absence of any other intervention in Sinai development.

In the event of rapid acceleration of land reclamation or industrial activities, energy consumption will undoubtedly increase at much higher rates than for Egypt as a whole. This is inevitable due to the scarcity of freshwater near the surface in much of Sinai and the fact that energy requirements for any major industrial growth in the near future will represent large per capita increases in energy consumption due to the relatively low population.

Based on CEDCO demand projections and recent petroleum product consumption, continued development of Sinai at current rates could result in increases in total electrical consumption of as much as 30 to 40 percent per year between 1981 and 1985, with increases of 75 to 100 percent in 1981 and 1982 being quite possible. This rapid growth could result in a per capita consumption of as much as 2,000 kWh/yr by the year 2000. This contrasts with per capita projections for annual electrical demand for Egypt as a whole of 700 kilowatt-hours in 1985, 1,000 kilowatt-hours in 1990, and 1,600 kilowatt-hours in 2000 (Ministry of Electricity and Energy).

The rate of increase in petroleum product usage not associated with electrical generation will probably not be as great. However, rates of increase of 50 percent or more for 1981 and 1982 would not be unexpected, and a 20 to 30 percent yearly rate of growth through 1985 is also quite possible. In the event that a sustained commitment to develop Sinai is maintained for the next 10 to 15 years, energy usage can be expected to increase dramatically, and total petroleum product usage will probably be in the range of 700 to 1,200 kilograms of petroleum equivalent per capita per year.

In light of the difficulties in making accurate projections due to the scarcity of data and Sinai's unique features, estimates of future energy consumption rates for the region should probably be based primarily on energy requirements for operations in different sectors--which can often be estimated with reasonable accuracy and are presented in the subsequent sections of this report.

General conclusions regarding energy consumption in Sinai are that any accelerated development program will result in much more rapid energy consumption rates than for Egypt as a whole; that even without much future impetus for development, completion of ongoing programs will create high consumption rates; and that electrical energy is and will continue to be a large portion of the total energy demand.

6.2 PROJECTIONS BY SECTOR

6.2.1 Residential Energy Consumption

The Joint Egypt/U.S. Cooperative Energy Assessment (U.S. Department of Energy, April 1979) estimated the current and projected consumption of energy for residential use in Egypt. These estimates were based on the degree of saturation of energy-using appliances in Egyptian households, and the calculated yearly consumption of appliances. Table 6-1 contains typical annual energy requirements for the appliances that account for the majority of residential energy consumption. Table 6-2a includes current and projected annual energy consumption figures for households using electricity, butagas, or kerosene. Current and projected percentages of saturation for these three forms of energy are shown in Table 6-2b.

Residential electrical usage in Egypt is primarily for lighting, television, and refrigeration, and these three usages will probably continue to consume more than 60 percent of residential electric energy through the year 2000. As electric hot water heaters become more common in urban households, they will also become a significant factor in residential electrical consumption. Projected energy consumption in residences will be influenced by the pricing of electricity and the introduction of appliances that have higher energy efficiencies. While the figures for current electrical usage in Table 6-2a are probably appropriate for Sinai, the projected consumption for the year 2000 is likely to be decreased by as much as 20 percent due to the increased use of solid-state televisions, more efficient lighting and refrigeration, and solar hot water heating.

The primary residential uses of butagas in Egypt are for cooking and hot water heating, with some households using butagas to provide space heating. The usage per household, as shown in Table 6-2a, reflects the projected increasing use of hot water heaters. As expected to be the case for Egypt as a whole, butagas

TABLE 6-1

Typical Annual Energy Requirements for Appliances (per household)

Appliance	Unit Consumption
Electricity (kilowatt-hours)	
Lights	150 - 300
Refrigerator	500
Air conditioner	750
Television	350
Hot water heater	1,500
Butagas (kilograms)	
Stove	170
Hot water heater	120
Space heater	90
Kerosene (liters (kilograms))	
Stove	228 (180)
Lights	170 (135)

SOURCE: U.S. Department of Energy, April 1979.

TABLE 6-2a

Current and Projected Annual Residential Energy Consumption (per household)

	1975	1985	2000
Electricity (kilowatt-hours)			
Urban	570	1,360	3,170
Rural	360	530	860
Butagas (kilograms)			
Urban	190	220	240
Rural	170	200	230
Kerosene (liters (kilograms))			
Urban	290 (230)	280 (225)	270 (215)
Rural	290 (230)	400 (320)	360 (290)

TABLE 6-2b

Current and Projected Annual Energy Usage (percent of total households in Egypt)

	1975	1985	2000
Electricity			
Urban	77	90	100
Rural	18	30	50
Butagas			
Urban	35	55	75
Rural	2	8	20
Kerosene			
Urban	65	43	15
Rural	82	70	50

SOURCE: U.S. Department of Energy, April 1979.

consumption in Sinai will increase considerably as gas replaces kerosene and noncommercial fuels for cooking in urban households. Discoveries of natural gas in north Sinai could also have a significant impact on butagas usage during the 1990's.

