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Joint Egypt/United States Report on Egypt/United States Cooperative Energy Assessment

MASTER

Volume 3 of 5 Vols.
Annexes 2-5

April 1979

U.S. Department of Energy
Assistant Secretary for
International Affairs

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Prepared collaboratively by representatives of the Government
of Egypt and the United States Department of Energy with the
assistance of the United States Department of State.

U.S. Department of Energy

Assistant Secretary for
International Affairs
Washington, D.C. 20585

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1.0 SUMMARY

1.1 Objectives

The principal objectives of Gordian Associates assistance to the U.S. Department of Energy's International Cooperative Energy Assessment for Egypt were:

1. To develop an understanding of the current status of the principal energy users in Egypt's industrial and agricultural sectors.
2. To estimate the energy demand and efficiency for each selected subsector within these major sectors.
3. To identify opportunities for fuel type changes, technology switches or production pattern changes which might increase the efficiency with which Egypt's energy is used both now and in the future.
4. Based on options identified, to forecast energy efficiencies for selected Egyptian subsectors for the years 1985 and 2000.

The principal areas finally selected for study to meet these objectives were:

For the Industrial Sector

o Iron and Steel	o Petrochemicals
o Aluminum	o Cement
o Fertilizers	o Textiles
o Chemicals	o Automotive Manufacture

For the Agricultural Sector

o Drainage and Irrigation
Mechanization	o Food Processing

This selection was finalized after a preliminary assessment of their importance as energy users and after discussions held in Egypt during which it became apparent that, under the structure being followed, the Petroleum Refining and Utilities subsectors were more closely allied to the function of the Supply team than to the Demand team. These two subsectors were therefore not included in the list of selected industries for demand analysis, although the petrochemicals subsector was included because, although currently only at the planning stage with respect to most products, this subsector is likely to become a significant energy user.

The principal methodology used to realize the objectives was to discuss with as wide a cross section of Egyptian experts as possible all energy technical and production aspects for the selected industries. Wherever possible, these discussions were reinforced by a plant visit and a meeting with the site technical staff. The data gathered in Egypt was then used, together with published data, to estimate energy use and efficiency figures.

The development of options and the forecasts of energy efficiencies were made by Gordian staff familiar with the specific subsectors; this was performed in New York and London. In order to ensure that the options so developed were meaningful in the Egyptian context, Gordian personnel that had visited Egypt were used to conduct critical appraisals of the expert's suggestions. Wherever possible, the ideas developed were also discussed with other members of the U.S. team and U.S. and European industrial experts.

1.2 Principal Options and Observations

During the course of this study, a number of options were developed which might serve to reduce the energy demand of the industrial and agricultural sectors, or at least to reduce their dependence on imported energy sources. In many cases, quantitative assessment of their energy effects cannot be made without further detailed investigation. It may happen, therefore, that some of the options will prove to be trivial in terms of energy savings. In addition, while some options may prove attractive in energy terms, the political and economic acceptability of options are separate issues and a matter of Government policy. Hence, any decisions on options, which might trade off energy efficiency for other social or environmental goals, will clearly lie with the Egyptian Government.

Over and above these options, a number of general observations were made, all of which have a direct or indirect relationship to energy demand in the industrial and agricultural sectors. These observations are as follows:

1.2.1 Improved maintenance: Evaluation of energy efficiency and plant visits suggest that there are many areas where plant maintenance, particularly planned or preventive maintenance, is suffering. The factors which cause this should be identified and rectified. They may include such items as lack of scheduled downtime, need for improvement in spare part inventory control, need to maximize local capability for spare part manufacture, and improved quality control and specification for high mortality spare part items. With modern high throughput continuous processes, a production stoppage, often caused by a fairly minor piece of equipment, can mean a loss of production for little or no reduction in energy usage. The frequency and duration of such stoppages are a function of maintenance, and therefore an important area of investment for energy efficiency improvement is the field of planned preventive maintenance aimed at keeping downtime to a minimum. Such a

program requires investment in capital spares and personnel but has the benefit of improving productivity, so serving the market better and reducing costs. Additionally, the marginal energy requirement per unit of production is often very low, thus raising overall energy efficiency.

1.2.2 Improved management: A second area of "investment" which would utilize one of Egypt's great assets -- its trained workforce -- would be the development of an improved middle management. Policies should be sought to promote the training and establishment of an effective middle management layer within the industry, which would relieve pressure on top management. This middle management cadre would be charged with implementing specialized management techniques and energy efficient practices.

1.2.3 Energy efficiency awareness: At all levels, there appears to be an opportunity for increasing energy efficiency through the creation of a better awareness of the need for optimum energy resource utilization and of the technical means for implementing improvements. Practical training, both before assignment to operating positions and from time to time thereafter, could be of great value to plant operators and their supervisors.

1.2.4 Improved reliability of electrical supply: The present Government policy of discouraging industries from providing their own source of power supply should be reviewed. This observation should be considered in light of the breakdowns in power supply experienced in some areas, and the disproportionate cost of re-starting plants and the loss of production this entails.

1.2.5 Waste heat recovery: Opportunities for waste heat recovery should be sought. For example, excess medium- or low-pressure steam which is produced in one plant may find a use in another adjacent plant. Specific applications of waste heat might include textile finishing (e.g., dyeing, washing) and food processing (e.g., washing down, sterilizing). Options for improved energy efficiency for most of the industries covered in the study include a "maximum conservation" case, in which waste heat recovery plays a useful role.

1.2.6 Cogeneration The Government policy of discouraging plants to generate their own power is a constraint to the cogeneration of electricity and process steam by industry. Such installations can offer a major improvement in energy utilization, as they can raise the thermal efficiency from about 30 percent for electricity generation alone to perhaps double this figure for cogeneration systems.

1.2.7 Development priorities: Development of energy-intensive industries often requires large amounts of capital investment as well as a significant call upon national energy resources, for which these industries may generate relatively few direct employment opportunities. The assessment of development priorities should therefore balance

considerations of energy use against national objectives. An illustration of this situation may be drawn from the petrochemicals subsector, where a planned ethylene cracker is expected to require an investment of a quarter of a billion dollars and generate no more than 500 jobs. In contrast, a PVC plant is expected to cost \$100 million and generate the same number of jobs.

1.2.8 Development of related industries: The practicality of integrating complex industries, such as petrochemicals, from basic feedstock through intermediates to consumer products should be thoroughly reviewed. For example, it may prove advantageous from an energy and employment viewpoint to import intermediate products (e.g., ethylene, chlorine) and to concentrate on the establishment of plants to make finished consumer products. Plants which will consume relatively little energy will offer good employment opportunities and will provide high added value in the manufacturing sequence. An example of this situation may be seen in the petrochemicals area, where Egypt plans to develop a completely integrated industry encompassing all manufacturing stages from naphtha cracking to producing ethylene, through intermediate plants (VCM, DMT, chlorine, etc.) to final product plants (LDPE, HDPE, PVC, polyester fibers, etc.). The opportunity appears to exist to import basic materials such as ethylene and propylene, and perhaps intermediate materials such as VCM and chlorine, from neighboring oil-rich states and to concentrate on the development of consumer product plants within Egypt. Chemicals within this category include pharmaceuticals, dyestuffs, resins, detergents, and rubber products.

With respect to specific industry and agricultural subsectors, the principal options for improving energy utilization discussed in the main body of the report are the following:

Iron and Steel Increase use of direct reduction (followed by the electric furnace route or in the open hearth system)
 Import scrap
 Use Egyptian coal in coking blends
 Maximize energy conservation programs

Aluminum Reduce anode current density
 Increase pot insulation
 Use domestic petrocok for anodes

Cement Maximize production of blended cements
 Fuel switching
 Change cement specifications (or operate closer to specifications)
 Shift to bulk transportation
 Clinker importation
 Load management and use of off-peak power
 Improve cement distribution
 Increase use of concrete

<u>Chemicals</u>	Replace mercury cells with diaphragm cells Import chlorine Vent hydrogen recovery for fuel use Use of petrocake in line kilns Maximize energy conservation programs
<u>Fertilizers</u>	Phase out Kima electrolytic plant Maximize use of natural gas as feedstock Maximize energy conservation programs Promote phosphatic fertilizers
<u>Petrochemicals</u>	Appraise possibilities for import of intermediates from energy-rich neighboring countries rather than manufacturing in Egypt (e.g. ethylene, chlorine) Promote more labor intensive downstream processing Delay LDPE plant construction pending development of improved Union Carbide process Review paraxylene project logistics
<u>Textiles</u>	Maximize energy conservation programs (e.g., heat recovery)
<u>Agricultural- General</u>	Use waste materials/solar energy
<u>Agriculture- Food Processing</u>	Maximize energy conservation programs

2.0 INTRODUCTION TO THE MAIN REPORT

2.1 Introduction to the Work Undertaken

Egypt in 1978 reflects the classical problem of many of the world's developing nations; it has a large, youthful population which is growing at a rate in excess of that which the finances of the country can readily support. Despite this, the country is better placed than many, having numerous natural resources, a well-developed educational and administrative system, and many of the world's finest antiquities providing the basis for a strong tourist trade.

The need to develop these resources to serve the population is well understood and is being pushed ahead as fast as the country's limited finances will permit. To achieve its plans, the country's own financial resources are being supplemented by aid from the richer Arab nations and most recently through the encouragement of foreign investment capital.

The net effect of the past and planned development has been to convert Egypt's energy supply-demand balance from a net surplus in the recent past to a predicted shortfall in the near future. The Department of Energy's study, of which this report forms a part, aims to clarify this supply-demand picture and illustrate ways in which increased usage can be made of the available energy. Two areas which form important parts of Egypt's economy and constitute a significant portion of the country's energy demand are studied in this report: the industrial sector and the agricultural sector. The two sectors are best placed in perspective within the economy by knowledge of the fact that they account for more than half the labor force, generate 48 percent of the gross domestic product and account for nearly 90 percent of the country's exports. Their growth and development are therefore clearly important to Egypt and must be expected to vitally affect the country's demand for energy.

This report studies the current state of these two sectors, estimates their energy usage and efficiency in 1975 and wherever possible predicts energy efficiencies for 1985 and 2000. Clearly a comprehensive study of all the subsectors within the industrial and agricultural sectors would be a massive task, quite outside the scope of this brief review. It was therefore necessary to select for study a limited number of the major energy users within the sectors and study them in some detail.

While this was done in principle, the difficulties encountered in collecting and collating data for even this limited number of processes and plants in the short time available, when superimposed upon the normal problems of data collection and verification in a developing country, made the accuracy of some of the data extremely questionable. Gordian has attempted to confirm the data wherever possible by comparison with standard reference data; however, this has not always been possible

or meaningful. The estimates and forecasts within the study can therefore only be regarded as a first estimate of energy demand, which in aggregate reflect the sectoral picture reasonably but can in no way be regarded as definitive estimates at the subsectoral level. To achieve a reasonable level of accuracy at this disaggregated level, it would be necessary to embark upon a much larger and more detailed study of each end-use.

2.2 The Industrial Sector

Unlike many of the other Middle Eastern states and lesser developed countries, Egypt has a diverse, well-established, and relatively old industrial sector. Egypt's industry has developed since the turn of the century from a single product economy based on cotton to the point where it is well down the road to becoming a multiproduct, consumer-oriented economy. Although agriculture remains dominant in terms of production and employment, an indication of the position of the industrial sector within the economy is given by the fact that industry has accounted for some 20 percent of Egypt's GNP for more than a decade. In the context of this particular study, the industrial sector is much more important than the agricultural, as it is a major energy user accounting for some 60 percent of the electric energy consumed in 1976. It is thus of paramount importance that in the near future, when energy might become a limiting factor in Egypt's growth, the industrial sector examine with great care the manner and efficiency with which it utilizes energy. If Egypt is to continue to grow and meet its peoples' needs and aspirations, it is essential that the maximum output be attained for any given energy input.

Some of the more prominent products representing higher energy usage within Egypt's industrial sector are identified below:

Aluminum	Iron and Steel
Bricks	Petroleum Products
Cars	Pulp and Paper
Cement	Refined Sugar
Chemicals	Soaps and Detergents
Copper	Synthetic Fibers
Edible Oils	Textiles
Fertilizers	Trucks

This list indicates the diversity of products and suggests the level of technology already operational within the country. It must be noted that much of the manufacturing equipment used for the production of these products, especially textiles, is old and has suffered as a result of the economic constraints on the importation of spares. The foreign exchange burden of capital spares and planned maintenance programs appears to have led to a severe curtailment of essential revamping and routine overhauls, and this in turn has resulted in production falling behind nominal throughputs. Seen from the point of view of plant management, we would say that the maximum attainable plant throughput has declined as a result of plant aging and inadequate maintenance.

After the revolution in 1952, the need for massive industrialization was identified as a principal objective and this was to be achieved by an increasing participation by the Government in all but the most minor of industrial units. The result of this approach is that some 80 percent of the value of production of the industrial sector is controlled by the Ministry of Industry, and even then this figure leaves out cement, bricks, pulp, and paper which come under other Ministries. Thus at the present time, the Government effectively controls all industrial production. Notwithstanding the current status, the new "open door" policy of the Egyptian Government is actively encouraging private ownership, foreign investment, and joint ventures and will, if successful, undoubtedly afford the industrial sector an opportunity to renew its capital assets, acquire new technology, and adopt modern management techniques.

The industrial sector has two major tasks within Egypt's overall development plan: firstly, to provide the country with the materials, goods, and services needed to provide a reasonable standard of living for a rapidly growing population, and secondly, to provide employment opportunities for a large, young population. Remembering always that these tasks will be undertaken in an atmosphere of continuing capital scarcity, it is particularly important in reviewing the study at hand to remember that factors such as the employment of people and the reduction of foreign exchange requirements may rate well above the efficient use of energy as national priorities. Thus, in the development of options which are essentially aimed at utilizing Egypt's energy resources more efficiently, Gordian has borne in mind Egypt's preoccupying desire to utilize one of its major resources, people.

Of Egypt's many resources, the two major ones are the fertile lands of the Nile Valley and the huge pool of manpower. The country has a well established educational system that has a long history of providing technical and professional personnel to the Arab world. The availability of experienced technical personnel might perhaps be a limiting factor to extremely rapid growth but cannot be regarded as such a serious constraint as the great lack of middle management can. This shortage, which has already led to a gross overburdening of the senior technical and managerial personnel, is unlikely to be rectified in the immediate future. A major prerequisite to the expansion and rejuvenation of Egypt's industrial sector must therefore be the training of middle managers and, through them, the adoption of basic modern management and control techniques. This drive to develop and invigorate the middle and lower management levels will need to be supplemented by a program which ensures a good supply of skilled workers to what must increasingly become technologically sophisticated industries.

Industry, or rather its geographical location, can and will play a major role in meeting many of the Government's objectives, most particularly by providing nuclei for the development of new communities. Notwithstanding the desirability of decentralizing both the population and industry, it must be recognized that location decisions based on political--and not merely technical-economic--premises may well adversely affect the energy efficiency of a project and hence add to the country's energy burden.

To date, the industrial development of Egypt has been based upon its comparative advantages in agriculture, "endless" supply of cheap labor, and a need to replace imports and so reduce the requirement for foreign exchange. Although such policies seem likely to persist in the near future, the growing effectiveness of centralized planning may tempt the country to shy away from the smaller projects in favor of the larger, more prestigious, and almost certainly higher energy-consuming projects. Because Egypt may well no longer be able to accommodate energy-intensive or energy-inefficient projects, the planners will have to think carefully about the energy implications of all new schemes, even allowing for the fact that most energy is paid for internally and therefore has only a small foreign component.

Thus to summarize: Egypt has a useful, diverse industrial base that is aging rather rapidly; it has an ample supply of personnel and a massive captive market. It should therefore be able to grow and renovate in confidence, provided sufficient cognizance is taken of energy implications so as to ensure these do not become a limiting factor.

2.3 The Agricultural Sector

The agricultural sector in Egypt accounts for approximately 30 percent of their GNP. It is the dominant sector, employing just under half the labor force, and is a major earner of foreign exchange. Between 1955 and 1965 the sector grew approximately 3.5 percent to 4.0 percent per annum; since then growth has been around 2.0 percent p.a. and only more recently has picked up as a result of Government programs for improving productivity.

The total cultivated area is estimated to be about 6 million feddan, 5.5 million in the Delta and Nile Valley area (old land) and 0.5 million on the fringes (new land). Crops account for about 75 percent of agricultural output, as opposed to livestock. Grain crops are grown on one-third of the cropping area, while cotton, vegetables, fruit, sugar cane and berseem account for the other major crops (see table 1). Livestock products are playing an increasingly important role in the sector.

The two main factors which underlie Egyptian agriculture are an ample water supply and a restricted land area. Government policies aimed at increasing productivity and at overcoming the constraints in the sector may be summarized under the following broad categories:

1. Drainage, rehabilitation, and management of the irrigation system.
2. Reclamation of desert lands.
3. Mechanization.
4. Development of the agro-industrial sector.

TABLE 1

EGYPT: PRODUCTION OF MAJOR CROPS, 1972-74
AVERAGE AND 1975-77(1)

<u>Crop</u>	<u>Average 1972-74</u>	<u>1975</u>	<u>1976</u>	<u>1977(2)</u>
		1000 metric tons		
Cotton (lint)	483	383	412	425
<u>Major Cereals</u>				
Wheat	1,810	2,034	1,970	1,690
Rice (paddy)	2,274	2,423	2,300	2,350
Maize	2,457	2,782	2,710	2,815
Sorghum	836	775	800	832
Barley	98	118	123	125
Total	7,475	8,132	7,903	7,812
<u>Oil Seeds</u>				
Cottonseed	854	652	677	735
Flaxseed	18	24	25	25
Sesame	20	17	16	18
Peanuts	28	28	30	33
Total	920	721	748	811
Horse Beans	289	234	264	295
Lentils	56	39	40	41
<u>Major Vegetables</u>				
Tomatoes	1,658	2,107	2,230	2,500
Potatoes	700	720	923	990
Onions	536	585	751	780
Cabbages	287	321	335	345
Total	3,181	3,733	4,239	4,615
<u>Major Fruits</u>				
Oranges	757	856	898	950
Grapes	171	225	242	270
Bananas	110	112	115	120
Dates	369	405	410	415
Total	1,434	1,598	1,665	1,755

(1) Ministry of Agriculture and USDA, ERS estimates.

(2) Preliminary

Drainage and Irrigation

In order to increase the cropped area, Government policy has concentrated on the improvement of old lands and the creation of new lands.

Where old lands are concerned, productivity has been falling due to waterlogging and rising salinity. The creation of the Aswan Dam in 1965 led to the shift to perennial irrigation resulting in a rising groundwater table. The additional irrigation water has proven excessive for the existing drainage system. Seepage from the canals and consumers' wasteful usage of water of up to 5 billion m³ per year (water is provided free of charge) have created water logging conditions which have seriously affected agricultural production. The rising water tables have increased soil salinity.

In 1960 the Government launched a program to improve drainage in 5 million fd of irrigated land. However, between 1960 and 1970 only 500,000 feddans were drained in the Delta area, and 80,000 fd in Upper Egypt. The World Bank and AID are currently financing drainage projects both in the Delta area and in the Upper Egypt. The Government plans to complete its drainage program involving 6 million fd by 1985. According to the World Bank this project should increase crop yield by 30 percent.

Reclamation of Desert Land

The "new lands" policy is for the extension of the canal network on the one hand and the development of groundwater resources on the other. The new valley project ultimately envisages the cultivation of 3 million fd. The objective of the policy is to reclaim 250,000 to 300,000 fd per year. Programs for 1978 cover 1.1 million fd of which 450,000 fd will use groundwater resources in the western desert.

Mechanization

Animal and manual power still play an important role in Egyptian agriculture. In addition, non-commercial energy (animal dung, crop residues, and some firewood) contribute to about one-third of total energy consumption. Mechanization in Egypt has been a slow process: for example, from 5,000 units in 1950, the tractor inventory of fully operational machines is estimated to be only 16,000 in 1976. Other major items used are chisel ploughs, stationary threshers, sprayers, and sprinklers.

Development of Agro-Industries

The food processing industries are estimated to consist of 1,000 establishments employing about 80,000 persons. Major emphasis has been on developing the sugar industry, on oil processing, and on soap manufacture (See table 2).

TABLE 2

INVESTMENT IN FOOD PROCESSING AND RELATED INDUSTRIES
1960 - 1974

	Million Pounds	% of Total
Sugar	112.6	60.7
Oil and Soap	26.5	14.3
Tobacco and Cigarettes	11.6	6.3
Dairy Produce	5.5	3.0
Canning	5.6	3.0
Bottling and Beverages	12.9	7.0
Other	<u>10.6</u>	<u>5.7</u>
	185.3	100.0

2.4 Subsector Identification

As discussed above, it was necessary within the industrial and agricultural sectors to identify a limited number of areas or subsectors which could be reviewed in the time available. This selection was done with due regard to the known high energy industries and the importance of an industry in the Egyptian context. The initial selection, made before the team went to Egypt, was modified when the demarcation between the supply and demand teams was clarified.

It is believed that the subsectors considered account for the vast majority, probably 90 percent or more, of the energy used within industry and agriculture.

2.5 Data Collection

The scope of work involved in this part of the demand analysis covered eight major industrial subsectors and three agricultural subsectors. In collecting data of sufficiently good quality on which to make reasoned judgements, the team was constrained by the factors described below.

2.5.1 Limitations

2.5.1.1 Inadequacy of time: A period of just over 3 weeks had been allocated for data collection. This length of time would have only proved sufficient had the data already been collected and analyzed in the various Government ministries and industrial organizations. In any event, this data was not readily available and the team had to use whatever information could be collected within the time available. In this respect, the team would like to thank Dr. Maksoud and Eng. El Amin of GOFI, without whose assistance we would not have been able to conduct the number of interviews and visits which took place. Nevertheless, the time needed to arrange interviews, as well as the logistics of traveling across Cairo and the non-operation of the telephone system, effectively cut down the number of interviews and means of gathering data which might have been achieved elsewhere.

2.5.1.2 Inadequacy of data: It should be noted that in almost all cases no data had been collected on energy consumption in the various individual subsectors. Only an overall figure was available on electricity consumption for the industrial sector as a whole and for the agricultural sector.

In a number of cases, such basic data as the number of plants and output by plant or by sector as a whole was not available.

At the same time data has in general proven inconsistent. Estimates of actual production given by various departments has differed from published data. Statistics given by individual plants have proven to be different, both with regard to range of products manufactured and to output, from those available either in published form or in various Government departments.

Where future projects are concerned, there appears to be a divergency among information in published plans, the statements of planners, and the intentions of individual sectors and factories. These inconsistencies could not be resolved in the time available, and the team has had to make its own judgments on the likely outcome of future development.

2.5.2 Approach to data collection: In view of the above factors, the approach adopted was to submit a detailed questionnaire for each industrial subsector and for agriculture to the General Organization for Industry (GOFI). These were then forwarded by GOFI to the relevant department and interviews were arranged for data collection.

However, as noted above, data required was not generally available and even obtaining basic data sometimes required two visits. In a number of cases (e.g., textiles, cement) questionnaires were sent out to factories, but had not been returned by the time the team left Egypt.

Data was collected from the following sources:

- (1) Official Government published statistics;
- (2) Industry sectoral reports published by the Government or by foreign aid agencies;
- (3) Feasibility studies (where available) on individual plants;
- (4) Discussions with sectoral organizations, e.g. general organization for food industries; and
- (5) Individual plant visits.

Where plant visits were concerned, members of the team attempted to visit those plants which were considered to be major users of energy, e.g., Helwan Iron and Steel Plant, Kima fertilizer plant, etc. A list of meetings and plant visits attended by the Gordian team is attached.

An attempt was also made to visit at least one plant in each of the sectors. Factories were visited in iron and steel, aluminum, cement, chemicals, fertilizers, petrochemicals and the automotive industries subsectors. However, there was not time to visit a textile plant or any food processing industries, apart from sugar. The data collected during these visits was often at variance with information collected elsewhere. Data on energy consumption and efficiencies was in most cases not available.

2.5.3 Reliability of data: For the reasons given above, the data on which the assessment of energy usage and efficiency has been based is considered to be insufficient in order to arrive at a truly realistic picture. Guess estimates have been made on the present status of many plants of Egyptian industry and agriculture. Energy usage assessments have been based in some cases on typical utilization factors in other countries, and the figures have been modified to take account of Egyptian conditions based on the plant visits.

Regrettably, the lack of detailed and accurate data on the energy usage in each plant broken down by fuel type has meant that it is not possible to break out even the 1975 data by fuel type. The necessity to use typical data from other parts of the world where the fuel type mix is different has further aggravated the situation.

MEETINGS HELD BY GORDIAN TEAM IN EGYPT
27TH APRIL 1978 - 17TH MAY 1978

<u>DATE</u>	<u>NAME/PURPOSE OF MEETING</u>	<u>EGYPTIAN CONTACT</u>	<u>GORDIAN ATTENDEES</u>	<u>BUSINESS UNDERTAKEN</u>
3/27/78	U.S. DEMAND TEAM	NIL	VK/CMM	INTRODUCTORY DISCUSSION
3/27/78	SUBCOMMITTEE - ENERGY DEMAND	GOFI - DR. SHAFUS	VK/CMM	FORMAL REVIEW OF REFERENCE ENERGY SYSTEMS
3/28/78	DEMAND OPTIONS GROUP	GOFI - DR. MAKSOUD	VK/CMM	DISCUSSED NEED FOR QUESTIONNAIRE
3/29/78	DEMAND PROJECTIONS GROUP	NPI - DR. SHAFIE	VK	PRELIMINARY DISCUSSIONS
3/29/78	DEMAND OPTIONS GROUP	GOFI - DR. MAKSOUD	CMM	SUBMITTED QUESTIONNAIRES
3/29/78	SUPPLY/DEMAND TEAM	NIL	VK/CMM	PREVENT DUPLICATION OF CONTACTS
3/30/78	U.S. SUPPLY TEAM	NIL	CMM	INFORMATION EXCHANGE
3/30/78	DEMAND OPTIONS GROUP	GOFI - DR. MAKSOUD	CMM	IRON/STEEL INDUSTRY REVIEW
3/30/78	DEMAND PROJECTIONS	NPI - DR. SHAFIE	VK	METHODOLOGY AGREED
3/30/78	U.S. GROUP STATUS	NIL	VK/CMM	FIRST REVIEW MEETING
4/1/78	REFINERY VISIT	DR. KAROCOS	VK/CMM	DISCUSSED REFINERIES HISTORY
4/1/78	CHEMICALS MEETING	DR. EL HAMI DR. ROSHDY	CMM	RECEIVED INSTALLED POWER CAPACITIES, FUEL AND GAS USAGES
4/2/78	MIN. OF IRRIGATION - WATER RESOURCES	ENG. SARWHAT FAHAMY	VK	DISCUSSED IRRIGATION, LAND RECLAMATION
4/2/78	MIN. OF IRRIGATION - MECH. DEPARTMENT	MR. ABDUL GHANI AASSAN	VK	DISCUSSED PUMPS, ETC.
4/2/78	HELWAN - IRON/STEEL	DR. EL MAGHRABI	CMM	DISCUSSED HELWAN COMPLEX
4/2/78	MINISTRY OF HOUSING/ RECONSTRUCTION	DR. EL KASHIF	CMM	MEETING ABORTED - TIME CHANGE
4/3/78	HELWAN - FERTILIZER	MR. SABRI IGAL/YEHICE KOTB	VK	)
	- COKER	MR. FOUAD EL GUINDY	VK	)
	- CEMENT	MR. FOUAD ABBAS	VK	)
4/3/78	IRRIGATION	MR. ABDEL MOSHEM AZMY	CMM	DISCUSSED AVAILABILITY OF INFORMATION
4/4/78	EGYPT CHEMICAL COMPANY	MR. ABU EL FADL FARAG DR. TUSAN KAMEL	VK	PRODUCTION STATISTICS MEETING
4/4/78	TEXTILES/SYNTHETICS	DR. HASSAN SALLAM	CMM	DISCUSSED SYN. AND NAT. TEXTILE MANUFACTURE
4/4/78	EGYPTIAN SUGAR COMPANY	MR. ABDEL MEDGID EL GISH	VK	ARRANGED REFINERY VISIT
4/4/78	NASCO	DR. GAZARIN	VK	ARRANGED APPOINTMENT
4/4/78	EGYPTIAN ALUMINUM COMPAY	MR. GALAL	VK	DISCUSSED MARKETING ASPECTS
4/4/78	U.S. AID (R.J. EDWARDS)	NIL	VK	DISCUSSED IRRIGATION PROGRAM

MEETINGS HELD BY GORDIAN TEAM IN EGYPT

27TH APRIL 1978 - 17TH MAY 1978

<u>DATE</u>	<u>NAME/PURPOSE OF MEETING</u>	<u>EGYPTIAN CONTACT</u>	<u>GORDIAN ATTENDEES</u>	<u>BUSINESS UNDERTAKEN</u>
4/4/78	MINISTRY OF IRRIGATION	DR. MOSHEM AZMY	CMM	
4/5/78	DEMAND TEAM MEETING	DR. SHARKOS	CMM/VK	REVIEWED PROGRESS
4/5/78	TEXTILES	DR. REDAN	CMM	SUBMITTED QUESTIONNAIRE
4/5/78	CHEMICALS	DR. EL HAMI	CMM	ARRANGED FOR QUESTION- NAIRE TO BE SENT OFF
4/6/78	MINISTRY OF AGRICULTURE	MR. MOUNIR ABDEL MALEK HASSAN ABOULLAH	VK	DISCUSSED POWER CONSUMP- TION
4/6/78	MINISTRY OF AGRICULTURE RURAL DEVELOPMENT		VK	ARRANGED CONTACT
4/6/78	U.S. TEAM MEETING	NIL	VK	REVIEWED PROGRESS
4/6/78	PETROCHEMICALS	ENG. F. HASHAT	CMM	DISCUSSED FUTURE PLANS
4/7/78	KIMA FERTILIZER CO.	DR. HAMED AMER ENG. OKAAL	CMM	DISCUSSED PLANT ENERGY USAGES
4/7/78	MINISTRY OF AGRICULTURE STATISTICS/MECHANIZATION	ALI HOSSAIRY	VK	DISCUSSED AGRICULTURAL MECHANIZATION
4/7/78	MINISTRY OF AGRICULTURE FOOD PROCESSING		VK	ARRANGED CONTACT
4/8/78	EGYPTIAN ALUMINUM COMPANY	ENG. HASSAN HALLAH	CMM	DISCUSSED PLANT AND ENERGY USAGES
4/8/78	SUGAR REFINERY VISIT HOWAMDJA		VK	VISITED PLANT AND DISCUSSED SUGAR INDUSTRY
4/10/78	IRON AND STEEL COMPLEX	DR. MASSAWI	VK	DISCUSSED AVAILABILITY OF DATA AND RELATED PROBLEMS
4/10/78	ELECTRICITY AUTHORITY	DR. SWIDAN	VK	DISCUSSED POWER CONSUMP- TION IN SECTORS
4/10/78	GENERAL ORG. FOR FOOD INDUSTRY	MR. ALI BEN ASIDIN	VK	ACQUIRED DATA ON FOOD PROCESSING INDUSTRIES
4/11/78	AMERIYA REFINERY - ALEXANDRIA	DR. WAULD SALEM	VK/PMT	COLLECTED DATA ON REFINERY DISCUSSED ITS OPERATION
4/12/78	EGYPTIAN COPPER WORKS - ALEXANDRIA	ENG. MHD KHATTAS	PMT/VK	COLLECTED DATA AND DIS- CUSSED OPERATIONS
4/12/78	MISR RAYON COMPANY - KAFR EL DAWAR	ENG. SHOKRI ELKALZA	PMT/VK	COLLECTED DATA AND DIS- CUSSED OPERATIONS
4/13/78	IRON AND STEEL COMPLEX	ENG. MASSAWI	CMM	DISCUSSED DATA ACQUIRED ON IRON/STEEL
4/13/78	MINISTRY OF AGRICULTURE STATISTICS & MECHANIZATION	DR. ALI HOSSHIRY	VK	ACQUIRED DATA
4/15/78	NASCO	ENG. ZAKI	PMT	ACQUIRED DATA
4/15/78	CHEMICALS	ENG. EL HAMI	VK	CONFIRMED DATA ON FUTURE PROJECTS
4/16/78	TOURAH CEMENT COMPANY - HELWAN		VK	DISCUSSED OPERATIONS, COLLECTED DATA

MEETINGS HELD BY GORDIAN TEAM IN EGYPT
27TH APRIL 1978 - 17TH MAY 1978

<u>DATE</u>	<u>NAME/PURPOSE OF MEETING</u>	<u>EGYPTIAN CONTACT</u>	<u>GORDIAN ATTENDEES</u>	<u>BUSINESS UNDERTAKEN</u>
4/17/78	ALEXANDRIA CEMENT PLANT	ENG. RAMADAN	PMT/VK	DISCUSSED OPERATIONS
4/17/78	MISR CHEMICALS - ALEXANDRIA	ENG. HELMI MOMAP	PMT/VK	DISCUSSED OPERATIONS AND VISITED PLANT

NOTE

GOFI = GENERAL ORGANIZATION FOR INDUSTRY
NPI = NATIONAL PLANNING INSTITUTE
VK = VICTOR KUMAR
CMM = CHRIS MOORE
PMT = PAUL THORNE

3.0 INDUSTRIAL SUBSECTOR ENERGY ASSESSMENT

3.1 Iron and Steel Industry

3.1.1 Background: Within the "Metallurgical Products" sector of the Egyptian economy, iron and steel production is the principal industry accounting for almost all the output value, with the non-ferrous metals making up the balance. The sector is principally publicly owned with only some 10 percent of the output value in private hands, and that being generated mainly in small jobbing shops and foundries.

The major iron and steel facility, an integrated complex, belongs to the Egyptian Iron and Steel Company and is situated near Helwan just south of Cairo. There are a number of smaller steel-making facilities which produce reinforcing rod using open hearth furnace technology. The principal companies here are:

	<u>Capacity Metric Tonnes Per Year</u> *	
	<u>Steelmaking</u>	<u>Rolling</u>
Copper Works, Alexandria	100,000	100,000
Abu Zaabel, Abu Zaabel	100,000	250,000
Delta Steel Co., Cairo	50,000	80,000

The Abu Zaabel facility has just opened a new rolling shop with a capacity of 150,000 tons per annum. This takes the total rolling capacity to 250,000 tons/yr. Clearly, both the Abu Zaabel complex and the Delta Steel Company will have to buy steel for rolling from the Helwan complex for the time being until and if they are allowed to raise their own steelmaking capacity. Outside of these few rolling facilities, the existing Egyptian Iron and Steel industry consists entirely of the complex at Helwan.

The planning for the complex started in 1955; blast furnace no. 1 was commissioned in 1958 and was followed by no. 2 in 1960. The German made furnaces were identical, with a nominal capacity of 150,000 tpa each when using a charge of Aswan ore. Table 3 lists the major facilities which include coke ovens, sinter plant, steel furnace and rolling and finishing mills in addition to the blast furnaces mentioned above. The period covered by the facility list is 1958 to 1969, at which time a Russian strip mill was added.

* All reference to tonnages in this section mean metric tonnes (1.1023 short tons)

TABLE 3

MAJOR FACILITIES AND CAPACITIES, 1958-1969:
EGYPTIAN IRON AND STEEL COMPANY, HELWAN

Coke ovens	1-50 oven battery with annual capacity of 380,000 tonnes
Sinter Plant	1-50m ² sintering machine producing 330,000 tonnes/year of self-fluxing sinter from Aswan ore (42-43% Fe, 6% Si, 1.1% P.)
Blast furnace	2-550m ³ German built furnaces producing 290,000 tonnes/ year of hot metal.
Steel furnaces	3-17 ton Thomas furnaces (basic Bessemer furnaces) with an annual steel ingot capacity of 265,000 tonnes/yr using blast furnace hot metal. 2-12 ton electric arc furnaces with an annual steel capacity of 40,000 tonnes/yr. of steel ingots using yard and imported scrap.
Rolling facilities	<u>Tonnes/yr</u>
	Blooming mill 480,000 ingots
	Heavy section mill 125,000 total output
	Bar and rod mill 55,000 bars and rods
	Plate mill 35,000 plates
	Strip mill 300,000 steel setup ^a

(a) Russian strip mill built in 1969.

Aswan ore is rather low in iron content (42-43 percent) and, in some instances, high in silicon. It is planned to phase out the use of Aswan ore as the El-Gedida ore deposit at Bahariya Oasis is developed.

The energy demand for the facility was furnished in its early days by a dedicated 60 MWe power station, fuel oil and imported coke. Steel-making was done in 17 ton Thomas converters, of which four were eventually installed, two with each blast furnace. Thomas converter technology was selected because of the high phosphorous content of the Aswan ore. This phosphorous, which remains in the residue in the converters, has always been sold as fertilizer; however, due to its unsuitability for most Egyptian soil conditions, a large portion of it has had to be exported.

As the use of imported coke represented a heavy drain on foreign exchange resources, the next major development at Helwan was the installation of a coking plant. The original coking plant, of Russian design and origin, was a 50-oven battery with an annual capacity of 380,000 tonnes. It was commissioned in 1965 using an imported coke blend, as there was no coal of coking quality in Egypt. Some of the coke oven gas from the cokery was used for firing its own ovens, after which the surplus was piped across the road for use in the steel works. A

second battery of coke ovens was installed in 1972, raising the coke capacity to 740,000 tons/yr. This moved the gas balance into surplus and led to the establishment of a fertilizer plant (calcium ammonium nitrate) to utilize this excess coke oven gas.