Kerosene is used for lighting and cooking in many Egyptian households. The use of kerosene is expected to decline in urban areas as it is replaced by butagas and electricity. The increased use of kerosene for lighting in rural areas and the replacement of noncommercial fuels for cooking will cause rural residential use of kerosene to increase. However, the continued electrification of rural areas will tend to reduce kerosene usage for lighting by the end of the century.

The figures in Tables 6-2a and 6-2b are for Egypt as a whole, and projections are based on economic growth trends and rates of increased saturation of energy sources in Egyptian households. The figures for annual energy consumption per household are, in general, equally applicable to Sinai, since they are primarily based on the use of a small number of appliances with reasonably predictable energy consumption rates. The main factors that might influence these figures would be the availability of pipeline gas for residential use (primarily in El Arish), and more efficient electrical use brought about by higher prices and better equipment.

The number of households using different energy forms in Sinai is difficult to predict. In light of the plans now being implemented by CEDCO, most urban households in Sinai will probably be electrified by 1985. Rates of rural electrification are much harder to anticipate.

The current electrical system does not permit a reasonable estimate of the number of rural houses using electricity, and since the electrical distribution system is changing very rapidly, this information would probably not be particularly useful. In the absence of other information, the values in Table 6-2b are probably useful guidelines for predicting rural electricity consumption. The degree of usage of butagas and kerosene in Sinai households can probably be reasonably estimated by using the figures for Egypt as a whole. The main factors that would influence these values are more rapid rural electrification than projected, and the availability of pipeline gas.

6.2.2 Commercial Energy Consumption

No data were obtained for commercial use of energy, but some estimates can be provided on the basis of figures for Egyptian commercial consumption. The primary energy requirement in the commercial sector is for lighting. This need is provided primarily by electricity, though kerosene may be used in rural areas. The Joint Egypt/U.S. Cooperative Energy Assessment (U.S. Department of Energy, April 1979) recommends that electrical consumption in the commercial sector be considered as two-thirds of residential consumption. This report also suggests that the commercial use of kerosene will amount to less than 10 percent of residential use.

6.2.3 Tourism

Currently there are no first-class tourist hotels in Sinai. Estimates of energy requirements are based on consumption data for the Nile Hilton in Cairo (Hartmann, 1981) and figures provided by the Ministry of Tourism (El Masry, 1981). For the Nile Hilton, with an average occupancy of 95 percent, the annual electrical consumption is approximately 33,000 kilowatt-hours per room, annual gas usage is 635 cubic meters per room, annual fuel oil (sular) consumption is 3,000 liters per room, and annual water usage is 2,400,000 liters per room. In addition to its 400 guest rooms, the Nile Hilton serves between 3,500 and 5,000 meals per day, or roughly 9 to 12 meals per room per day. These figures should serve as rough estimates of expected energy requirements for a five-star hotel in Sinai, and are consistent with the total electrical capacity requirements estimated by the Ministry of Tourism of 10 kilowatts per room for a five-star hotel, and 5 kilowatts per room for a three- or four-star facility.

6.2.4 Community Energy Systems

Most of the energy required for community systems is for water or wastewater treatment and municipal lighting. The main energy requirements for water treatment are for pumping, and these requirements will be similar to those for irrigation systems (Section 6.2.7). Municipal lighting requirements vary considerably according to the number of lights installed, efficiency, length of roadways, etc. One estimate of electrical requirements for municipal lighting can be based on experience in the Canal Governorates, where the requirement is 50 percent of total domestic use (El Reweny, July 1981). This is a very high ratio, but in view of the fact that municipal lighting is one of the first major electrical loads on new systems, this estimate is probably accurate for the next 2 or 3 years. However, based on current consumption and projections for Egypt as a whole, municipal lighting should ultimately represent between 1 and 2 percent of the total electrical requirement, or less than 10 percent of the residential demand.

6.2.5 Transportation

Energy requirements for transportation are affected by a large number of factors, including road quality, vehicle and fuel types, weights and types of cargos, average length of trips, and average number of passengers. Table 6-3 provides estimates of fuel requirements for a number of transportation systems in urban and intercity travel. The recommendations given in the table are reasonable bases, in most instances, for projecting transportation energy requirements for Sinai.

6.2.6 Industry

If petroleum operations are considered as part of the industrial sector, industry is the largest single user of energy in Sinai--accounting for more than half of the petroleum products consumed at present. In general, industrial projects have energy requirements that can be accurately identified. Of the proposed industrial projects for Sinai, the ferromanganese plant at Abu Zenima will have an electrical demand of 12 to 14 megawatts. The gypsum operations north of Abu Zenima will require 5 megawatts.

The Suez Oil Company north of Abu Rudeis will have an installed capacity of 48 megawatts by 1983, and 72 megawatts in later years. It is assumed that the Petrobel operation in Abu Rudeis has an equal or larger electrical plant capacity. In the case of both petroleum operations, the fuel for electrical generation and the generating equipment are provided by the oil companies to ensure reliability of the power source. The energy needs of petroleum companies have generally not been considered in other discussions of projected demands for Sinai. As viable industrial operations are identified, the corresponding electricity and petroleum needs can readily be established and considered in relation to the energy needs and resources for all of Sinai.

6.2.7 Irrigation/Agriculture

The availability of freshwater is an important factor in virtually all potential development activities in Sinai. Water can be obtained by pumping from aquifers, transporting from remote sources, or distilling or desalinating brackish or salty water. All of these activities require the use of energy. (The energy requirements for water desalination methods will be discussed in the water report.) Pumping is

TABLE 6-3

Transportation Energy Requirements--Recommended Values

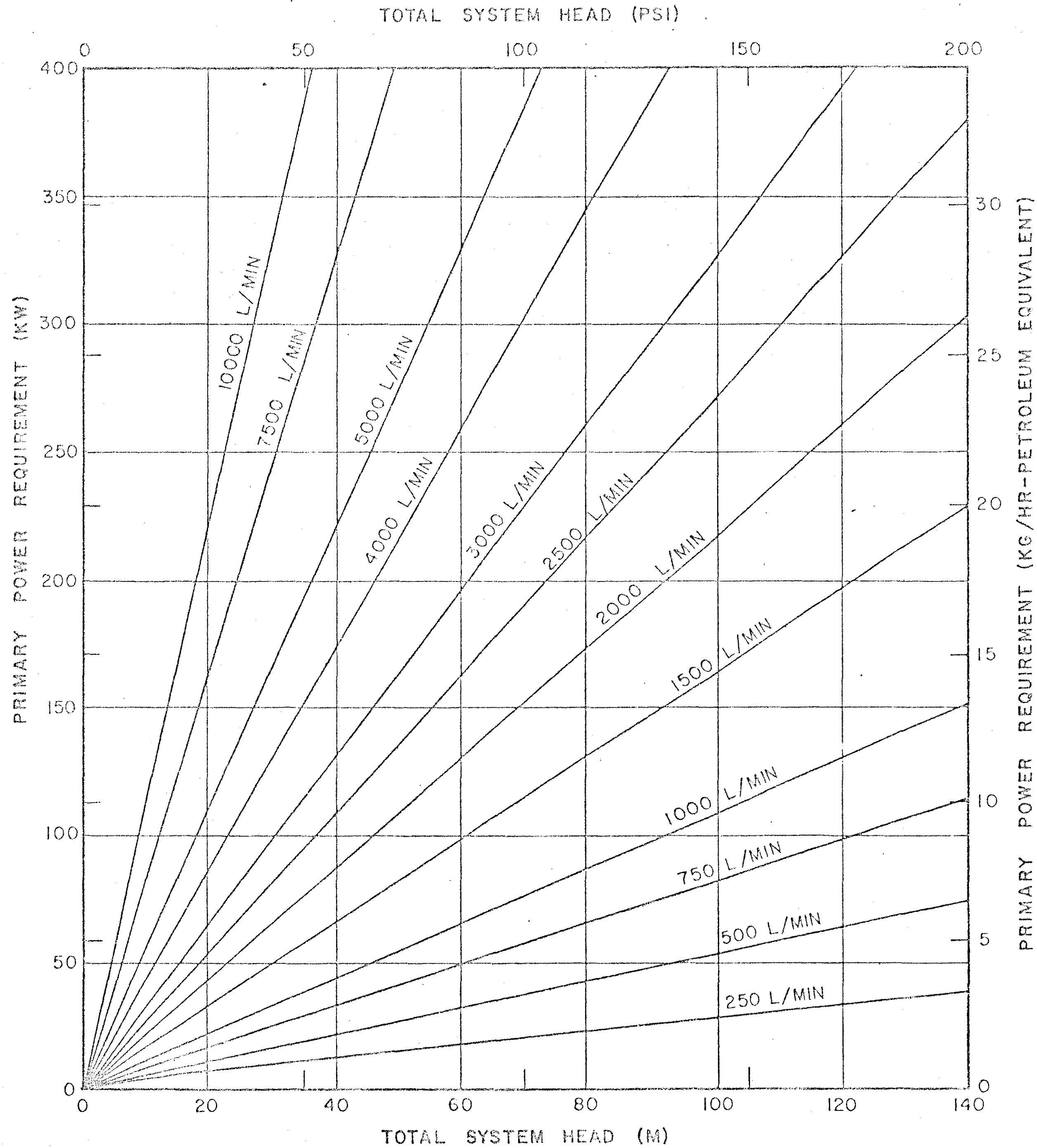
Automobiles	liters/100 km	gigajoules/100 km
Urban	7.7	0.26
Intercity	6.8	0.23
Motorcycles	4.8	0.16
Trucks (benzene)	liters/100 ton-km	gigajoules/100 ton-km
Urban	4.3	0.14
Intercity	3.2	0.11
Trucks (diesel)		
Urban	2.9	0.11
Intercity	2.3	0.09
Railroads		
Freight	0.9	0.03
	liters/100 seat-km	gigajoules/100 seat-km
Passenger		
Urban	1.4	0.06
Intercity	1.0	0.04
Buses		
Urban	1.2	0.05
Intercity	0.8	0.03

SOURCE: U.S. Department of Energy, April 1979.

the primary energy requirement in water transportation activities. Diesel and electric pumps have approximately the same fuel efficiencies, taking into consideration the heat rate of electrical generation. Figure 6-4 shows pumping power requirements for a number of water flow rates, expressed in terms of primary power and fuel needs and based on a total system efficiency of 15 percent. The actual efficiency of a given pumping application will depend on the type and condition of equipment being used, the electrical distribution system, and other factors.