The single power supply of the early days had proven unreliable, particularly on foggy days when earth leakage was a major problem. To alleviate this, the management installed an additional supply line from a second power station before eventually having the facility connected to the High Dam grid.

As regards rolling capacity, facilities were commissioned in 1958 along with the first blast furnace giving an ability to roll plate, sheet and heavy sections (for details see table 3). In 1969, the rolling capability was further extended by the installation of a Russian strip mill with a capacity of 300,000 tpa. This facility had to be started using imported slabs because of steel production shortfalls and for quality reasons.

Naturally, some capacity was needed for handling the steel scrap generated in the complex. This was provided by two 12-ton electric arc furnaces which were commissioned in 1958. They utilized both imported and local scrap to give a production of 40,000 tons/yr.

Early energy conservation was achieved by using the blast furnace gas to drive a Hungarian gas turbine power plant (capacity 45 MWe). This power station, which can be run on distillate fuel oil as well as blast furnace gas, was started up in the 1960's.

In 1964, the decision was taken to embark upon a major expansion of the Helwan complex to raise the capacity to 1.5×10^6 tpa of steel (1.75×10^6 tpa pig iron). This was to be achieved by the installation of two new 1,033 m³ Russian blast furnaces each with a capacity of 670,000 tons/yr. This, together with an expansion of the two existing furnaces to 300,000 tons/yr steel (410,000 tons/yr pig iron), would give the following total capacity:

		<u>Annual Capacity (tonnes)</u>
Blast furnaces 1 & 2		410,000
Blast furnace 3		670,000
Blast furnace 4		670,000
		<u>1,750,000</u>

The increase in the capacity of the old blast furnaces was to be achieved by changing to Bahariya ore and using a 100 percent sintered feed. The necessary sintering capacity was achieved in 1968 when a Russian sintering plant with a capacity of 30,000 tpa came on stream. A detailed description of the expanded facility at the first stage and at full development is shown in table 4.

TABLE 4

MAJOR FACILITIES AND CAPACITIES (1980)
AND PLANNED 2nd STAGE EXPANSION
EGYPTIAN IRON AND STEEL COMPANY, HELWAN

Coke ovens	1st Stage:	2-50 oven batteries with annual capacity of 683,000 tonnes of coke from 964,000 tonnes of imported coking coal.
	2nd Stage:	will add 1-65 oven battery. Coke capacity at this stage will be 1.244 million tonnes/yr from 1.756 million tonnes/yr of imported coal.
Sinter plant	1st Stage:	1-50m ² and 2-75m ² sinter machines with annual capacity of 2.2 million tonnes of self-fluxing sinter from El-Gedida ore (52% Fe, 9-10% Si, 0.3% P) to supply 1.7 million tonnes of sinter; 77% average operating ratio.
	2nd Stage:	will add 2-75m ² sinter machines to above complement. Annual capacity will be 3.530 million tonnes of self-fluxing sinter and production will be 3.147 million tonnes.
Blast furnace	1st Stage:	2-550m ³ and 1-1033m ³ furnaces producing 960,000 tonnes of hot metal.
	2nd Stage:	will add another 1033m ³ furnaces. Total hot metal capacity will be increased to 1.75 million tonnes/yr.
Steel furnaces	1st Stage:	3-17 ton Thomas furnaces producing 230,000 annual tonnes of ingot steel. 2-80 tonne basic oxygen furnaces producing 600,000 annual tonnes of continuously cast slabs and billets. 2-12 tonne electric furnaces with an annual steel capacity of 40,000 tonnes. Total steel capacity at this stage is 870,000 tonnes/yr.
	2nd Stage:	will add another 80 tonne basic oxygen furnace and continuous casters. Total annual BOF capacity will be 1.2 million tonnes. Thomas furnace capacity will be increased to 260,000 tonnes/yr. Total mill steel capacity will be 1.75 million tonnes/yr.
Rolling facilities:		
	<u>1st Stage</u>	<u>2nd Stage</u>
Hot rolled products	210,000	210,000
Cold rolled products	110,000	250,000
Medium sections	40,000	240,000
Total	360,000	700,000

Current planning is aimed at eventually shutting down the Aswan iron ore mine and relying solely upon the better quality Bahariya ore (Fe 52 percent, Si 8 percent, lower P). It should be noted that the iron ore mines but not the cokery are owned by the Egyptian Iron and Steel Company. The new mine at El Gedida near the Bahariya Oasis is an open pit operation which started functioning in 1974. It appears that reserves are sufficient for approximately 15 years at current consumption rates. It has a dedicated railway line to the Helwan complex, although it uses normal shunting and marshalling techniques and not the unit train method. The expansion of the iron and steel making capacity is being implemented in two stages, the first of which was completed when no. 3 blast furnace commenced operations in 1974. At this stage, half the new sinter plant (full capacity 3.3×10^6 tons/yr), no. 3 blast furnace, and three of the six continuous casters were operational. The second stage, which will include the no. 4 blast furnace, is scheduled for start-up in late 1978.

As regards the steelmaking capacity in the expanded plant, this will be provided by three 80-ton basic oxygen furnaces. One of these was started in 1974 along with the no. 3 blast furnace, and the remaining two will be commissioned with the no. 4 blast furnace. Additional coke production will be provided by a new 65-oven battery with a capacity of 550,000 tpa, raising the total coking capacity to 1.25 million tons/yr.

The switch to Bahariya ore has caused some difficulties with the old Thomas converters and it has been found necessary to add phosphate rock to the feed to raise the phosphorous level. A decision on the future of the Thomas converters will be made on receipt of U.S. Steel's study of the whole Helwan complex.

3.1.2 Energy considerations: In the early days of the Helwan complex, energy conservation was achieved by utilization of blast furnace gas to generate power. At this stage, the only energy sources available to the complex were fuel oil, power and coke.

With the advent of the coking plant, coke oven gas was added to the available energy sources. However, it was found that the supply became somewhat erratic after the ammonium nitrate plant was started up adjacent to the cokery; and since the arrival at the site of natural gas in October 1977, there has been a concerted effort to switch the complex facilities away from coke oven gas. This process is still under way.

The emphasis in the Helwan complex has been more towards reducing the coke rate than on pure energy conservation because of the effect of coke imports on the foreign exchange position. To this end the coking plants were installed, allowing coke imports to be replaced by cheaper coking blends. Although it was stated above that there is no coking coal in Egypt, there is in fact a poor quality deposit in the Sinai. It is a high-ash, high-volatility coal which, it is believed, might be used in a 1:3 mix with high-quality, imported coke blend. Plans under consideration before the 1967 war were to mine this deposit at 300,000

tons/yr. There has been a lot of discussion about the use of local petcoke in the coking blend, but this is still in the early experimental stage. The high-sulphur levels in the coke may well discourage its eventual use.

As mentioned above, the capacity of the old blast furnaces nos. 1 and 2 were to be raised by injecting fuel oil into the tuyeres. This was, in fact, superseded by the injection of oxygen enriched natural gas. The oxygen concentration is currently 23 percent, but the target is for 27 percent as the maximum. No. 3 blast furnace was switched to unenriched natural gas in March 1978, and this has led to an immediate reduction in the coke rate from 750 kg per tonne when injecting fuel oil to 620 kg per tonne with natural gas. Oxygen at Helwan has been provided to date by electric driven air compression and separation unit. The final phase of the expansion will include an additional new oxygen plant, possibly to be based on steam turbine technology.

With the commissioning of the no. 3 blast furnace and the arrival of natural gas in 1977, the complex had access to a diverse range of energy sources, namely:

- o coke oven gas
- o natural gas
- o waste heat from the converters
- o blast furnace gas
- o fuel oil
- o coke
- o electric power

They were thus able to -- and in most instances did -- take the opportunity to maximize their energy utilization efficiency. However, all energy considerations at the Helwan complex have to reflect the high foreign exchange component of coke regardless of its relative merits in terms of overall energy efficiency terms.

The two new blast furnaces (nos 3 and 4) will be accompanied by six new continuous casters, three for slabs and three for billets. While continuous casting is energy efficient, a utilization level of the three commissioned casters of 25 percent in 1976 is very low and may reflect an opportunity for improvement.

Blast furnace slag will continue to be quenched, granulated, and sent to the nearby cement works for conversion to blast furnace cement. In addition, research is currently under way into the practicality of converting the blast furnace slag into slag wool for insulation purposes.

As regards maintenance practices, these are extremely difficult to assess; however, in view of the shortage of capital, the plant machinery appears to be well looked after and the general housekeeping is fair. Indicative of the quality of the personnel was their ability to rebrick one of the old blast furnaces in less than 3 months. Opinions vary as

to the life of the first set of refractory bricks, but 7 to 9 years would appear to be probable. The refractory bricks are currently imported, although studies are in hand which will assess the feasibility of local production. The complex has major maintenance facilities and looks after nearly all its own repair and spares requirements.

3.1.3 Assessment of current demand and efficiency: A discussion of energy consumption presently used for the production of iron and steel in Egypt, and the efficiency with which this energy is used, cannot be based on actual operating data. Sufficient data on which to base an analysis is simply not available. In its place, design data for the first- and second-stage developments of the Helwan iron and steel works were used. At the very least, this data will permit an estimation of the kinds of energy sources and the minimum quantities that could be used, provided the plant operates at design conditions. Departures from design conditions and some of their causes will be treated later.

The Helwan iron and steel mill was originally designed to operate on three energy sources: coking coal, fuel oil, and electricity. Actually, fuels such as coke oven gas and blast furnace gas are also used, but these represent fuels derived from coal (or coke). Table 5 shows the quantities of each energy source used in the integrated production of iron and steel and the total thermal energy equivalent of each. Total energy input to the mill is seen to be 34.98 million GJ or 39.89 GJ per tonne of steel produced. In addition to the 877,000 tonnes of steel capacity, the energy shown also accounts for 83,000 tonnes of surplus pig iron which is sold. Also shown in table 5 are fuel and energy sources required per tonne of product steel; the major conversion factors are recorded in table 6. These specific quantities will be used later to project total energy consumption by fuel type for steel produced from blast furnace hot metal.

Conversion fuels, which leave the plant for consumption elsewhere or are used internally to generate electric energy, are shown as credits for the process. The total energy credit of 3.54 GJ reduces the energy consumed to a net total of 31.44 million GJ or 35.85 GJ/tonne steel.

It is difficult to compare this net specific energy consumption with U.S. practice, because energy usage is sensitive to the mix of final products produced. However, U.S. energy consumption for all stages through to finished products can vary anywhere from a low of 35 GJ/tonne of structural mill products to a high of 49 GJ/tonne of tin-plated steel strip. On this basis the energy consumption shown for Egyptian steel based on design data is quite good.

Actual energy consumption is probably considerably above that calculated from design data. Actual production of steel in 1976 was 700,000 tons compared to almost 900,000 of capacity. Operating a mill below its rated capacity will always lead to less efficient use of energy. Also, the continuous casting equipment, which should serve to

TABLE 5

FUELS AND ENERGY SOURCES USED TO PRODUCE
IRON AND STEEL AT HELWAN IN 1978

	Quantity Per Tonne of Steel	Total Quantity	Energy (10 ⁶ GJ) (a)
<u>Input Fuels and Energy Sources</u>			
Coking coal	1.099 t/t	964,000 tonnes	29.34
Fuel oil	0.136 t/t	118,900 tonnes	5.14
Electricity	158.5 kWh/t	139(10 ⁶) kWh	0.50
Total Consumption			34.98
<u>Fuel Credits</u>			
Blast furnace gas b	52.2 Nm ³ /t	51(10 ⁶)Nm ³	0.18
Coke oven gas b	122.0 Nm ³ /t	107(10 ⁶)Nm ³	1.99
Tars and pitch	0.035 t/t	31,000 tonnes	1.08
Light oil	0.008 t/t	7,000 tonnes	0.29
Total Credits			3.54
Total energy consumption = $\frac{34.98 \times 10^6 \text{ GJ}}{877,000 \text{ tonnes of steel}}$ = 39.89 GJ/tonne			
Net energy consumption = $\frac{31.44 \times 10^6 \text{ GJ}}{877,000 \text{ tonnes of steel}}$ = 35.85 GJ/tonne			

(a) Fuel heating values and thermal equivalent of energy sources will be found in table 6.

(b) Surplus gases diverted to the fertilizer plant.

TABLE 6

FUEL HEATING VALUES AND ENERGY SOURCE
EQUIVALENT THERMAL VALUES

	English Engineering Units ^a	SI Units ^b
Coal, bituminous	26.2 mm Btu/ton	30.44 GJ/tonne
Fuel oil, residual	149,600 Btu/gal	41.39 GJ/tonne
Coke oven gas	500 Btu/Ncft	0.01861 GJ/Nm ³
Natural gas	1,000 Btu/Ncft	0.03722 GJ/Nm ³
Blast furnace gas	95 Btu/Ncft	3.536(10 ⁻³) GJ/Nm ³
Tars and pitch	150,000 Btu/gal	34.77 GJ/tonne
Crude light oil	130,000 Btu/gal	41.39 GJ/tonne
Oxygen	500 kWh/ton	606 kWh/tonne
	25.5 kWh/1000 Ncft	0.866 kWh/Nm ³
Electric energy	3,413 Btu/kWh	3.60 (10 ⁻³) GJ/kWh
Electric energy generation	10,500 Btu/kWh	0.0111 GJ/kWh

^a Mass units in short tons (2000 lb).

^b Mass units in metric tonnes (1000 kg).

produce 600,000 tonnes of BOF steel, is reported to have been used only 25 percent of the time. The use of the cast ingot route will considerably increase actual energy used relative to design estimates. Apparently there also has been some difficulty with the high salt and silicon content in the El-Gedida ore, which has caused some upsets in the operation of the blast furnaces. Finally, the low phosphorus El-Gedida ore has required that this element be artificially added to the Thomas furnaces in order to produce good quality steel.

3.1.4 Discussion of options: As mentioned previously, tentatively planned new steel capacity has been proposed using two technologies: the traditional blast furnace-BOF steel convertor route and the emerging direct reduction-electric furnace route. Although there is general agreement that the direct reduction-electric furnace route does not necessarily reduce total energy consumption in steelmaking, it does have one significant virtue for Egypt's emerging iron and steel industry. Most direct reduction processes for the production of sponge iron substitute a reducing gas -- generally reformed natural gas -- for the coke used in the blast furnace process. This, of course, is an important consideration due to the lack of metallurgical coke in Egypt and the general availability of natural gas.

It is logical that any alternative to steel production by the presently existing technology should involve exploiting fuels and energy sources readily available in Egypt. These energy sources include natural gas, fuel oil and electricity, although there is some concern about the future availability of electricity. Traditional thinking invariably couples direct reduction iron with steel produced in the electric furnace, because of the view that sponge iron is the equivalent of scrap steel. However, it is entirely possible to produce steel from sponge iron by the open hearth process and thereby replace electric energy used by the electric furnace with fossil fuels. Although a greater amount of total energy per ton of steel produced is required by the open hearth process than by the electric furnace, a reduction in electric energy usage would result if open hearth technology is principally used.

Based on these considerations, there are four options that should be explored with respect to developing the Egyptian steel industry.

1. A major expansion of steel production through the direct reduction-electric furnace route and a minimization of iron produced by blast furnaces. This option will reduce the industry's dependence on coking coal, which must be imported, and require the use of energy resources available, namely, natural gas, fuel oil and electricity.
2. A similar processing sequence could be based on direct reduction followed by the use of an open hearth steel furnace fired by fuel oil and operating in 100 percent cold charge. This option

is compared with (1) in Section 3.1.5 below.

3. A large part of the burden to produce iron by importing major quantities of iron and steel scrap can be avoided. This option will reduce fuel oil and natural gas consumption and require no more electricity than would be used by electric steel furnaces operating on iron made by direct reduction.
4. The possibility exists of reducing the steel industries dependence on imported coking coal by finding suitable alternatives more readily available. As mentioned before, in the Sinai a poor quality coal exists and could be blended with imported coal for the production of coke. Also, there is the possibility that petroleum coke, if it could be produced in sufficient quantity and of the appropriate quality, could be used to replace or diminish the need for imported coking coal to support blast furnace operations.

In addition, there is a fifth option for improving energy efficiency. That is the promotion of rigorous energy conservation programs in all plants. Among the measures which may prove effective in reducing energy consumption are better combustion operations (minimum excess air, combustion air preheat, etc.), scrap preheating, maximum use of continuous casters, insulation of reheat furnaces and soaking pits, and installation of furnace recuperators. A target for energy efficiency improvement of 9 percent from 1972 to 1980 has been set for the U.S. primary metals industry, of which 3 percent has been achieved. It is reasonable to expect that a 5 percent improvement is achievable by "old" plants in Egypt by 1985, and a further 10 percent by the year 2000. The capacity of these old plants corresponds to about 300,000 tons/yr steel production. It is not believed likely that major energy efficiency savings can be achieved from the newest plants, and therefore potential energy savings, based entirely on 300,000 tons/yr steel production, are estimated as follows:

	"Old Plant" <u>Energy Consumptions</u>	<u>Annual Savings</u> <u>for 1985 (5%)</u>	<u>Additional</u> <u>Annual Savings</u> <u>by 2000 (10%)</u>
Coking coal tons/yr	330,000	16,500	33,000
Fuel oil tons/yr	40,800	2,000	4,100
Electricity million kWh	47,500	2,400	4,800

In the projections of energy efficiency for 1985 and 2000 which follow, these savings have not been included. Section 3.1.5 is concerned primarily with energy consumptions based on design data for the newer plants in the Egyptian steel industry.

3.1.5 Projection of energy efficiency for 1985 and 2000: The energy efficiencies of three steelmaking processes need to be quantified for projection to 1985 and 2000. These are the blast furnace-BOF route, the direct reduction-electric furnace route, and direct reduction-open hearth process.

Projected energy effectiveness for making steel from blast furnace pig iron, BOF steel production, and continuous casting to finished products must be taken as about 36 GJ/tonne as developed previously. Although there is some indication that by manipulation of fuel injectants into the blast furnace, coke rate has significantly decreased, there is too little evidence to reduce the estimated coking coal energy consumption per ton of mixed finished steel products from the original design goal. The specific fuels and energy sources currently used in Egypt to produce 1 ton of mixed steel products are shown in table 5. These same fuel rates are used to estimate projected energy requirements for future steel industry growth in Egypt, when the source of iron for steel production is from blast furnace hot metal.

For the production of steel by the direct reduction sponge iron route followed by the electric furnace or open hearth (assuming in both cases continuous casting and finishing of mixed products), estimates are shown in table 7 of specific fuels and total energy consumed. The fuel consumption for the direct reduction of iron ore applies to either the Midrex or HyL processes.

Fuels and energy sources for producing steel in the open hearth are shown in table 7 with and without oxygen lancing. The use of oxygen lancing in open hearth technology is for the purpose of increasing productivity by replacing the slow diffusion of oxygen in air into the molten iron with high purified oxygen injected directly. It is not mandatory that oxygen lancing be used but, as stated above, productivity is increased by reducing the time to produce steel. However, oxygen production is electric energy intensive, consuming about 600 kWh/tonne* oxygen. Because open hearth steelmaking is being considered as an alternate to electric furnace steel in order to reduce electricity consumption, it is conceivable that the electric energy burden to produce oxygen for lancing in the open hearth process might not be desirable.

* Based on steam turbine driven compressors, this represents a fuel requirement of 4.2 GJ/tonne oxygen.

TABLE 7

FUELS AND ENERGY CONSUMED FOR THE PRODUCTION OF ONE TONNE OF STEEL PRODUCTS BY
DIRECT REDUCTION, ELECTRIC FURNACE, OPEN HEARTH STEEL, AND CONTINUOUS CASTING

	Natural Gas (Nm ³)	Fuel Oil ^b (kg)	Electricity (kWh)	Oxygen (Nm ³)	Total Energy (GJ)
Direct Reduction Iron	469	-	-		17.5
Electric Furnace Steel ^a	-	2.8	606	8 ^c	2.3
Open Hearth Steel ^a	-	90	17	38 ^c	3.8 (3.9) ^c
Continuous Casting, Reheat Furnace, Finishing ^d	-	90	2	4	3.7
Total (Electric Furnace Route)	469	92.8	608	12	23.5
Total (Open Hearth Route)	469	180	19	4(42) ^c	25.0 (25.1) ^c

^a Assumes 100% cold charge for electric furnace and open hearth steel.

^b It is assumed that all energy for thermal heating comes from fuel oil. If a mixture of natural gas and fuel oil is to be assumed, the substitution rate should be evaluated as 1.16 Nm³ of natural gas per kg of residual fuel oil.

^c Quantities in brackets indicate oxygen quantity or energy assuming oxygen lancing (electric compressors); without brackets assume no oxygen lancing. For steam compressors, 3.9 becomes 4.0 GJ.

^d All new steel pouring capacity at Helwan employs continuous casting. It is assumed throughout this report that all future steel capacity will also use continuous casting. If the ingot route is used (ingot casting, soaking pit, primary rolling, reheat furnace, finishing) then fuels and energy used per ton of steel are as follows: fuel oil, 114 kg; electricity, 37 kWh; oxygen, 4 Nm³; total energy, 5.09 GJ.

3.1.6 Forecast of energy requirements, 1985 and 2000:

3.1.6.1 Projecting of iron and steel industry growth: In addition to the previously described planned expansion at Helwan, which is expected to be completed by 1982, there is a tentative schedule of new iron and steel facilities in Egypt to the year 2000. Although there is no commitment to locations or the type of facilities, present concepts indicate the rate of growth and the anticipated technology which might be employed. A summary of the tentative expansion is shown below and in greater detail in table 8.

<u>Year</u>	<u>Site</u>	<u>Technology</u>	<u>Steel Capacity</u> (10 ⁶ tons)
1982	Helwan	Blast furnace, BOF steel	0.8
	El Dekhela,		
	Alexandria *	Direct reduction, electric steel	0.8
	El Sadat City	Direct reduction, electric steel	0.8
1987	Nubiria Canal *	Blast furnace, BOF steel	2.0
1990	El Dekhela*	Direct reduction, electric steel	1.6
	El Sadat City *	Direct reduction, electric steel	1.6
	--	Direct reduction, electric steel	1.8
2000	Helwan *	Blast furnace, BOF steel	1.5
	Nubiria Canal *	Blast furnace, BOF steel	2.0
	--	Direct reduction, electric steel	1.8
Total increase			14.7 x 10 ⁶ tons

(* Tentative)

The decision to include direct reduction for iron production and electric furnace steel technology is due to the expected availability of natural gas and electricity, compared with the need to import coking coal to support steel production from blast furnace reduction of iron ore. The priority access to natural gas by the iron and steel industry (and for fertilizer production) is a policy decision that makes direct reduction an attractive alternative for producing iron.

A direct reduction steel plant is scheduled for the El Dekhela site with initial operation using imported sponge iron pellets from Brazil. To accompany this, development of a reinforcing bar plant is planned for Samelout with a capacity of 400,000 tonnes. This plant will use 340,000 tonnes of sponge iron and 160,000 tonnes of scrap annually.

3.1.6.2 Projected energy requirements, 1985 and 2000:

Planned capacity additions for steel produced from iron by the blast

TABLE 8

INCREMENTAL AND TOTAL IRON AND STEEL CAPACITY FOR THE PERIOD 1978-2000*

<u>Year</u>	<u>Incremental Steel Capacity</u>	<u>Total Steel Capacity</u>	<u>Total Iron Capacity</u>	<u>Total Iron by Process</u>		<u>Incremental Iron Capacity^c</u>	
				<u>Blast Furnace</u>	<u>Direct Reduction</u>	<u>Blast Furnace Pig Iron</u>	<u>Iron by Direct Reduction</u>
1978	-	1,127 ^a	960 ^a	960 ^b	0	-	-
1982	2,225	3,352	3,350	1,750	1,600	790	1,600
1987	2,000	5,352	5 350	3,750	1,600	2,000	-
1990	5,000	10,352	10,350	3,750	6,600	-	5,000
2000	5,300	15,652	15,650	7,250	8,400	3,500	1.800

<u>Facility</u>	<u>Steel Capacity (10³ metric tonnes)</u>
Helwan	877
Copper Works, Alexandria	100
Abu Zaabel	100
Delta Steel. Cairo	50
	1,127

* All data in 10³ metric tonnes.

^a Total existing steel making capacity is distributed as follows:

^b Iron making capacity (blast furnace) currently exists only at Helwan.

^c New capacity based on highly tentative data.

furnace route and direct reduction route, described in table 8, were combined with fuels and energy sources required by each route, as shown in table 5 and 7. For each route, the quantities and energy value of fuel sources are multiplied by anticipated capacity for 1985 and 2000. The results of these calculations are shown in table 9 and 9a. With the exception of electric energy, it is seen that all other energy sources are greater for the blast furnace route than for steel produced from direct reduction-electric furnace route. Of course, the conventional direct reduction route is highly electric-energy intensive because of steelmaking in the electric furnace and therefore, should the option to utilize a variation of the open hearth technology be developed, then the demand for electricity can be reduced as indicated in table 9a.

TABLE 9

PROJECTED FUELS AND ENERGY CONSUMED FOR STEEL PRODUCTION, 1985 and 2000
 * (Combination of Blast Furnace/BOF Steel and Direct Reduction/Electric Furnace Steel)

	1985			2000		
	Blast Furnace Route	Direct Reduction Route	Total	Blast Furnace Route	Direct Reduction Route	Total
Steel Capacity (10 ³ tonnes)	1,750	1,600	3,350	7,250	8,400	15,650
Fuels & Energy Consumed						
Coking Coal (10 ³ tonnes)	1,923	-	1,923	7,968	-	7,968
Fuel Oil (10 ³ tonnes)	238	148	386	986	780	1 766
Natural Gas (10 ⁶ Nm ³)	-	750	750	-	3,940	3,940
Electricity (10 ⁶ kWh)	227	973	1,250	1,149	5,107	6,256
Oxygen (10 ³ Nm ³)	-	19	19	-	101	101
Energy Credit (10 ⁶ GJ)	7	-	7	29	-	29
Total Energy (10 ⁶ GJ)	63	38	101	260	197	457
Specific Energy (GJ/tonne)	36	24	30 ^a	36	23	29 ^a

^a Weighted average specific energy.

TABLE 9a

PROJECTED FUELS AND ENERGY CONSUMED FOR STEEL PRODUCTION, 1985 and 2000
(Combination of Blast Furnace/BOF Steel and Direct Reduction/Open Hearth Steel)

	1985			2000		
	Blast Furnace Route	Direct Reduction Open Hearth Route ^b	Total	Blast Furnace Route	Direct Reduction Open Hearth Route ^b	Total
Steel Capacity (10 ³ tonnes)	1,750	1,600	3,350	7,250	8,400	15,650
Fuels & Energy Consumed						
Coking Coal (10 ³ tonnes)	1,923	-	1,923	7,968	-	7,968
Fuel Oil (10 ³ tonnes)	238	288	526	986	1,512	2,498
Natural Gas (10 ⁶ Nm ³)	-	750	750	-	3,940	3,940
Electricity (10 ⁶ kWh)	227	30	307	1,149	160	1,309
Oxygen (10 ⁶ Nm ³)	-	6(67)	6(67)	-	34(353)	34(353)
Energy Credit (10 ⁶ GJ)	7	-	7	29	-	29
Total Energy (10 ⁶ GJ)	63	40(40)	103(103)	260	210(211)	470(471)
Specific Energy (GJ/tonne)	36	25(25)	31(31) ^a	36	25(25)	30(30) ^a

^a Weighted average specific energy.

^b Quantities in brackets indicate either quantity of oxygen or energies including the use of oxygen lancing.

3.2 Aluminum

3.2.1 Background: Aluminum production technology is new to Egypt, with the only production facility built at Nag Hammadi in 1976. This facility was developed along with the Kima Fertilizer Plant to take advantage of the hydroelectric capabilities of the Aswan and High Dams. The industry is dominated by the Aluminum Company of Egypt, which operates the smelter at Nag Hammadi based on imported alumina, producing raw unfinished metal in a variety of shapes for final sale. The Arab Aluminum Company is planning to build a full range of extruding, fabricating, and finishing facilities for start-up in 1978. Egypt has no economic deposits for bauxite; therefore, it is most likely that the industry will continue to import its raw materials.

At present, the company imports international grade alumina from Australia; it is landed at the Red Sea port of Safaga and then trucked some 250 km to Nag Hammadi in the Nile Valley. The plant's location was chosen on the basis of its relative proximity to the Red Sea coast, the Nile, and the hydropower from Aswan, with the prior existence of the road from the coast to the town being the final deciding factor. A railway is currently planned to carry phosphate rock from the New Valley in the Western desert through Nag Hammadi to Safaga. When operational, it is intended that it will carry the alumina to the plant from the port on its return trip. The aluminum produced by the plant is transported by barge or rail to Alexandria for export to Europe, although a portion is returned to Australia or at least sold on their behalf in payment for the alumina.

The facility is currently rated at 100,000 tons/yr, with local demand representing some 20,000 tonnes of the total production of 75,000 tonnes in 1977. Thus, the company is essentially export oriented. The bulk of production is sold in the ingot and T-section form, since they presently have no extruding, rolling, or wiredrawing facilities except for a continuous caster for 9mm-diameter wire, which is shipped to Cairo for cold drawing down to 4mm.

As an aside, it should be noted that the smelting of imported alumina is not unusual provided:

1. the real cost of electricity is low enough at the plant site; and
2. the transport and transshipment pattern is attractive (this may not be so for Nag Hammadi).

The reason is that bauxite conversion to alumina (the Bayer process) must be carried out on a very large scale to be economic, i.e., in the region of 1 million tons/yr, a size considerably greater than could be justified for Egypt even if domestic bauxite were available.

3.2.2 Assessment of current energy demand and efficiency: The level of energy utilization in the aluminum facility is illustrated in table 10. As shown, the primary use of energy is for electrolysis, with a small amount of energy used for miscellaneous plant operations (e.g., ventilation) and for melting pitch, which is used to make prebaked anodes. For reference, a simplified illustration of an aluminum reduction cell appears in fig. 1.

TABLE 10

ENERGY CONSUMPTION IN ALUMINUM PRODUCTION

Electric Power Usage:	16,500 kWh/metric ton for electrolysis 1,500 kWh/metric ton for other operations
Steam Usage*	1.23 tonnes/tonne of product; 13 atmospheres
Carbon Usage	600 kg/metric ton

* Steam is raised in fuel oil fired boilers and is used primarily to meet pitch used for anodes.

The quantity of electricity used for electrolysis (7.5 kWh per pound of aluminum) is reflective of a typical modern facility and is quite comparable to present utilization levels in the United States and other countries. Ancillary uses of electricity and steam are also at a level corresponding to a typical modern facility in the United States, and the reported consumption of coke for anode material is not unusually high.

3.2.3 Discussion of options: Because the cost of power is always a significant part of the operating expense in an aluminum smelter, operators continually strive to optimize power consumption. One effective way of doing this is to reduce anode current density, which results in a proportionate reduction in heat loss through the exterior surface of the pot. Figure 2 illustrates the effect of this option for prebaked anode pots. A reduction in anode current density from 7.5 amps/in² to 7 Amp/in², for example, reduces power consumption by about 0.5 kWh/lb, or about 6.7 percent of present electricity consumption in the Nag Hammadi plant. Of course, the production rate drops accordingly, but at the plant's present level of 75 percent capacity utilization, this should present no major supply problems.

An additional possibility is increasing the quantity of insulation on the pots. Levels of thermal insulation vary as a function of plant size, but for a 100,000 tons/yr plant, insulation levels should typically amount to about 18,000 dt³.

Fig. 1. Aluminum Reduction Cell

Fig. 2. Pot-Room Power Consumption as a Function of Anode Current Density

Source: J. R. Chapman, "Aluminum," Symposium on Abundant Nuclear Energy, CFSTI, may 1969, p. 150.

At present, the company is buying anode paste from Italy and Switzerland and then baking anodes on-site. However, they are planning to install equipment which will allow them to integrate backwards. When the plant is available (scheduled for 1979) they will be buying calcined coke and eventually (about 1981) uncalcined coke. Thus, the Egyptian petroleum industry will be required to supply a suitable petrocake in order to avoid importing the material. However, the problem with this (as with all of Egypt's oil products) is the presence of sulfur and vanadium in the crude, which accumulates in the petrocake. Although the sulfur can be partially removed by calcining raw coke, the vanadium and nickel is intimately held in the coke and has so far proven impossible to remove satisfactorily. This notwithstanding, if the aluminum were produced solely for local consumption, a reduction in the specification and use of local petrocake might have been possible. However, since the industry is export oriented, it is necessary to enforce tight international specifications, and locally-produced petrocake cannot be used until the current high levels of sulfur and vanadium can be reduced. This puts Egypt in the undesirable position of importing coke, yet "exporting" hydropower in the form of aluminum metal.

At present, there appears to be no waste heat recovery except for some minor preheating of the boiler feedwater by running the pipes around some of the pots. The exit gas from the pots is cleaned by electrostatic precipitators and scrubbed with caustic soda in cyclones before leaving the stack at 40-50°C. The effluent stream from the cyclone washers goes to an asphalt-lined mud lake for solar evaporation and concentration. The possibility exists, therefore, for utilizing the sensible heat contained in these streams in order to preheat combustion air in melting or holding furnaces. Although no quantitative estimates of the energy savings associated with this option are available, the potential saving is thought to be very small and perhaps insignificant in comparison to the total quantity consumed in smelting operations. This option must therefore be explored in detail on-site to determine the cost-benefit situation.

3.2.4 Projection of energy efficiency As stated in the previous section, current levels of energy consumption in the alumina plant are comparable to world levels in large modern facilities. New techniques, such as the use of silicon rectifiers for converting AC to DC, have already been built into the plant and relatively few options remain for effectively reducing energy consumption. Furthermore, the plant utilizes power generated from hydroelectric sources, so that the cost of power is a smaller part of the operating expense than it ordinarily would be in a location using thermally-generated power. Hence, at the present time, little incentive exists for efforts aimed at conserving energy in production operations, as it is very unlikely that the resultant savings would outweigh the costs involved in conservation actions.

Given external incentives to alter the cost-benefit equilibrium point, the aluminum company would probably consider a reduction in

anode current density. As described in the preceding section, a typical reduction would probably decrease unit energy consumption by 6.5 to 7.0 percent, although it would also decrease the production rate. Because the plant is not operating at capacity, and with scheduled additions, will be operating below capacity for at least the next decade, this latter effect should not be detrimental.

Addition of more pot insulation will also reduce energy consumption by a small amount, depending on the presently existing insulation level. A rough figure of 0.5 to 1.0 percent of the energy presently consumed is estimated to be the conservation potential of adding insulation at the level described in the previous section, bringing the total conservation potential to about 7.5 percent on a unit basis.

An additional important issue is the use of locally-produced coke versus imported coke for anode production. Coke consumption amounts to about 0.6 lb per lb of metal produced; with a calorific value of about 14,000 Btu/lb, this translates into 8,400 Btu of imported coke per pound of aluminum produced, or about 1.4×10^{12} Btu per year to support the present-day production of 75,000 metric tons/yr. With future plant expansion planned to increase production capacity to 166,000 metric tons/yr (see next section), the total coke requirement will total 200 million pounds annually -- over 3 trillion Btu/yr. In order to avoid importing this energy, it is vital that a method be developed for reducing sulfur and metals levels in Egyptian petrocoke to acceptable levels. Although this is not energy conservation in the strict sense, it will have a significant effect on the Egyptian demand for imported energy.

Taking into account the possible energy efficiency improvements, and assuming that these options are implemented by 1985, the data below illustrates current and projected future levels of energy consumption per pound of aluminum produced.

ENERGY CONSUMED PER POUND OF ALUMINUM

	<u>Electricity</u>		<u>Fuel</u>	<u>Coke</u>		<u>Total</u>
	kWh	Btu ¹	Btu ²	lbs.	Btu ³	Btu
1978	8.2	27,860	1845	0.6	8400	38,105
1985 ⁴	7.6	25,940	1845	0.6	8400	36,185
2000 ⁴	7.6	25,940	1845	0.6	8400	36,185

¹ Kilowatt-hours of electricity converted to Btu at 3412 Btu/kWh.

² Represents fuel fired in boilers for steam production, assuming a boiler efficiency of 80 percent.

³ Calorific value of coke taken to be 14,000 Btu/lb.

⁴ Although additional reductions in energy consumption are possible in the 1985-2000 time frame via the anode current density reduction option, the resultant drop in production precludes its consideration.

3.2.5 Projection of industrial development: As previously stated, the only aluminum production facility in Egypt is owned by the Aluminum Company of Egypt and presently has a production capacity of 100,000 metric tons/yr. Local demand, in contrast, totals only 20,000 tons/yr. and the industry is primarily export oriented. Power for the facility is supplied from available hydropower of 240 MWe.

Construction is currently underway to raise the capacity of the plant to 166,000 tons/yr. by 1981. Electric power requirements will, at that time, total 400 MWe and will exhaust remaining hydro reserves. Future expansions must then be based on expensive thermally-generated power

Local aluminum demand, presently at 20,000 tons/yr, has been forecasted to rise to 50,000 tons/yr by 1985, but even at this level it will represent less than a third of available production capacity. Therefore, it can be safely assumed that the company will remain export-oriented. Because of limited local demand and the exhaustion of available hydropower, it is unlikely that further plant expansions will take place through the year 2000. Table 11 illustrates available and projected production and capacity data.