Energy requirements for a specific irrigation project can be readily determined on the basis of well depth, type of irrigation system, planned schedule for watering, area to be irrigated, and peak and average watering requirements. Figures 6-5 and 6-6 were prepared as estimates of annual energy needs and pump horsepower ratings based on assumptions for irrigation systems that might be applicable in Sinai. The general assumptions were that a single pumping station could handle six separate plots of land (six duty cycles per day), and that daily irrigation requirements during peak periods were five times the average daily requirement for the entire year. In addition, the pressure difference between the pump and field was assumed to be 5 meters of water (7 $lb/in.^2$) for surface (flood) irrigation; 28 meters (40 $lb/in.^2$) and 18 meters (26 $lb/in.^2$) for medium- and low-pressure sprinklers, respectively; and 17 meters (25 $lb/in.^2$) for drip irrigation. Annual water requirements were considered to be 4,500 m^3/feddan/yr for surface irrigation, 3,200 m^3/feddan/yr for sprinklers, and 1,200 m^3/feddan/yr for drip irrigation.

For large land reclamation projects, the energy requirements should ultimately be calculated on the basis of the specific characteristics of the region and the land reclamation program. The values in Figures 6-5 and 6-6 can be used to estimate energy needs when the circumstances roughly correspond to the assumptions.



Sinai Development Study Phase 1
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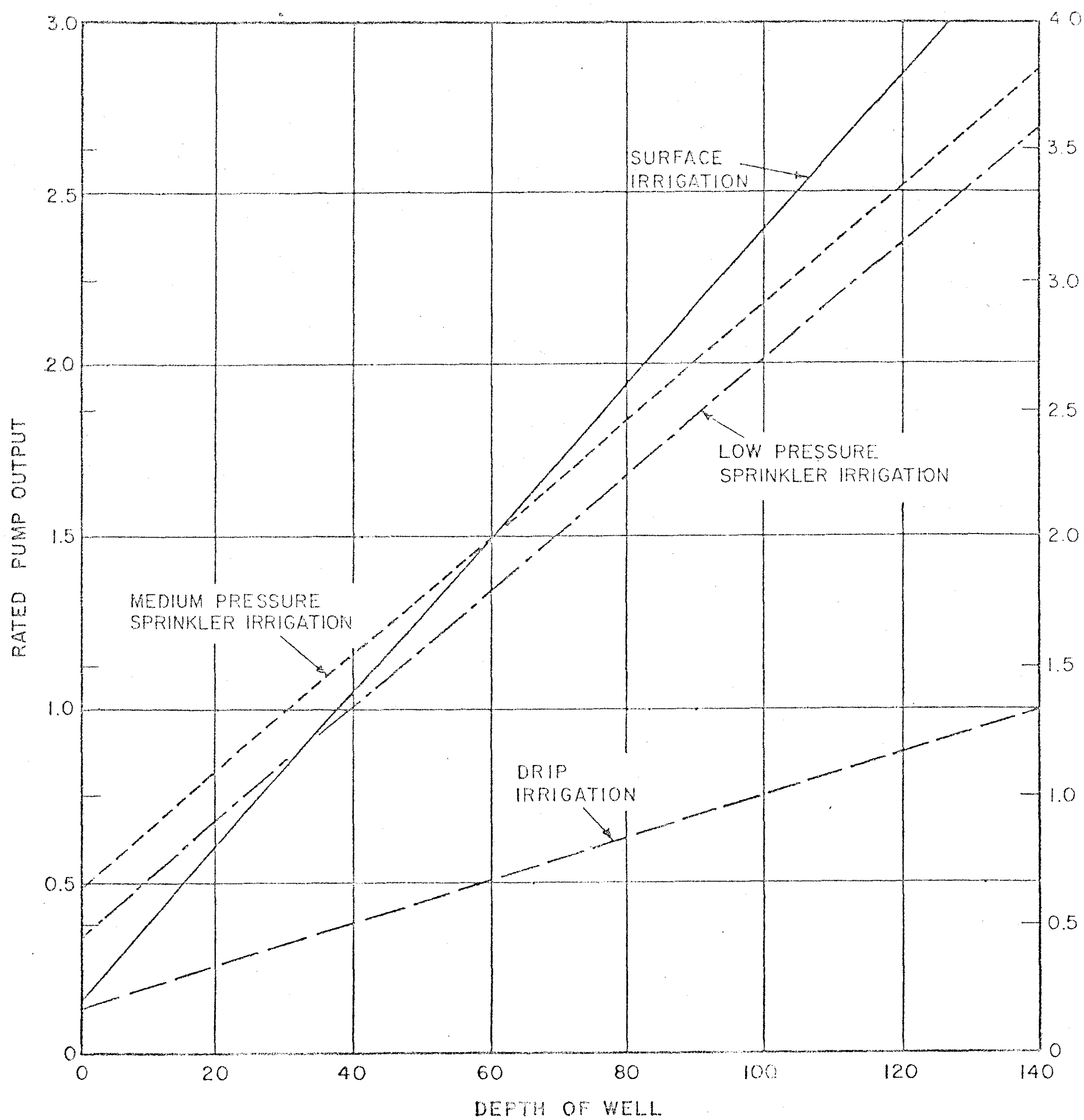
Dames & Moore

PRIMARY POWER DEMAND FOR PUMPING
SYSTEM EFFICIENCY OF 15%

FIGURE 6-4



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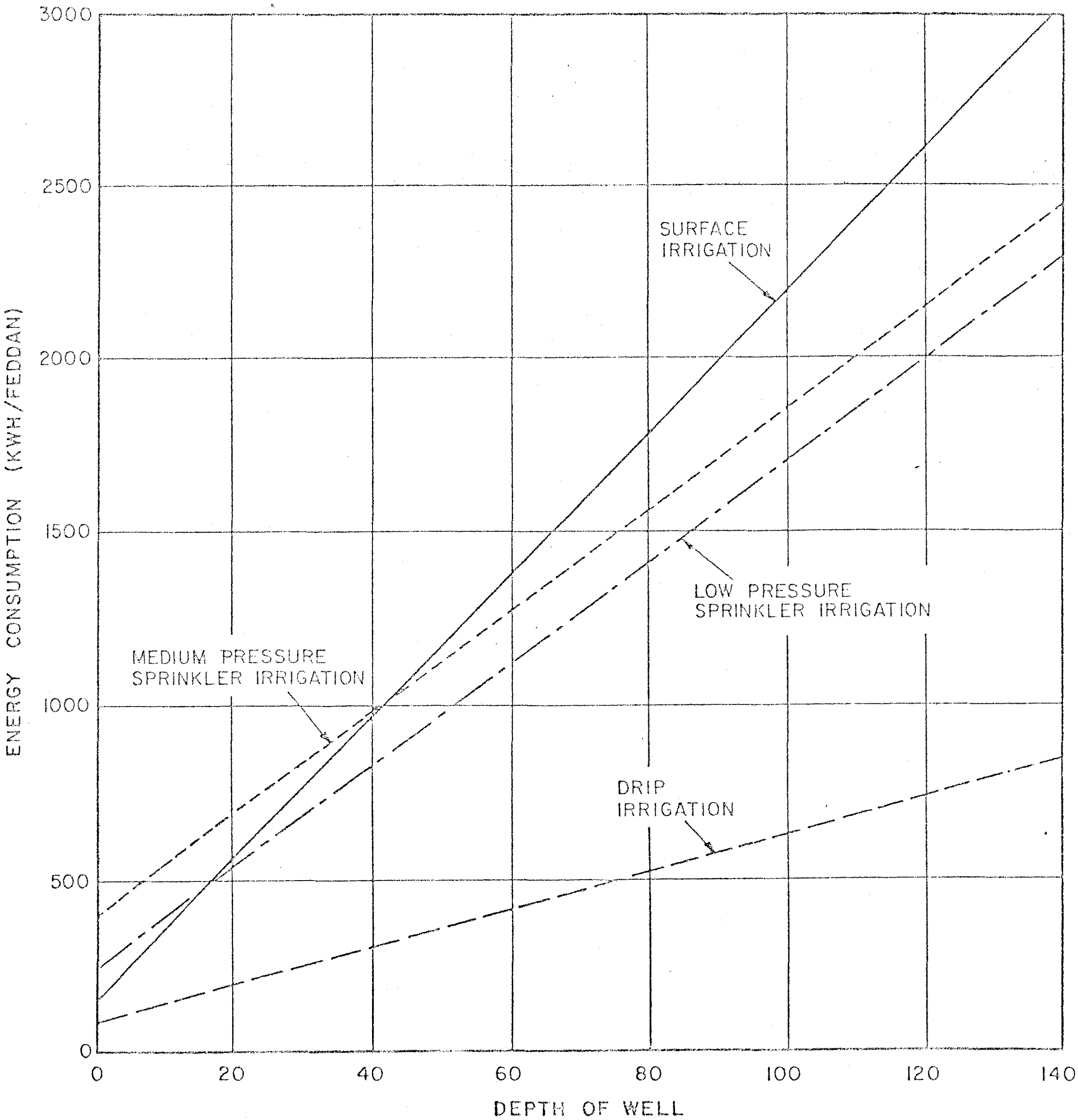
REQUIRED PUMP POWER PER FEDDAN OF IRRIGATION (60% PUMP EFFICIENCY)

FIGURE 6-5



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ANNUAL ENERGY CONSUMPTION FOR IRRIGATION (60% PUMP EFFICIENCY)

FIGURE 6-6

7.0 SUPPLY-DEMAND RECONCILIATION

At present, most commercial energy in Sinai--with the exception of that required by petroleum-producing operations--is transported across the Suez Canal in the form of various petroleum products, primarily diesel oil (sular) and benzene. A significant portion of this fuel, perhaps 90 percent, is allocated for the production of electricity. Since many areas are only now beginning to be electrified, the main demand for electrical energy outside of El Arish is currently for public buildings and lighting. The petroleum products not used for electrical generation are used mainly for transportation, fishing, cooking, and irrigation. Noncommercial fuels are used extensively for cooking.