3.2.6 Forecast energy requirements for 1985 and 2000: As was shown in table 10, current aluminum production operations consume a total of 18,000 kWh of electricity; 1.23 tonnes of steam at 13 atmospheres, and 600 kg of carbon per metric ton of aluminum. Based on a boiler efficiency of 80 percent, and a calorific value of 14,000 Btu/lb for coke, this translates into a requirement of 18,000 kWh of electricity plus 22.6×10^6 Btu of fuel products per metric ton of aluminum. Therefore, the total amount of energy consumed in 1977 for aluminum production in Egypt, based on industry output of 75,000 metric tons, totaled:

Electricity: 1.35×10^9 kWh

Fuel products: 1.7×10^{12} Btu

Note that the hydroelectric Btu's consumed (i.e. at 3413 Btu/kWh) totalled 4.6×10^{12} Btu, but if the electricity were generated in a thermal power station (i.e., at a heat rate of about 10,500 Btu/kWh) the Btu's of fuel required for its generation would total 14.2×10^{12} Btu. The practice of exporting over two-thirds of the aluminum produced, in a sense, is tantamount to exporting a corresponding amount of hydropower, yet thermally generating an equivalent amount for use elsewhere. In other words, for every kilowatt hour of hydroelectric power used to make aluminum for export, the country must generate a kilowatt hour from fossil fuels in order to provide electricity to other users. In this sense, the aluminum industry is a drain on the country's available cheap energy resource. In addition, the previous section points out that the unsuitability of locally produced coke results in importing 1.4 of the 1.7×10^{12} Btu of fuel products required per year at present production levels.

At a production rate of 166,000 metric tons/yr, which is forecast for the middle 1980's onward, assuming a 7.5 percent decrease in unit electricity requirements, the industry will consume 2.8×10^9 kWh of electricity plus 3.8×10^{12} Btu of fuel for steam generation and anode materials. Presumably, by that time, the sulfur and vanadium problems will be solved, and the coke requirement (3.1 out of the 3.8×10^{12} Btu of fuel products) will be satisfied locally.

TABLE 11

ALUMINUM PRODUCTION AND CAPACITY
(metric tons/yr)

	<u>Actual Production</u>	<u>Installed Capacity</u>
1975	8,000	33,000
1976	50,000	66,000
1977	75,000	100,000
1978		100,000
1979		133,000
1980		133,000
1981		166,000
1985		166,000
2000		166,000

3.3 Cement

3.3.1 Background: The cement industry is a well established subsector of Egyptian industry, having been producing regularly since the beginning of the century. The first units were two vertical shaft kilns with a total capacity of 100,000 tonnes/yr. These were superseded in 1929 by the introduction of the first modern wet process rotary kilns.

There are currently four cement plants in Egypt, commonly called Tourah, Helwan, National, and Alexandria. Of these, all but the last are in the Helwan area near Cairo. Total capacity of the four plants, which use wet process technology, was 3.85 million metric tons/yr in 1975. Installation of major new facilities is planned at or adjacent to National, Tourah, and Alexandria, in addition to much needed revamping of the older kilns and equipment. All the new kilns will utilize dry process technology and, where kilns are being revamped, they will either be converted to dry process or provision will be made for a future changeover to dry.

With respect to current operating efficiency, the industry has not renewed equipment as it should have because, as is common with much of Egypt's infrastructure, expansion has used up all available financial resources. However, within this limitation, the four plants appear to be operated relatively efficiently and competently.

The sale of cement, both in distributive and pricing terms, is controlled by the Government. Sales are almost exclusively in bags, with bulk transportation used only for a few major projects. Although it was stated that bulk transportation was desirable, the highly dispersed and small usage points do not allow a complete changeover to bulk, even supposing adequate foreign exchange were to be made available for equipment purchase.

With the heavy emphasis in the Government's planning on reconstruction and the creation of new cities, the cement industry will undoubtedly continue to be very important. The country has an abundance of raw materials and is planning to meet all local demand from domestic production. To achieve this, the previously-mentioned major increases in manufacturing capacity are planned. Table 12 summarizes the anticipated cement production capacity, according to data developed in Egypt.

3.3.1.1 Tourah: The Tourah Cement Company began production in 1929 and was the first company to introduce modern wet process manufacture into Egypt. There are currently two plant areas designated "old" and "new" for convenience. All kilns use the wet process. The "old" facility contains four kilns ranging in capacity from 300 to 600 tonnes/day, dating from 1929 to 1948. These kilns are equipped with electrostatic precipitators to reduce dust losses.

The "new" plant has two kilns dating from 1956 and 1967, and a third kiln presently under construction. All are fitted with electrostatic precipitators. The newest kiln has a grate cooler while the others have planetary or internal coolers. One of the kilns (by Fives-Lille-Cail) appears to suffer from design deficiencies and only works at 75 percent capacity. Similar problems have been met by the same type of kiln at Helwan.

The plant has its own power station, but this has gradually been run down as Government policy has been to encourage use of the national grid. However, breakdowns in supply have led to loss of production, estimated at 6,000 tonnes in March 1978 alone, for example. The plant uses 3 to 4 MWe from its own station and draws on 15 to 17 MWe from the grid.

The Tourah plant makes a range of seven different cement products. The total capacity is 1.35 million tonnes/yr. The planned expansion of 700,000 tonnes/yr will use suspension preheater dry process technology. A subsequent expansion of about 1 million tonnes/yr capacity is planned prior to 1985.

The Tourah Cement Company operates a factory for the manufacture of paper sacks imported from Kraft paper.

TABLE 12

PRODUCTION CAPACITY SUMMARY

	Capacity Utilization in 1973	Estimated Capacities, Million Tonnes Cement per Year			Remarks
		1975	1980	1985	
Alexandria	102%	0.50 W	0.50 W 0.30 D	0.45 W 0.30 D	0.3 expansion fully operational by 1980
Helwan	93%	1.30 W	1.25 W	1.20 W	
National	95%	0.70 W	0.65 W 0.85 D	0.60 W 2.05 D	0.5 expansion fully operation by 1980 and later expansion (1.2) by 1985.
Tourah	92%	1.35W	1.30 W 0.70 D	1.25 W 2.05 D	First expansion (0.7) fully operational by 1980.
Alexandria New Plant	-	-	-	0.5 D	Operational by 1983-84.
Assuit New Plant	-	-	-	0.5 D	Operational by 1983-84.
Cairo New Plant (at Tourah)	-	-	-	1.0 D	To be operational by early 1980's.
Suez New Plant	-	-	-	1.0 D	To be operational by early 1980's.
Subtotals W		3.85	3.70	3.50	No conversion of wet to dry prior to 1985.
Subtotals D		-	1.85	6.05	
Totals		3.85	5.55	9.55	

W = Wet Process

D = Dry Process

3.3.1.2 National: The National Cement Company was established in 1956 for specializing in the production of blast furnace slag cement and is sited near the Helwan steel works. The plant currently uses wet process technology to make 700,000 tonnes/yr; two kilns were commissioned in 1960 with a capacity of 360,000 tonnes, and a third in 1969 with a capacity of 340,000 tonnes. The plant produces blast furnace slag cement, typically 65 percent clinker and 35 percent slag.

A new expansion to the National plant based on the dry process will add capacity equivalent to 850,000 tonnes/yr of slag cement. This is expected to be in operation prior to 1980, and a further expansion of 1.2 million tonnes/yr by 1985.

3.3.1.3 Alexandria: The Alexandria Portland Cement Company started production in 1950 with a single kiln of 120,000 tonnes/yr capacity. A second kiln was added in 1963 and a third in 1966. Present installed capacity is about 500,000 tonnes/yr. With the installation of a new 1,000 tonnes/day kiln, production is expected to reach 850,000 tonnes/yr by about 1981. Capacity is, however, likely to fall back to perhaps 600,000 tonnes/yr by 2000 due to inefficient operation of kiln No. 1. The range of cements manufactured includes ordinary portland cement, rapid-hardening cement and blast furnace cement.

A new dry process plant is planned in the Alexandria area with a nominal capacity of 1 million tonnes/yr, and this is expected to be commissioned by about 1983.

3.3.1.4 Helwan: This company started production in 1930 with a capacity of 100,000 tonnes/yr. Major additions have raised capacity to about 1.3 million tonnes/yr. In addition, a white cement plant was installed in 1967 with a capacity of 40,000 tonnes yr. Like the Tourah plant, the Helwan facility produces a range of seven different types of cement. The plant has its own power station as well as drawing electricity from the national grid.

The Helwan Cement Company operates a factory for the manufacture of paper sacks from imported Kraft paper. The total industry needs for paper sacks are met by the Helwan and Tourah factories (although constraints on paper sack manufacture have been known to restrict cement output).

3.3.2 Assessment of current energy demand and efficiency:

3.3.2.1 Energy efficiency of cement manufacturing processes:

The production sequence for the manufacture of portland cement can be divided into the following activities:

1. acquiring raw materials,
2. preparing raw materials,
3. producing clinker, and
4. grinding and mixing product cement.

There are two common processing sequences based on these steps, the wet and the dry process. In the dry process, raw materials are ground and blended dry. In the wet process, these operations are carried out using a slurry of the materials in water. In other respects the processes are essentially the same. There are also variations of the basic process such as semiwet or semidry systems, in which raw materials are fed into the kiln in the form of nodules or pellets. These processes, however, are generally less common than the wet or dry processes. Currently, all Egyptian cement plants use the wet process, while all new plants are expected to use the dry process.

The energy consumed within a cement plant is primarily in the form of fossil fuel, since the key process in making cement is the "burning" of the raw materials in a rotary kiln. The kiln is a long, cylindrical brick-lined furnace, mounted at a slight incline to the horizontal, which rotates slowly on its axis. Heat is provided by the firing of coal, oil, or gas, or combinations of these fuels. It is also possible to utilize other fuels such as petroleum coke in combination with conventional fuels.

Raw materials are introduced at the top of the kiln and the processed materials leave the kiln at the lower end as clinker, rough-textured lumps or pellets ranging from about 0.1 to 2 inches in diameter. The outgoing clinker is cooled, the heat removed normally being used to preheat incoming combustion air. A number of different clinker coolers are commercially available. Some are based on moving-grate systems; others consist of tubes mounted externally along the kiln periphery near the clinker outlet ("planetary" coolers). Clinker falls into these tubes and tumbles along them toward the outlet. Air, introduced into the tubes normally through induced draft, is preheated before being used in the combustion of kiln fuel. It is important for overall energy efficiency that heat recovery be maximized. Indeed, most modern kilns (such as those proposed for Egypt) are preceded by a preheater system in which hot exit gases give up heat to the cold incoming raw materials.

Of the energy used in cement manufacture, typically 80 percent is consumed as kiln fuel, and the remaining 20 percent is supplied as electricity for raw material grinding, clinker grinding, kiln rotation, electrostatic precipitators, and other miscellaneous applications.

In terms of energy efficiency, there are significant differences among the processes mentioned previously. The energy consumption of a cement plant is a function of parameters such as the age and size of the plant, characteristics of the raw materials, steadiness of operation and operator experience -- all of which are peculiar to a particular plant. On the basis of "best practice/large plants," however, it is possible to generalize energy consumption by process category.*

* Gordian Associates Inc. "International Data Base: The Cement Industry," NATO/CCMS No. 46, 1976.

ENERGY CONSUMPTION FOR "HIGH EFFICIENCY OPERATION"
(Fossil Fuel Only)

<u>Process</u>	<u>Kcal/kg cement</u>	<u>mmbtu/tonne</u>
Dry (long kiln)	860	3.42
Wet (long kiln)	1,300	5.16
Semidry (grate preheater Lepol type)	850	3.37
Dry (suspension preheater)	790	3.13

With respect to electricity consumption, this will be a function of such parameters as the extent of final product grinding (fineness of the cement product), the hardness and composition of raw materials, the level of dust removal demanded from electrostatic precipitators, and the extent of mechanical conveying (versus manual labor for materials handling throughout the plant). A representative figure* for high efficiency operation of modern plants would be about 100 kWh/tonne of cement, as achieved in typical modern European plants. However, there may be considerable variability in electricity consumption from plant to plant. For example, differences in the fineness of the final cement product can account for 15 to 20 kWh/tonne for cement grinding alone, while the type of clinker cooler may also have a noticeable effect.

kWh PER TONNE OF CLINKER

Planetary	0.5 - 1.5
Shaft	6 - 9
Grate Cooler	4 - 9

Indeed, for a variety of reasons, the average electricity consumption for the U.S. industry is about 140 kWh per tonne of cement produced.

3.3.2.2 Reported energy consumption data: The data received on energy consumption for the existing plants was organized into a consistent format and is summarized below for 1975. Where data was not available, or where data appeared inappropriate for the type of plant being operated, estimates were made based on industry practice in Europe or the United States. In addition, plant capacities are shown below, and a weighted average for the energy efficiency of the cement industry was derived from the basic data listed.

	<u>Capacity MTPY</u>	<u>Fuel Use Kcal/kg Cement</u> ¹	<u>Electricity kWh/Tonne Cement</u>
Alexandria	0.50	1500	100 ^{2 3}
Helwan	1.30	1800 ²	120 ²
National	0.70	1485	100 ^{2 3}
Tourah	<u>1.35</u>	<u>1565</u>	<u>95</u>
Totals	3.85	1620	105

- ¹
- ² Fuel use based on lower heating values. All plants operate wet process.
- ³ Estimated.
- Figures reported are very low by industry standards: 67 for Alexandria and 79 for National.

The total annual energy demand for the cement industry subsector, based on 1975 data, is thus estimated to be 6.24×10^{12} Kcal in terms of fossil fuel and 404×10^6 kWh as electricity.

With respect to fuel types, data is not comprehensive. However, Tourah burns fuel oil (mazout) predominantly, while National appears to burn mostly gas. It is believed that fuel oil is the favored fuel for most of the existing plants.

To put the Egyptian energy consumption data in perspective, the following figures are taken from a recent comparison of energy efficiency in the United States and various European countries.* All data refers to wet process plants only:

	<u>Fuel, Kcal/kg Cement</u>	<u>Electricity kWh/tonne Cement</u>
Egypt (1975)	1620	105
Germany (1974)	1440-1330	NA ¹
Italy (1974)	1410	106
UK (1974)	1516	94
US	1614	137

¹ Industry average about 112.

3.3.3 Discussion of options: Based on the reported data on energy efficiency, it appears that the existing plants are operated at an acceptable level of efficiency. This indicates that operating personnel and management are generally aware of all the "standard" measures to reduce energy consumption such as:

- o use of improved refractories
- o proper clinker coating of refractories
- o optimal use of chains
- o maintenance/repair of kiln seals
- o rigorous combustion control (control of excess air)
- o reduction of water content of slurry (careful operation, thinners, filter, etc.)
- o use of waste heat for preheating slurry
- o installation of waste heat boilers
- o enlargement of feed end of kiln (to reduce gas velocities, cut dust losses, etc.)
- o use of grinding aids in clinker grinding
- o use of superior raw materials (where choice is available)
- o use of roller mills for raw meal grinding

* Gordian Associates Inc., "International Data Base: The Cement Industry," NATO/CCMS No. 46, 1976.

The potential for wet to dry conversion is also clearly appreciated. In fact, however, the economics of conversion may well be quite unfavorable, especially bearing in mind the low fuel prices current in Egypt. Since all new plants are expected to employ the latest suspension preheater/precalciner technology, the remaining options for improving efficiency in the cement industry subsector appear somewhat limited. However the following ideas should be considered:

3.3.3.1 Maximize production of blended cements: Slag cements are already being produced in Egypt. Presumably, as steel production expands, more slags will be available and thus increasing quantities of slag cement will be produced. There is also the possibility that other "waste" materials might be available for blended cement manufacture, such as fly ash and naturally-occurring pozzolans, although availability of these materials may be limited in Egypt. In view of this and the fact that Egypt is already producing blended cements, we would estimate that no more than a 10 percent improvement in industry energy efficiency is attainable through maximum adoption of blended cements (over and above current levels).

3.3.3.2 Fuel switching: The use of premium quality gas as a kiln fuel should be discouraged, as it would appear more logical for gas to be reserved for feedstock uses, or at least for fuel uses requiring a clean fuel. A cement kiln can be operated successfully on a broad range of fuels, including low-grade lignites, high-ash coals, high-sulfur coal and oil, low-grade petroleum coke, and even on waste materials such as municipal garbage and agricultural residues (e.g., rice husks). There are limitations on the amounts of low-grade fuel and "contaminants" (sulfur and metals, for example) that can be introduced. Thus, a low-sulfur petroleum coke might represent up to 90 percent of kiln fuel, with 10 percent provided by oil or gas to provide volatiles for maintaining combustion. On the other hand, a high-sulfur petroleum coke (over 5 percent sulfur) might have to be limited to say 40 percent of the fuel intake. As a general rule, no more than about 2.5 percent by weight of sulfate should be introduced into the clinker from the fuel, as the raw materials also introduce sulfate and the final cement product specification will undoubtedly limit the amount of gypsum that can be added for set control.

With respect to the heavy metals^{*} content of petroleum coke, it may be desirable to limit the quantity introduced into the clinker to about 0.2 percent for reasons of cement quality.

The effect of fuel switching on energy efficiency is in principle nil; however, it is possible that the use of low-grade fuels could increase the energy needed per tonne of cement output, because of poorer firing conditions in the kiln. On the other hand, the use of waste materials (e.g., refuse derived fuels, waste lubricating oils, rice

* Primarily tin, lead, zinc and copper.

husks) could contribute to reducing the quantity of conventional fuels used to make cement. For this reason, we judge that this option will have a small effect on overall energy efficiency, perhaps up to 5 percent by 2000.

3.3.3.3 Change cement specification (or operate closer to specifications): There was no data provided on the actual properties of cement made to BS 1958. With regard to fineness, it is possible that a less fine cement could be produced, or that grinding aids could allow some reduction in the energy needed for final product grinding. In the absence of specific data, we would judge that a 5 percent reduction in electricity consumption might be attainable through careful "control" of grinding; this would amount to about 5 kWh per tonne of cement, or about 4 to 5 Kcal/kg cement.

3.3.3.4 Shift to bulk transportation of cement: Most cement is sold in bags; and, therefore, there is a scope for a rationalization of the distribution system to utilize more bulk deliveries. There will, of course, remain the need to deliver small quantities of cement in bags to the smaller construction sites, but a move towards bulk deliveries should lead to:

- (a) savings of the energy used in making bags and in the bagging operation itself;
- (b) savings of the paper imported to make bags; and
- (c) removal of a potential constraint to cement production, that is, a storage of cement bags.

In terms of energy savings, this option is difficult to quantify. Much of the saving resulting from improved distribution will accrue to the transportation sector, while the energy used to make bags and in bagging is relatively small and certainly is unquantified at the present time. We cannot, therefore, attribute a specific energy saving to this option.

3.3.3.5 Clinker importation: Should a particularly rapid increase in cement demand not be met by increasing domestic production, it may prove economic for clinker to be imported and locally ground to cement, incorporating domestically-mined gypsum. Clinker is more readily shipped and stored than cement, and gypsum is abundantly available in Egypt. The effect of this strategy on energy use patterns will be to delay consumption of kiln fuels until domestic plant capacity catches up with demand, while electricity consumption would rise in proportion to the amount of clinker being ground in Egypt (requiring about 60 kWh per tonne of cement). As a short-term strategy, clinker imports may obviate energy or equipment bottlenecks which might otherwise constrain cement production.

Regarding the transportation of clinker from the cement plants to local sites for local grinding, we see little energy advantage in this activity, although there may be advantages in terms of storage and handling. However, in view of the many grades of cement produced, including slag cements, there is a danger that quality control might suffer were cements to be produced at a number of different sites throughout the country. In fact, since most of the construction activity is in the Delta area (between the Alexandria and Helwan plant areas) distances are quite short and therefore any "transportation gains" resulting from cheaper transport of clinker in bulk to local markets are unlikely to offset to any real extent the energy currently used in bagging cement.

3.3.3.6 Load management and use of off-peak power: This option will have little or no effect on the energy efficiency of cement manufacture, but may allow significant savings of capital investment to be made in electrical generating capacity. By scheduling certain operations at a cement plant to off-peak hours, the most effective use of electrical generating capacity can be made, avoiding the need for excess capacity and the need to operate inefficient peaking units. Activities amenable to rescheduling include raw material and clinker grinding; provided adequate grinding and storage capacity are available, these can be performed primarily during the night. This option may be important for the overall management of the Egyptian electrical generating system.

3.3.3.7 Improve cement distribution: It is reported that the Egyptian cement distribution system is inefficient (e.g. World Bank report 608-EGT). Currently, about 95 percent of cement deliveries are made by road, 3 percent by rail and 2 percent by barge. Increased use of barge transport may allow useful energy savings to be made in the transportation sector, although there is not likely to be any effect on the energy efficiency of cement manufacture.

3.3.3.8 Increase use of concrete: The increased use of concrete as a construction material should be encouraged due to its relatively low-energy content.* A comparison of the energy content of common building materials is given as table 13.

Again, this option will have no impact on energy efficiency in the manufacturing operation, but could have significant beneficial effects on the energy situation of the Nation.

* Gordian Associates Inc. "International Data Base: The Cement Industry," NATO/CCMS No. 46, 1976.

TABLE 13

ENERGY COSTS OF CONSTRUCTION MATERIALS*

<u>Material</u>	<u>Energy Cost, kJ/kg</u>	<u>Construction Unit</u>	<u>Mass/ Construction Unit</u>	<u>Energy Cost/ Construction Unit/kJ</u>
Concrete				
Lightweight	538.0	m ³	1200 kg/m ³	645.6 x 10 ³
Ordinary	538.0	m ³	2400 kg/m ³	1.29 x 10 ⁶
Bricks	2.81 x 10 ³	m ²	1700 kg/m ²	4.78 x 10 ⁶
Plaster (10mm)	1.8 x 10 ³	m ³	7.5 kg/m ³	13.5 x 10 ³
Wood		m ²	650 kg/m ²	1.09 x 10 ⁶
Glass, window (3 mm)	15.0 x 10 ³	m ²	7.5 kg/m ²	112.5 x 10 ³
Glass wool (25 mm)	15.0 x 10 ³	m ²	0.3 kg/m ²	4.5 x 10 ³
Plastic Pipes, PVC	115.6 x 10 ³	m run	1.5 kg/m	173.4 x 10 ³
Thermoplastic flooring, 40% PVC, (2 mm)	115.6 x 10 ³	m ²	3 kg/m ²	138.7 x 10 ³
Cast-iron Pipes (10 mm)	22.8 x 10 ³	m run	15 kg/m ²	342.0 x 10 ³
Asphalt (10 mm)	210.0	m ²	20 kg/m ²	4.2 x 10 ³

* Data are from D. Barnes and L. Rankin, the Energy Economics Building Construction, Build International, 8: 31(1975).

3.3.4 Projection of energy efficiency:

3.3.4.1 Baseline Projections: Energy efficiency data for existing plants and estimates of the expected efficiency of capacity additions through 2000 were compiled and are shown in table 14. In addition, estimates were made of the likely effects of efficiency of conversions from wet to dry process configurations (or of the phasing out of wet process plants, which would have much the same effect). The impact of other options to improve energy efficiency are not included in the "Base Case" of table 14.

Plant capacity data also are shown in table 14, based on existing plant capabilities, planned expansions, and on estimates of capacity additions through 2000. These estimates were based on the approximate projections shown in figure 3.

By combining the capacity and energy efficiency data of table 14, weighted averages for the energy efficiency of the cement industry as a whole were calculated through 2000. In summary, these are as follows:

	<u>1975</u>	<u>1980</u>	<u>1985</u>	<u>2000</u>
Fuel Kcal/kg cement	1620	1410	1180	885
Electricity kWh/tonne	105	112	114	108
Total Kcal/kg cement	1710	1506	1278	978

The trend towards the highly efficient operation indicated for 2000 is illustrated clearly in figure 4.

In terms of fuel types, the data on current energy consumption is not complete, nor are projected fuel use data generally available. Existing plants use gas and fuel oil; in fact, cement kilns may usually be fired by any available fossil fuel or combinations of fuels and may also burn a proportion of petroleum coke or various refuse derived fuels (e.g., plant wastes, municipal refuse). Both new plants and existing plants are likely to continue to burn oil or gas, or combinations of both, with small amounts of petroleum coke if this is available. As discussed in the previous section, coke of a high quality could represent up to 90 percent of the fuel intake in any given kiln, while high sulfur coke might be limited to about 40 percent, depending on the sulfur content of the raw materials.

3.3.4.2 Effect of options: Completely new technologies, such as the use of plasma arcs for kiln firing or fluidized beds for clinker manufacture, are not expected to have any impact on the Egyptian industry prior to 2000. However, with respect to the options for improving energy efficiency discussed in Section 3.3.3, it is believed that some energy savings can indeed be achieved over the short to medium term future. We estimate the following effects:

TABLE 14
ENERGY EFFICIENCY PROJECTIONS (BASE CASE)

Plants	1975			1980			1985			2000		
	Cap	Fuel	Elec	Cap	Fuel	Elec	Cap	Fuel	Elec	Cap	Fuel	Elec
Alexandria	0.5 W	1500	100	0.5 W	1600	110	0.45 W	1700	120	0.5 D	950	100
				0.3 D-SP	850	110	0.3 D-SP	850	110	0.3 D-SP	900	110
Helwan	1.3 W	1800	120	1.25 W	1850	125	1.2 W	1900	130	1.0 D	950	100
National	0.7 W	1485	100	0.65 W	1150	110	0.6 W	1600	120	0.6 D	950	100
				0.85 D-SP	850	110	2.05 D-SP	850	110	2.0 D-SP	900	110
Tourah	1.35 W	1565	95	1.3 W	1625	105	1.25 W	1675	115	1.0 D	950	100
				0.7 D-SP	870	110	0.7 D-SP	870	110	0.7 D-SP	920	110
Alexandria (New)	-	-	-	-	-	-	0.5 D-SP	850	110	0.5 D-SP	900	110
Assuit (New)	-	-	-	-	-	-	0.5 D-SP	850	110	0.5 D-SP	900	110
Cairo (New)	-	-	-	-	-	-	1.0 D-SP	850	110	1.0 D-SP	900	110
Suez (New)	-	-	-	-	-	-	1.0 D-SP	850	110	1.0 S-SP	900	110
All Other New Capacity (Existing and New Locations	-	-	-	-	-	-	-	-	-	8.9 D-SP	850	110
Totals	3.85	1620	105	5.55	1410	112	9.55	1180	114	18.0	885	108

Key

Cap - Capacity, million tonnes of cement/yr.
 Fuel = Fuel use, Kcal/kg cement
 Elec = Electricity consumption kWh/tonne cement
 W = Wet process
 D = Dry process
 SP = Suspension preheater kiln system

Fig. 3. Cement Demand/Sales and Plant Production Capacity Estimates

KCal/Kg
(Fuel & Elec.)

Fig. 4. Cement Manufacturing Energy Efficiency Trends

Cumulative effects (kcal/kg)

	<u>1985</u>	<u>2000</u>
Baseline efficiency	1278	978
Increased use of blended cements	1214	880
Fuel switching/use of wastes	1214	840
Less fine grinding of clinker	1210	835

3.3.5 Forecast energy requirements for 1985 and 2000: In the absence of detailed data on proposed production levels, the following estimates of energy requirements are based on projected plant capacities:

	<u>1985</u>	<u>2000</u>
Fossil fuel, 10^{12} Kcal	7.8	15.9
Electricity, 10^6 kWh	622.0	1944.0

3.4 Chemicals

3.4.1 Background: In the strictest sense, this subsector would expect to include the whole range of Egypt's general organic and inorganic chemical production, with perhaps an exception being made in the case of the petrochemical industry, which is often considered a separate area. However, due to the unusual structure of Egypt's chemical sector and its overwhelming dominance by fertilizers and fertilizer production, it was decided to study fertilizers as a subsector in its own right (see section 3.5). Similarly, the petrochemical industry, which is in the early stages of development at present but is certain to become an important subsector, has been reviewed in a separate section, namely section 3.6. As a result of these decisions, the remaining chemical sector is a miscellany of generally small production units making a wide range of goods, from basic chemicals to tires and leather. As defined in Egypt, it also includes a number of plants which are not strictly chemical in nature, but make use of chemical or related products and have therefore been included in the chemical sector for the purposes of this study.

As would be expected in a populous developing country like Egypt, the chemical industry consists of a number of mainly small manufacturing plants designed to convert imported feedstocks into products for sale in the local marketplace. Until recently, no concerted effort had been made (outside of fertilizers) to develop the subsector as an integrated industry capable of utilizing the country's resources to manufacture chemical products for export as well as the local market. Since the revolution and the subsequent nationalization of Egypt's industry, change has been possible as the Government has had a much more prominent role in planning and development. In fact, the public sector now accounts for some 73 percent of the chemical industries value of production (including fertilizers) and controls directly or indirectly nearly all the larger firms. The private sector is concentrated mainly in smaller firms in the leather and woodcraft areas. Despite these changes, the sector has run a considerable deficit for some time due to the need to import equipment, raw materials, and finished products; there seems little prospect of this changing in the near future.

In the longer term, with the new open door policy and the concomitant encouragement of private enterprise and foreign investment, it is reasonable to assume that the chemical industry, or at least the consumer end of it, is an area into which entrepreneurs may be expected to move. Such a development will undoubtedly place the onus on the public sector to develop a good basic chemicals industry to prevent the escalation of imports and consequential degradation of the foreign exchange position. That such planning is already occurring is illustrated by the installation of plants to extract paraxylene at the refineries and convert it to DMT for use as feedstock to the new polyester plant. It would therefore seem likely that the chemical sector will steadily integrate backwards by replacing, wherever possible, raw material imports with materials of local manufacture.

With the limited time available "in country" for the collection of data, it was obviously not possible to review the entire chemical sector. Efforts were therefore concentrated on obtaining an overview of the industry, the range of products made, the state of repair of the industry and an assessment of the energy utilization of the more important plants.

The complexity of the industry and its relative maturity for a developing nation can be measured by the fact that the 31 public companies in the fertilizer and chemical subsectors employ some 50,000 people who make, among other things:

Nitrogenous Fertilizers	Industrial Gases
Phosphatic Fertilizers	Paints
Chlorine	Insecticides
Caustic Soda	Matches
Soda Ash	Glass
Hydrogen Peroxide	Vehicle Tires
Hydrochloric Acid	Plastic Products
Dyes	Rubber Products
Particle Boards	Edible Oils
Paper Conversion	

As mentioned above, the dominance of the chemical industry by fertilizer production in both production and energy requirement terms has led to the decision to deal with fertilizers in a separate section. This left a subsector which has numerous minor energy users, some half dozen medium users, and the MISR chemical plant at Alexandria and the glassworks as the principal users.

The MISR Chemical Company makes a range of inorganic chemicals based on the electrolytic production of chlorine; the full range includes caustic soda, chlorine, hydrochloric acid, calcium oxychloride, soda ash, and hydrogen peroxide.

In addition to the MISR plant at Alexandria, there is one other plant making some 4,000 tons/yr of chlorine, and there will be, of course, additional chlorine production for the VCM balanced-oxychlorination project to be established by the Petrochemicals Group (see table 15). As would be expected, the MISR plant, which has been making a range of highly corrosive materials for some years, is not in a good state of repair and has been operating below design capacity. The plant management is aware of the problems and is gradually replacing the 40 Denora mercury electrode cells which have now been in operation for some 17 years, or twice their normal life. This action will undoubtedly improve both the production achievable and the energy efficiency realized in doing so. The cells are being replaced with new cells of a similar type, as this minimizes the investment required through utilizing the existing ancillary equipment, such as foundations and switchgear. Mercury-amalgam cells have lost favor worldwide because they pose a high pollution risk through the leakage of mercury to the plant effluent.

TABLE 15
ENERGY USAGE IN CHLORINE AND GLASS PRODUCTION

		<u>Egyptian Energy Usage</u>				<u>Expected Energy Requirement</u>	
	NOMINAL PRODUCTION (tpa)	POWER (MW)	STEAM (tph)	COKE (tph)	TOTAL ENERGY (joules/ annum)	ENERGY EFFICIENCY (joules/tonne)	ENERGY TOTAL (joules/annum)
<u>MISR PLANT</u>							
Chlorine	15,000	15			3.2×10^{15}	4.4×10^{10}	0.7×10^{15}
Caustic	17,000		100				
Soda Ash	100,000	4			0.1×10^{15}		
Ca(OCL) ₂	21,000			70	0.7×10^{15}		
<u>El Nasr Co.</u>							
				<u>FUEL OIL</u> (tpa)			
Glass factories	71,000	1		35,000	1.28×10^{15}	1.8×10^{10}	1.28×10^{15}
<u>Other</u>							
Chlorine	4,000					4.4×10^{10}	0.2×10^{15}

Notes:

1. Chlorine production at the MISR plant was estimated at 15,000 tpa, of which 5,000 tpa is sold bottled and the rest converted to derivatives.
2. Electric power was assumed to be consumed at 90% of MW rating for 330 days of 7,920 hours per annum in continuous production plants.
3. The calorific value of the coke used in the bleaching powder plant was estimated at 30.2×10^9 joules/tonne.
4. Steam was assumed to have a net calorific value of 0.81×10^6 kcal/tonne and be raised in boilers with an efficiency of 80%.
5. Energy efficiency for the glass production was 17×10^6 Btu/tonne (1.8×10^{10} J/tonne) or normal Western world standards.
6. The chlorine energy usage figure calculated from the data collected in-country was so high that there was assumed to be some error. Normal world figures were used in the various estimates.

A block diagram of a typical chlorine electrolysis and Solvay complex, as exists at the MISR plant at Alexandria, is shown in figure 5. The process uses electric power in the mercury cells to electrolyze a solution of sodium chloride (rocksalt) to produce chlorine and hydrogen at the electrodes and convert the cell solution to caustic soda. A separate section of the plant calcines limestone with coke to produce gaseous carbon dioxide and calcium oxide. The calcium oxide is slaked with water before being reacted with chlorine to produce bleaching powder, a mixture of calcium hypochlorite and calcium chloride. The particular kilns used at the MISR works to burn the limestone to calcium oxide have not been achieving the theoretical yield of 80 percent, but have, more typically, been producing a yield of 65 to 70 percent. The cause of the difficulty is believed to be inefficient combustion, whereby a coke rate equivalent to an 80 percent theoretical production is only achieving the lower actual production. Quite clearly this is an area of energy inefficiency which could be rectified with some technical assistance and research.

A third section of the plant, commissioned in 1974, uses the Solvay process to make soda ash (sodium carbonate) from brine, carbon dioxide, and recycled ammonia. The carbon dioxide comes from the burning of the limestone in the bleaching powder process, the make-up ammonia normally from ammonium chloride solution and the brine by the solution of rock salt in water. The plant was built to Rumanian design under a Solvay license and has operated at only 50 percent of the design capacity. Both operating and design problems are believed to be the cause of the reduced throughput; these are under close scrutiny and the plant management is confident that design throughput will be achieved by 1980. The current nominal capacity is 100,000 tons/yr, but it is intended that this be raised to 200,000 tons/yr by 1985.

The other principal energy user in the chemical industry subsector is the El Nasr Glass and Crystal Company which produces a comprehensive range of glass products (see table 15). It was established on a small scale in 1968 and later expanded to its present nominal throughput of 85,000 tons/yr when the new 48,000 tons/yr plant at Mostorod was commissioned. Unfortunately, due to the limited time the team had in Egypt and glass productions's somewhat tenuous relationship to the chemical industry, it was decided not to include the glassworks in the site visit schedule. As a result, no detailed information was received. Nevertheless, two facts emerged, namely that the company achieved a production of 71,000 tonnes in 1977, and that they are intending to open a new sheet glass plant with a capacity of 60,000 tons/yr in the near future.

The other chemical plants listed in table 16 were selected on the basis of their being the larger of the remaining energy users within the chemical industry. As they are relatively small energy users, individually at least, they have been collected for analysis purposes under the heading "other chemical plants" and have been assumed to be a representative sample accounting for 80 percent of the demand of all such plants in the chemical industry.

Fig. 5. Block Diagram of Typical Solvay Process Complex for Sodium Carbonate Production

TABLE 16
EXISTING PRINCIPAL ENERGY USERS IN THE CHEMICAL SECTOR

COMPANY	LOCATION	MAIN PRODUCTS	PRODUCTION (tpa)	RATED POWER (MW)	FUEL OIL (tpa)
1. MISR Chemical Company	Alexandria	Caustic Soda Chlorine Soda-Ash Hydrogen Peroxide Hydrochloric Acid			
2. Trailco		Tires for cars, bicycles, lorries Tubes Natural and synthetic feeds all imported	15,000	4	8,000
3. Esmadye Co.	Near Alexandria	Fat dyes, direct dyes, reactive dyes for textile industry	not at full capacity	4	
4. Model Tannery	Cairo	Four productive units		6	2,000
5. Plastics Co.	Alexandria	Electric and general plastic products		2	
6. National Plastics	Cairo			3	
7. NASR	Shobra	Rubber products - four factories		3	3,000
8. Tanta Flax Co.	Tanta	Fibres, particle board, oil		1.2	6,500
9. Industrial Gases Company	Mostorod, largest of eight plants			1.5	
10. Paints and Chemicals Co.	Four plants near Cairo			0.8	2,000
11. Muharana Co.	Alexandria	Printing and converting paper		1	1,600
12. Paper Converting Company	Alexandria	Three plants		4	

TABLE 16 (Cont'd)

EXISTING PRINCIPAL ENERGY USERS IN THE CHEMICAL SECTOR

13. Match Factory			0.3	2,000
14. Insecticide			0.5	
15. El Nasr Glass and Crystal Co.	Mostorod	Glass		71,000
16. Egyptian Woodwork		Four plants	0.3	3,000
Energy requirement of identified "Other Chemical Plants" is: - Total Rated = 31.6 + 28,100				
		Used	= 0.5×10^{15} j + 1.5×10^{15}	
			= 2×10^{15} per annum	

Notes:

1. Energy requirements were estimated for the Esmadye Company and the Egyptian Woodwork Company.
2. Fuel oil calorific value was assumed at 40×10^9 joules/tonne.
3. For chemical sector, except MISR plant and glassworks assumed 2 shift x 6 day week, or 5000 hours per year, and actual average load of 90 percent of rated power.
4. For details of the glass company's energy requirements see table 16.

3.4.2 Assessment of current energy demand and efficiency: The 1975 energy demand of the chemical industry has been estimated by summing the energy demands for the MISR chemical works, the El Nasr glass company, and the "other chemical plants." The estimated total energy usage on this basis was approximately 5.0×10^{15} joules in 1975 (a detailed breakdown is given in table 17).

It should be noted that this is based upon a number of assumptions, the principal ones being that:

- (1) the El Nasr Glass and Crystal Company operates at average "Western world" energy efficiency levels, and
- (2) the known energy usage for the "other chemical plants" represents 80 percent of the total usage by that category.

The question of energy efficiency in the chemical industry poses a far greater problem, as the miscellany of products made within the industry makes the measurement of output on a tonnage basis quite meaningless. The alternative of measuring the output on a monetary basis would be misleading as Egypt has a number of complex and widespread subsidy and assistance programs. It is thus not possible to generate an energy efficiency for the Egyptian chemical sector which has any meaning or could be related to world norms. Wherever possible, expected energy efficiencies, on a process-by-process basis, have been quoted (table 15) for comparative purposes.

3.4.3 Discussion of options: The plants and processes that comprise Egypt's chemical subsector are principally well established mature technologies that in the main are unlikely to undergo any major innovations in time for them to be in common use before the year 2000. While it may be assumed that the processes used will be largely unchanged, the same is not necessarily true of their energy efficiency; with the current preoccupation with energy and its conservation, it is reasonable to expect that the efficiency with which these plants utilize energy can improve steadily over the period.

Moreover, within Egypt's existing chemical industry there is undoubtedly room for energy efficiency improvement based upon the installation of modern practices of energy recovery and conservation. Egypt will undoubtedly find, like all other nations, that major savings can be made in the early days of such a program. Against these possible gains stands the mix of processes within the sector and the difficulties of applying energy-savings modifications to such a wide spectrum of generally small energy users. Therefore, it is to be expected that the cumulative effects of energy efficiency improvements will be lower than in a high-energy usage industry like steel.

On the basis of these factors, it is estimated that the energy efficiency for a particular process will improve by approximately 12 percent in the decade from 1975 to 1985 and by 25 percent between the

TABLE 17

CHEMICAL SECTOR ESTIMATED ENERGY REQUIREMENTS FOR 1975

1975

PLANT	Production (tpa)	Energy Efficiency (joules/tonne)	Total Energy Used (joules/annum)
MISR - Chlorine/Caustic Plant	15,000	4.4×10^{10}	0.7×10^{15}
- Soda Ash	50,000		0.1×10^{15}
- $\text{Ca}(\text{OCl})_2$	21,000		0.7×10^{15}
Glass Plant	40,000	2.1×10^{10}	0.84×10^{15}
Other Chemical Sector Plants	SEE TABLE 15	-	2.5×10^{15}
Other Chlorine Production	4,000	4.4×10^{10}	0.2×10^{15}
TOTAL			5.0×10^{15}

Notes:

1. The chlorine/caustic plant energy usages are based upon cell power requirement of 3,300 - 3,400 kWh/tonne Cl_2 and total plant energy usage of 4.4×10^{10} J/tonne per tonne chlorine.

2. The figures listed in table 16 for the identified "other chemical plants" energy usages were assumed to represent 80 percent of total usage. Hence total annual usage by "other chemical plants" was calculated as follows:

$$\frac{(0.5 + 1.5) \times 10^{15}}{0.8} = 2.5 \times 10^{15} \text{ joules.}$$

3. Actual throughput for the Soda Ash plant in 1975 was 50,000 tonnes due to operating and design problems. The implied energy efficiency given in table 15 was believed to be low as it does not include any fuel oil usage for the calcining operations. Therefore total energy for 50 percent operation was estimated at 0.1×10^{15} joules/annum.

4. Glass production was estimated at 40,000 tonnes for 1975. This was based upon a sheet glass production of 10,000 tonnes and an assumed mix of products.

5. The glass production energy efficiency of 2.1×10^{10} joules/tonne is an estimate of the efficiency achieved at a production rate significantly below design. The design efficiency was 1.8×10^{10} (table 15) to which 15 percent was added to give 2.1×10^{10} as a more realistic level.

base year of 1975 and 2000. These improvements reflect the combined effects of an adoption of the most common energy conservation techniques and the building of new plants to modern standards.

In addition to these savings, however, there appears to be a case for promoting energy conservation programs to a greater degree than might normally take place. This "maximum conservation" program would require a major commitment by company management to energy conservation, and implies the availability of capital to effect retrofit of energy-efficient technology in existing plants. The savings deemed possible through a maximum effort on conservation are judged to be 15 percent by 1985 and a further 25 percent by 2000 (see section 3.4.4). Measures that will contribute to these savings include improved combustion control, improved insulation, improved process control and chemical analyses, heat integration within and between processes, and many other housekeeping and maintenance items.

The identification of specific options in the "other chemical plants" category is particularly difficult because of the lack of specific knowledge of the local configurations and energy usages in what is a large variety of processes and plants. Clearly, if a detailed study of the plants comprising the subsector were undertaken, it would then be possible to identify options which might produce meaningful changes in energy utilization. Nevertheless, in the overall context of Egypt's energy supply and demand balances, the chemical industry's usage is low and spread across a multitude of users; it would thus be a severe dilution of effort to concentrate too much attention on the area.

One of the areas where meaningful energy improvements might be made is the MISR chlorine/caustic complex at Alexandria. Two mutually exclusive options, although not practicable in the short run due to the current revamping of the plant, are to replace the mercury cells with diaphragm cells or to purchase chlorine from neighboring Arab states. The energy saving to be realized for each tonne of chlorine that is imported, and therefore no longer made locally, would be 4.4×10^{10} joules. Offsetting this energy advantage would be the foreign exchange burden of importation, the dangers and cost of shipping a highly poisonous gas like chlorine, and the need to buy or make elsewhere the caustic soda that is otherwise produced as a byproduct of the electrolysis. On balance it would seem that unless the country's chlorine production is scheduled to grow very quickly it is not a very attractive option.

The other option, to change to diaphragm cells, is considerably more attractive as it gives an energy-saving boost of some 15 percent per tonne of chlorine as well as removing the high pollution risk inherent in the mercury cells. Although a decision to change over to diaphragm cells would appear illtimed in view of the current cell renewal program, the cell life at 7 to 8 years is so short as to require a decision in principle at least in the near future. Such a changeover

would reduce the energy requirements per cell from approximately 3,300 kWh/tonne (1.2×10^{10} joules/tonne) to nearer 2,700 kWh/tonne (0.98×10^{10} joules/tonne), a saving of 0.22×10^{10} joules/tonne of chlorine produced. Additional energy savings could be realized by using the currently vented byproduct hydrogen as a fuel within the plant. Hydrogen has a high calorific value of 114×10^8 Btu/tonne (12×10^{10} joules/tonne) and is produced at a rate of 0.3 tonnes per tonne of chlorine in the electrolysis process. If it were to be totally recovered and used as fuel it would give a site heat-saving of some 3.6×10^{10} joules/tonne of chlorine produced. At present the MISR works make use of some of the hydrogen by converting it to hydrogen peroxide, but vents the remainder. Clearly, if there is a market for hydrogen peroxide then this should be the preferred usage, otherwise, until and if the plant is converted to gas and so able to burn the hydrogen it could be bottled for sale.

The MISR plant management has already effected an energy-saving option in the electrolysis plant by changing from consumable graphite anodes to coated metal anodes in all but six of the forty cells. This will have reduced the energy used in each cell by 15 to 20 percent of 0.25×10^{10} joules/tonne.

An option which may be open to the soda ash section of the plant, specifically the limestone kilns, is to switch from using a blend of imported and Helwan coke to petrocok. Such a move would not save energy but would utilize petrocok, soon to be available from Egyptian refineries, which in view of high sulfur and vanadium must be regarded as a low-quality energy source. Before giving serious consideration to this option, it will be necessary to establish the effect of these same impurities on the Solvay process. It is known for example that sulphur dioxide, which will almost certainly be produced when the high-sulphur petrocok is burnt in the kiln, reacts with hot quicklime to produce calcium sulphite.

No meaningful options have been developed for the glassworks as the plant is relatively new and presumed therefore to be of modern energy-efficient design. The major portion of the energy used in a glassworks is used to melt the raw materials; normal heat retaining practices should be carried out to minimize losses in the area.

In summary, none of the identified "technological" options offer major energy savings, and any forecast improvements in energy efficiency will have to be based upon minor technological changes within existing processes combined with plant-wide energy conservation programs, the "maximum conservation" option.

3.4.4 Forecast energy requirements: For the reasons elucidated in section 3.4.2 above, it is not possible to develop an energy efficiency for the chemical sector. Clearly therefore, it is impossible to use energy efficiency as a means of forecasting the subsector's energy requirements. Rather, the energy requirements must be developed from knowledge of the plans for the industry, which give details such as new plant capacity and scheduled start-up dates, so enabling an energy usage to be calculated from details of each individual plant. However, in this instance even such an approach as this is not possible, because the current five-year plan only covers the period through to 1982 and thus falls far short of the information required for an assessment of the energy required in 1985, let alone the year 2000.

An approach to the problem which, although highly unsatisfactory, does at least generate figures for use in sensitivity analysis, is to assume varying levels for the rate of growth of energy usage and use these levels to forecast energy demand. This has been done below for the chemical sector using the estimated 1975 usage as the base and including two conservation cases, the "expected" and a "maximum conservation" case.

	<u>1975</u>	<u>1985</u>			<u>2000</u>		
		<u>Base</u>	<u>With Cons.</u>	<u>Max. Cons.</u>	<u>Base</u>	<u>With Cons.</u>	<u>Max Cons.</u>
<u>Sectoral growth</u>							
at 5% p.a.	5.0	8.1	7.1	6.9	16.9	12.7	10.1
at 10% p.a.	5.0	13.0	11.4	11.1	54.2	40.7	32.5
at 15% p.a.	5.0	20.2	17.8	17.2	164.6	123.5	98.8

(energy demands, 10^{15} joules/year)

The savings indicated for the conservation cases will accrue in terms of electricity and fuels, approximately 25 percent and 75 percent respectively.

3.5 Fertilizers

3.5.1 Background: Agriculture and its related industries, primarily cotton ginning and textile manufacture, have long been one of the major foreign exchange earners and account for approximately half of Egypt's employment. Agricultural activity in Egypt is founded upon the fertile soils of the Delta and the Nile Valley which amounts to some 6.5 million feddans. Traditionally, the farming community has relied upon the annual Nile floods and the consequential deposition of silt as the means by which the fertile capacity of Egypt's agricultural land was replenished. This historic pattern has been disturbed in recent times by two major developments, a rapid growth in the population and the building of the High Dam at Aswan. The first has increased the pressure on the land and led to intensified agricultural practices, while the latter has restricted the deposition of silt and increased the land's cropping potential through the provision of perennial irrigation. The combined effect of these changes has been to increase massively the country's need for fertilizers.

The chemical industry has responded by developing a production capability in nitrogenous and phosphatic fertilizers which amounted to some 270,000 tonnes of nutrient in 1975. The first fertilizer plant was constructed in 1937 for the production of a single superphosphate; since then, two more phosphate and no less than four nitrogenous plants have been built. Despite this, local production has fallen well short of requirements in most years and has had to be supplemented by imports. The imports have generally been restricted to nitrogenous-based fertilizers, with the demand for phosphates having to be satisfied with whatever is produced locally.

Estimates of the demand for fertilizers in Egypt are difficult and misleading, as foreign exchange limitations often place an artificial ceiling on imports. Bearing this in mind, fertilizer usage in Egypt in 1972 has been estimated at approximately 40,000 tonnes of nutrient. The vast majority, some 83 percent, was for nitrogenous fertilizers while the remainder was for the locally-produced single superphosphate. There is at present only a very limited usage of potash and no significant usage of mixed or complex fertilizers. The ratio of nitrogenous to phosphatic nutrients applied in Egypt has held steady near 5 to 1 for at least the last two decades. The ratio is high in world terms and the Egyptians intend to improve upon it, yet the only firm plans of which the team was made aware of were for nitrogenous products.

As mentioned above, the industry has been unable to meet the demand in recent years for nitrogenous fertilizers from its three operating plants at Helwan, Aswan and Talkha. The fourth existing, but inoperative, plant is at Suez and is currently being revamped after suffering war damage. Current plans are for it to be restarted during 1979. Two new urea plants, one currently under construction at Talkha and one proposed for Abu Qir, are scheduled for start-up during 1979 and by 1985, respectively. When at full capacity, they will produce some 500,000 tons/yr of nitrogen nutrient, more than doubling the country's nitrogenous fertilizer production.

The two plants at Talkha and the planned plant at Abu Qir have all been located and designed to utilize the methane-rich local natural gas supplies, while the plants at Helwan and Suez are designed to run on locally available byproduct gases, namely coke oven gas and refinery gas.

The phosphatic fertilizer is all produced in the single superphosphate form from rock phosphate and sulphuric acid in plants at Kafr Al Zayaat, Abu Zaabel, and Assiut. The plants range in age from 9 to 30 years old, and although there are plans to mine rock phosphate for conversion into elemental phosphorous and phosphoric acid, it is not known if any increase in phosphatic fertilizers is planned.

In energy terms, the industry is dominated by the Kima plant at Aswan which at full production would use 7.6×10^{15} joules of energy per annum to produce 112,000 tonnes of nitrogen as prilled calcium ammonium nitrate. The plant was built in 1960 to utilize the spare hydropower available from the Aswan Dam to produce hydrogen by electrolysis for ammonia manufacture. The plant has operated successfully since its inception and is currently one of the largest plants in the country. At present it is undergoing a small expansion and at the same time is having the older electrolytic cells replaced. The plant and its surrounding complex represent a major investment of great importance to the Aswan area. Regrettably, the high-energy requirement of the plant must make it a prime target for conservationists should energy become a scarce resource in Egypt. Despite its poor energy efficiency, however, its social and political importance and place as a major fertilizer producer make its closure or abandonment quite impossible.

A list of the principal fertilizer plants in Egypt is given in table 18 and detailed nameplate capacities for each of these plants are given in table 19. Nutrient production capacities (see table 20) and fuel usage for the fertilizer plants (see table 21), for both planned and existing plants, are also given.

3.5.2 Assessment of current energy demand and efficiency: The energy requirement of the Egyptian fertilizer industry during 1975 was estimated at 8.5×10^{15} joules (see table 22 for details). This energy was used to produce some 182,000 tonnes of nitrogenous nutrient and 93,000 tonnes of phosphatic nutrient. The implied energy efficiencies calculated from the figures in table 22 are:

Nitrogen	4.3×10^{10}	Joules/tonne nutrient
P_2O_5	0.5×10^{10}	Joules/tonne nutrient

These figures can be regarded only as approximations as there remain a number of unresolved discrepancies in the base data from which the above were calculated. These discrepancies have been circumvented by using standard industry figures wherever necessary.

TABLE 18

EGYPT'S FERTILIZER PLANTS

PLANT LOCATION	PRIMARY PRODUCT	DATE OF START-UP	PRODUCTION CAPACITY (tpd of product)
Suez	Calcium Nitrate	1951	758
Aswan-Kima	Calcium Ammonium Nitrate	1960	1100
Helwan	Ammonium Sulphate	1964	24
	Calcium Ammonium Nitrate	1971	364
Talkha I	Calcium Ammonium Nitrate	1975	1000
Kafr Al Zayaat	Single Superphosphate	1937	600
Abu Zaabel	Single Superphosphate	1948	600
Assiut	Single Superphosphate	1969	600
Talkha II	Urea	1979	1650
Abu Qir	Urea	(by 1985)	1500
Helwan	High Phosphorous Slag	1958	145

Note:

- 1) The ammonia plant supplying the Talkha I CAN plant was designed and bought in 1965 although it was not used until 1975. Thus, it is of older design, having been built before the development of high efficiency plants using steam turbine driven centrifugal compressors.
- 2) The high phosphorous slag produced at Helwan is a byproduct from the Thomas convertors.

TABLE 19

DETAILED NAMEPLATE CAPACITIES
FOR EGYPT'S FERTILIZER PLANTS

PLANT LOCATION	H ₂ SO ₄ From Sulfur	H ₂ SO ₄ From Pyrites	HNO ₃	NH ₃ By Elec.	NH ₃ From Coke Oven Gas	NH ₃ From Natural Gas	NH ₃ From Ref. Gas	Calcium Nitrate	Calcium Ammonium Nitrate	Ammonium Sulphate	Single Super- Phosphate	Urea
ASWAN - KIMA			1200	440					1050			
HELWAN			282		170				364	24		
KAFR EL ZAYAAT	200	50									600	
ASSIUT	250										600	
SUEZ			572				230	758		200		
TALKHA I			1050			400			1000			
TALKHA II						1200						1650
ABU-ZAABEL	542	227									600	
ABU-QIR (Projected)						1000						1500

Notes:

- 1) These figures do not include the byproduct blast furnace slag which is sold as fertilizer.
- 2) All figures quoted are in metric tonnes per day.

TABLE 20

PLANNED AND EXISTING NUTRIENT PRODUCTION
CAPACITY IN EGYPT

PLANT	PRODUCT		CONTAINED NITROGEN		CONTAINED P ₂ O ₅	
	TYPE	TONNES/YR	%	TONNES/YR	%	TONNES/YR
ASWAN - KIMA	CAN	360,000	31	112,000		
TALKHA I	CAN	340,000	31	105,000		
HELWAN	AN	132,000	33.5	44,000		
SUEZ	CN	260,000	15.5	40,000		
ABU ZAABEL	SSP	204,000			15	31,000
KAFR AL ZAYAAT	SSP	204,000			15	31,000
ASSIUT	SSP	204,000			15	31,000
TALKHA II	UREA	561,000	46	258,000		
HELWAN	BLAST FURNACE SLAG	50,000			10	5,000
ABU QIR	UREA	510,000	46	235,000		
TOTAL				794,000		98,000

NOTES:

- 1) It was assumed that the plants operated at 100% efficiency for 340 days in a working year.
- 2) The figures quoted for the percentage of nutrient per tonne of product are approximations as the actual figure can be varied according to the plant operation.

TABLE 21

FUEL USAGE BY TYPE FOR EGYPT'S FERTILIZER
PLANTS BOTH PLANNED AND EXISTING

PLANT LOCATION	FERTILIZERS PRODUCED	PRODUCTION OF NUTRIENT (TONNES PER YEAR)	EGYPTIAN ENERGY USAGE				
			POWER RATING MW	FUEL OIL (TONNES/YR)	NATURAL GAS (TONNES/YR)	BLAST FURNACE GAS (TONNES/YR)	ANNUAL REQUIREMENT (JOULES/YR)
ASWAN -KIMA	CALCIUM AMMONIUM NITRATE	112,000	225	13,000	-	-	7.6×10^{15}
TALKHA I	CALCIUM AMMONIUM NITRATE	105,000	36	-	33,000	-	2.8×10^{15}
HELWAN	CALCIUM AMMONIUM	44,000	13	5,800	-	13,000	1.6×10^{15}
SUEZ	CALCIUM NITRATE	40,000	29	-	38,000	-	2.8×10^{15}
ABU ZAABEL	SINGLE SUPER PHOSPHATE	31,000	3.6	-	-	-	0.1×10^{15}
KAFR AL ZAYAAT	SINGLE SUPER PHOSPHATE	31,000	1.8	-	-	-	0.08×10^{15}
ASSIUT	SINGLE SUPER PHOSPHATE	31,000	2.3	-	-	-	0.06×10^{15}
TALKHA II	UREA	258,000	22.5	-	133,000	-	7.0×10^{15}
ABU QIR	UREA	235,000	20.5	-	121,000	-	6.4×10^{15}

Notes:

- 1) The figures given for gas usage are for the portion used as fuel and do not include any used as feedstock.
- 2) Data used is based either on planned production or on actual performance during 1975-1977.
- 3) Of the 7.6×10^{15} used by the Kima plant at Aswan, approximately 7.1×10^{15} joules per year are used to produce the ammonia with the balance going to the HNO_3 production, prilling and neutralising operations.
- 4) The Helwan blast furnace slag is assumed to have no energy requirement as it is a byproduct.

TABLE 22

ENERGY DEMAND FOR THE EGYPTIAN FERTILIZER INDUSTRY
IN 1975

PLANT LOCATION	1975		
	ENERGY EFFICIENCY		TOTAL ENERGY USE
	(10 ¹⁰ JOULES/TONNE)	(10 ¹⁵ JOULES)	FEEDSTOCK
Aswan - KIMA	6.8	4.3	Electrolytic
Talkha I	2.7	2.0	Abu Mahdi NG
Helwan	3.6	1.6	Coke oven gas
Suez	-	-	Refinery gas
Abu Zaabel	0.5	0.15	Phosphate rock
Kafr Al Zayaat	0.5	0.15	Phosphate rock
Assiut	0.5	0.15	Phosphate rock
TOTAL		8.35	
Nitrogenous Production		182,000 tonnes	
Phosphatic Production		93,000 tonnes	

Notes:

- 1) Aswan produced 203,000 tonnes of CAN in 1975.
- 2) Talkha I produced 242,000 tonnes of CAN in 1975.
- 3) For phosphatic fertilizer production, theoretical values for energy efficiency were assumed.
- 4) For the CAN plant at Suez, an energy efficiency equal to that used for the theoretical efficiency was assumed.

3.5.3 Discussion of options: Fertilizer process technology is well established and seems unlikely to undergo any fundamental changes in the near future. In addition, the long lead-time between technological innovation and commercial acceptance ensures that any such changes occurring after 1990 can have little effect on the fertilizer industry's energy efficiency before the end of the century.

Nevertheless, a great deal of research effort is being directed to the specific area of energy conservation in response to the increased cost of energy. Thus, it may safely be assumed that energy efficiencies in the world's fertilizer industries will improve gradually despite the relatively mature nature of the technology. As 1975 is the base data year for the RES model, and if it is also taken as the base for measuring fertilizer process efficiency, then an average annual increase of around 2 percent in energy efficiency would mean a reduction in the energy used per tonne of product of 40 percent by the year 2000. Such a target would seem to be the maximum that could be achieved if the stock of fertilizer plants were refitted with energy-efficient equipment or replaced by the latest available technology over the period in question. In Egypt's case, with an existing, aging collection of plants and a requirement to keep them producing as long as possible in order to maximize output, a more realistic target would be an improvement of 25 to 30 percent. This energy savings through conservation is only part of the whole picture; there are, in addition, some policy options which can decrease the energy used per tonne of nutrient.

The Kima electrolytic fertilizer plant at Aswan should be considered first because of its unique position as a major user of Egypt's electrical energy. The plant is one of a very limited number in the world that uses electric power in electrolytic cells to produce one of the basic feedstocks for ammonia production: hydrogen. This conversion of hydropower into fertilizer seemed wise in the early 1960's, when the idea was conceived and the plant was built. At that time the Egyptian oil industry was small in world terms and had to import to satisfy local demand, while at the same time there appeared to be an excess of hydropower. In the decade and a half since then, the demand for electric power has increased greatly, and is predicted to continue to rise fairly rapidly. The oil industry, in the meantime, has grown from being a modest producer of only 3.8 million tonnes per annum in 1961 to a moderate producer with nearly 17 million tonnes per annum in 1976. This burgeoning of the country's oil production has turned Egypt from a net importer into a net exporter. Hence, the reverse of the situation that prevailed when the Kima plant was commissioned is now true. Hydropower, or more strictly electric energy, is no longer in surplus even with the new High Dam, while oil has become an exportable energy source. Thus, wherever technically feasible and energy efficient, it makes sense to switch energy duties from electricity to oil. The Kima plant is one such situation where in the long-term it would be more efficient if the

complex were to derive its major energy requirements from oil. The plant uses the bulk of its energy input in the ammonia production stage; this is then converted at minimal energy cost into ammonium nitrate and ultimately, CAN. Considering only the process through to the ammonia stage, energy requirements in an electrolysis-based plant such as Kima amount to some 5.1×10^{10} joules/tonne of ammonia. In contrast, the processing energy required in plants based on more conventional technology, such as the steam reforming of naphtha or the partial oxidation of fuel oil, is less than a third of this amount. Even when the energy value of the naphtha or fuel oil feedstock is added to the processing energy, the total represents no more than 80 percent of the energy used in Kima:

	10^{10} Joules per Tonne Ammonia		
	<u>As Process Energy</u>	<u>As Feedstock</u>	<u>Total Energy Used</u>
Naphtha-Steam Reforming	1.6	2.5	4.1
Fuel Oil-Partial Oxidation	0.9	3.2	4.1
Water-Electrolysis	5.1	-	5.1

If the electric power for Kima is assumed to be available exclusively from a hydropower course, then the total energy utilization is only 20 percent higher than that in the more conventional fertilizer processes and the difficulties and expense involved in a change may not be warranted. If, however, the electrical power source were to be a thermal power station with a typical energy efficiency of 25 percent, then the energy equivalent of the fuel fed to the power station would be 20×10^{10} joules. In this instance, the electrolysis route would be about five times more inefficient. Such a situation is valid in the case of Egypt, as the country has largely exploited its hydroelectric potential and the electricity used to produce hydrogen can be regarded as equivalent to the thermally-generated power used for essential services elsewhere in the country.

Clearly, additional fertilizer production is going to be required in Upper Egypt if, as expected, the results of perennial irrigation are to raise the cropping rate and increase the amount of land under agriculture. Equally as certain, in view of the limited electric power available both now and in the future, is that no matter where the additional capacity is located it will not be based on electrolysis. In the absence of any supplies of natural gas in Upper Egypt, the production must be based on the steam reforming of naphtha or the partial oxidation of fuel oil. When such a situation arises and a decision to build new productive capacity has been taken, cognizance should be taken of the energy situation at the Kima plant. It would be both feasible and practical to build the new production facilities at Kima with sufficient excess capacity to allow the slow phasing out of the electrolysis cells as their efficiency falls. A slow phasing out program would overcome the political and social objections by ensuring continuity and growth for the Kima plant and its surrounding township. The effect on Egypt's electrical power network would be to slowly release power equivalent to a medium sized thermal station into the grid.

The management of the Kima plant is known to have considered the use of either fuel oil or naphtha as the feedstock for any additional capacity that might be required. They have studied the alternative processes and have narrowed their objections to a concern over the ability of the railway system to deliver the required tonnages of feedstock (up to 400 tpd for a plant capacity equal to the existing) on a regular basis. A possible solution to this problem would be to ship the feedstock up the Nile on custom built barges owned and operated by the fertilizer company. Utilization of the barges could be maximized by carrying fertilizer and/or other products as deck cargo on the return trip.

An estimate of the impact on resources of converting the Kima plant to natural gas or naphtha was made as follows for a production level of 112,000 tons/yr nutrient (136,000 tons/yr ammonia):

Current total annual energy use 7.6×10^{15} joules (electrolytic process)

<u>Alternative bases</u>	<u>Natural gas</u>	<u>Naphtha</u>
Process fuel, 10^9 kcal	462	489
Power, 10^6 kWh	1.3	3.4
Total process energy 10^9 kcal	476	503
Total process energy 10^{15} joules	2.0	2.1
Feedstock tons/yr	70,720	74,800

A second major option which should be given serious consideration by the planning authorities is to actively promote the use of phosphatic fertilizers and thus raise the phosphate to nitrogenous fertilizer ratio. While it is understood that the soil in Egypt is not particularly well-suited to phosphatic fertilizers, the current application ratio of 1:5 (P to N) is well below world values. An increase in the phosphate application to a level as high as is compatible with good agricultural practice and nearer to world levels would improve the overall energy efficiency of the industry. This is shown in the data below where it is illustrated that the production of phosphatic fertilizers is far less energy consuming than the production of nitrogenous fertilizers on a tonne-for-tonne nutrient basis:

10^{10} Joules of Energy Required per Tonne of Nutrient

	<u>Process</u>	<u>Feedstock</u>	<u>Total</u>
Nitrogenous	2.5	8.1	10.6
SSP (Single superphosphate)	0.5	-	0.5
TSP (Triple superphosphate)	0.2	-	0.2

Thus to the extent that, in keeping with good agricultural practice, Egypt can raise its production and consumption of phosphatic fertilizers without a corresponding increase in nitrogenous fertilizer usage, there is a massive saving in energy to be made. The additional fertilizers, like the existing production, could be produced from local phosphate

rock with sulphuric acid produced from ex-refinery sulphur. The sulphuric acid process is a low energy user and production could be either at the refinery or perhaps, more conveniently, at the fertilizer plant. Depending upon the configuration chosen, it would be necessary to transport either elemental sulphur or sulfuric acid from the refineries. The data above suggest that it is more energy efficient to produce a tonne of phosphorous nutrient as TSP than as SSP. Once again, soil conditions may dictate the use of one type over the other, but, to the extent practicable, phosphatic fertilizer production in Egypt should be as TSP rather than SSP.

There would appear to be little else that Egypt can do to lessen the burden that the fertilizer industry places on the country's energy resources. The existing plants were installed with the best available technology and, as can be seen from table 23, they apparently are still performing close to world standards. The extremely good performance of the SSP plants, (well above world standards), has been attributed to inaccuracies or at least misinterpretation of the data. However, as their total energy usage is low and therefore of little importance to the overall picture, resolution of the differences will not be pursued any further.

It must also be said within the context of options, that wherever possible new nitrogenous fertilizer capacity should be based upon Egypt's high methane natural gas, as this requires less capital outlay and is more energy efficient. The figures are given below:

<u>Feedstock:</u>	<u>Energy for ammonia production (fuel and feedstock) 10^{10} Joules/tonne ammonia</u>
Natural gas	3.4
Naphtha	4.1
Fuel Oil	4.1

In summary, conversion of the Kima plant at Aswan to a conventional process, the increased use of phosphatic fertilizers, the basing of future nitrogenous production on natural gas, and a major effort to develop and implement energy conservation programs should considerably increase the nutritional benefit Egypt will achieve for each joule of energy used by the fertilizer industry.

3.5.4 Forecast energy requirements and efficiencies: In discussing the energy requirements and efficiencies of the fertilizer industry, it is best to consider the two principal classes of fertilizers, namely nitrogenous and phosphatic, separately. Each product class is produced by a different type of process with dissimilar energy requirements and each serves different nutritional requirements. All of the nitrogenous fertilizer processes use the country's energy resources both in the processing stages and as a feedstock, while the phosphatic processes only use energy in the processing stages. As mentioned in section 3.5.3, Egypt's energy usage for fertilizers per tonne of foodstuff can

TABLE 23

ENERGY REQUIREMENTS OF PLANNED AND
EXISTING FERTILIZER PLANTS AT FULL PRODUCTION

PLANT LOCATION	FERTILIZERS PRODUCED	PRODUCTION OF NUTRIENT (TONNES PER YEAR)	EGYPTIAN ENERGY USAGE		EXPECTED ENERGY REQUIREMENTS	
			ANNUAL ENERGY REQUIREMENT (JOULES) 10^{15}	ANNUAL ENERGY EFFICIENCY (JOULES/TONNE) 10^{10}	ANNUAL ENERGY REQUIREMENT (JOULES) 10^{15}	ENERGY EFFICIENCY (JOULES/TONNE) 10^{10}
ASWAN -KIMA	CALCIUM AMMONIUM NITRATE	112,000	7.6	6.8	2.8	2.5
TALKHA I	CALCIUM AMMONIUM NITRATE	105,000	2.8	2.7	2.6	2.5
HELWAN	CALCIUM AMMONIUM NITRATE	44,000	1.6	3.6	1.1	2.5
SUEZ	CALCIUM NITRATE	40,000	2.8	7.0	-	-
ABU ZAABEL	SINGLE SUPER PHOSPHATE	31,000	0.1	0.32	0.15	0.5
KAFR AL ZAYAAT	SINGLE SUPER PHOSPHATE	31,000	0.08	0.26	0.15	0.5
ASSIUT	SINGLE SUPER PHOSPHATE	31,000	0.06	0.19	0.15	0.5
TALKHA II	UREA	258,000	7.0	2.7	8.0	3.1
HELWAN	BLAST FURNACE SLAG	5,000	-	-	-	-
ABU QIR	UREA	235,000	6.4	2.7	7.4	3.1

NOTES:

- 1) No fuel oil usages were given for the SSP plants; this may explain the discrepancies between the two sets of figures.
- 2) All efficiencies are quoted in joules per tonne of nutrient.
- 3) The extremely high figure for the energy efficiency for Calcium Nitrate is presumed to be due to inaccurate data.
- 4) For Aswan-Kima, current Egyptian energy usage is based on electrolysis. The expected energy requirements are based on fossil fuel use.

be reduced to the extent that increased usage of phosphatic fertilizer can displace nitrogenous tonnage. Estimation of the effect of this change is not possible within the scope of this report, as it would require a detailed study to establish the replacement rate of P_2O_5 for nitrogen under Egypt's somewhat unique soil conditions. Nevertheless, a tonne of P_2O_5 as SSP uses approximately 5 percent of the energy required for a tonne of nitrogen, and this alone makes a study in this area imperative.

In addition to the above option, which might be termed "habit switching", certain crude estimates can be made as to the effect of energy conservation practices and technological improvements on overall energy efficiencies. It has been found elsewhere in the world that when energy first becomes a scarce or expensive commodity, rapid improvements in energy efficiency are achieved through fairly simple conservation practices. There is no reason to suppose that the situation in Egypt will be different. For this reason, the energy efficiency in the production of nitrogenous fertilizers is predicted to improve by 15 percent over the period 1975 to 1985 (see table 24). After an initial surge during the decade to 1985, improvements will become more difficult and will depend largely upon changes in existing technology and the installation of new energy-efficient plants. On this basis, the energy efficiency for nitrogenous fertilizers is predicted to improve a full 30 percent between 1975 and the end of the century. If such a change were to be achieved, it would reduce the energy used per tonne of nitrogen, for the existing production, from a 1975 level of 4.5×10^{10} joules to 3×10^{10} joules. Superimposed upon this development could be the effect of the change-over of the Aswan fertilizer plant from electrolysis to a more conventional process. This would improve the energy efficiency in the year 2000 by another 0.9×10^{10} joules/tonne to 2.1×10^{10} joules/tonne nitrogen nutrients. A figure of 2.1×10^{10} joules/tonne equals an improvement of 15 percent over the current industry standards of 2.5×10^{10} joules/tonne and is, therefore, a fair estimate of Egypt's overall efficiency in the year 2000.

No allowance has been made in these estimates for possible improvements in the ratio of product nutrient-to-feedstock requirements (e.g., naphtha, fuel oil, gas) because of the established nature of the industry. Also, the estimates do not include the energy content of the feedstocks. The effect of adding the energy content of the feedstock is discussed in section 3.5.3; it raises the apparent energy efficiencies of the conventional processes to within 20 percent of the electrolysis route. However, as noted, the argument for phasing out the electrolysis plant is strengthened if the low energy efficiency (approx. 25 percent) of "equivalent" thermal power plants is considered.

As for the phosphatic fertilizers, the energy requirement is expressed either as an efficiency or in total terms. Therefore, there clearly is less room for meaningful savings. For this reason, and since the initial data collected in Egypt suggests that the plants are already performing above normal world standards, the predicted improvements in

TABLE 24

ENERGY EFFICIENCY-CURRENT AND FORECAST FOR EGYPTIAN
FERTILIZER INDUSTRYFigures are 10^{10} joules per tonne nutrient

	<u>1975</u>	<u>1985</u>	<u>2000</u>
<u>"Expected" conservation</u>			
Nitrogenous	4.3	3.6	3.0
Phosphatic	0.50	0.46	0.43
<u>"Maximum" conservation</u>			
Nitrogenous	4.3	3.6	2.7
Phosphatic	0.50	0.46	0.40

Notes:

- 1) Figures for 1975 for nitrogenous fertilizers are based on actual performance; those for phosphatic are based on "world" efficiency level.
- 2) All figures are based on processing energy only; they do not consider the effect of energy sources used as feedstock or the efficiency effect of thermal power stations.

energy efficiency are much smaller. For this study, it has been assumed that the plants were in fact operating at normal world efficiencies in 1975 (see table 23). Using 1975 as the base year, it has been estimated that conventional energy conservation and steady technological development will improve energy efficiency by 8 percent in the decade from 1975 to 1985, and by 15 percent in the quarter century from 1975 to 2000.