Crude oil and natural gas production in Sinai far exceeds local energy needs. The only portion of this resource that is used at present is that which is required to provide energy and water for petroleum operations. The use of associated natural gas that is currently being flared and the reconstruction and upgrading of the existing skimming plant in Wadi Feiran to provide refined petroleum products will enable Sinai to meet most or all of its energy needs with local resources. The use of Maghara coal for thermal electric generation will ensure that Sinai becomes an exporter of both electrical energy and petroleum. Ongoing exploration for oil and natural gas will probably lead to increases in the quantity of energy exports from Sinai.

Demand for all forms of energy is expected to grow rapidly; assuming responsible use of energy, conventional energies produced in Sinai should continue to meet this demand through the year 2000.

Industry and agriculture will represent increasingly larger percentages of total energy demand in Sinai, and probably most of the energy required for these sectors will be in the form of electricity. Tourism may also represent a significant portion of the electrical energy demand. Petroleum products will continue to be used primarily for transportation, irrigation, cooking, and fishing.

Conservation and alternative energies can be viewed primarily as a means of reducing the demand for fossil fuels, rather than as a means of augmenting the supply of energy. In this context, conservation and alternative energies are important in Sinai in that they can contribute to increased exports of energy from Sinai and Egypt as a whole. Also, the rapid development of renewable energy systems and the practice of conservation---to the extent that they represent capitalization of energy costs--are a means of providing some economic security in the face of future increases in energy costs.

8.0 SPECIAL PROJECTS

President Sadat has requested that the new city of Mit Abou El Kom become a site for the demonstration of practical applications of solar energy and other renewable energy resources. As of July 1981, West Germany had agreed to provide solar equipment for a variety of uses. Seventy domestic hot water heating systems will be installed using flat-plate collectors, and a crop drying facility with a horizontal plastic air collector will be supplied. Other projects will use photovoltaic cells to provide electricity for a variety of devices--a small hospital refrigeration unit, microphones for a mosque, and a small water-purification unit. The water purifier is intended to demonstrate the feasibility of this application in remote areas, since New Mit Abou El Kom will have its own water treatment plant.

APPENDIX A

REFERENCES

Edesess, M., J. Henderson, and T. S. Jayadev, A Simple Design Tool for Sizing Solar Ponds, TR-351-347 (Solar Energy Research Institute, 1979).

Helwa, N., "Desalination of Solar Energy," Proceedings of German-Egyptian Workshop on Solar Collectors (Cairo: Supreme Council for Energy, 1981).

Jayadev, T. S., and M. Edesess, Solar Ponds, TR-731-587 (Solar Energy Research Institute, 1980).

Joint Egypt/U.S. Report on Egypt/U.S. Cooperative Energy Assessment, DOE/IA-0002 (U.S. Department of Energy, April 1979).

Kreith, Frank, and Jan F. Kreider, Principles of Solar Engineering (1978).

Maghara Coal Project Report on Reserves and Relevant Geology (Cairo: Powell Duffryn Technical Services, Ltd., for the General Organization for Industrialization, May 1966).

Nor El Din, A., A Clear Cut National Program in Rationalization of Energy Consumption and Improving the Efficiency of its Application (Cairo: The Egyptian General Petroleum Company, 1979).

Nor El Din, A., Predictions of Energy Consumption During the Years 1985, 1990, 1995, and 2000 (Cairo: Supreme Council for Energy, 1980).

Primary Study for the Electrical Projects Required for the Development of the North and South Sinai Governorates (Cairo: Ministry of Electricity and Energy/Canal Electricity Distribution Company, August 1981).

Ramly, I. M., "Recent Review of Investigations of Thermal and Mineral Springs in the UAR," Twenty-Third International Geological Congress, Vol. 19 (1969).

Renewable Energy in Egypt: An Analysis of Options, MTR-79W00460 (The MITRE Corporation, July 1980).

Research and Development Authority Report (Israel: Applied Research Institute, Ben Gurion University, August 1976).

Salton Sea Study to Determine Electrical Generation Potential (Solar Engineering, April 1980).

Sinai Electrical Projects Report (Canal Electricity Distribution Company, 1980).