In addition to the energy efficiency improvements indicated above, there is also the possibility of even greater improvements which could be attained through the development and implementation of major energy conservation programs in all plants. This implies the commitment of plant management to the investment of time and money for personnel upgrading and of sufficient capital for refitting existing plants with new energy-efficient equipment or for building new plants where appropriate. It is estimated that the following savings should be attainable:

	<u>"Expected" conservation</u>		<u>"Maximum" conservation</u>	
	<u>Nitrogenous</u>	<u>Phosphatic</u>	<u>Nitrogenous</u>	<u>Phosphatic</u>
1975-1985	15	8	15	8
1985-2000	15	7	25	12
	<hr/>	<hr/>	<hr/>	<hr/>
	30	15	40	20

These percentages are translated into energy efficiencies in table 24. Table 25 presents a brief description for existing and contracted fertilizer plants, and table 26 displays typical energy usage by type.

TABLE 25

BRIEF PROCESS DESCRIPTION FOR EXISTING AND CONTRACTED FERTILIZER PLANTS

Talkha I

The CAN plant uses partial oxidation technology and has a double train unit of 360 tpd capacity. Ammonia will also be supplied from Talkha II. The equipment was 10 years old at start-up, having been moved from Suez. The ammonia unit is a BASF design with a liquefaction unit from Linde. The nitric acid plant by Uhde is a standard low pressure design based on nine reactors and the emphasis throughout is on energy saving. The ammonium nitrate neutralization section is standard and is followed by a concentration tower and prilling unit.

Talkha II

This plant will be based on a single-train, centrifugal compressor-driven ammonia plant of 1,200 tpd and licensed by Stamicarbon. This will be followed by a twin-stream urea plant with a capacity of 1,725 tpd. The ammonia plant design will be based on steam-reformed natural gas, with compression, heat, and energy recovery based on steam-turbine centrifugal machines. The urea plant is designed as a stripping process using centrifugal compression, maximum thermal recycling and heat recovery. The product will be in prilled, uncoated form, (material balance shown in fig. 6).

Helwan

The process uses the partial oxidation of coke-oven gas in small units, followed by conversion to ammonia in two reactors, each with a nominal capacity of 85 tonnes. Half the ammonia is oxidized to 55 percent nitric acid while the remainder is retained and used to neutralize the nitric acid to produce ammonium nitrate. The plant uses all the coke-oven gas available from the nearby coker. The ammonium nitrate plant licensor is Stamicarbon.

Aswan

This plant utilizes electrolysis to produce H_2 from a weak caustic potash solution. The H_2 is then mixed with N_2 from an air liquefaction and separation plant, before being compressed to 325 atmospheres for synthesis to ammonia. Part of the ammonia is oxidized over a catalyst and absorbed in water to produce 53 percent nitric acid. The acid is then reacted with the remaining ammonia to produce ammonium nitrate. This is prilled with calcium carbonate to give 31 percent CAN. (Block diagram in fig. 7.)

TABLE 25 (CONTINUED)

BRIEF PROCESS DESCRIPTION FOR EXISTING AND CONTRACTED FERTILIZER PLANTS

Suez

The units, which are small and inefficient, use partial oxidation technology to convert refinery gas to CO and H₂. The ammonium sulphate plant has, in fact, been closed since 1969 due to damage to the sulfuric acid plant and interruptions to the refinery gas supply. A new 300 tpd sulfuric acid plant is being built and will allow production to begin again shortly.

Abu Qir

This plant is believed to be in the study phase and is expected to be operated using a local field of natural gas for ammonia production. Urea output is planned at 1,500 tpd.

TABLE 26

TYPICAL ENERGY USAGE BY TYPE

	ESTIMATE OF % ENERGY USED AS	
	POWER	FUEL
<u>PRODUCT</u>		
Calcium Ammonium Nitrate	5	95
Urea	2	98
Phosphatic Fertilizers	10	90

Note:

- 1) These vary widely, depending upon the utility balance on site and the existence of cogeneration or heat recovery facilities.
- 2) Assumes electric power bought from the grid; no allowance is made for power plant inefficiencies.

Figures Per Tonne of Urea at 100% Capacity Utilization

Fig. 6. Material Balance for Talkha II.

Fig. 7. Block Diagram of the Kima Fertilizer Plant at Aswan

3.6 PETROCHEMICALS

3.6.1 Background: Despite Egypt's relatively long history of industrialization, including the production of cement, fertilizers and basic chemicals, the country, like most developing nations, has not yet established a petrochemicals industry. To date, the enormous finances and large local or guaranteed demand, which are the necessary prerequisites for establishing such an industry, have been lacking. However, this picture is changing, as the predicted growth in Egypt's population and the efforts being made to build a strong industrial base will ensure vigorous growth in the consumption of the high volume plastics even if the per capita consumption continues to lag world norms (as expected). In anticipation of this growing need for plastics, the Petrochemicals Projects Group has developed plans and is initiating design and engineering work which will develop a petrochemical industry at Alexandria over the next decade and a half.

In addition to these plans, which reflect a deliberate desire to shift into a new industrial area, two existing industries, namely petroleum refining and coking, are also integrating into petrochemical processing. The principal projects covered by these shifts in emphasis are the installation of a paraxylene plant at the Mostorod refinery and a plant to collect the distillates from the Helwan coke plant for subsequent separation and recovery.

These various plans for development of local petrochemical industries should culminate in the 1990's in an ability to convert Egyptian crudes, through all the various intermediates, into plastics and synthetic fibers. Such an industry will undoubtedly provide a useful tool for achieving the country's development plans and meeting the aspirations of the people.

As mentioned above, Egypt currently has no petrochemical production capability and an oil refining industry which consists of fairly straightforward low gasoline units with no catalytic cracking facilities. This has meant that, to date, the feedstocks normally associated with a petrochemical industry have not been available within the country. This situation will change with the installation of the Mostorod paraxylene unit, the availability of distillates from the Helwan coker, and the planned availability of ethylene from a cracker at Alexandria.

The planning for the petrochemical industry may be divided into two categories: synthetic fiber intermediates and bulk plastics. The first of these, synthetic fibers intermediates, centers upon the production of paraxylene at the Mostorod refinery near Cairo, and its subsequent conversion to dimethylteraphthalate (DMT) at the NASR refinery at Alexandria. The second category, bulk plastics, will be based upon the development of a petrochemical complex at Alexandria for the production of low-density polyethylene (LDPE), high-density polyethylene (HDPE),

and polyvinyl chloride (PVC). The planning and execution of the production of these two categories of products will be undertaken by two separate Egyptian authorities, the Egyptian General Petroleum Corporation in the case of the fiber intermediates and the Petrochemical Projects Group in the case of the bulk plastics. Such a split in responsibility is probably the best management method in view of the quite different processes and products involved, and the fact that the fiber intermediates reflect expansion of existing complexes whereas the bulk plastics require totally new facilities.

In-country discussions led team members to believe that the authorities have decided upon polyester as the major synthetic fiber for Egypt because of its superior handle and comfort qualities in hotter climates, its good wearing characteristics, and its ability to blend with cotton and so utilize existing textile machinery. Thus, even though the country has modest facilities for the production of rayon and nylon 6, these will not be expanded as there is already a polyester plant under construction and a further unit of the same size planned. These plants, at 25,000 tons/yr apiece, are, unlike the existing synthetic fiber plants, of world economic size and will require some 57,000 tons/yr of DMT. Although initially supplies of DMT will have to be imported, it is planned that the paraxylene extracted and recovered at the Mostorod refinery will be converted to DMT at the NASR refinery.

The plant to be constructed at Mostorod, will use UOP, Parex, and Isomar processes to separate and purify 40,000 tons/yr of paraxylene from the refinery reformat, (see figure 8). At the time of this study, the contract for construction of the paraxylene plant had not been made public, but start-up is believed to be scheduled for 1982-1984. The liquid product paraxylene will then be transported to the NASR refinery at Alexandria for processing to DMT. Although the capacity and process to be used in the proposed DMT plant is not known to Gordian, most probably it will be based upon the Witten process as it is for fiber grade polyester and will have a capacity of approximately 60,000 tons/yr, if it is to supply the planned production of polyester and to utilize the planned 40,000 tons/yr of paraxylene. The team was not made aware of any plans to build plants for the production of methanol or ethylene glycol, the other major petrochemical intermediates required for DMT and polyester production. Therefore it has been assumed that all glycol requirements will be imported, as will the methanol required over and above that recycled from the polyester plant. Many Middle Eastern nations are currently installing, or have plans to install, facilities to produce methanol and ethylene glycol, and therefore supplies should be readily available in the area.

The development of the bulk plastics sector of the petrochemical industry is well in hand. It has been designed to be implemented in three phases, with the first plant, for PVC production, scheduled for commissioning in 1981. Details of the phases are:

Fig. 8 Typical Xylenes Separation and Isomerization Complex

- Phase I - Low-Density Polyethylene (LDPE)
 High-Density Polyethylene (HDPE)
 Polyvinyl Chloride (PVC)
- Phase II - Chlorine
 Vinyl Chloride Monomer (VCM)
- Phase III - Ethylene

This phasing is based upon the desired order of plant installation and hence product availability. Thus, the final product plants for the bulk plastics LDPE, HDPE, AND PVC will be commissioned first, followed by the intermediate chemicals for the PVC plant, namely chlorine and VCM, and finally the ethylene steam cracker. Naturally, until the latter plants have been commissioned and are able to provide the required tonnages, the earlier phase plants will be provided with imported feedstock. Once all of the plants have been commissioned, the only feedstocks required will be rock salt for the chlorine electrolysis and naphtha for the steam cracker. The former can be produced locally, either from desalination plants or salt evaporation ponds, while the latter is already available from Egyptian refineries and, therefore, should pose no problem. When all the plants are in operation, Egypt will have completed the chain from crude oil through plastics.

The technology which will be used in all new production facilities will be the best available at the time of design. Thus, the new plants will reflect the norms for energy conservation in the Western world as of the time of design. Clearly, the relevant authorities will have the task of balancing the capital cost of maximizing energy efficiency with the energy saving to be achieved and its worth to Egypt.

3.6.2 Assessment of current energy demand and efficiency: As Egypt's petrochemical industry essentially is only in the planning stage; there is little or no energy usage currently. There are, in fact, some small firms in Egypt which produce plastic products for the consumer market and are currently operational. They have been included in the chemical industry sector as they are largely "converters", buying in plastic chip or powder for blow or injection moulding.

3.6.3 Discussion of options: It must be recognized that development of this industry will require large amounts of capital and energy, in return for which the industry will generate relatively few direct employment opportunities. This statement can be modified by noting that, in general, the nearer a process is to making the final article for the consumer, the greater are the employment opportunities per dollar invested within the industry. The point is well illustrated for Egypt by the planned ethylene unit which will require at least a quarter of a billion dollars (in 1978 terms) and 9×10^{15} joules of energy per annum yet will generate no more than 500 jobs. In contrast, a PVC plant of equivalent tonnage would cost approximately \$100 million and use 4×10^{15} joules per annum to generate the same number of jobs.

As presently planned, the Egyptian petrochemical industry will develop by producing first LDPE, HDPE, PVC and polyester fibers, and then integrating backwards into paraxylene, DMT, chlorine, VCM, and finally, ethylene. Recent press announcements show that phase I (the LDPE, HDPE and PVC complex) will be developed as a joint venture with Montedison of Italy. Work will begin on a 350-acre site near Alexandria in the latter half of 1978. The scheduled commissioning dates for the various plants and an estimate of their costs is given in table 27.

That such a massive program should be undertaken is not being questioned; yet if energy utilization is to be a serious consideration and a major determinant in future planning, then this expansion should be reviewed as a major user of the country's limited energy resources. The latter phases of the program, particularly the electrolytic production of chlorine and the cracking of naphtha to produce ethylene, are large energy users which will account for some 11×10^{15} joules per annum or the equivalent output of one medium-sized thermal power station. If the energy value of feedstock naphtha is added to the conversion energy, the total annual energy used rises considerably.

Not only will the proposed plants add to Egypt's energy burden, but they will be producing in direct competition to the many others being planned for the Middle East. These competitors, principally the oil-rich Arab nations, will presumably be the same nations to whom Egypt will appeal to for financial assistance for the proposed petrochemical projects. Many of these states in close proximity to Egypt have gas available at minimal opportunity cost and are building large export-oriented plants to convert this low-value gas into marketable, internationally-traded petrochemicals. These developments are highly logical and ensure that many nations in the Gulf area will be looking for markets for their products in the future. Such nations would represent suppliers who have the added advantage of being able to offer financial assistance in exchange for secure markets.

An option therefore, may be to redirect the money currently destined for the latter two phases of petrochemical production into chemical industries that are more labor and less energy intensive. Chemical industries in this category are fine chemicals, drugs, dye-stuffs, plasticizers, catalysts, flavorings, resins, detergents, and perhaps, certain rubber products. These industries have the advantage of using less energy and capital, while providing many more jobs per dollar invested. Moreover, they are not as reliant on being grouped together in major complexes, and therefore, can be used as the nuclei for new industrial areas. A particular advantage to Egypt's moving in this direction is that the many and varied skills of the country's numerous professional and scientific personnel might be better utilized.

A second option worthy of consideration by the responsible Egyptian authority would be to delay the construction of the proposed LDPE plant in order to take advantage of the new low-energy processes that are developing. Production of LDPE in the conventional process takes place at extremely high pressures (1,000 to 3,000 atmospheres) and consequently,

TABLE 27

PETROCHEMICAL DEVELOPMENTS PLANNED BY
THE PETROCHEMICALS PROJECTS GROUP AND EGPC

PHASE	ESTIMATED CAPITAL COSTS		ESTIMATED COST IN 1978 \$	ESTIMATED COST IN ACTUAL \$
	START-UP DATE	CAPACITY (TONNES/YR)		
<u>I</u>				
PVC Suspension	JAN 1981	80,000	47×10^6	63×10^6
PVC Compound	JUNE 1981			
LDPE	JAN 1982	90,000	123×10^6	198×10^6
HDPE	JUNE 1982	50,000	41×10^6	66×10^6
<u>II</u>				
Chlorine/Caustic	JAN 1986	40,000	40×10^6	94×10^6
VCM	JAN 1986	60,000	39×10^6	92×10^6
<u>III</u>				
Ethylene	JAN 1989	250,000	230×10^6	784×10^6
TOTAL			568×10^6	
DMT	1983	30,000	60×10^6	
	1987	30,000		
TOTAL			628×10^6	

NOTES:

- (1) Cost estimates assume that the cost of construction in Egypt is 25% more expensive than on the U.S. Gulf coast.
- (2) Inflation at 8 percent/yr has been assumed for Egyptian construction costs when expressed in U.S. dollars.
- (3) The chlorine capacity has been quoted only for the chlorine/caustic plant.
- (4) If the now low pressure process for LDPE reaches commercial status in time, this capital cost may be reduced.
- (5) Capacity and start-up data for the DMT plants were estimated by Gordian.

requires large amounts of energy for compression duties. A new process, currently under commercial appraisal by Union Carbide, is a gas phase process which operates at moderate pressures of only 6 to 20 atmospheres. It is claimed that this reduces energy requirements by as much as 50 to 75 percent. The process, if successful, should be well proven and available for license by the early 1980's. Although it is appreciated that a decision to await the outcome of trials of the new process might delay the plant by as much as 5 years, if, as seems likely, the plant proves commercially viable, then Egypt could have one of the earliest low-energy, low-cost LDPE plants and be in an extremely strong competitive position. On the other hand, to commence installation of a conventional high pressure plant in the near future, would mean a strong probability of its being commissioned just at the time the new, more energy-efficient plants were being constructed. If the claimed energy saving of 75 percent could be achieved for the 90,000 ton/yr plant planned for in Egypt, the energy saved would amount to 1×10^{15} joules/annum, a significant amount.

An option with a much smaller effect on energy utilization concerns the plans for the polyester production chain whereby the paraxylene will be made at Mostorod near Cairo, transported to the NASR refinery at Alexandria for conversion to DMT, and finally, moved to the polyester plant at Kafr El Dawar. The overall effect of this split is to add at least 140 km to the distance the principal product must travel and to increase by a multiple, the handling, storage, and coordination problems. Clearly, it would simplify the whole procedure were the paraxylene to be converted to DMT at Mostorod and then go directly to the polyester plant. Offsetting the advantages generated by the simplified scheme is the fact that methanol, produced as a byproduct of the polyester process, would have to be transported to the DMT plant at Mostorod in Cairo, a distance of approximately 190 km, instead of going to Alexandria some 80 km away. Establishing the net energy and cost savings of the alternative scheme requires detailed analysis.

Makeup methanol required for the DMT process presumably will be imported, as it will constitute a requirement of no more than 5,000 tons/yr. Notwithstanding, this methanol could undoubtedly be produced in Egypt from natural gas. Moreover, as methanol is being promoted by many experts as a convenient way of transporting energy, its production for use as a chemical feedstock and transportable energy form is an option open to the petrochemical industry which should be considered. Despite its fashionable appeal, however, its status as a world traded energy source must remain in considerable doubt until some major users, such as utility companies in the United States, convert significant proportions of their plants to methanol usage. Without such an assured export market, a producer would have to look to local demand to underwrite his investment. For Egypt, with its limited energy resources, a countrywide power grid, and fairly widespread natural gas supplies, it would not be a meaningful option to convert gas to methanol for transport to the more remote areas. Rather, the high energy users should be located with due regard to the available energy sources. As a chemical feedstock, methanol's principal limitation is that, although a widely-used chemical, it does not have any high volume uses upon which a country like Egypt could base major industrial development.

In summary, if the first two of the options discussed above were to be implemented, they would reduce the energy requirement of the planned petrochemical industry by some 12×10^{15} joules/annum besides releasing about three quarters of a million tonnes of naphtha which would have been needed as feedstock.

3.6.4 Projection of energy efficiency: Beyond the above-mentioned plans, no firm decisions as to the future of the petrochemical industry have been made. Mention has been made of polypropylene, butadiene, dodecylbenzene, and propylene tetramer as being the next logical group of products for the industry to consider. Interestingly, during discussions in Egypt, no mention was made of the extent to which the byproducts, which will be produced in the ethylene cracking operation, will be recovered. The economics of modern steam crackers based on naphtha are such that byproduct recovery needs to be maximized. That means finding a market for butadiene, propylene, and the aromatics. In Egypt, these products would provide the feedstocks required for the kind of products suggested as the next generation of petrochemical development.

The treatment, separation, and purification of the coke plant distillates (phenol, cresols, and crude naphthalene) would appear to be a firm project for the near future. Aside from this, little is known about the future plans for petrochemicals, although it is believed that production of 2,000 tonnes/yr of anthra quinone and 1,200 tonnes/yr of dodecylbenzene are envisaged. Nothing is known of the planned process or start-up date for these projects, however, it is believed that at least some are to be based on the separation and extraction of the components of coker distillates. Therefore, the energy duty is unlikely to be large.

For all petrochemical development, it must be assumed that all plants will be installed to the best modern standards at the time of design, this applies equally to energy efficiency and process route.

It should be clarified at this juncture that there is no such thing as an energy efficiency for the petrochemical industry. The petrochemical industry is a heterogeneous grouping of many products made by many different methods. It is simply not meaningful to group them all together to derive a figure for the "energy required per tonne of petrochemical production." Energy efficiencies are derived in table 28 on a product-by-product basis. These efficiencies are based on currently attainable efficiencies and might be the level Egyptian industry can expect to achieve if they operate their plants to normal efficiency levels. As Egypt's petrochemical plants begin to age, near the end of the century, these efficiencies may be expected to fall by 10 to 15 percent and perhaps more if maintenance is not of a high standard.

TABLE 28

PETROCHEMICAL INDUSTRIES ENERGY REQUIREMENTS

PROJECTS	CAPACITY	EGYPTIAN ENERGY USAGE				GORDIAN ENERGY ESTIMATE	
		POWER (MW)	FUEL OIL (TPH)	GAS (kcal/hr)	ANNUAL ENERGY REQUIREMENT (JOULES)	ENERGY EFFICIENCY (10 ¹⁰ JOULES PER TONNE)	ANNUAL ENERGY REQUIREMENT (10 ¹⁵ JOULES)
PVC Suspension	80,000	10				1.5	1.2
PVC Compound							
LDPE	90,000	34				1.3	1.2
HDPE	50,000					0.7	0.4
PHASE I TOTAL		44	6	3.5×10^6	3.1×10^{15}	-	2.8
Chlorine/Caustic	40,000	10	19	7.5×10^6	6.6×10^{15}	4.4	1.8
VCM	60,000					1.3	0.8
PHASE I AND II TOTAL		54	25	11	9.7×10^{15}		5.4
Ethylene	250,000	9				3.5	8.8
PHASE I, II AND III TOTAL		63	25				14.2
Para-xylene	40,000					3.8	1.5
DMT	60,000					1.5	0.9
OTHERS							2.0
PETROCHEMICAL TOTAL							18.6

TABLE 28 (continued)

NOTES:

- (1) Average power usage assumed at 90% of MW rating.
- (2) Productive hours for continuously operated plants were assumed at 7,920 hours per year.
- (3) Net calorific value of fuel oil was taken as 40×10^9 joules/tonne (9,650 Kcal/kg).
- (4) The major discrepancy between the two sets of energy usage figures for the chlorine/caustic and VCM plant is attributed to the fact that the fuel usage figure supplied may include that used for firing boilers and for power generation.
- (5) The steam cracker feedstock was assumed to be full range naphtha.
- (6) Steam cracker gas will be used both in the furnaces and to drive a 10 MW onsite power station. Hence although no actual gas usage was given, a portion of the feedstock is, in effect, burned as fuel.
- (7) The energy usage figures given by the Egyptians for the LDPE, HOPE and PVC plants were based on production rates of 100,000, 300,000, and 800,000 tonnes/yr, respectively. However, since the energy usages were not given for each process individually, the minor adjustments necessary to reflect the new tonnages could not be calculated.
- (8) "Others" includes the recovery and operation of the coker distillates plant.
- (9) For paraxylene production, it was assumed that the paraxylene constitutes 50% by weight of the product stream.

3.6.5 Forecast energy requirements for 1985 and 2000: The energy requirement of 5.0×10^{15} joules as forecast in table 29 for 1985 is believed reasonable and can be assumed as the most likely maximum demand as of that date. For forecasts thereafter, the lack of any detailed plans or even desired production figures disaggregated on a product-by-product basis makes a denumerable prediction impossible. The figures shown in table 28 must be regarded as the absolute minimum demand on the assumption that no plans, other than those already envisioned, are brought to fruition. Since the current 5-year plan only covers the period through to 1982 and the firm plans of the Petrochemical Group extend no further than 1989, conjecture as to future demand is not possible other than on a highly speculative, assumed growth rate basis. The representative energy usage by type is presented in table 30.

In summary, therefore, the estimated energy demand of 5.0×10^{15} joules/annum by 1985 may be assumed as reasonable. For the year 2000, it can only be said that if all the envisioned plans materialize, the demand will not be less than 16.6×10^{15} joules/annum.

TABLE 29

FORECAST ANNUAL ENERGY REQUIREMENTS FOR EGYPT'S
PETROCHEMICAL INDUSTRY

	ANNUAL ENERGY REQUIREMENTS (JOULES X 10 ¹⁵)			DIRECT EMPLOYEES
	1975	1985	2000	
PVC Suspension and Compounding	-	1.2	1.2	37
LDPE	-	1.2	1.2	44
HDPE	-	0.4	0.4	44
Chlorine/Caustic	-	-	1.8	24
VCM	-	-	0.8	37
Ethylene	-	-	8.8	48
SUB-TOTAL	-	2.8	14.2	234
DMT	-	0.4	0.9	
Paraxylene	-	0.8	1.5	
Others	-	1.0	?	
TOTAL		5.0	unknown	

NOTES:

- (1) As the figures for the year 2000 include only the plants currently planned, clearly, the energy requirements will be higher than shown when plans for the period 1989-2000 are fully developed and implemented.
- (2) The figure for employment consists only of plant operating labor and supervision directly associated with the production, storage and associated dispatch of the products and byproducts. If maintenance, site services, and administration, etc. and a factor for the higher manning levels prevalent in Egypt were taken into consideration, the total labor force employed as a result of the first seven projects would be approximately 2,000.
- (3) Energy estimates for DMT and paraxylene assume 25,000 tons/yr DMT production by 1985 and 50,000 tpa DMT by year 2000.

TABLE 30
 REPRESENTATIVE ENERGY USAGE BY TYPE

<u>Product</u>	<u>Estimate of % Energy Used as</u>	
	<u>Power</u>	<u>Fuel</u>
PVC	10	90
HDPE	50	50
LDPE	40	60
Chlorine/Caustic	30	70
VCM	10	90
Ethylene	1	99
DMT	10	90

NOTE

- (1) The ratio for LDPE production may vary enormously depending upon the principle energy form used to drive the compressors. The above figures assume electric drivers.
- (2) The ratio may vary widely from plant to plant depending upon the utility balance on the site, the existence of cogeneration, or heat recovery facilities.
- (3) Assume electric power purchased from the grid and no allowances for power plant inefficiency.

3.7. Textiles

3.7.1 Background: The textile industry is one of the major industries in Egypt, as well as being one of the oldest. It accounts for about 50 percent of employment in the industrial sector, and in 1974 provided 52 percent of the production value of the sector as a whole and 43 percent of exported manufactured goods. The industry naturally has been based around cotton and cotton processing, particularly long and extra-long staple. Although rayon has been produced since 1947, emphasis has been given to synthetic fibers only relatively recently, and plans are underway for a major expansion in this area.

Despite its importance as an export earner, production of cotton in Egypt decreased in the early 1970's due to Government policies of reducing cotton growing areas and switching them to food production. At the same time, a high domestic demand has meant that exports have suffered, e.g., Egypt's quotas for textiles to the United States and the European Economic Community have not been filled. In this situation, the industry will have to look to synthetics and imported lower quality cotton to satisfy the local market in order to free the higher quality long staple cotton for export markets.

The textile industry covers a range of activities such as spinning, weaving, converting, knitting and garment manufacture. Cotton ginning also is considered in this sector, although strictly speaking it is an agricultural activity. In this sector, more than most, the availability of data is very limited and unreliable in view of the large number of small companies involved. Since the nationalization of the textile industry in 1961, all spinning and converting, 70 percent of weaving, 45 percent of knitting, and 30 percent of garment manufacturing have been part of the public sector, the balance being carried out by hundreds of small companies in the private sector. Statistics on consumption and production need to be treated with caution in view of the effects of fabric smuggling and the fact that little data on energy usage has been kept. Accordingly, in the evaluation below, the data used has been based mainly on the statistics of public sector companies.

Data on the production of the major sections of the textile industry are shown in table 31. As can be seen from this table, cotton accounts for the major output in the industries. Details of cotton production, productivity and sales are shown in table 32. Production, consumption, importation, and exportation of textile fabrics are shown in table 33. Further comments of specific sections of the industry follow.

Cotton Ginning: This aspect of the industry comes under the Egyptian Cotton General Organization (ECGO), which is the holding company for 12 subsidiary companies: five for ginning, six for cotton exporting, and one for pressing cotton bales for export. The five ginning companies (three of which are located in Alexandria) each operate from twelve to fifteen gineries.

TABLE 31

OUTPUT OF MAJOR SECTIONS OF THE TEXTILE INDUSTRY

(Metric Tonnes)

	<u>1973</u>	<u>1974</u>	<u>1975</u>
Cotton Yarn	182,000	179,000	186,000
Cotton Textiles	118,000	120,000	141,000
Wool Yarn	12,000	12,000	
Wool Textiles	4,000	3,500	
Synthetic Yarn	10,000	10,000	
Synthetic Textiles	23,000	22,000	

Source: 1973 and 1974 GOFI, Ministry of Industry, 1975 World Bank Estimates.

TABLE 32

THE TEXTILE INDUSTRY IN EGYPT-PRODUCTION AND SALES STATISTICS

	<u>1967</u>	<u>1968</u>	<u>1969</u>	<u>1970</u>	<u>1971</u>	<u>1972</u>	<u>1975</u>
Number of Spindles (000)	1,501	1,531	1,615	1,697	1,763	1,840	2,120
Number of Looms (000)	25.5	25.5	25.8	28.7	29.1	29.2	33.6
Production of Cotton Products:							
- Cotton Yarn (000 tonnes)	157.5	157.4	162.4	162.5	171.0	179.2	186.0
- Cotton Fabrics (000 tonnes)	92.7	102.3	106.1	110.3	113.6	115.9	141.0
- Average Cotton Count	24.2	24.5	24.7	25.1	25.3	26.2	n.a.
- Production per Spindle (kg/yr)	105.0	103.0	101.0	97.0	97.0	97.0	87.7
Consumption of Cotton Products:							
- Cotton Yarn: % Local	76	75	72	73	76	74	79
% Export	24	25	28	27	24	26	21
- Cotton Fabrics: % Local	81	81	79	80	81	82	90*
% Export	19	19	21	20	19	18	10

Source: Yearbook of the Federation of Egyptian Industries, 1973, and World Bank Estimates for 1975.

* Including imports.

TABLE 33

PRODUCTION, CONSUMPTION, IMPORTS AND EXPORTS OF TEXTILE FABRICS IN EGYPT

PUBLIC SECTOR AVAILABLE FOR HOME MARKET															Apparent Consumption	
Year	-----Production-----			-----Imports-----			Exports Cotton	-----Woven-----			Knitted Cotton	Private Sector Knitted & Woven	Grand Total	Population (million)	per Capita	
	Cotton	Other	Total	Cotton	Other	Total		Cotton	Other	Total					m	kg
1970	507	34	541	-	6	6	152	355	40	395	32	240	667	33.3	19.9	3.5
1971	524	35	559	-	8	8	169	355	43	398	36	244	676	34.1	20.5	3.6
1972	586	31	617	-	9	9	141	445	40	485	39	250	774	34.8	22.2	3.9
1973	554	27	581	-	12	12	135	429	39	468	45	254	767	35.6	21.5	3.8
1974	504	23	527	5	10	15	97	407	33	440	50	260	755	36.4	20.0	3.7
1975	547	26	573	55	6	61	123	474	32	506	46	260	627	37.2	21.9	3.9

Source: EGOSW and Werner International Management Consultants Interim Report, October 1975.

Notes:

1. Including synthetic fabrics smuggled into the country (estimated).
2. There is some export of clothing but not fabrics from the private sector; actual figures are not available.
3. Excluding jute and flax.
4. Estimated.

In Egypt the industry was geared to supplying the needs of the United Kingdom textile industry and grew at a very rapid rate. By 1950 there were 105 ginneries with 6,475 ginstands, but this over capacity had gradually been reduced to 73 ginneries with about 4,700 ginstands. Most of these are very old operations, only three having been constructed in the past 30 years. The industry is badly in need of modernization.

Spinning and Weaving: There are at present 30 companies in the public sector which were incorporated into the Egyptian General Organization for Spinning and Weaving (EGOSW) until 1975 and are now directly responsible to the Ministry of Industry. These companies had combined sales of LE 401 million and employed 266,000 people in 1974. They account for 100 percent of the sector output of yarn and 70 percent of fabrics.

Finishing: Only limited data for finishing is available from the public sector, where 18 finishing companies dominate the market. In 1977 these companies produced $731 \times 10^6 \text{ m}^2$. Of this total, two companies (who specialize in finishing only) have some 26 percent of the market. They are MISR El Beida Dyers with a production in 1977 of $135 \times 10^6 \text{ m}^2$ and Cairo Dyeing and Finishing with a 1977 production of $55 \times 10^6 \text{ m}^2$. The other companies are fully integrated, doing spinning and weaving as well as finishing.

Knitting: The knitting sector is dominated by the public sector which has some 60 percent of the market. There are 676 knitting machines, all of the circular type. However, the private sector is superior in numbers of machines. The cut-and-sew sector is represented by seven or eight companies in the public sector and the five-year plan calls for an additional six. An estimate of private sector interest in this subsector has not been possible. However, they appear to be a small force in the volume garments but a dominating factor in the tailoring business.

Synthetics: Synthetic textiles are a growing market, and it is expected that Egypt will follow the worldwide trend towards use of polyester and polyester-cotton blends. Apart from a small plant in Cairo (ESCO) which manufactures 5 tonnes/day, synthetic fibers are wholly manufactured by the MISR Rayon Company in Kafr El Dawar. All immediate plans for expansion in the sector are concentrated on this plant. At present the plant manufactures rayon and nylon. Polyester will also be manufactured.

The company started production of rayon in 1947. Presently capacity for rayon is thirteen tonnes/day of filament within a denier range of 75 to 300 De. The types manufactured include wool and cotton in different colors. Production is both batch (12 lines) and continuous. No high net modulus grades are produced. In addition, the plant manufactures ordinary and moisture-proof cellophane (6 tonnes/day). Auxiliary plants manufacture sulfuric acid (60 tonnes/day) and carbon disulfide (12 tonnes/day). Ammonium sulfate is produced as a byproduct. A spinning plant is under construction with a capacity for 20 tonnes of blended staple (with cotton or polyester). In commercial terms, the market for rayon staple fiber has been poor, but the situation is improving as cotton prices rise.

The raw material used is wood pulp, imported in sheets from Scandinavia and North America. High grade (96 percent cellulose) is used for filament and low grade (90 percent cellulose) for staple. Consumption of wood pulp is approximately 1.6 tonnes of pulp/tonne of product filament. Studies have been carried out to consider alternative sources of raw material such as bagasse, rice straw, poor quality cotton, and pine needles. However, many of these studies were carried out in the late 1950's and early 1960's, and blends such as cotton with wood pulp were not considered. Sulfur is imported from Iraq, and caustic soda (of which 10,000 tonnes/year is used) is brought in from the plant near Alexandria as well as being imported.

The process design was originally by Oskar Kohorn, but the plant is being redesigned by Cetex of France (see fig. 9, 10, 11). Equipment consists of 6,400 spinning positions for the rayon filament. The original Westinghouse motors (which are no longer manufactured) are being replaced by Siemens and Kuiki.

Estimated production of rayon is 68 percent first grade, 27 percent second grade and 5 percent to 6 percent inferior quality. Current production level is 100 percent of capacity for filament and about 50 percent of capacity for staple. Plans have been made to shut down rayon production in the plant by 1985 and replace it with the production of polyester.

The nylon plant manufactures 1.6 tonnes/day of staple and 1.3 tonnes/day of filament nylon (De 40 and De 70 Nylon 6 grade). A conventional hot melt spin system with draw twisting machines is used on the Zimmer design. The plant has a polymerization unit and also imports chips from BASF. Its own chips are treated separately. It has 15 spinning heads for staple fiber and 18 for filament. Annual production is 1,000 tonnes/yr of which 80 percent is first grade. Any waste fiber is moulded.

The polyester project is under construction and is due to start in mid-1979 based on the Rhone-Poulenc process using APCT machinery. Polyester will be produced using DMT and ethylene glycol. Initially, the DMT will be imported, but it will ultimately be supplied by the El Nasr refinery and Alexandria which will be using paraxylene manufactured at Mostorod. Glycol, however, will be imported and special unloading and storage facilities are planned in Alexandria. A block diagram of the proposed process is attached, (see figure 8).

In addition to the polyester plant which is under construction, the following projects are planned by MISR Rayon:

1. Expansion of the nylon filament plant to feed a nylon carpet making plant (1,000 to 1,500 tonnes/yr.)
2. Polyester spun filament (continuous) from staple 3,000 tonnes/yr.
3. A second polyester plant for 25,000 tonnes/yr.

Fig. - 9. Block Diagram for MISR Planned Polyester Plant

Fig. 10. Block Diagram for MISR Rayon Plant.

Fig. 11. Block Diagram for MISR Nylon 6 Plant.

4. Expansion of the viscose staple spinning plant by the addition of 19,000 spindles to reach a total of 52,000 spindles. The addition of another 50,000 spindles and 279 looms for blending cotton/polyester and viscose.

3.7.2 Energy demand and efficiency in 1975:

3.7.2.1 Cotton ginning As noted above, virtually all of the ginneries are outmoded and are in need of rehabilitation. Most of the operations are done manually. Mechanical equipment is in a poor state of maintenance and productivity is low. In addition, environmental conditions are far from satisfactory.

Ginning is a process used to separate lint from seed. There are two basic types of gins: the "saw" gin and the "roller" gin. "Roller" gins are more appropriate for the long staple and extra long staple of Egyptian cotton, and these gins are commonly used in Egypt. Ginneries are basically labor intensive, and modern machines are very similar to the old ones still being used in Egypt, with the exception that blending operations, transportation of seed cotton to ginstands, and the transportation of lint to condensing, humidifying and pressing tend to be mechanized nowadays. Present energy consumption for ginning is, therefore, very low. The volume of cotton ginned in 1975-1976 was estimated to be 450,000 tonnes. Energy consumption is estimated to be about 0.2×10^{15} joules.

3.7.2.2 Spinning and weaving; Estimated production of textile fabrics in 1975 was 875 million m². In the Egyptian textile industry, the vast majority of looms are electric powered, shuttle types. Steam production has been diesel-based, but some companies are now switching to natural gas. In order to calculate energy consumption, consumption factors are used which are regarded as typical for the industry as a whole.

In spinning mills, the machines consume a large quantity of energy/kg of yarn produced. Some types of machines (e.g., ring spinning frames) use much more electricity than others. In general, about 50 percent of the electrical energy used in a spinning mill is consumed by these machines. Consumption varies between 2,000 kWh and 3,300 kWh/tonne depending upon the yarn count. The cotton count in Egypt has varied between 24.2 and 26.2 in recent years. Typical energy requirements for such a count would be 13.9×10^9 joules of total energy/tonne yarn. Production of cotton yarn was estimated to be 186,000 tonnes in 1975. Energy consumption is therefore 2.6×10^{15} joules.

Weaving mills use from 2,400 kWh/tonne depending upon the weight of the cloth and the amount of air conditioning needed.

Technical data is not immediately available on detailed specifications of cloth produced in Egypt; a typical weaving mill consumes a total of 11.7×10^9 joules/tonne of cloth. Production of textiles in 1975 was estimated to be 141,000 tonnes, and on this basis energy consumption is calculated to be 1.6×10^{15} joules.

3.7.2.3 Finishing: The finishing department includes operations such as bleaching dyeing, printing, and other "wet" operations. Energy consumed is related to providing steam, such as for the vat dyes, and to providing drying facilities such as convection driers including the stenter frame, hot flue, short loop, and convection devices. Typical consumption of electrical energy is 800 kWh per tonne of fabric. However, thermal energy accounts for more than 95 percent of energy consumption in finishing. Typical total energy consumption in a cotton finishing mill is about 53.7×10^9 joules/tonne of finished cloth.

Taking the production of textiles in 1975 as 141,000 tonnes, total consumption of energy for finishing is estimated at 7.5×10^{15} joules.

3.7.2.4 Summary for cotton textiles: Therefore, total present energy consumption for the cotton textiles industry as a whole is estimated to be as follows:

Cotton Ginning	0.2
Spinning	2.6
Weaving	1.6
Finishing	<u>7.5</u>
Total	11.9×10^{15} joules

3.7.2.5 Synthetic fiber: For synthetic fibers, actual annual production and energy usage for the MISR Rayon Company are shown in table 34. These figures may be considered representative of the sector, as there is only one other small plant in operation in Egypt.

3.7.3 Discussion of options: The textile industry is one of the oldest in Egypt. As such, the equipment used in the industry is largely obsolete. According to a World Bank estimate, 72 percent of the looms and 44 percent of the spindles are over 25 years old, and 25 percent of all textile equipment has been in use for over 30 years. Operating efficiency of the industry, therefore, is very low. According to one estimate, 1 million spindles and 10,000 looms plus auxiliary equipment will need replacing over the next 10 years.

3.7.3.1 The use of energy in textile plants: In general, cotton ginning, spinning and weaving use mainly electrical energy (assumed to be about 95 percent). Dyeing and finishing, on the other hand, use mainly thermal energy (assumed to be about 95 percent) with relatively smaller amounts of electrical energy. It is in dyeing and finishing that most of the energy used in textile manufacturing is consumed, and potential savings of energy are the greatest. It should be noted that the energy requirements of various fiber types differ, and thus their nature becomes a fundamental factor in determining energy costs in dyeing and finishing

TABLE 34

MISR RAYON COMPANY - ANNUAL PRODUCTION

PRODUCT	ANNUAL PRODUCTION TONNES/YEAR	TOTAL ENERGY USAGE kWh/YEAR
Nylon - Staple fiber	450	6,639,920
Cont. fil.	400	
Rayon - Staple fiber	3,000	42,296,830
Cont. fil.	4,700	

Total energy consumption is calculated to be 48.9×10^6 kWh per year or 0.2×10^{15} joules.

In textile plants, hot water is used for chemical treatment and/or dyeing and for washing fabrics. For chemical processing and dyeing, there is an essential heat requirement which depends upon the basic nature of the process. In washing, where energy is used to remove impurities, high temperatures are not as essential and washing can be carried out even at low temperatures. In all these processes, heat losses from machines occur through radiation, conduction, and convection, and through the evaporation of hot water. Evaporative losses are significant and closed machines have a large advantage over open machines, but the main energy "sink" is hot waste water. During drying and heat setting, a major proportion of the energy leaves the machine in the form of hot air.

Typical values for the energy balance in continuous washing, stenter drying, and stenter heat-setting are shown in figures 12, 13, and 14. These figures show the high proportion of these losses which appear in the form of hot water running to waste or hot air vented to the atmosphere.

The Egyptian textile industry has traditionally used steam heating in the stenters, but over the last few years some companies have changed to using indirect heating with fuel oil. Some finishers use hot water to heat the stenters, but this does require equipment of a different design. The dyeing is done by soaking the cloth in hot water dye tanks at 100°C and atmospheric pressure. At the end of the dye run, any dye and liquid not taken up is put to drain. There is, therefore, a great deal of room for energy conservation in the industry.

3.7.3.2 Heat recovery: The major scope for improving efficiency in the textile industry is in the recovery of waste heat and harnessing of expelled steam. The temperature of expelled steam is usually very high. In some cases the temperature of baths poured into sewers is around 100°C , the temperature of air leaving driers about 130°C to 140°C , and the temperature of steam leaving the agers about 100°C .

The two major areas of loss are steam from condensate containers and heat escaping with the flue gases of the boilers. Hot flue gas cannot be used directly. However, if it is passed through a heat exchanger, typically about half its heat content can be recovered economically so that the hot gas, in falling from 200°C to 100°C, will heat combustion air at room temperature to 100°C or, alternatively, it can be used to heat water.

The energy usage within a particular finishing works is dependent upon many factors, some of which vary considerably from factory to factory; therefore, accurate figures can be arrived at only by individual examination of each location.

3.7.3.3 Potential options: Potential options for saving energy in the areas of water using processes and drying and heating processes include the following estimates of typical savings made by the Shirley Institute of the United Kingdom:

<u>OPTION</u>	<u>TYPICAL SAVING</u> <u>10⁹ JOULES/TONNE</u>
<u>(A) WATER-USING PROCESS</u>	
1. AVOID UNDERLOADING	approx. PROPORTIONAL TO LOADING
2. RE-USE OF HOT WATER	1.9
3. USE COUNTERFLOW	1.4
4. LIMIT IDLING LOSSES	0.9
5. REDUCE RINSING WATER	1.4
6. REDUCE WATER TEMPERATURE	0.9
7. RECOVER HEAT WHERE POSSIBLE	35% OF TOTAL
<u>(B) DRYING AND HEATING PROCESS</u>	
1. MAXIMIZE MECHANICAL DRYING	0.2
2. AVOID OVER-DRYING	0.5
3. MINIMIZE SETTING AND DYE-FIXATION TIMES	0.2
4. REDUCE EXHAUST AIR TO PRACTICAL) MINIMUM)	
MONITOR HUMIDITY OF DRYING)	25% OF TOTAL
PROCESS)	
5. EXAMINE THERMAL EFFICIENCY OF FORCED CONVECTION SYSTEMS	
6. REDUCE IDLING LOSSES, e.g., BY SWITCHING OFF EXHAUSE AIR	0.5
7. RECOVER HEAT FROM EXHAUST AIR	25% OF TOTAL

* "Practical Considerations in the Use of Energy in Textile Processing, Dyeing and Finishing," Shirley Institute, Manchester, UK.

Fig. 12. Energy Balance in Typical Continuous Washer.

Fig. 13. Energy Balance in Stenter Drying.

Fig. 14. Energy Balance in Stenter Heat Setting.

Clearly, major savings can be made in heat recovery in both areas. The impact of these actions could be considerable, and these kinds of conservation activities are included in the goals developed for the U.S. textile industry by the Federal Energy Administration Industrial Energy Conservation Program:

GROSS ENERGY EFFICIENCY IMPROVEMENT GOALS

<u>Component</u>	<u>1972 Efficiency</u> (kWh/kg)	<u>Projected 1980 Efficiency</u> (kWh/kg)	<u>Component</u> <u>Goals (%)</u>
Spinning	5.40	4.86	10
Weaving	4.76	3.68	23
Knitting	1.75	1.29	26
Finishing			
(woven fabric)	18.67	10.77	42
Yarn dyeing	11.81	9.12	23

Clearly these goals would not be directly applicable to the Egyptian industry in view of the different type and age of equipment being used, as well as the operating methods. It is proposed, therefore, to adopt a lower target figure for Egypt for the expected energy efficiency performance. A possible improvement rate in efficiency of 10 percent is proposed for the spinning and weaving sectors; and a rate of 25 percent in the finishing section where greater savings could probably be made.

In addition to these savings, a concentrated effort in all plants could lead to further savings in line with the goals previously mentioned. The impact of this "Maximum Conservation" case is discussed in section 3.7.5 and shown in table 35.

3.7.4 Future developments and energy efficiency:

3.7.4.1 Cotton ginning: A program is currently under way for the rationalization of the ginning industry. Of the 73 ginneries in operation, it is expected that 42 can be rehabilitated, while 31 will be closed down. Thirteen new plants will be constructed (with 72 ginstands per ginnery). By 1985, the number of ginstands will be reduced from 4,722 to 4,594. Ginning capacity will increase, however, by 15 percent due to better capacity utilization and improved productivity, brought about by additional mechanization relating mainly to feeding, distributing, and conveying equipment.

The amount of cotton ginned is expected to reach 4,927,000 cantars (770,000 tonnes of seed cotton) by 1985, an increase of 70 percent over 1975. However, increased fuel consumption is projected due to the greater use of bale lift trucks. It is therefore assumed that energy consumption will double in 1985 to reach 0.4×10^{15} joules. The amount of cotton ginned will increase by the year 2000 but this increase is not expected to be substantial in view of the land limitations on growing cotton. Most of the increased cotton production should result from better productivity/feddan. The same figures for energy consumption are proposed for 2000 as for 1985 on the assumption that there will be some improvement in energy efficiency.

3.7.4.2 Spinning and weaving: Total production of woven fabrics in Egypt is expected to increase by 20 percent by 1985 compared to 1975. Production of yarn should reach 225,000 tonnes and of woven fabrics, 170,000 tonnes. With replacement of obsolete equipment, there will be a radical improvement in productivity and a lower energy consumption by the new machines. The industry plans to continue using conventional electric-powered shuttle looms, and new plants will be equipped with high speed cards. Productivity can be expected to decrease more on existing machines. Electricity will continue to be the main source of energy supply in this area.

No statistics are available on the number of new spindles and looms planned to be in operation by 1985. The major project in this sector concerns the textile plant at Kafr El Dawar. Here, 50,000 new spindles for spinning polyester-cotton and 51,000 spindles for spinning 100 percent cotton will be added. The total number of spindles by 1985 in Egypt could reach 2.5 million. The Kafr El Sawar project also envisions 448 new looms of various widths for polyester cotton and 448 new looms for 100 percent cotton. The total number of looms in Egypt should be around 35,000 by 1985.

The average productivity of spindles in Egypt in 1975 was estimated to be 88 kg/yr which is well below the rate achieved by new equipment. In calculating energy consumption, it would be reasonable to assume an improvement in efficiency of about 10 percent to a level of 12.5×10^9 joules/tonne of yarn and 10.5×10^9 joules/tonne of cloth. Total consumption in 1985, therefore, is estimated to be:

Spinning :	3.2×10^{15} joules
Weaving :	1.8×10^{15} joules

It is assumed that this level of efficiency will be maintained until the year 2000.

3.7.4.3 Finishing: Assuming an increase in production of 20 percent by 1985 over 1975, a total level of 170,000 tonnes of woven cloth can be expected to be treated. Applying a factor of 25 percent in improvement in energy efficiency, total consumption is estimated to be 6.9×10^{15} joules. As noted above, virtually all this consumption will be thermal energy.

It is assumed that there will be no significant expansion in the cotton textile industry between 1985 and 2000 with emphasis being more on producing polyester-cotton mixtures, and that the same level of efficiency will be maintained.

3.7.4.4 Synthetics: By 1985, it is expected that all current plans of MISR Rayon will be implemented. The rayon plant is expected to be shut down by then, the polyester plant of 25,000 tonnes will have started production, and the viscose staple plant will have expanded. Energy consumption is expected to increase from 9 MW at present to 24 MW when all projects have been implemented. A typical

consumption rate for a polyester plant is estimated to be 5.3×10^6 kcal/tonne. The polyester plant, therefore, will require 0.6×10^{15} joules. Taking into account the expansion of the viscose plant, energy requirements are estimated to be 0.8×10^{15} joules.

By the year 2000, the second polyester plant of 25,000 tonnes will have come into operation. In line with worldwide trends, and taking into account the limitations that exist for expanding cotton textiles and the development of the chemical industry in Egypt, there is no doubt that synthetic fiber production will expand rapidly between 1985 and 2000. Accordingly, it is assumed that capacity will more than double, and an energy consumption of 2.0×10^{15} joules is assumed for the year 2000.

3.7.5 Energy requirements: Estimates of energy requirements in the textile sector are summarized in table 35. For the year 2000, expected energy consumption is shown, as well as the estimated maximum possible savings which could be achieved based on the assumption that Egypt will achieve, by the year 2000, the gross energy efficiency goals recently set for the U.S. industry for 1980.

For cotton ginning, no significant savings are expected. However, for spinning and weaving, savings of 0.2×10^{15} are possible in each case. Where spinning is concerned, it is assumed that 50 percent of the spindles will be replaced by 1985. Accordingly there should be scope for improving energy efficiency on the remaining 50 percent old spindles in operation, and it is assumed that a savings of 10 percent (0.2×10^{15} joules) will be made on these. Similarly for weaving, where 30 percent of looms are expected to be replaced by 1985, energy savings are expected to be made on the other looms. A 15 percent improvement is considered realistic between 1985 and 2000, which represents a saving of 0.2×10^{15} joules. As noted above, considerably greater savings are to be made in the finishing section, and potential savings could be around 20 percent, representing 1.4×10^{15} joules, in order to arrive at a savings figure comparable to that for the U.S. industry. Therefore, total energy savings through conservation measures could reach 1.8×10^{15} joules, of which about 25 percent would be electricity and the rest residual fuel oil.

TABLE 35

ESTIMATED ANNUAL ENERGY REQUIREMENTS AND
POTENTIAL SAVINGS IN THE TEXTILE INDUSTRY

SECTOR	ANNUAL ENERGY REQUIREMENTS (JOULES $\times 10^{15}$)					
	1975	1985	2000		Possible Savings	
			Esti- mated	With Maximum Conservation	Electr.	Fuel Oil
Cotton Ginning	0.2	0.4	0.4	0.4	--	--
Spinning	2.6	3.2	3.2	3.0	0.19	0.01
Weaving	1.6	1.8	1.8	1.6	0.19	0.01
Finishing	7.5	6.9	6.9	5.5	0.10	1.30
Synthetics	0.2	0.8	2.0	2.0	--	--
Total	12.1	13.1	14.3	12.5	0.48	1.32

3.8. Automotive Manufacture

3.8.1 Background: The El-Nasr Automotive Manufacturing Co. (NASCO) is Egypt's only current manufacturer of cars, trucks and buses, and is state-owned. The manufacturing plant is located at Helwan, near Cairo. The Helwan site was established in 1960, and a total of about 11,000 people are currently employed. Car production is carried out under license from Fiat, while truck production is under license from Magirus-Duetz. The licensors specified the major equipment and machinery installed in the plant, which is modern and of West European manufacture.

Current production is as follows:

<u>Product</u>	<u>Number per Year</u>
Heavy trucks	1,700
Buses	500
Agriculture tractors	3,000
Trailers	250
Passenger cars	13,000
Additional engines	800

The manufacture of tractors and cars consists primarily of assembly of imported components, while truck, bus, and trailer activities consist of assembly and some manufacturing operations which constitute about 40 percent of the finished product value.

Projects are under development which are expected to be in production in the 1981-1985 period. Total production is expected to reach the following:

<u>Product</u>	<u>Number per Year</u>
Trucks and buses	5,000
Passenger cars	35,000
Agriculture tractors	5,000
Trailers and truck bodies	3,000

Truck, bus, and car expansions will be at the existing Helwan site, and the tractor project is likely to be moved to Alexandria. The trailers/truck bodies operation has no site identified to date.

Another company active in the automotive sector is Tramco, with plants at Helwan and Giza, both near Cairo. This company produces JAWA motorcycles under a Czechoslovakian license. Energy consumption for this relatively small operation is believed to be minimal. Ford has a factory in Alexandria which is currently dormant. Plans are being developed to commence assembly of 10,000 light trucks/yr in 1981 and to manufacture 50,000 engines/yr from 1982. About 80 percent of the engines and 50 percent of the trucks would be for export. However, the prospects for these projects are uncertain.

3.8.2 Assessment of current energy demand and efficiency: The data available relating to energy efficiency is incomplete. Energy consumption split according to product lines was not available. Energy efficiency is not a major topic within the company, as energy contributes a relatively small part of total production costs. Management considers the machinery to be electrically efficient in view of its West European origin and relatively recent purchase.

Energy consumption consists of electricity used for rotating machinery, presses, welding, lighting and electric furnaces for heat treatment. Power is supplied from the grid at 6.3 V and onsite transformers provide a 380 V/50 cps supply to machinery. There is no onsite electrical generation and currently, there are no plans to install any such facilities. A recent feasibility study showed this to be an unattractive option. Power failures are officially said to be "no problem," occurring perhaps once or twice a year. However, this may be understating the true situation, as other sources indicate that failures occur more frequently (once per week or so).

Total plant electrical energy consumption is reported as 12 million kWh per year. Essentially, the plant operates with a single 8-hour shift, although a minor amount of two-shift working does occur. The average electrical load is thus about 5.6 MWe (assuming 270 days/yr operation).

Steam of 75 psig is generated from fuel oil at about 8 tonnes/hr and is used in various plant operations such as degreasing, cleaning upholstery, washing, and some heat treatment operations. Boiler efficiency is not known, but was said to be normal for small steam generators. The boilers are, in fact, of low-pressure design and there are four, each with a 2 tonnes/hr output. Assuming that boiler efficiency is about 70 percent, the fuel oil consumption amounts to approximately 1,370 tonnes/yr (operational 270 days/yr, 8 hr/day).

The number of vehicles produced per year totals about 18,450 (not including extra engines). On a "per unit" basis therefore, energy consumption amounts to:

$$\text{Electricity} : \frac{12 \times 10^6}{18,450} = 650 \text{ kWh vehicle}$$

$$\text{Fuel Oil} : \frac{13,720 \times 10^6}{18,450} = 0.74 \text{ million kcal per vehicle}$$

This assumes that energy consumption is directly proportional to vehicle output, and makes no allowance for fixed energy usage, on which no information is available.

3.8.3 Discussion of options: The automotive manufacture sub-sector appears to be a relatively low-energy user compared to other major process industries. The Helwan plant electrical requirement may rise to about 23 MW if all projects are implemented by 1985. There appears to be little that can be done to save energy, except perhaps to investigate the possibility of operating on a two- or even three-shift basis. It is likely that there is significant waste of electrical and thermal energy during the start-up and shut-down of operations, and therefore a one-shift operation is not likely to be the most energy efficient. There may, of course, be overriding social reasons for maintaining single-shift working; this would have to be investigated thoroughly.

Since most machinery is electrically driven, as is the practice in the industry and in modern manufacturing, there seems to be little potential for improving electrical efficiency. There may be some potential to improve boiler or furnace efficiencies, but this could be determined only by detailed site studies.

3.8.4 Projection of energy efficiency: In the absence of specific information on future expansion plans for the automotive subsector, there is no reason to forecast any difference in energy efficiency for 1985 and 2000 from the figures quoted previously:

Per Vehicle

Electricity	:	650 kWh
Fuel Oil	:	0.744 million kcal

This, of course assumes a continuation of one-shift working, as is prevalent today. Should plant operations be rescheduled for two- or three-shift operation, it seems reasonable to forecast a 10 percent improvement in efficiency due to the elimination of much of the unproductive start-up and shut-down time associated with the single shift. Efficiency might improve, therefore, to:

Per Vehicle

Electricity	:	585 kWh
Fuel Oil	:	0.67 million kcal

3.8.5 Forecast energy requirements for 1985 and 2000: In the absence of reliable forecasts for the level of production anticipated for the automotive manufacturing subsector, no estimate of total energy requirements can be made.

4.0 THE AGRICULTURAL SECTOR

4.1 Background

From the point of view of energy utilization, the agricultural sector can be divided into three areas:

- (1) the use of pumps for irrigation and drainage;
- (2) agricultural mechanization, especially the use of tractors, and
- (3) growth of food processing and agro-industries.

According to the Sanderson Porter Report, total electrical energy consumption in the agricultural sector was estimated to be 1.4 terrawatt hours (twh) in 1977 (5×10^{15} joules), accounting for almost 7 percent of total electric energy sales. In addition, energy was consumed in the sector in the form of diesel and fuel oil.

4.2 Drainage and Irrigation

4.2.1 Present energy requirements: The drainage and irrigation network is split essentially between the Ministry of Irrigation and the public authorities, with the farmer at a secondary level. The Ministry is responsible for the pumping from all primary and some secondary canals. The capacity of all major existing pumping stations is shown in table 36. Total installed horsepower is estimated to be almost 700,000, of which the Ministry estimates 95 percent (665,000) is based on electricity and only 5 percent on diesel. The total number of pumping stations is estimated between 1,000 and 1,200, ranging from 300 kW to 2000 kW -- the size of pump units ranges from 50 kW to 500 kW. Total annual consumption of electricity is estimated to be about 600 million kWh.

Pumping by the private sector, mainly from tertiary and smaller channels, consists of animal driven pumps and small diesel and electric pumps, typically in the 7 to 15 size range. As an example of the types of pumps used, the present pattern of irrigation in Upper Egypt is shown in table 37. Samples of purchase orders by the Ministry of Irrigation show that pumps with capacities of $150\text{m}^3/\text{hr}$ to $300\text{m}^3/\text{hr}$ have been ordered. In addition to Government purchases, pumps have been bought by agricultural cooperatives and individual farmers. According to an estimate of the Ministry of Irrigation, the total number of small pumps for irrigation is about 82,000 at present, virtually all of which are concentrated in the Nile Valley and the Delta. However, a large number of these pumps are likely to be inoperative due to maintenance problems and lack of spare parts. Assuming that 50 percent of these pumps are operating effectively, the number of small pumps is estimated to be around 40,000, virtually all of which are likely to be diesel. No figures are available on current consumption of fuel by pumping units.

TABLE 36

ESTIMATED CAPACITY OF PUMPING STATIONS
(hp for all pumps whether electric or diesel)

Alexandria	2,908
Daman Hur	8,550
Tanta	28,670
Shebin el kon	55,350
Zagazig	91,794
Monsoura	27,482
El Luxor	43,000
Ber Ni Sawhaf	16,970
El Marya	57,664
Assiut	75,940
Soheg	159,230
Kuea	<u>132,582</u>
TOTAL	686,652

Source: Ministry of Irrigation, Mechanical Division.

TABLE 37

AREA DISTRIBUTION BY IRRIGATION CATEGORY IN
BENI SUEF, MINIA, ASSIUT, SOHAG, QENA

<u>Type of Irrigation</u>	<u>Area (fd)</u>	<u>Percent</u>
Gravity	133,907	14
Low lift diesel pumps	666,574	69
High lift diesel pumps	54,201	5
Animal-powered water wheels	<u>114,360</u>	<u>12</u>
TOTAL	969,042	100

Source: "A Technical and Economic Feasibility of Electrifying Tertiary Pumping Means in Middle and Upper Egypt," Louis Berger, 1978.

On the basis of 2 gallons/pump/day, total annual consumption is estimated to be around 100,000 tonnes of diesel fuel.

Current government policy is to recover all old lands by 1985. Current programs for drainage are as follows:

(in feddans)	<u>Irrigated Areas</u>	<u>Priority Area for drainage</u>	<u>Area drained (1970)</u>	<u>World Bank Project</u>
Lower Egypt	4,000,000	3,500,000	500,000	950,000
Upper Egypt	2,000,000	1,500,000	80,000	800,000

Source: World Bank Appraisal of Nile Delta Drainage.

The World Bank project is concerned with the drainage of almost 1 million feddans (fd) in the Nile Delta region, of which 400,000 will be drained by gravity and 600,000 will be evacuated through seven existing and four new pumping stations. The latter stations will have 14 electric driven pump units with capacities varying from 1 m³ to 5 m³ per second. In addition 800,000 fd will be involved in Upper Egypt.

An estimated total number of 2.8 million fd ultimately will be involved in the drainage program. In line with the policy of the Ministry of Irrigation, it is expected that all pumping units will be electrified by 1985. As an approximate guideline to energy use, the World Bank estimates that each fd requires 0.14 kW for drainage purposes. Assuming that pumps are operating 325 days/yr and 18 hr/day, total annual energy consumption for the drainage program is expected to be $2,293 \times 10^6$ kWh, when the full program of draining 2.8 million fd is achieved in 1985.

In addition to the development of lands in the Nile Valley and in the Delta area, a major project currently under way is the development of the New Valley, the ultimate aim of which is to bring 3 million fd into use as agricultural land by using groundwater resources. By 1975, 50,000 fd had been reclaimed, of which 20,000 fd were actually involved in production. The water table generally is not considered to be very deep and low lift pumping from artesian wells is probably used.

In order to calculate the energy required for the New Valley, a factor of 2.0 kW/fd is used. This is an estimate by the World Bank of requirements for irrigation purposes in Egypt. On this basis, total consumption in 1975 is estimated to be around 32×10^6 kWh, equivalent to about 2,500 tonnes of diesel fuel.

Therefore, total present energy consumption for pumping purposes is estimated to be:

Electricity	:	600×10^6 kWh
Diesel fuel	:	102,500 tonnes

This represents a consumption of energy equivalent to 6.8×10^{15} joules.

4.2.2 Future energy requirements: Energy requirements are considered separately for drainage and irrigation as policies will differ in each subsector in the future.

4.2.2.1 Drainage: Forecasts of future pumping capacity cannot be extrapolated from growth, and estimates of future energy requirements must be closely related to Government policies concerning the drainage of existing waterlogged lands and the creation of new lands. Drainage programs will be concentrated mainly in the Delta region and the Upper Egypt Nile Valley, particularly in respect to improvements to "old lands."

After 1985, it can be expected that drainage requirements will be drastically reduced because all the "old lands" will have been drained and also as government policies on better water management are implemented. Accordingly, for projections beyond 1985, a figure of 10 percent of 1985 usage or about 30×10^6 kWh is retained.

4.2.2.2 Irrigation: Both pumping requirements and the use of electric energy for irrigation purposes can be expected to increase for a number of reasons. The wastage of water, estimated at 5 billion m³ per year, has led to waterlogging and increasing salinity. In addition to the drainage program, the Ministry of Irrigation is combating this problem in two ways; first, they are regulating the flow of water from the barrages to match the needs of individual farmers, and second, the Ministry's policy is to lower the level of water in the canals and to force farmers to pump water out according to their own needs (an indirect way of charging for the water). At the same time, the government is encouraging a shift from the use of diesel towards the use of electricity. In fact, according to the Ministry of Irrigation, it is expected that within 5 to 7 years all pumping in Egypt will be based on electricity.

One of the major projects which will have an effect on electricity consumption for pumping is the electrification of tertiary pumping in middle and upper Egypt covering an area of almost 1 million fd (see the Louis Berger Report). According to the feasibility study for the project, it is planned to install 28,475 low lift and 835 high lift electric pumps to replace all existing animal-driven and diesel pumping units. In accordance with government policy, the program is designed to replace gravity flow of water by lift water delivery. An electrical network will be established to serve the project consisting of LT distribution lines, medium tension 11 kV lines, distribution power transformers, new or extension main transformer stations, and the necessary overhead lines. In fact, some diesel pumps are likely to be retained and an annual consumption of 50,000 tonnes of diesel is estimated for these.

In order to estimate energy requirements for irrigation purposes by farmers and co-operatives, it is proposed to take a factor of 0.2 kW/fd (as estimated by the World Bank). The total number of fd under cultivation is estimated to be 6 million. Taking into account the development of new lands both in the Nile Valley and in the New Valley, it is assumed for the purpose of calculating energy requirements that 7 million fd in total will be under cultivation by 1985 and 9 million by the year 2000. Therefore, total estimates for irrigation are:

1985: 682×10^6 kWh
 2000: 877×10^6 kWh

To this must be added the public sector pumping usage which is currently estimated at 600 million kWh. The Ministry of Irrigation is planning an additional 85 stations (an increase of 8 percent on existing capacity), and these plants are expected to be operational by 1985.

On this basis, consumption is expected to be about 660×10^6 kWh in 1985. The estimated life of pumping stations is about 25 years and very little replacement is expected by the year 2000. At the same time, the establishment of new pumping stations can be expected to slow down as the more eligible "new lands" are covered by expansion programs. Accordingly, it is assumed that an additional 100 stations will be built between 1985 and 2000, representing an added annual consumption of 60×10^6 kWh.

4.2.2.3 Total energy demand: The current and projected pattern of energy demand for irrigation and pumping is shown in table 38₁₅. Between 1985 and 2000 total demand is expected to remain around 8×10^{15} joules.

4.2.3 Energy options: There are a number of options which could improve efficiency in pumping, distributing and utilizing water resources. These are:

- (1) the use of irrigation pumps which are more efficient than conventional ones;
- (2) irrigation wells with minimum drawdown head at rated pumping capacities
- (3) better irrigation water distribution systems;
- (4) improved irrigation pump prime motor efficiency; and
- (5) energy efficient irrigation systems using systems design and optimization techniques.

TABLE 38

SUMMARY OF ENERGY REQUIREMENTS FOR
IRRIGATION AND PUMPING

	<u>CURRENT</u>	<u>1985</u>	<u>2000</u>
A. <u>ELECTRICITY</u> (10^6 kWh)			
IRRIGATION			
PUBLIC SECTOR	600	600	720
PRIVATE SECTOR	Negligible	682	877
DRAINAGE			
PUBLIC SECTOR	*	330	30
TOTAL (10^6 kWh)	600	1,672	1,627
* Included in public sector irrigation			
B. <u>DIESEL FUEL</u> (Tonnes)			
IRRIGATION			
PRIVATE SECTOR	102,500	50,000	50,000
TOTAL	102,500	50,000	50,000
C. <u>TOTAL ENERGY EQUIVALENT</u> (10^{15} joules)	6.8	8.2	8.0

Of these, the major option to be considered in this sector is the choice between electric pumps and diesel pumps for irrigation and drainage. The Louis Berger Report evaluated the alternative means of pumping including animal driven, diesel, gasoline, and electric pumps. The report concluded that, from the commercial point of view electric pumps were the most economic insofar as they had a lower capital cost, lower operating and maintenance costs, and twice the life of diesel pumps.

Animal-driven pumps are excluded from consideration as an option for the future since they are the most inefficient. At the same time, their replacement by diesel or electric pumps would enable many of the animals to be available for dairy industry.

In terms of energy usage, there is little basis for choice between diesel-operated and electric pumps. The typical operating efficiency of diesel pumps is about 20 percent, while electric pumps are estimated to have efficiencies in the range of 20 to 25 percent (based on an operating efficiency range of 22 to 28 percent for thermal power stations, with a 5 percent loss for transmission and 5 percent for motor losses). Technological developments, however, obviously could affect energy usage by either these systems.

A second option for consideration here is the use of solar energy. As yet, solar pumping has not been commercially developed. The Ministry of Irrigation is planning to install some experimental pumps for the New Valley project. If successful, these types of pumps could be in use by the year 2000.

4.3 Agricultural Mechanization

The range of agricultural equipment used in Egypt is indicated in table 39. Figures are shown for 1973, the latest year for which detailed data are available. Tractors account for virtually all the energy consumption in this sector. In 1976 it was estimated that there were 31,352 tractors in the country. However, according to the Ministry of Agriculture, between 40 percent and 45 percent of these were inoperative, and fully operational numbers are estimated to be 16,000 units. Assuming that each tractor consumes 32 barrels per year (bbl/yr), total consumption is estimated to be 512,000 bbl/year of diesel oil or approximately 70,000 tonnes.

In order to forecast future requirements, it is assumed that 4,000 tractors/ yr will be assembled locally by NASCO from the year 1980; this is 80 percent of the NASCO production target figure. Assuming further, that 10 percent of tractors become inoperative every year through lack

* This analysis excluded the cost of setting up an electrical distribution network.

TABLE 39

MECHANIZATION IN AGRICULTURE
ESTIMATES FOR 1973

A.	<u>AGRICULTURAL TRACTORS</u>	<u>QTY</u>	<u>Remarks</u>
1.	<u>Wheel Tractors</u>		
	Less than 35 hp	3,752	Produced locally by NASCO
	35-50 hp	10,739	
	50-65 hp	<u>5,907</u>	
	Total	20,393	
2.	<u>Crawler Tractors</u>		
	Less than 50 hp	1,059	All imported from Western and Eastern European Countries
	50-70 hp	4,261	
	70-100 hp	<u>214</u>	
	Total	5,534	
B.	<u>PLOWS AND CULTIVATORS</u>		
1.	Mounted culti- vators-7/9 times	8,530	Locally manufactured
2.	Trailed culti- vators-7/9 times	16,228	Locally manufactured
3.	Plow	304	Imported
4	Ridger	2,000	Locally manufactured
5.	Subsoiler	273	Imported
6.	Disc Plow	184	Imported
7.	Rotovators	205	Imported
8.	Ditchers (ridger type)	<u>118</u>	Locally produced
	Total	27,842	

TABLE 39 (continued)

C. <u>OTHER AGRICULTURAL EQUIPMENT</u>	<u>QTY</u>	<u>Remarks</u>
Cotton and corn planters	148	Imported from U.S.S.R.
Seed drills	138	Imported from East European countries
Fertilizer sprayers	221	Imported from East European countries
Fertilizer and weed cutter	258	Imported
Land leveller (firm levelling)	36	Locally produced
Spike tool harrow	514	Locally produced
Scrapers	257	Locally produced
Ditchers	235	Locally produced
Post hole digger	127	Imported
Ridger	125	Locally produced
Harvesting machine	139	GRD-USSR imported
Thrashing machine	457	Bulgaria and local
Small portable thrashing m/c	4,875	Local production
Windrower	3,000	Local production
Wheat and Barley mower	10	Imported
Pick-up baler (for hay)	81	Imported
Stationary baler	977	Imported
Corn Harvester	44	Imported
Motor corn sheller	81	Locally produced
Agriculture trailer	11,553	Locally produced
Green fodder cutter	27	Locally produced
Mower	209	Imported
Harvester	23	Imported
Corn picker	61	Imported
Fodder Cutter	33	Local production
Potato harvester	10	Imported
Nut thrasher	15	Imported
Swash rakes	20	Imported
Seed cleaner	20	Imported
Nut sheller	9	Imported
Melon seed extractor	27	Imported
Melon	14	Local production
Coke crusher	19	Local production

Source: General Engineering Dept., Ministry of Agriculture

of spare parts or through old age, an annual increase can be expected of about 3,500 tractors. This will increase the tractor fleet to 37,500 by 1985 and 90,000 by the year 2000. On this basis, the annual consumption of diesel oil by tractors can be expected to be:

Current	70,000 tons (3.2×10^{15} joules)
1985	165,000 tons (7.5×10^{15} joules)
2000	395,000 tons (17.9×10^{15} joules)

In addition, allowance should be made for other agricultural equipment. Since these are not major consumers of energy, the above estimates are increased by 5 percent to take account of them. Total energy consumption for the sector is therefore estimated to be:

Current	3.36×10^{15} joules
1985	7.95×10^{15} joules
2000	18.80×10^{15} joules

4.4 Food Processing Industries

The two main areas in the agro-industrial sector are the food processing industries and the cotton fibers industry. Cotton ginning is treated in the section on the textile industry.

4.4.1 Current energy consumption: The food processing industry consists of numerous products of which sugar, tobacco and cigarettes, oil and soap, beverages, canned products, starch and yeast, dairy products, biscuits, and essences are the major products. Production for 1975 of all products in the agro-industrial sector is shown in table 40. The industry consists of over 1,000 establishments; the sales value of the major companies is shown in (table 41). Food industries account for 31 percent of total industrial production.

Estimating energy consumption in the sector is extremely difficult due to the number of companies as well as the number of different products and processes involved. In the time allowed for carrying out the study, it was possible to visit only a sugar factory. The sugar industry is, of course, a major factor in the food processing subsector. Current production is as follows (in tonnes/yr):

TABLE 40

FOOD PROCESSING INDUSTRIES IN EGYPT

ESTIMATED PRODUCTION 1975

Tonnes (unless otherwise stated)

Cassonade (Crude Sugar)	260,842 (1974)
Castor Sugar	269,408
Refined Sugar	265,210
Molasses	253,230
Particle Board	9,381
Paper Pulp	12,055
Alcohol ('000 liters)	32,046
Dry and Fresh Yeast	6,247 (1974)
Cigarettes (Millions)	20,863
Tobacco (Cigarettes)	1,859
Molasses tobacco	3,201
Edible Oil (First Grade)	150,040
Hydrogenated Oil and Margarine	126,534
Laundry Soap	171,745
Toilet Soap	20,257
Cotton Seed Cake	461,167
Fodder	530,289
Detergents	20,606
Pasteurized Milk	41,224
Yoghurt	2,431
White Cheese	1,302
Kaskaral	557
Processed Cheese	6,257
Juices, Canned Fruit	12,629
Jams	6,412
Tomato Products	2,867
Pickles, Canned Vegetables and Meat	1,983
Canned Beans	5,335
Canned Fish	2,769
Frozen Products	1,219
Dates Products	1,602
Biscuits	8,887
Toasted Bread	1,232
Toast	1,182
Chocolate	1,392
Candy	1,496
Carmels	2,188
Halva Tahan	3,296
Soft Drinks (Cola)('000 Boxes)	16,119
Various Soft Drinks ('000 Boxes)	8,708

TABLE 40 (continued)

ESTIMATED PRODUCTION 1975

Tonnes (unless otherwise stated)

Aromatic/Flavors	410
Aromatic Paste and Essential Oils (Kilos)	5,108
Brewery Products (Hecto liters)	286
Malt	6,868
Brandy	2,000
Wines	1,810
Grapes	4,367
Rum	6,060 (1974)
Zebieb	74
Dehydrated Onions	6,095
Dehydrated Vegetables	307
Starch	18,243
Glucose	38,663
Sulfonated Alcohols	2,284
Macaroni	1,725
Crude Maize Embryo Oil	1,315
Salt	175,692
Table Salt	153,309 (1974)
Kitchen Salt	4,950

Source: General Organization for Food Industries, Ministry of Agriculture.