APPENDIX B

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APPENDIX C

STANDARD UNITS AND CONVERSION FACTORS

General conversion factors:

1 ton	=	1 metric ton	=	1,000 kg	=	2,205 lb
1 bbl	=	1 barrel of oil	=	159 l	=	42 gal
1 m^3	=	1,000 liters	=	35.31 ft^3		
1 Btu	=	1,054 joules				
1 kWh	=	3.6×10^6 joules	=	3,413 Btu		

Energy conversion factors for Egypt:

Fuel: Egyptian Nomenclature	Fuel: U.S. Nomenclature	Energy Content (joules/ton x 10^{10})
Butagas	LPG	4.708
Benzene	Gasoline	4.617
Kerosene	Kerosene	4.420
Gas oil (sular)	Gas oil	4.463
Diesel oil	Diesel oil	4.463
Fuel oil (mazout)	Residual fuel oil	4.071
Natural gas	Natural gas	4.65
Crude oil	Crude oil	3.99
Coal	Coal	2.94

Densities:

Crude oil	0.91 kg/l
Natural gas	0.81 g/l

One ton of oil equivalent = 4.186×10^{10} joules

APPENDIX D

RECOMMENDATIONS FOR PROMOTING ENERGY CONSERVATION

The following are suggestions--most of which require some governmental action or intervention--to help ensure that energy is used as efficiently as possible in the process of Sinai development.

- Transportation
  - Limit speeds on highways with stiff penalties for violators.
  - Promote use of mass transit by developing efficient bus systems in El Arish and other cities, and by providing buses or trains on major intercity routes.
  - Use buses with diesel engines.
  - Develop and enforce performance standards (by periodic inspections or other means) for trucks, buses, and automobiles.
  - Limit the subsidy of fuels to private owners by rationing the use of subsidized benzene.
- Residential/Commercial
  - Encourage the use of solid-state televisions (by reducing import tariffs, subsidies, etc.).
  - Discourage the use of nonessential energy-using appliances (such as air conditioners) by taxing these items.
  - Reduce the subsidy of butagas and kerosene to commercial establishments (especially tourist facilities) by rationing the subsidized sale of these fuels or by other means.
  - Develop and promote the use of efficient kerosene cookers, and discourage the use of butagas.
  - Where possible, make natural gas available for residential and commercial use.
  - Develop insulation and performance standards for household appliances that consume energy.

- Encourage the use of solar water heating by providing subsidies and promoting large volumes of production of solar water heaters to achieve economies of scale.
- Develop performance standards for solar systems.
- Encourage the use of efficient lighting (by energy pricing, subsidies, etc.).
- Set standards for residential and commercial structures to reduce the need for cooling and heating.
- Plan urban development and establish zoning laws to reduce energy consumption (design roadways to ensure smooth flow of traffic, set standards for municipal lighting, ensure solar exposure, reduce cooling loads by density and spacing regulations).
- Manufacture and install plumbing fixtures that require minimal maintenance and have low water consumption.

o <u>Industry</u>

- Require large industrial developments to evaluate energy requirements and examine alternatives.
- Encourage the use of waste heat recovery to increase the energy efficiency of industrial operations or to provide water desalination or energy for other uses (such as refrigeration).
- Promote the use of energy control and load management systems.
- Establish performance standards for specific industries.

o <u>Agriculture</u>

- Where feasible, use drip irrigation to minimize water requirements.
- Replace the use of fossil fuel driers with solar driers where this is a viable option.
- Use wind power for pumping along the east coast of the Gulf of Suez.
- Encourage the use of electric pumps in areas where an electrical network exists (primarily to achieve reduced maintenance costs).

- General

  - Establish pricing schemes for water that encourage the conservation of this resource and promote the use of lower cost water.
  - Set pricing policies for electrical energy, to include off-peak rates, power factor penalties, and incentives for local and private power production and cogeneration.
  - Provide incentives to local governments to improve energy use and reduce the waste of power and water in government facilities.

APPENDIX E

CRUDE OIL PRODUCTION IN EGYPT
(1978-1979)

TABLE E-1

Crude Oil Production

	Planned (1979)			Actual (1979)			1978		
	(thousand tons)	(thousand tons)	(%)	(thousand tons)	(thousand tons)	(%)	(thousand tons)	(thousand tons)	(%)
General Company	1,359	1,479	5	1,294	1,408	5	1,353	1,471	5
GAPCO	18,194	21,162	73	19,008	22,090	73	17,983	20,931	75
ROROCO	362	397	1	453	497	2	233	256	1
Shaab Ali	--	--	--	118	136	--	--	--	--
PETROBEL	4,700	5,231	18	4,948	5,504	18	18	4,194	17
WEPCO	493	588	2	460	549	2	2	520	2
Suez Oil Company	247	286	1	28	32	--	--	--	--
TOTAL PRODUCTION	25,355	29,143	100	26,306	30,216	100	19,589	27,372	100
Organization's share from crude oil	18,987	21,763	75	21,220	24,343	81	18,241	20,980	75

TABLE E-2

Average Daily Production of Crude Oil*

	Planned (1979) (thousand barrels)	Planned (1979) (%)	Actual (1979) (thousand barrels)	Actual (1979) (%)	Planned (1978) (thousand barrels)	Actual (1978) (%)
General Company	25	5	24	5	25	5
GAPCO	356	73	381	73	361	75
ROROCO	7	1	9	5	5	1
Shaab Ali	--	--	2	--	--	--
PETROBEL	90	18	95	18	80	17
WEPCO	10	2	9	2	11	2
Suez Oil	5	1	1	--	--	--
TOTAL PRODUCTION	493	100	521	100	482	100
Organization's share from crude oil	376	75	419	80	362	75

*The production rates are not regular because of the observation period. The oil fields were taken back on November 25, 1979. The average daily production from November 25 to December 31, 1979 = 31,000 barrels.