TABLE 41

MAJOR FOOD PROCESSING AND RELATED INDUSTRIES IN EGYPT BY SECTOR
ESTIMATED VALUE OF PRODUCTION 1975

COMPANY	VALUE OF PRODUCTION L.E. '000
VEGETABLE OILS AND SOAPS	
Egyptian Salt and Soda Company	28,263
Alexandria Company for Oils and Soap	21,824
Tant Company for Oils and Soap	13,777
Cairo Company for Oils and Soap	10,265
Mior Company for Oils and Soap	7,964
El Nil Company for Oils and Soap	9,134
Extracting Oils Company	7,749
CANNING	
Mior Company for dairy and foods	10,624
Edfina Company for canned foods	9,349
El Nasr Company for canned foods, Kaha	8,067
CONFECTIONARY	
Egyptian Company for foods, BISKOMISR	7,327
Alexandria Confectionary and Chocolate Company	6,798
BOTTLING PLANTS	
El Nasr Bottling Company	8,891
Egyptian Bottling Company	4,279
BEVERAGES	
Pyramid Beer Company	7,159
The Egyptian Grape Producers and Distillation Company	4,133 (1974)
ESSENCES	
Cairo Food Flavours and Essence Company	5,673
STARCH/DEHYDRATION	
El Nasr Company for Dehydrating Agricultural Produce	3,449
Egyptian Company for Starch and Yeast	8,127
Egyptian Company for Starch and Glucose	5,355

Source: General Organization for Food Industries, Ministry of Agriculture.

	<u>Location</u>	<u>Cane</u>	<u>Sugar</u>	<u>Wood Board</u>	<u>Paper Pulp, etc.</u>	<u>Molasses</u>	<u>Year of Establishment</u>
1.	Kom Ombo	1,000,000	110,000	15,000	X	4%	1912
2.	Edfu	800,000	90,000	X	18,000	4%	1962
3.	Ermant	800,000	90,000	X	X	4%	1969
4.	Kous	1,000,000	110,000	X	X	4%	1968
5.	Dishna	1,000,000	100,000	X	X	4%	1977
6.	Nag Hammadi	1,500,000	160,000	X	X	-	1896
7.	Abu Korkas	600,000	60,000	X	X	-	-
8.	Hawamdia	-	350,000	-	-	-	-

* Other products include alcohol, carbon dioxide gas, dry yeast, and acetic acid.

Source Egyptian Sugar and Sugar Processing Company.

From the point of view of energy consumption the most important of these plants is the one at Hawamdia which consists of a refinery and a distillery. Virtually all of the sugar plants in Egypt are self-sufficient in terms of energy insofar as they fire their boilers and provide power and steam by using bagasse and waste materials as fuel. The refinery and distillery at Hawamdia, however, draws power from the national grid. The factory has three turbines of 1.25 MW each which were installed in 1947. These are working at present at 70 percent efficiency and to be replaced soon by two new turbines of 4.5 MWe each. At present, the refinery uses 180 tons of fuel oil per day. In addition to its own power, the refinery draws 15,000 kWh from the grid every day. The distillery uses 5,000 to 7,000 kWh per day of its own power and draws a further 15,000 to 20,000 kWh from the grid. The Hawamdia generates about 160 tonnes/hr of steam for a wide range of uses. Therefore, the total current annual energy consumption is estimated to be:

Fuel oil : 59,400 tonnes

Electric power : 38×10^6 kWh

A new factory with a capacity of 1,400 tonnes of sugar/day is planned for and is expected to have an electrical load of 6.5 MWe.

In estimating energy requirements for the industry as a whole, a typical ration is estimated to be 60,000 kWh for refining 1,000 tonnes of sugar. At present production levels of almost 1 million tonnes,

annual energy consumption is estimated, therefore, to be 60 million tonne kWh. The production target for 1980 is 1,419,000 tonnes. Thus, for the future, it is expected that capacity should reach 1.5 million tonnes by 1985 and about 2.5 million tonnes by the year 2000. This represents an energy consumption of 90 million kWh by 1985 and 150 million kWh in 2000. In summary, the industry is expected to consume the following amounts of energy:

1975	0.216 (10^{15} joules)
1985	0.324
2000	0.540

In estimating energy consumption for other major agro-industries in Egypt factors are used for some of the industries based on the experience of similar industries in other developing countries. The factors are shown in table 42, and should be treated as indicative of the broad area in which consumption of energy is likely to lie and are only used to obtain a general idea of total consumption in the sector. Assuming the energy consumption for the major industries listed in table 42 represents about three-quarters of the subsector consumption, total annual energy use in the food processing industries is estimated to be about 3.0×10^{12} Btu or 3.2×10^{15} joules.

4.4.2 Discussion of options: For the food industry, energy consumption can be discussed only in general terms in view of the variety and numbers of different products. A general comment on this sector is that the majority of energy consumed is for boiler steam (see table 43).

The major impact on energy utilization would lie in the area of energy conservation rather than in the options available in switching fuels. Potentially important conservation techniques available to the food industry are listed below.

A. Waste Energy Recovery

1. Use waste heat from plant equipment (cookers, dryers, kilns, mechanical compressors).
2. Recover heat in waste service hot water.
3. Recover heating or cooling effect from ventilation exhaust air to precondition incoming ventilation air (e.g., use "heat wheel" or other heat exchanger to cross-exchange building exhaust air with make-up air).
4. Reduce building exhausts and thus make-up air or recycle air for heating, ventilation and air conditioning to maximum extent.
5. Increase regeneration in fluid heat/cooling recovery by increasing size of heat exchanger.
6. Use low temperature waste effluent to cool input streams.

B. Improved Electrical Energy Usage

1. Optimize plant power factors by (i) de-energizing excess transformer capacity and (ii) installing capacitor banks to increase power factor.
2. Optimize motor sizes and pumps with loads to improve power factor and efficiency.
3. Use more efficient light sources, i.e., convert to florescent, mercury, sodium, or high intensity direct lighting.
4. Reduce or eliminate general lighting where natural light provides sufficient illumination. Limit higher lighting levels to task areas only.
5. Reduce general illumination to minimum necessary for safety.
6. Reduce exterior buildings and grounds illumination to minimum necessary for safety.
7. Consider replacing electric motors with back pressure steam turbines and use exhaust steam for process heat.
8. Use multiple capacity compressors for refrigeration.

C. Increased Boiler and Steam Efficiency

1. Minimize boiler blowdown.
2. Use better feedwater treatment to reduce blowdown need.
3. Recover heat from hot blowdown.
4. Return more steam condensate to boiler.
5. Use flue gas heat to preheat boiler feedwater and combustion air.
6. Use waste heat from hot flue gases to generate low pressure steam or hot water.
7. Reduce combustion air flow to optimum and improve combustion control capability.
8. Install and repair steam traps.
9. Descale boiler tubes more frequently.
10. Insert turbulators or spinners in boilers to increase heat transfer to water.
11. Improve oil atomization (use compressed air rather than steam).
12. Better maintenance of burners and injection systems.
13. Minimize use of standby boilers or boilers operating at low power.

D. Use of Insulation

1. Insulate steam and condensate lines.
2. Upgrade insulation and linings in furnaces, boilers, kilns, ovens, cookers, and other process equipment.
3. Insulate walls, ceilings, and roofs.

E. Refrigeration and Space Conditioning

1. Maintain space temperature lower during the winter season and higher during the summer season.
2. Air condition only space in use.
3. Reduce air conditioning load by evaporating water from roof.
4. Shut down air conditioning during non-working hours.
5. Reduce heating level when building is not in use.

6. Use process waste heat for space heating.
7. Use double doors or curtains between heated and cooled areas.
8. Install air seals around truck loading dock doors.
9. Keep loading dock door closed when not in use.

F. Dryers, Evaporators, and Other Process Equipment

1. Improve evaporator efficiency by installing additional effects.
2. Use mechanical vapor recompression in evaporation process.
3. Use ring dryers rather than straight through dryers.
4. Use larger screw and pneumatic presses to dewater product before drying.
5. Improve maintenance on heat transfer surfaces.
6. Eliminate after burners by installing other pollution control equipment.
7. Minimize air intrusion into ovens for use of air fans.
8. Match air compressors to actual requirements.
9. Use microwave drying and cooking to eliminate long steam heating times.
10. Install agitators in vacuum pan of evaporators to improve heat transfer.

G. General Energy Management

1. Salvage and re-use process waste.
2. Use optimum sized equipment.
3. Use most efficient equipment at its maximum capacity and less efficient equipment only when necessary.
4. Minimize operation of equipment required to be maintained in standby condition.
5. Shutdown process heating equipment when not in use, or at least reduce temperature of process heating equipment when on standby.
6. Reduce operating time of equipment to that actually required.
7. Use a small number of high output units instead of many small inefficient units.
8. Clean or replace filters regularly.
9. Convert from batch to continuous operation.
10. Convert from indirect to direct firing (e.g., ovens).
11. Convert liquid heaters from underfiring to immersion or submer-sion heating.
12. Replace steam use by high temperature water to eliminate steam losses.

4.4.3 Future energy requirements: Tentative projects proposed in the current National Plan are shown in table 44. Projects likely to be important energy users are associated with the sugar industry, soap production, canning, soft drinks bottling, and the new beer plant. Major emphasis also is being placed on the poultry industry.

TABLE 42

ESTIMATED ENERGY CONSUMPTION IN MAJOR FOOD PROCESSING INDUSTRIES

INDUSTRY	ENERGY CONSUMPTION PER TONNE (Million Btu's)			ESTIMATED 1975 PRODUCTION (TONNES)	TOTAL ENERGY CONSUMPTION (10 ¹² Btu's)
	Fuel	Electricity	Total		
Edible Oils	7.04	1.07	8.11	150,000	1.217
Hydrogenated Oils	4.97	0.38	5.35	126,500	0.677
Dairy Products					
- Milk	1.59	0.34	1.93	41,200	0.080
- Cheese	12.22	1.12	13.34	8,000	0.107
Canned Foods (Fruit and Veg.)	4.62	0.42	5.04	30,000	0.151
TOTAL					2.23 x 10 ¹² Btu's

TABLE 43

PERCENTAGE OF ENERGY TYPICALLY CONSUMED FOR BOILER STEAM
IN THE FOOD PROCESSING INDUSTRY

<u>Industry</u>	<u>Percent</u>
Brewing	81
Food Canning	82
Fluid Milk	69
Cane Sugar	75
Cooking Oils	92
Soft Drinks	67
Poultry and Egg Processing	67

Source: FEA "Target" Documents

TABLE 44

TENTATIVE NEW PROJECTS IN THE AGRO-INDUSTRIAL SECTOR
IN THE FIVE-YEAR PLAN
1976 - 1980

PROJECT	SITE	ANNUAL PRODUCTION		
		UNIT	QTY.	VALUE
1. Baliana Sugar Plant and Refinery	Baliana	1,000 ton	150 Sugar 67 Molasses	24,390
2. Tugs for Nile Transport	Kom-Ombo		- Services -	
3. Land Reclamation of Wadi El Charbet	Kom-Ombo		- Services -	
4. Armant Railway (Narrow Gauge)			- Services -	
5. Soap Continuous Production		TON	456,000	17,664
6. Units for Hydrogenation of Edible Oil		1,000 TON		17,609
7. Replacement and Extension of Animal Fodder Plants		"	150	15,000
8. One Unit for Sulfonation		"	20	8,000
9. Units for Bottling Edible Oil in P.V.C.		Ton	- Services -	
10. Glucose Plant		1,000	60	9,000
11. Yeast Plant	Alexandria	1,000 Ton	11	2,600
12. Extension of Canning Food at Edfina Co.	"	"	10	4,400
13. Extension of Canned Food at Kaha Co.		"	6	2,500
14. Production of Agar-Agar	Alexandria	Tons	330	147
15. 9 Prod. lines for soft drinks (MISR Co.)		Mln Box	27	13,500
16. 7 prod. lines for soft drinks (MISR Co.)		Mln Box	21	10,500
17. New Beer Plant	Suhag	HK Lit.	100,000	2,400
18. New Malt Plant	Alexandria	1,000 Ton	9	1,260
19. Extension of MISR Dairy Co.	Ismailia Cairo	"	9	3,600
20. Extension for the Egyptian Food Co. (Bisco MISR)	Cairo			6,500
21. Extension for the Alexandria Confectionery and Chocolate Co.	Alexandria	Ton		8,500
22. Extension for Cairo Food Flavours and Essence Co.	Giza	1,000	3.6	15,000

The sugar industry is presently largely self-sufficient in generating its own power through burning bagasse as a fuel in its boilers. Experience in other countries, such as Peru, indicates that it is technically feasible to use bagasse as a raw material for the manufacturing of paper pulp as well for fuel purposes. Most sugar plants in Egypt do manufacture particle board from waste products, and the plant at Edfu has a paper pulp line. Also a new unit for manufacturing newsprint from bagasse is planned there. Should all the bagasse in the industry be used for this purpose, there would be an added demand for energy from conventional sources.

Where other agricultural residues are concerned, the MISR Chemical Works has considered the possibility of using materials such as low quality cotton, "gaswarina," eucalyptus pine needles, rice straw, and bagasse for rayon and viscose manufacture. These have, however, been rejected on technical and economic grounds.

In order to predict future requirements, it is assumed that the subsector will grow at an annual rate of 5 percent until 1985 and thereafter at 2.5 percent/yr. The general strategy for the 1978-1982 Plan presupposes a rate of growth of 9 percent to 11 percent/yr for industry but only 3.5 percent/yr for the agriculture sector. However, much emphasis is being placed on food processing industries and a rate of 5 percent would seem more appropriate. After 1985 the rate of growth is expected to drop as the more obvious opportunities probably will have been exploited by then. Applying the above-mentioned rates of growth, energy consumption is forecast as follows:

1975	3.2×10^{15} joules
1985	5.2
2000	8.7

4.4.4 Potential energy savings: In order to estimate the possible savings in energy in food processing industries by the adoption of the techniques described above, it is assumed that the proposed energy improvement goals which have been recommended for this sector in the U.S. for the year 1980 should be achieved in Egypt for the year 2000. These rates vary from between 7 percent for corn milling to 19 percent for chocolate production. The average improvement suggested for the sector is 14 percent. Assuming an improvement in energy usage of 4 percent before 1985 and 10 percent between 1985 and 2000, potential annual savings in the sector could be 0.08×10^{15} joules and 0.35×10^{15} joules for the two periods, respectively. Typically, the industry in the U.S. uses 15 percent electricity and 85 percent other fuels, and this ratio could be applied to Egypt.

4.5 Energy Requirements in the Agricultural Sector

Estimated present and future energy consumption in the agricultural sector is shown in table 45. Agricultural equipment which presently accounts for only 25 percent of consumption is expected to increase its share to over 50 percent by the year 2000, a reflection of the present low level of mechanization.

TABLE 45
ESTIMATED ENERGY CONSUMPTION IN THE AGRICULTURAL SECTOR
(10^{15} Joules)

	<u>Current</u>	<u>1985</u>	<u>2000</u>
1. Irrigation and Pumping	6.8	8.2	8.0
2. Agricultural Equipment	3.4	7.9	18.8
3. Food Processing Industries	3.2	5.2	8.7
	<hr/>	<hr/>	<hr/>
TOTAL	13.4	21.3	35.5
	<hr/>	<hr/>	<hr/>

5.0 APPENDIX - LIST OF DATA SOURCES AND REFERENCES

The following list of data sources and references covers the major sources of information presented in this study of specific Egyptian industrial and agricultural subsectors. In particular, Dr. Maksoud and Eng. El Amin of GOFI provided invaluable assistance in arranging interviews and plant visits, and thus, in gathering the necessary information for a broad range of topics and industries.

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5. "Energy Use Patterns in Metallurgical and Non-Metallic Mineral Processing," U.S. Bureau of Mines Open Report 80-75.
6. Gordian Associates Inc., "Industrial International Data Base: The Plastics Industry," NATO/CCMS No. 58, 1977.
7. U.S. Federal Energy Administration, "Draft Target Support Document on Developing a Maximum Energy Efficiency Improvement Target for SIC 28: Chemical and Allied Products," July 1, 1976 (including Appendices, Revisions, and Addenda).
8. Gordian Consulting Services Ltd., "Data Base," study for Metra Consulting, 1978.
9. Gordian Associates Inc., study for the First Boston Corporation, New York, 1977.

Fertilizers

1. Discussions with Dr. Salah Rashidy, Chairman of the Chemical Industries Sector, Ministry of Industry.
2. Discussions with Dr. El-Hami, Chemical Industries Sector, Ministry of Industry.
3. Discussions with Mr. Saki Aglan, National Fertilizer Plan, Helwan.
4. Discussions with Mr. Said Gad and Eng. Okaal of the Kima Fertilizer Company, Aswan.
5. World Bank Report No. 456-UAR.
6. U.S. Federal Energy Administration, "Draft Target Support Document on Developing a Maximum Energy Efficiency Improvement Target for SIC 28: Chemical and Allied Products," July 1, 1976 (including Appendices, Revisions, and Addenda).
7. Gordian Consulting Services Ltd., in-house data on ammonia and fertilizer production.

Petrochemicals

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2. Discussions with Eng. Abdulghani Hassan, Mechanical Division, Ministry of Agriculture, Cairo.
3. Discussions with Eng. Sarwhat Fahmy, Ministry of Irrigation.
4. Discussions with Eng. Adel Hussein Ezzy, Technical Consultant, Ministry of Agriculture and Land Reclamation, Cairo.
5. Discussions with Mr. Abdeen Aly, Chairman, Higher Council for Food-stuffs Industries, Cairo.
6. Discussions with Dr. H.A. El Tobgy, Undersecretary of State, Ministry of Agriculture, Giza.
7. Discussions with Mr. Abd-El-Megid El-Ghaish, General Manager, Egyptian Company for Sugar and Sugar Refining, Hawamdia.
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RESIDENTIAL/COMMERCIAL

BY

RESOURCE PLANNING ASSOCIATES

U.S. - EGYPT COOPERATIVE ENERGY ASSESSMENT

SEPTEMBER, 1978

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1.0 SUMMARY

As part of the U.S.-Egypt Cooperative Energy Assessment effort, this annex quantifies by fuel type and by utilizing device the energy consumed by Egyptian residential, commercial, and community sectors in 1975, and forecasts these quantities for the years 1985 and 2000. As such, it is a picture of the lifestyle of the Egyptian population in energy terms today; and it is an attempt to show how that energy lifestyle will change with increases in urbanization, electrification, and the standard of living.

This annex proposes several options for improving Egypt's energy equation. The options include the use of more energy-efficient appliances and the replacement of energy devices using scarce fuels with others using readily available or renewable forms of energy. First-order quantifications of the benefits of these options are provided; the quantifications are to be evaluated by the Integration Team of Egyptian and American specialists in light of their knowledge of relevant supply and technical, economic, social, and political factors. Assuming consensus on the validity of these quantities, it is now the task of the team supply specialists - especially those dealing with electricity, natural gas, kerosene, and solar energy - to evaluate the feasibility and economics of implementing these options, and that of the developmental specialists to evaluate their political and social implications.

2.0 PRESENT AND PROJECTED USE OF ENERGY IN THE RESIDENTIAL/COMMERCIAL/COMMUNITY SECTORS

The residential building sector comprises all Egyptian dwellings, both urban and rural. The commercial sector is a large miscellany comprising all buildings not in the residential or industrial sectors, e.g., offices, shops, bazaars, mosques, theaters, hospitals, and hotels. Community systems include street lighting, water supply, and sewage and solid-waste treatment and disposal systems.

In the United States, residential and commercial energy usage patterns differ significantly from each other because they are dominated by built-in space conditioning systems. These systems vary with building type, location, age, size, and use. On the other hand, the Egyptian climate, the temperature-moderating effects of the thick masonry wall architecture of Egypt, and the costliness of Western space conditioning technology have combined to make space heating and cooling in both residential and commercial buildings rare throughout the country. Fixed central systems are virtually nonexistent, thus obviating the major differences that exist between these sectors in the U.S.

The relatively small scale of space conditioning and lighting appliance production dictates that the few standard models produced in Egypt be used in both types of buildings: air conditioner/compressor

units found in offices are the same as those in homes, and personal observation has revealed no difference between the lighting fixtures, fans, and elevators used in homes, shops, and office buildings. The easily replaceable, non-fixed nature of these devices also means that little distinction exists between devices found in old and new buildings. Accordingly, it has been assumed that the energy-utilizing devices examined in the Egyptian residential sector are the same as those in the commercial sector, although utilization proportions differ.

It has also been assumed that new and old buildings have the same energy usage patterns and efficiencies, and that the degree of climatic difference from one part of the country to another is small enough to preclude energy use differences by region. According to economist and city planner Karema Korayem, the new cities and settlements proposed for Egypt are not planned to provide any energy-using amenities in residential and commercial buildings that are not common in existing urban areas.

The main fuels used in the residential sector are electricity (primarily for lights, televisions, refrigerators, and space conditioning), butagas (for cooking and water heating and some space heating), and kerosene (for cooking and lighting). The commercial sector uses electricity (for lighting and space conditioning) and kerosene (for lighting); and the community services sector uses electricity (for water pumping and street lighting). It is recognized that, strictly speaking, electricity is not a fuel in the same sense as butagas and kerosene; for the purposes of this discussion, however, all three types of energy are considered as fuels. As Egypt approaches the twenty-first century, its use of energy in the three sectors is expected to increase dramatically. Table 1 shows Egyptian energy use in these sectors in 1975 by fuel and by energy utilizing device. This table also forecasts these values for the years 1985 and 2000. The method by which these values were derived is described in the attachment to this annex.

3.0 OPTIONS FOR IMPROVING ENERGY BALANCE

There are two general areas in which the Egyptian energy balance can be improved. The first involves the use of more efficient appliances in households. The second concentrates on substituting abundant fuels for scarce ones in various residential and commercial activities.

3.1 Conservation and Efficiency Improvement Options

Most energy conserving options proposed for U.S. residential and commercial buildings are directed at their space heating and cooling systems and thus are not relevant to Egypt. Because per-capita use of energy for other purposes, such as lighting, is at the subsistence level (less than 100 kWh total annual electricity usage per person in electrified areas, for example) and because of the people's acute awareness of energy costs, no means of reducing fuel use by existing appliances was

TABLE 1
FUEL CONSUMPTION BY UTILIZING DEVICE

	1975	1985	2000
<u>ELECTRICITY</u> (10^6 kWh)			
<u>Residential</u>			
Ovens	0	100	763
Lighting	853	2006	5310
Water heating	0	315	2639
Refrigerators	261	750	2957
Air conditioners	24	157	1049
Fans	46	98	277
TV	453	1371	3288
Iron	46	165	869
Washing	3	18	162
Vacuum	11	30	137
Dishwasher	0	29	332
Miscellaneous	0	95	476
<u>Commercial</u>			
Air conditioners	80	523	3493
Fans	153	326	921
Lighting	898	2574	7759
<u>Community Systems</u>			
Street lighting	98	227	598
Water pumping	449	1287	5386

BUTAGAS (10^3 M.T.)

<u>Residential</u>			
Stove-cooking	175	391	875
Water heater	19	113	419
Stove-water heating	29	64	94
Space heating	1	8	30

KEROSENE (10^3 M.T.)

<u>Residential</u>			
Stove-cooking	611	799	910
Lighting	570	530	443
Stove-water heating	107	204	281

KEROSENE (10^3 M.T.)

<u>Commercial</u>			
Lighting	143	132	111

NONCOMMERCIAL FUELS (10^{15} J)
output

<u>Residential</u>			
Cooking (non-baking)	14	7	2
Baking	49	58	76

found applicable. Furthermore, architectural design and town planning in Egypt employ siting and materials well-suited to the climate. The butagas and kerosene cooking, heating, and lighting devices used by residential and commercial sectors are extremely simple devices common throughout the world and have high efficiency levels (70-80 percent) that cannot be significantly improved.

However, three options for efficiency improvement that will result in significant energy savings are the use of lighting reflectors, conversion to fluorescent lighting, and increased television transistorization. The savings are shown in table 2 and the calculations from which they are derived are shown in the attachment.

3.2 Lighting Reflectors

Personal observation has revealed that a great number of people string lightbulbs from the ceiling without any kind of reflector or light concentrator. Simple foil reflectors, probably costing 10 piasters or less, attached to low wattage bulbs provide task illumination levels equivalent to the bare, higher wattage bulbs. If one-fifth of the residential illumination in Egypt is provided by such bare bulbs, and if reflectors could lower their energy requirements by 20 percent, then 2 percent of the electricity used by households could be saved. Greater availability of reflectors through lightbulb distribution channels could probably achieve most of these savings.

3.3 Fluorescent Lighting

The quality and color of fluorescent illumination are apparently more acceptable to Egyptians than to Americans for use in the home, and many Egyptians have realized significant electricity savings by putting fluorescent lighting in every room of their homes. Subsidy of electrical fixtures would probably be necessary to accomplish this measure on a large scale, and the trade-off between fixture and operating costs would have to be reviewed.

3.4 Television Transistorization

Because of the magnitude of electricity consumption by television sets in Egyptian homes, improvement of TV energy efficiency through greater use of solid-state circuitry could result in significant energy savings. For example, the Egyptian Government Organization for Industry describes TV sets produced in Egypt today as requiring 100 watts for black-and-white models and 250 watts for color models. However, it is common to find sets produced in other countries using half or even one-third as much power as this. Using such televisions could reduce residential energy consumption by 13 percent today. A start toward achieving these savings could be made by reviewing product design economics with the ministry controlling TV-set manufacturing. Since televisions have an expected lifetime of less than ten years, all of the 1985 and 2000 savings shown can be achieved if the design is changed immediately.

TABLE 2

OPTIONS FOR IMPROVING EGYPTIAN ENERGY BALANCES: 1985 AND 2000

Option Name	Level	% of Sector Use of that			% of Sector Use of that		
		Fuel Saved 1985	Fuel Saved 1985	Fuel Substitute Needed	Fuel Saved 2000	Fuel Saved 2000	Fuel Substitute Needed
1) Light reflectors	1-5	85x10 ⁶ kWh	2%	-	212x10 ⁶ kWh	1%	-
2) Fluorescent lighting	1-5	584x10 ⁶ kWh	(total 7% res/comm.)	-	1,666x10 ⁶ kWh	5 1/2% (total res/comm.)	-
3) TV transistori- zation	1-5	685x10 ⁶ kWh	13% res.		1,800x10 ⁶ kWh	10% res.	-
4) Solar water heating (for both bathing and cooking)	1	7x10 ⁶ kWh	see	-	144x10 ⁶ kWh	see	-
		7x10 ³ MT buta.	note 1	-	57x10 ³ MT buta	note 2	-
		5x10 ³ MT kero.		-	10x10 ³ MT kero		-
	2	67x10 ⁶ kWh	"	-	799x10 ⁶ kWh	"	-
		65x10 ³ kWh buta.		-	318x10 ³ MT buta.		-
		49x10 ³ MT kero.		-	56x10 ³ MT kero.		-
	3	241x10 ⁶ kWh	"	-	964x10 ⁶ kWh	"	-
		247x10 ³ MT buta.		-	384x10 ³ MT buta.		-
		173x10 ³ MT kero.		-	68x10 ³ MT kero.		-
	4	7x10 ³ MT buta.	"	-	68x10 ³ MT buta.	"	-
		59x10 ³ Mt kero.		-	215x10 ³ MT kero.		-
	5	42x10 ³ MT buta.	"	-	123x10 ³ MT buta.	"	-

TABLE 2 (CONTINUED)

Option Name	Level	Fuel Saved 1985	% of Sector Use of that Fuel Saved 1985	Fuel Substitute Needed	Fuel Saved 2000	% of Sector Use of that Fuel Saved 2000	Fuel Substitute Needed
5) Natural gas for cooking	1	9x10 ⁶ kWh 11x10 ³ MT buta. 8x10 ³ MT kero.	see note 3	21x 10 ⁶ m ³ nat.gas.	202x10 ⁶ kWh 85x10 ³ MT buta. 17x10 ³ MT kero.	see note 4	140x10 ⁶ m ³ nat. gas.
	2	88x10 ⁶ kWh 99x10 ³ MT buta. 80x10 ³ MT kero.	"	213x 10 ⁶ m ³ nat. gas.	1,119x10 ⁶ kWh 474x10 ³ MT buta. 88x10 ³ MT kero.	"	785x10 ⁶ m ³ nat. gas
	3	318x10 ⁶ kWh 381x10 ³ MT buta. 283x10 ³ MT kero.	"	788x 10 ⁶ m ³ nat.gas.	1,350x10 ⁶ kWh 572x10 ³ MT buta. 10 x10 ³ MT kero.	"	949x10 ⁶ m ³ nat. gas
6) Kerosene for water heating	1	3x10 ³ MT buta.	27% of buta.	171 x 10 ³ MT kero.	31x10 ³ MT buta. 174x10 ³ MT buta.	29% of buta.	460x10 ³ MT kero.
	2	33x10 ³ MT buta.					
	3	119x10 ³ MT buta.	"		209x10 ³ MT buta.	"	
	4	3x10 ³ MT buta.	4% of	23x	35x10 ³ MT buta.	7% of	110x10 ³ MT
	5	18x10 ³ MT buta.	buta.	10 ³ MT	64x10 ³ MT buta.	buta.	kero.

Note 1: Residential use savings are 64% for butagas, 40% for kerosene, and 6% for electricity.

Note 2: Residential use savings are 67% for butagas, 45% for kerosene, and 13% for electricity.

Note 3: Residential use savings are 86% for butagas, 29% for kerosene, and 8% for electricity.

Note 4: Residential use savings are 80% for butagas, 13% for kerosene, and 14% for electricity.

3.5 Fuel Substitution Options

Virtually all of the electricity supplied to these sectors is used to power equipment for which no other energy source is either possible or desirable, e.g., televisions and lighting. It is possible that electricity for such purposes could be generated through alternative means, such as using wind power to generate electricity for Red Sea coastal residences, or solar energy to provide electricity for municipal water pumping. However, since the end-use devices remain unchanged in these cases and are still powered directly by electricity, the description and quantification of these options are being accomplished by the electricity and solar specialists of the supply team.

Cooking and water heating are the chief functions where direct fuel substitution possibilities exist. Options for such substitutions often entail the replacement of self-contained portable devices using a scarce fuel (e.g. a butagas stove) with devices using abundant or replenishable fuels but requiring significant expenditures on fixed building systems (e.g. natural gas piping or solar energy rooftop collectors for heating water). Because of the large capital expenditures associated with such options, government programs would be needed for their implementation.

For planning purposes, the dwellings of Egypt could be separated into five categories according to the relative ease of deploying fuel substitution options:

Level one is the deployment of options only in the five new cities to be built in the next twenty-five years. Since construction has barely started and since the government has complete control over this city building process, this is the easiest level of deployment.

Level two is the deployment of options to all new urban construction outside of the new towns.

Level three is the retrofitting of existing urban dwellings.

Level four is the deployment of options on all new rural construction.

Level five is the retrofitting of existing rural dwellings.

Although not included here, an assessment needs to be made to examine the political and social aspects of the implementation effort at each of these levels, as well as the degree to which people living in each type of dwelling can be expected to adopt the various options.

3.6 Butagas Options

Although it is the task of the Integration Team to identify fuel "gaps" through their supply and demand analyses, it is nonetheless clear, even at this stage, that significant problems in meeting butagas demand already exist and will intensify.

The low butane content of Egyptian petroleum has forced the country to import three-quarters of its liquid butane. Assuming that the 224,000 metric tons of butagas consumed in Egyptian residences in 1975 represent all butagas usage in Egypt, and assuming an import cost of LE 1.75 per 10 kg, these imports amount to US \$57 million in scarce foreign exchange. Furthermore, the government subsidy of LE 1.10 per 10-kg bottle currently costs the government LE 36 million. Egypt plans to meet 70 percent of its butagas needs by the year 2000 internally, producing 992,000 metric tons in that year versus the 56,000 metric tons produced in 1975 (25 percent of 1975 usage). The accomplishment of this eighteen-fold increase in production may be extremely difficult. Thus, there is the real possibility that the six-fold increase in consumption predicted between now and 2000 will mean a sextupling of the adverse impact of 1975 butagas imports on the foreign exchange deficit unless substitution options are implemented. In addition, the critical shortage of butagas container bottles and the unfavorable economics of expanding distribution to rural areas will also have to be addressed.

3.7 Solar Water Heating

Theoretically, solar water heating could replace virtually all electric, butagas, and kerosene water heating, since even at Cairo's population densities the solar collectors would not require more than 20 percent of the roofspace, according to team solar expert Peter Teagan. Water pipes in Egypt generally run along the buildings' exteriors, even in high-rise construction, thus minimizing problems of retrofitting.

In addition, while team solar specialists have little enthusiasm for so-called "solar cookers," there may be a large potential for solar application to cooking due to the nature of the Egyptian diet. Most foods in Egypt are prepared in water that is brought to a boil and then simmered for a short time. Using water first heated to 160°F in a solar device rather than starting with water at ambient temperature, Teagan feels that cooking fuel requirements could be reduced by half.

Because most solar technology hardware can be manufactured in Egypt, all solar options have the benefit of using Egyptian labor (whose shadow price, considering the degree of underemployment, is negligible) to manufacture solar devices to replace butagas (which would reduce imports) or to replace kerosene or electricity (which would enable Egypt to export more of its oil production). The quantities of butagas, kerosene, and electricity that could be saved in heating water for washing and cooking are shown in table 2. Any of these substitutions improves Egypt's balance of payments as well as improving the employment situation. The cost of the solar collectors could be amortized by the consumer at a rate equal to his current butagas or kerosene expense. The Egyptians may have their own way of evaluating the trade-offs between the one-time expenditure on solar materials and labor costs versus the ongoing costs for importing, subsidizing, bottling, and distributing butagas.

3.8 Natural Gas for Cooking, Water Heating, and Space Conditioning

This option is considered independent of solar; and its deployment is deemed practical in urban areas only. Trade-offs of fuel quantities for different levels of implementation and for different functions are shown in table 2. Natural gas is currently burned at the wellhead when it is released during oil drilling. Because of this wasteful procedure its shadow price is negligible, as is that of labor. Consequently the main economic trade-off is the present cost of piping materials versus the continuing future cost of importing, subsidizing, and distributing butagas and kerosene.

3.9 Kerosene for Water Heating

For safety, health, and cleanliness reasons, it is doubtful that a family using butagas would willingly go back to using kerosene for cooking, but it may be possible to reintroduce kerosene as a fuel for heating bath and wash water. This option entails none of the construction activity of the previous two options, and could be fostered by tilting the balance of kerosene and butagas subsidies slightly more in favor of kerosene; fuel quantity trade-offs are shown in table 2. While this substitution decreases butagas imports, it also decreases Egypt's ability to export kerosene. Nevertheless, it will have a positive impact because butagas foreign shipping costs are saved as well as the high costs of manufacturing the heavy, bulky butagas bottles and continually transporting them back and forth for refilling every three weeks.

4.0 ATTACHMENT: METHODOLOGY FOR QUANTIFYING ENERGY CONSUMPTION IN EGYPT AND THE BENEFITS TO BE OBTAINED FROM IMPLEMENTING ENERGY OPTIONS

Developing the data on current and forecasted energy consumption in Egypt and quantifying the benefits of energy-use options were two very different tasks. The first primarily involved in-country research and the creation of an algorithm for generating the required information. The second task was a straightforward analysis of consumption data. This attachment describes and documents the methodology of these two phases of the work.

4.1 Researching and Quantifying Consumption

It should be noted that every other sector from which data was gathered for this assessment -- e.g. industry, transportation, oil and gas, and hydroelectric -- has a well-defined counterpart in the Egyptian government to use as primary contact and data source. However, because there is no organization in the Egyptian government focused on the residential and commercial sector or collecting energy-use data for this sector, data used to build this picture had to be drawn indirectly from a large number of ministries and directorates. A methodology had to be created to translate information available from these sources into an accurate statistical picture of the residential/commercial sector.

Because the data base inputs came from many sources (the Egyptian Five-Year Plan document, the Ministry of Housing and Reconstruction, the Government Office for Industry, the Institute of National Planning, the Cairo academic community, and personal observation), they are prone to inconsistencies arising from the independence of these sources. Some inconsistencies could not be resolved because of prohibitions against speaking with primary information sources, such as the Ministry of Petroleum and the Census Bureau. It is therefore an important function of this annex to describe in detail the techniques and calculations used to generate fuel usage quantities, to document the assumptions behind these calculations, and to highlight the areas where inconsistencies exist. The Integration Team of Egyptian and American specialists can then examine and resolve these inconsistencies to correct any errors in the energy profile shown in table 1.

One mechanism used to check the calculations shown in this attachment was to compare them with macro-level aggregated forecasts for fuel use provided by the Egyptian Institute of National Planning (INP). If the aggregated INP figures and trends were radically different from those developed according to the disaggregated approach described in this attachment, the calculations were presented to INP in the hope of revealing the basis for the discrepancy. Because these discussions sometimes did not uncover the cause of the discrepancies, the values generated in this attachment were used for the options analysis. However, both sets of values are presented here so that their inconsistency can be resolved in future interactions with the Egyptians.