TABLE E-3

Total Production from Condensate Oil and Gases

	Planned (1979)		Actual (1979)		Planned (1978)	Actual (1978)
	(thousand tons)	(%)	(thousand tons)	(%)	(thousand tons)	(%)
Condensate Oil						
GAPCO	122	12	111	10	123	16
PETROBEL	34	3	24	2	20	3
WEPCO	19	2	27	3	--	--
SUBTOTAL	175	17	162	15	143	19
Gases						
GAPCO	438	42	476	45	441	59
PETROBEL	230	22	166	15	142	19
WEPCO	169	16	221	21	--	--
SUBTOTAL	837	80	863	583	751	78
Percentage of liquid gases	36	3	41	25	--	3
TOTAL (condensate oil and gases)	1,012	100	1,025	100	894	100

TABLE E-4

Quantities of Refined Oil

	Planned (1979)		Actual (1979)		Planned (1978)	Actual (1978)
	(thousand tons)	(%)	(thousand tons)	(%)	(thousand tons)	(%)
Domestic crude oil	12,000	100	12,259	100	11,938	100
Imported crude oil	--	--	--	--	--	--
TOTAL	12,000	100	12,259	100	11,938	100
Distribution of Crude						
Suez Company						
Mosfarad Refinery	3,700	31	3,846	31	3,747	31
Tanta Refinery	750	6	601	5	798	7
El Suez Refinery	900	8	712	6	858	7
SUBTOTAL	5,350	45	5,159	42	5,403	45
El Nasr Company						
El Ammeria Refinery	2,700	22	2,535	21	2,128	18
El Suez Refinery	950	8	1,402	11	2,190	11
El Eskandaria Refinery	3,000	25	3,163	26	3,188	26
SUBTOTAL	6,650	55	7,100	58	7,506	55
TOTAL	12,000	100	12,259	100	12,909	100

APPENDIX F

ESTIMATED ENERGY COSTS

Petroleum Products

Crude oil (world market price):		U.S. $32 per barrel
Natural gas:	approximately	U.S. $0.10 to $0.14 per cubic meter

Electricity

Capital costs:

Gas turbine:	U.S. $600 per kilowatt
Thermal generator:	U.S. $1,000 to $1,500 per kilowatt
Waste heat recovery:	U.S. $400 per kilowatt

Total Production Costs: The current cost to the Canal Electricity Distribution Company is 9 millemes/kWh when purchased from the national grid. Actual generation and transmission costs in Egypt are approximately 4 piasters per kilowatt-hour (LE 0.04 per kilowatt-hour). Costs for electricity production using natural gas are estimated to be 5 to 8.5 piasters per kilowatt-hour, based on current world prices; and thermal electric costs using oil are approximately 8.5 to 10 piasters per kilowatt-hour.

Renewable energy technologies

Photovoltaic cells:

Capital costs:	25 to 70 piasters/peak watt (LE 1,000 to 2,500/kWh_e/day)

Flat plate collectors:

Capital costs:	25 to 70 piasters/peak watt (LE 40 to 100/kWh_e/day)

Solar ponds:

Capital costs:	LE 3 to 4 piasters/peak watt (LE 450 to 600/kWh_e/day)
Production costs:	10 to 11 piasters/kWh_e

Solar stills: LE 3.5/m^3 of water

Wind power:

Capital costs:	LE 2,000 to 10,000/rated kW

APPENDIX G

BIOGAS DIGESTERS

The following information is based on discussions with Dr. Abed Abdel Dayem of the National Research Center, Dokki, in June 1981.

General parameters

Retention time:	40 days
Yield of gas:	0.15 to 0.25 m^3/m^3 of digester volume/day
Fuel value:	5,600 kcal/m^3 (620 Btu/ft^3)
Solids content of slurry:	8%

A large animal (cow, donkey) will produce approximately 12 kilograms of manure a night, with 16 to 20 percent dry solids. A 1:1 mixture of water and waste is required to reduce the solids content to 8 percent. Digestion occurs at temperatures between 20° and 30°C (usually 2° to 3°C above ground temperature, due to the action of mesophilic organisms). The gas produced is 50 to 60 percent methane (Ch_4), 40 to 50 percent carbon dioxide (CO_2), and contains other gas in small quantities (most notably hydrogen sulfide, which gives the gas a distinctive odor). Both the Indian and Chinese designs are continuous processes in which spent slurry is forced out of the digester as fresh slurry is introduced.

Specific characteristics

- Indian design
  - Type: Constant pressure, variable volume
  - Agitation: Rotation of floating top, which has mixing vanes on the inside
  - Maintenance: Minimal, usually not required for long periods
  - Construction: Brick and sheet metal; relatively simple
  - Cost: Approximately LE 550 for a 10-cubic-meter digester

- Chinese Design
  - Type: Variable pressure, constant volume
  - Agitation: Occurs when slurry is introduced
  - Maintenance: Required periodic inspection
  - Contruction: Brick; requires some skilled labor
  - Cost: Approximately LE 350 for a 10-cubic-meter digester