4.1.1 Assessing and Forecasting Residential Consumption: Data used to generate the residential energy profile include national population statistics and forecasts, household size, urban/rural population mix, the proportion of urban and rural homes that have various energy-using appliances, and the amount of use these appliances typically receive. The number of households for 1985 and 2000 have been calculated using data from the 1978-1982 Egyptian Five-Year Plan, Volume II, as has the urban-rural mix, as shown in exhibit 1. The household size figures come from Preliminary Results of the Central Population and Housing Census - 1976. Electrical saturation in this exhibit has been obtained from the Ministry of Housing and Reconstruction.

Two conflicts between data sources are noted in this exhibit. First, the exhibit shows a 50/50 split between rural and urban populations in the year 2000, which conflicts with the opinions of many officials interviewed who felt a 64/36 urban/rural split would be more likely in 2000. (Urban is defined as a settlement size of more than 20,000 people). This 64/36 split keeps rural population density at its current level, whereas the 50/50 split either increases the density of population on already crowded agricultural land by more than 50 percent, or possibly assumes a constant population density, but a more than 50 percent increase in the amount of agricultural land available through desert reclamation projects. Since urban and rural energy usage patterns are significantly different and are expected to continue to be so, the urban/rural split is a key assumption and should be reviewed. The second conflict is that the exhibit shows 50 percent rural electrification by the year 2000, whereas the INP felt that 100 percent would be attained. Again, this assumption significantly alters forecasts and should be as accurate as possible.

Exhibit 2-a shows current and forecasted saturations of energy utilizing devices in Egyptian urban and rural homes. Saturation refers to the percentage of households owning and using a device; for instance, 60 percent of urban families used butagas (butane) stoves for cooking in 1975, while 70 percent are expected to do so in 1985 and 75 percent in 2000. Only 5 percent of rural families, on the other hand, used such stoves in 1975, but this is expected to rise to 20 percent by 2000.

The basis for change in the saturation of a particular appliance is the change in total national disposable income, its distribution, and its relation to appliance cost, personal values, and lifestyle. No attempt has been made to quantify these complex relationships, and U.S. models describing the correlation between appliance saturations and these variables were felt to be irrelevant because of the broad socio-economic differences between the two countries. Because no formal data exist in Egypt on either current or future levels of appliance ownership in Egyptian homes, the informed opinion of a roundtable discussion of officials from the Ministry of Housing and Reconstruction was used to estimate current and future saturations, assuming a quadrupling of per-capita real income by 2000. Adjustments made to their estimates after INP and other inputs are noted in exhibit 2-b.

EXHIBIT 1: EGYPTIAN DEMOGRAPHICS

	<u>1975</u>	<u>1985</u>	<u>2000</u>
Total population	38 x 10 ⁶	47 x 10 ⁶	66 x 10 ⁶
Average household size (both urban and rural)	5.2	5.2	5.2
Percent of population in urban areas	44%	46.5%	50%
Percent of population in rural areas	56%	53.5%	50%
Number of urban households	3.215 x 10 ⁶	4.203 x 10 ⁶	6.36 x 10 ⁶
Number of rural households	4.093 x 10 ⁶	4.835 x 10 ⁶	6.36 x 10 ⁶
Percent of urban households electrified (1975 from census)	77%	90%	100%
Percent of rural households electrified (1975 from census)	18%	30%	50%

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EXHIBIT 2-a: PERCENT SATURATION OF ENERGY-USING DEVICES IN EGYPTIAN RESIDENCES

		<u>1975</u>		<u>1985</u>		<u>2000</u>	
		Urban	Rural	Urban	Rural	Urban	Rural
		Percent	Percent	Percent	Percent	Percent	Percent
Cooking							
1)	Electric ovens	0	0	2	0	10	0
2)	Butagas stoves	35	2	55	8	75	20
3)	Kerosene stoves	65	43	43	68	15	75
4)	Wood/noncommercial stoves	0	55	0	24	0	5
		(100)	(100)	(100)	(100)	(100)	(100)
Lighting							
5)	Electric	77	18	90	30	100	50
6)	Kerosene	23	82	10	70	0	50
		(100)	(100)	(100)	(100)	(100)	(100)
Hot Water							
7)	Electric	0	0	5	0	20	1
8)	Butagas water heater	5	0	20	2	45	10
9)	Kerosene (on stove)	65	43	43	68	15	75
10)	Butagas (on stove)	30	2	32	6	20	9
		(100)	(45)	(100)	(76)	(100)	(95)
Refrigeration							
11)	Electric	15	1	25	5	60	15
12)	Ice box	30	5	35	10	30	20
		(45)	(6)	(60)	(15)	(90)	(35)
Space conditioning							
13)	Air conditioner/ compressor	1	0	5	0	20	2
14)	Butagas heater	1	0	5	0	10	2
15)	Fans	35	2	50	10	90	25
Others							
16)	TV	30	10	65	20	95	30
17)	Iron	10	0	25	2	70	25
18)	Washing machine	1	0	5	0	25	5
19)	Vacuum cleaner	10	0	20	0	50	10
20)	Dishwasher	0	0	2	0	15	0
21)	Blender, razor, hairdryer, etc.	-	-	-	-	-	-

EXHIBIT 2-b: NOTES ON SATURATION TABLE

- 1) Electric ovens - given at MOHR as urban 0/5/15%; reduced according to INP statement that electric cooking will be discouraged.
- 2) Butagas stoves - given at MOHR as urban 60/70/75%; rural 5/10/20%; reduced in 1975 and 1985 in order to get closer to INP's 1975 and 1985 projections.
- 3) Kerosene stoves - given at MOHR as urban 40/25/10%; increased in all years in order to make up for the reduction in butagas stoves.
- 4) Wood/noncommercial (not including rural bread baking) - a residual figure.
- 5) Lighting-electric - unchanged; equals percentage of electrification.
- 6) Lighting-kerosene - unchanged; a residual.
- 7) Electric hot water - given at MOHR as urban 0/2/5%; increased in response to INP's large jump in electricity usage for 2000.
- 8) Butagas hot water heaters - MOHR estimate: urban 30/40/80%; greatly reduced in response to personal observation and INP butagas use projections.
- 9) Kerosene water heating (on stove) - equals saturation of kerosene cooking.
- 10) Butagas (on stove) - equals butagas cooking saturation minus saturations of electric and butagas heaters.
- 11) Electric refrigeration - MOHR estimate; urban 50/90/95%; greatly reduced through personal observation and comments of Don Cole at AUC.
- 12) Ice box - from comments of Don Cole.
- 13) Air conditioner/compressor (heat pump) - given by MOHR as urban 5/20/40%; reduced on the basis of personal observation and air conditioner production statistics from GOFI.
- 14) Butagas heater - given by MOHR as urban 2/5/5%; adjusted to better fit with INP 1975 data and trends.
- 15) Fans - given by MOHR as urban 90/95/100%; reduced on the basis of personal observation.
- 16) TV - given by MOHR as urban 50/95/100%; rural 15/30/50%; urban reduced on the basis of personal observation; rural reduced similarly, in consideration of degree of rural electrification.

EXHIBIT 2-b: NOTES ON SATURATION TABLE (CONTINUED)

- 17) Iron - unchanged.
- 18) Washing machine - given by MOHR as urban 1/40/80%; reduced on the basis of saturations in U.S. and other developed countries.
- 19) Vacuum cleaners - unchanged.
- 20) Dishwasher - MOHR - urban 0/40/80%; reduced on the basis of U.S. saturation (currently 24%).

Fuel consumption rates for these appliances, as generated through discussions with officials from the Ministry of Housing and Reconstruction (MOHR), the General Office for Industry (GOFI), and the American University in Cairo (AUC) are described and noted in exhibit 3. One of the most complicated and unresolved issues is the allocation of kerosene and butagas stove fuel consumption to cooking and water heating functions, since the stove generally serves both purposes in Egyptian homes. Although people interviewed know precisely how much fuel their stoves consumed per month, no one had any idea as to how much to allocate to water heating and how much to cooking. Hence this question -- important because fuel usage for heating water increases with income while usage for cooking does not -- remains unresolved. Arbitrary assumptions have therefore been made in order to develop the framework for options analysis.

Exhibits 4, 5, and 6 draw data from the previous three exhibits and forecast the demand for electricity, butagas, and kerosene by Egyptian homes in 1975, 1985, and 2000 according to the following formula:

Total national residential fuel consumption by device A =

$$[(\text{Number of urban households}) \times (\text{percent of urban households using device A}) \times (\text{annual fuel consumption of this device in an urban household})] + [(\text{Number of rural households}) \times (\text{percent of rural households using device A}) \times (\text{annual fuel consumption of this device in a rural household})]$$

Exhibit 7 graphically disaggregates the use of each fuel by device.

It should also be noted that baking in urban areas is a commercial activity that has been examined by the Assessment Team's industrial analysts, while in rural areas it is a domestic activity carried out in dung-fueled "canoons" ovens. Because of the failure of past experiments to change the methods of rural baking, it is felt that the use of these traditional ovens will remain unchanged in rural areas through the year 2000. The estimates of their noncommercial fuel consumption have been made in exhibit 8.

As depicted in exhibit 9, there is a very high degree of fit between the forecasts derived by the U.S. Assessment Team for residential electricity consumption and those of the INP, with the INP forecasts rising slightly higher. It is clear that lighting is and will remain the most important single use of electricity by this sector; together with television and refrigeration, it accounts for more than 90 percent of current residential usage, and will still comprise 70 percent of residential usage in 2000. A miscellany of "luxury" energy using devices, such as irons, blenders, and washing machines, are expected to become a significant part of domestic energy use.

The discrepancy between the U.S. Team and the INP butagas forecasts shown in exhibit 9 could be caused by inconsistent data on usage patterns.

EXHIBIT 3: METHOD FOR CALCULATING FUEL CONSUMPTION BY APPLIANCES

- 1) Electric oven - Use U.S.A. standard consumption of 1,200 kWh/year
- 2) Butagas stove - Assume 10 kg bottle; one used every 3 weeks (according to Hosni Shaker of GOFI, El Kashif of MOHR, and Cole of AUC): 170 kg/year = 6,120 MJ/year of energy output (at 80% efficiency)
 assume 15% for hot water = 25 kg
 85% for cooking = 145 kg
- 3) Kerosene stoves - 19 liters/month total (Appendix 27 of World Bank Appraisal of a Rural Electrification Project, confirmed by interviews with users and Cynthia Nelson of Solar Village project) = 228 liters/year = 6,064 MJ/year of energy output (at 70% efficiency)
 assume 15% for hot water = 34 liters
 85% for cooking = 194 liters
- 4) Noncommercial fueled stoves - Diverse use of wood, dried dung, and crop residues. No tonnage calculated; energy value is calculated in exhibit 5.
- 5) Electric lights - Urban use 1975
 6 hours/day x 140 watts total = 300 kWh/year
 Urban-1985-estimated 50% greater = 450 kWh/year
 Urban-2000-estimated 50% greater = 675 kWh/year
 Rural-1975 6 hours/day x 70 watts total = 150 kWh/year
 Rural-1985 6 hours/day x 100 watts total = 210 kWh/year
 Rural-2000 6 hours/day x 150 watts total = 320 kWh/year
- 6) Kerosene light - Under 15 liters/month (4 U.S. gallons) = 170 liters/year (World Bank Appendix 27)
- 7) Electric hot water heater - Average U.S. consumption 3,400 kWh/year
 Assumed Egypt 1985 - 1,500 kWh
 2000 - 2,000 kWh Urban
 All years - 1,500 kWh Rural
- 8) Butagas water heater - Average 1 container/month @ 10 kg = 120 kg/year
 = 4,320 MJ/year
- 9) Kerosene water heating (see #3)

<u>Assume</u>	<u>Urban</u>	<u>Rural</u>
1975	34 liters (904 MJ)	34 liters (904 MJ)
1985	56 liters (1,500 MJ)	45 liters (1,200 MJ)
2000	75 liters (2,000 MJ)	57 liters (1,500 MJ)

- 10) Butagas stove water heating

<u>Assume</u>	<u>Urban</u>	<u>Rural</u>
1975	25 kg (900 MJ)	25 kg (900 MJ)
1985	41 kg (1,500 MJ)	33 kg (1,200 MJ)
2000	55 kg (2,000 MJ)	42 kg (1,500 MJ)

EXHIBIT 3: METHOD FOR CALCULATING FUEL CONSUMPTION BY APPLIANCES (CONTINUED)

11) Electric refrigerator - Average U.S. = 834 kWh/year

<u>Assume</u>	<u>Urban</u>	<u>Rural</u>
1975	500	500
1985	500	500
2000	650	500

12) Ice box - "Fueled" by ice delivery (produced by industrial sector) - no energy calculation.

13) Air conditioner/compressor - 2 hp = 1400 watts

Residential - 6 hours/day x 3 mo/yr = 750 kWh/yr
 2/3 cooling, 1/3 heating = 500 kWh/yr cooling
 250 kWh/yr heating
 Commercial - 5 hours/day x 6 mo/yr = 1,250 kWh/yr
 2/3 cooling, 1/3 heating = 833 kWh/yr cooling
 417 kWh/yr heating
 (250 kWh/yr @ 10.8 MJ/kWh @ 80% efficiency = 2,150 MJ/yr)

14) Butagas space heater - 2 cannisters/mo x 2 mo/yr = 40 kg/yr (1,440 MJ/yr)

15) Fans - 85 watt ceiling fan x 3 hrs/day x 6 mo/yr = 38 kWh

16) TV - Urban 1975 - 150 W x 6 hrs/day = 330 kWh (Khalil of GOFI)

1985 Assume increase due to larger TV sizes, 385 kWh
 higher proportion.
2000 of color, more 440 kWh
 hours of programming

Rural all years 330 kWh

17) Iron - U.S. standard = 144 kWh/year

18) Washing machine - U.S. standard = 85 kWh/year

19) Vacuum - U.S. standard = 36 kWh/year

20) Dishwasher - U.S. standard = 348 kWh/year

21) Miscellany (blenders, hairdryers, clocks, razors, toasters, etc.)

Urban - 1975 - Negligible
 1985 - 25 kWh/year for each electrified household
 2000 - 60 kWh/year for each electrified household

Rural - 1975 - Negligible
 1985 - Negligible
 2000 - 30 kWh/year for each electrified household

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EXHIBIT 4: CALCULATION OF RESIDENTIAL ELECTRICITY DEMAND

1975	Device	Annual Urban Consumption (kWh)	Number of Urban Households	% Urban Saturation	Total Urban Consumption (10 ⁶ kWh)	Annual Rural Consumption	Number of Rural Households	% Rural Saturation	Total Rural Consumption (10 ⁶ kWh)	Total Consumption (10 ⁶ kWh)	% of all Domestic Electricity Consumption
1)	Oven	1,200	3.215 x 10 ⁶	0	0	1,200	4.093 x 10 ⁶	0	0	0	0
5)	Lights	300		77	743	150		18	110	853	50
7)	Water	-		0	0	-		-	0	0	0
11)	Refrig.	500		15	241	500		1	20	261	15
13)	Air con.	750		1	24	750		0	0	24	1
15)	Fan	38		35	43	38		2	3	46	3
16)	TV	350		30	318	330		10	135	453	27
17)	Iron	144		10	46	144		0	0	46	3
18)	Wash.	85		1	3	85		0	0	3	
19)	Vacuum	36		10	11	36		0	0	11	1
20)	Dish.	348		0	0	348		0	0	0	
21)	Misc.	-		-	0	-		-	0	0	
TOTALS					1,429				268	1,697	100

[COMPARES WITH 1,692 FROM INP]

1985	Device	Annual Urban Consumption (kWh)	Number of Urban Households	% Urban Saturation	Total Urban Consumption (10 ⁶ kWh)	Annual Rural Consumption	Number of Rural Households	% Rural Saturation	Total Rural Consumption (10 ⁶ kWh)	Total Consumption (10 ⁶ kWh)	% of all Domestic Electricity Consumption
1)	Oven	1,200	4.203 x 10 ⁶	2	100	1,200	4.835 x 10 ⁶	0	0	100	2
5)	Lights	450		90	1,702	210		30	304	2,006	40
7)	Water	1,500		5	315	-		-	0	315	6
11)	Refrig.	500		25	630	500		5	120	750	14
13)	Air con.	750		5	157	750		0	0	157	3

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EXHIBIT 4: (CONTINUED)

Device	Annual Urban Consumption (kWh)	Number of Urban Households	% Urban Saturation	Total Urban Consumption (10 ⁶ kWh)	Annual Rural Consumption	Number of Rural Households	% Rural Saturation	Total Rural Consumption (10 ⁶ kWh)	Total Consumption (10 ⁶ kWh)	% of All Domestic Electricity Consumption
<u>1985</u>										
15) Fan	38	↑	50	80	38	↑	10	18	98	2
16) TV	385	↑	65	1,052	330	↑	20	319	1,371	26
17) Iron	144	4.203 x 10 ⁶	25	151	144	4.835 x 10 ⁶	2	14	165	3
18) Wash.	85	↑	5	18	85	↑	-	0	18	-
19) Vacuum	36	↑	20	30	36	↑	-	0	30	-
20) Dish.	348	↑	2	29	348	↑	-	0	29	3
21) Misc.	25	↑	90	95	-	↑	-	0	95	-
TOTALS		↓		4,395		↓		775	5,134	100
COMPARES WITH 4,900 FROM INP										
<u>2000</u>										
1) Oven	1,200	↑	10	763	1,200	↑	0	0	763	4
5) Lights	675	↑	100	4,293	320	↑	50	1,017	5,310	29
7) Water	2,000	↑	20	2,544	1,500	↑	1	95	2,639	14
11) Refrig.	650	6.36 x 10 ⁶	60	2,480	500	6.36 x 10 ⁶	15	477	2,957	16
13) Air con.	750	↑	20	954	750	↑	2	95	1,049	6
15) Fan	38	↑	90	217	38	↑	25	60	277	2
16) TV	440	↑	95	2,658	330	↑	30	630	3,288	18
17) Iron	144	↑	70	641	144	↑	25	228	869	5

EXHIBIT 4: (CONTINUED)

Device	Annual Urban Consumption (kWh)	Number of Urban Households % Urban Saturation	Total Urban Consumption (10 ⁶ kWh)	Annual Rural Consumption	Number of Rural Households	% Rural Saturation	Total Rural Consumption (10 ⁶ kWh)	Total Consumption (10 ⁶ kWh)	% of All Domestic Electricity Consumption
<u>2000</u>									
18) Wash.	85	↑ —	25	135	85	↑ —	5	27	162
19) Vacuum	36	6.36 x 10 ⁶	50	114	36	6.35 x 10 ⁶	23	23	137
20) Dish. PPpA	348	15	332	348	0	0	332		6
21) Misc.	60	100	<u>381</u>	30	50	<u>95</u>	<u>476</u>		—
TOTALS		↓ —	<u>15,512</u>		↓ —		<u>2,747</u>	18,259	100

COMPARES WITH 19,360 FROM INP

1975		Device	Annual Urban Consumption (kg)	Number of Urban Households	% Urban Saturation	Total Urban Consumption (10 ³ Metric tons)	Annual Rural Households	Number of Rural Households	% Rural Saturation	Total Rural Consumption (M.T. x 10 ³)	Total Consumption (M.T. x 10 ³)	% of All Domestic Consumption
2)	Stove-cooking	145	35	163	145	2	12	175	78			
8)	Water heater	120	5	19	120	0	0	19	8			
10)	Stove-water heating	25	30	27	25	2	2	29	13			
14)	Space heater	40	1	1	40	0	0	1	1			
	TOTALS			210				224	100			
1985												
2)	Stove-cooking	145	55	335	145	8	56	391	68			
8)	Water heater	120	20	101	120	2	12	113	20			
10)	Stove-water heating	41	32	55	33	6	9	64	11			
14)	Space heater	40	5	8	40	0	0	8	1			
	TOTALS			499				576	100			

← 3.215 x 10⁶

← 4.093 x 10⁶

→ 4.203 x 10⁶

→ 4.835 x 10⁶

COMPARES WITH 162 FROM INP

COMPARES WITH 484 FROM INP

EXHIBIT 5: CONTINUED

2000	Device	Annual Urban Consumption (kg)	Number of Urban Households	% Urban Saturation	Total Urban Consumption (10 ³ Metric tons)	Annual Rural Households	Number of Rural Households	% Rural Saturation	Total Rural Consumption (M.T. x 10 ³)	Total Consumption (M.T. x 10 ³)	% of All Domestic Butagas Consumption
2)	Stove-cooking	145	6.36 x 10 ⁶	75	691	145	6.36 x 10 ⁶	20	184	875	62
8)	Water heater	120		45	343	120		10	76	419	30
10)	Stove-water heating	55		20	70	42		9	24	94	7
14)	Space heater	40		10	25	40		2	5	30	2
	TOTALS				<u>1,129</u>				<u>289</u>	<u>1,418</u>	100

COMPARES WITH 1,237 FROM INP

ELECTRICITY

KEROSENE

BUTAGAS

*Calculated in exhibits 4-6.

EXHIBIT 8 CALCULATION OF THE ENERGY VALUE OF NONCOMMERCIAL FUELS

I. Cooking (excluding bread baking)

Step 1: Useful energy output of kerosene or butagas stove in 6,100 MJ/year/household (see exhibit 3, lines 2 and 3).

Step 2: 1975 - 55% of rural households cook over noncommercial fuels.
 4.093×10^6 rural households
 $6,100 \times 10^9$ J/year/household

Total energy output = 13.7×10^{15} J

Assume 25%
 efficiency input = 54.8×10^{15} J

1985 - 24% of rural households
 4.835×10^6 rural households
 6.1×10^9 J/year/household

output = 7.1×10^{15} J

input = 28.4×10^{15} J

2000 - 5% of rural household
 6.36×10^6 rural household
 6.1×10^9 J/year/household

output = 1.9×10^{15} J

input = 7.6×10^{15} J

II. Baking of Bread - Rural (urban is by industrial bakeries)

Step 1: Davidoff and Ezzatti collected bakery consumption forecasts stating that in 1975 bakeries consumed:

$0.05 \times 1.38 \times 10^{15}$	J of electricity (100% effic)	=	$.07 \times 10^{15}$	J
$0.7 \times .547 \times 10^{15}$	J of kerosene (70% effic)	=	$.27 \times 10^{15}$	J
$0.75 \times 21.05 \times 10^{15}$	J of gas/oil (70% effic)	=	11.05×10^{15}	J
$0.90 \times 42.88 \times 10^{15}$	J of mazout (10% effic)			
		=	27.01×10^{15}	J
			38.4×10^{15}	J

useful energy output

Step 2: This energy output is assumed to have produced bread requirements for the urban population in that year or 3.215×10^6 households. Per-household energy for bread baking is therefore 11.94×10^9 J/year.

EXHIBIT 8: (CONTINUED)

Step 3: Assuming that all rural bread baking is domestic, using noncommercial fuels, then rural bread baking energy requirements are:

1975 - 4.093×10^6 rural households $\times 11.94 \times 10^9$ J/year
annual requirements =

Energy output = 48.87×10^{15} J/year
At 25% efficiency, input = 198×10^{15} J/year

1985 - 4.835×10^6 rural households

output = 57.7×10^{15} J/year
input = 230×10^{15} J/year

2000 - 6.36×10^6 rural households

output = 75.9×10^{15} J/year
input = 304×10^{15} J/year

EXHIBIT 9: RESIDENTIAL ELECTRICITY CONSUMPTION FORECASTS

— U.S. Team
- - - Institute of National Planning

Most data sources, including GOFI, MOHR, and AUC indicated that typical butagas use is 1 to 1 1/2 bottles/ month (at 10 kg/bottle; this is approximately 150 kg/year). At the INP, however, Mr. Habib from the Egyptian General Petroleum Corporation gave a figure more than double this -- 333 kg/household/year or 2.8 bottles/month. Nonetheless, the trends for both the U.S. Team and the INP forecasts are similar, and the increasing use of hot water and space heating characteristic of improved living standards accounts for much of the increase.

In the case of kerosene, however, the trends of the two forecasts are not in the same direction. In the U.S. analysis, large-scale decrease of kerosene use in lighting and urban cooking tends to balance increases in kerosene use caused by the growing rural population and their increased hot water use. No understanding was achieved with the INP as to why its kerosene consumption figure more than doubles by the year 2000 despite these trends.

4.1.2 Assessing and Forecasting Commercial Consumption: The U.S. Team's definition of the scope of the commercial sector is so unlike the sector breakdown used by the INP that no cross-check can be made between the two. Parts of the U.S. Team's "commercial" sector are irretrievably buried in the INP's "industry," "transportation," "domestic," and "other" sectors. Even energy used by government buildings, which appears in all reports of the Egyptian Electrical Authority (EEA), cannot be isolated in the INP commercial sector breakdown.

The calculations in exhibit 10 are therefore derived entirely from the extremely limited data cited. As in the residential sector, lighting is the primary use of electricity with accelerated use of electricity indicated for space conditioning. Butagas use is negligible (away-from-home meals are generally cooked over charcoal). Kerosene use -- strictly for lighting in non-electrified areas -- is calculated in exhibit 11.

The first-class tourist hotel, which is probably the most energy-intensive nonindustrial building type in Egypt, was the only type of building observed to have any operating central space-conditioning systems. Because of their energy intensity and the expected large increase in the number of such facilities in the future, there would be a definite value to separating hotels from other commercial buildings in future studies. Applying per-room energy usage data from the Cairo Hilton or Meridien Hotels to Ministry of Tourism Hotel growth projections would be a significant step toward projecting future energy consumption by this important subsector.

4.1.3 Assessing and Forecasting Community Systems Consumption:

Community systems are a combination of traditional and modern techniques. Solid-waste disposal systems do not exist outside the major cities. In Cairo, private companies pick-up trash with carts. Metals and other materials of value are hand-sorted, and vegetable matter is consumed by animals. The rest is disposed of in desert landfill. Except for transportation, none of these activities either consumes or generates commercial energy forms.

EXHIBIT 10: CALCULATION OF THE DEMAND FOR ELECTRICITY BY THE COMMERCIAL SECTOR

Step 1: Dr. Mustafa Swidan of the EEA stated that in 1975 the residential sector consumed 18 percent of Egypt's electricity and the commercial sector as defined for this project consumed 12 percent of Egypt's electricity. Furthermore, he stated that this proportion of commercial to residential consumption - two-thirds - holds true for newly electrified areas and is expected to hold true generally in the future.

Therefore, total electrical consumption for this sector is:

$$\underline{1975} - 1,697 \times 10^3 \text{ kWh} \times 2/3 = 1,131 \times 10^6 \text{ kWh}$$

$$\underline{1985} - 5,134 \times 10^3 \text{ kWh} \times 2/3 = 3,423 \times 10^6 \text{ kWh}$$

$$\underline{2000} - 18,259 \times 10^3 \text{ kWh} \times 2/3 = 12,173 \times 10^6 \text{ kWh}$$

Step 2: Number of commercial sector air conditioners is double that of residential (GOFI, Khalil Meligy). Energy consumption per machine is:

1,250 kWh/year vs.

750 kWh/year for residential units

(see exhibit 3, item 13)

Thus, commercial air conditioner consumption of electricity =

$$2 \times \frac{1,250}{750} \times \text{residential} = 3.33 \times \text{residential}$$

$$\text{Air conditioning } \underline{1975} - 3.33 \times 24 \times 10^6 \text{ kWh} = 80 \times 10^6 \text{ kWh}$$

$$\underline{1985} - 3.33 \times 157 \times 10^6 \text{ kWh} = 523 \times 10^6 \text{ kWh}$$

$$\underline{2000} - 3.33 \times 1,049 \times 10^6 \text{ kWh} = 3,493 \times 10^6 \text{ kWh}$$

Step 3: Fans: Assume that fan-to-air conditioner usage proportion is the same for 1975 as in residential sector:

$$\text{Fans} - 43 \times 10^6 \text{ kWh} - 1.91, \text{ so fans in 1975} = 1.91 \times 80 = 152.8 \times 10^6 \text{ kWh}$$

$$\text{Air Cond.} - 24 \times 10^6 \text{ kWh}$$

$$\text{Fan-to-air conditioner ratio} = 1.91, \text{ so commercial fans in 1975 use } 1.91 \times 80 \times 10^6 = 152.8 \times 10^6 \text{ kWh}$$

Assume that use of fans grows at same rate as in residential sector:

$$\begin{aligned} \text{Residential fan use:} & - \underline{1975} - 46 \times 10^6 \text{ kWh} \\ & \underline{1985} - 98 \text{ " } \\ & \underline{2000} - 277 \text{ " } \end{aligned}$$

EXHIBIT 10: (CONTINUED)

Thus commercial fan electrical consumption =

1975 - 153×10^6 kWh
1985 - 326 "
2000 - 921 "

Step 4: Assume that the balance of commercial electricity use is for lighting.

<u>Summary</u>	<u>1975</u>	<u>1985</u>	<u>2000</u>
<u>TOTAL</u>	$1,131 \times 10^6$ kWh (100%)	$3,423 \times 10^6$ (100%)	$12,173 \times 10^6$ kWh (100%)
Air conditioners	80 " (7%)	523 " (15%)	3,493 " (29%)
Fans	153 " (14%)	326 " (10%)	921 " (7%)
Lighting	898 " (79%)	2,574 " (75%)	7,759 " (64%)

EXHIBIT 11 CALCULATION OF THE DEMAND FOR KEROSENE BY THE COMMERCIAL SECTOR

In 1975, residential and commercial use of electricity for lighting were about equal. Consumption of kerosene for commercial lighting, however, should be far less than for residential because:

- o commercial activity on a per-capita basis tends to be much less in rural areas (where most kerosene is used) than in urban areas;
- o commercial facilities with major lighting requirements -- e.g., hotels and government office buildings -- tend to be located in electrified areas only;
- o kerosene cannot be used for advertising and display lighting; and
- o electrically-lit commercial buildings use lighting during the daytime while those illuminated by kerosene do not.

Therefore, assuming that commercial kerosene consumption for lighting is only one-fourth that of residential, projections for fuel consumption are:

1975 570×10^3 M.T. x 25% = 143×10^3 M.T.
1985 530×10^3 M T. x 25% = 132×10^3 M.T.
2000 443×10^3 M T. x 25% = 111×10^3 M.T.

Sewage in all rural and most urban areas is piped through small septic systems or goes down the Nile untreated. According to the 1975 Area Handbook report, 100 of Egypt's 120 largest cities have no sewage treatment facilities, and half of Cairo's sewage enters the Nile untreated.¹ Treatment facilities use chemicals for sewage treatment and electricity is used to power pumps.

Water in rural areas is generally supplied from artesian wells or underground sources requiring hand pumping. In urban areas there is significant electrical pumping of water from the Nile into treatment ponds and then through underground piping networks and into buildings.

Street lighting, which exists in virtually all electrified areas, is the major community service provided.

Electricity is the only energy form that can be used for these functions. The only data received on electricity consumption was from the Institute of National Planning, with allocation among the different uses provided to Jack Davidoff in a meeting with El Behiry, as shown in exhibit 12. The 547×10^6 kWh figure for 1975 is close to the 532×10^6 kWh figure shown for 1976 for "public utilities" in the EEA Annual Report for 1976. However, the illustration of an electrical streetcar in the "public utilities" section of the EEA report suggests that the electrical tramways and "metro" of Cairo are included in this figure as well. The breakdown between lighting and water pumping -- weighted heavily toward water pumping -- is also somewhat surprising since street lighting is found nearly everywhere while sewage treatment facilities are scarce. The energy intensity of the Egyptian municipal water supply should thus be reviewed. The trend towards pumping becoming a larger percentage of the community services total, however, does seem logical in light of plans to greatly expand water treatment capacities as well as plans to use more energy-efficient sodium vapor lamps for street lighting.

5.0 QUANTIFYING THE IMPACT OF THE ENERGY-USE OPTIONS

The preceding fuel use calculations are the sole basis for calculating the impact of various options for improving the fuel balance described in this annex. These fuel impacts are shown in exhibits 13 through 20.

Exhibit 13 shows the numbers of households comprising each implementation level.

Exhibit 14 shows the calculation of electricity savings through using lighting reflectors. Exhibit 15 calculates electricity saved through fluorescent lighting, and exhibit 16 calculates electricity saved through TV transistorization. Since these three options do not affect building structure, they are not broken into levels of implementation.

¹ U.S. Area Handbook for Egypt, 1975, p. 102.

Exhibit 17 shows the assumed fuel energy values for all options calculations. Exhibit 18-a shows the calculations used to derive fuel savings through solar water heating for bathing and washing, and exhibit 18-b shows the calculations for deriving fuel savings through cooking with solar-heated water. Exhibit 19 calculates the quantities of electricity, butagas, and kerosene that can be saved in urban areas by introducing natural gas. It also shows the requirements for natural gas in this option. Exhibit 20 uses the same method to calculate butagas savings achievable through the reintroduction of kerosene for water heating.

EXHIBIT 12: DEMAND FOR ELECTRICITY BY COMMUNITY SERVICES FROM INP PROJECTIONS

	<u>1975</u> kWh	<u>1985</u> kWh	<u>2000</u> kWh
Street lighting	98 x 10 ⁶ (18%)	227 x 10 ⁶ (15%)	598 x 10 ⁶ (10%)
Pumping for water supply and sewage	449 x 10 ⁶ (82%)	1,287 x 10 ⁶ (85%)	5,386 x 10 ⁶ (90%)
Total sectoral demand	547 x 10 ⁶ kWh	1,514 x 10 ⁶ kWh	5,984 x 10 ⁶ kWh

EXHIBIT 13: CALCULATION OF NUMBERS OF HOUSEHOLDS INCLUDED IN EACH IMPLEMENTATION LEVEL

Level One (new cities)

Five new cities, each planned to have populations of 100,000 by 1985 and 500,000 in 2000; average household size of 5.2, or:

$$\text{Total new city households in 1985} = \frac{100,000 \times 5}{5.2} = 96,000 \text{ households}$$

$$\text{Total new city households in 2000} = \frac{500,000 \times 5}{5.2} = 480,000 \text{ households}$$

Level Two (new urban construction outside of new cities):

Referring to exhibit 1, the number of urban dwellings is expected to increase by 988,000 by the year 1985 (96,000 inside the new cities and 892,000 in existing cities) and by 3,145,000 from 1975 until the year 2000 (480,000 in the new cities and 2,665,000 in the existing cities).

Level Three (urban retrofitting):

Use 3,215,000 dwellings existing in 1975.

Level Four (new rural dwellings):

Calculated as for urban dwellings; 745,000 by 1985 and 2,270,000 by 2000.

Level Five (rural retrofitting):

Use 4,090,000 dwellings existing in 1975.

EXHIBIT 14: CALCULATION OF IMPACT OF USING LIGHTING REFLECTORS

1975 electricity usage in lighting = 853×10^6 kWh/year (see exhibit 4)

853×10^6 kWh/year $\times$ 20% savings $\times$ 1/5 lighting share =

34×10^6 kWh saving or 4 % of residential lighting usage

4% savings in residential lighting usage in 1985 = 85×10^6 kWh
in 2000 = 212×10^6 kWh

EXHIBIT 15: CALCULATION OF IMPACT OF EXPANDED USE OF FLUORESCENT LIGHTING

Current production of lightbulbs in Egypt is 6 million fluorescent bulbs/year (at 40 watts) and 80 million incandescent bulbs/year (50 watts average), according to Khalil Meligy at GOFI. Assuming that this represents the proportion of fluorescent/incandescent lighting in place today, that fluorescent and incandescent lights are used the same number of hours per day, and that fluorescent lightbulbs last three times as long as incandescent bulbs, then fluorescent lighting currently accounts for:

$$6 \times 10^6 \times 40 \text{ watts}$$

$$80 \times 10^6 \times 50 \text{ watts} + (6 \times 10^6 \times 40 \times 3) =$$

15% of all residential and commercial lighting usage

Assuming that one-quarter of the remaining incandescent lighting in both residential and commercial sectors could be replaced by fluorescent lighting with 40 percent of the power requirements, energy savings in 1975 would have been:

$$(853 \times 10^6 \text{ kWh domestic} + 898 \times 10^6 \text{ kWh commercial}) \times (.85) \times 1/4 \times 60\% \text{ savings} = \underline{223 \times 10^6 \text{ kWh}}$$

$$1985: (2,006 \times 10^6 \text{ kWh domestic} + 2,574 \times 10^6 \text{ kWh commercial}) \times (.85) \times 1/4 \times 60\% \text{ savings} = \underline{584 \times 10^6 \text{ kWh}}$$

$$2000: (5,310 \times 10^6 \text{ kWh domestic} + 7,759 \times 10^6 \text{ kWh commercial}) \times (.85) \times 1/4 \times 60\% \text{ savings} = \underline{1,666 \times 10^6 \text{ kWh}}$$

EXHIBIT 16: CALCULATION OF ENERGY SAVINGS THROUGH TELEVISION
TRANSISTORIZATION

<u>Year</u>	<u>Electricity TV Set Consumption (from Exhibit 4)</u>	<u>Power Reduction</u>	<u>Electricity Savings</u>
1975	453×10^6 kWh	50%	226×10^6 kWh
1985	$1,371 \times 10^6$ kWh	50%	685×10^6 kWh
2000	$3,602 \times 10^6$ kWh	50%	$1,800 \times 10^6$ kWh

EXHIBIT 17: ASSUMED FUEL ENERGY VALUES FOR ALL OPTIONS CALCULATIONS

Butagas: 45 MJ/kg (80% efficiency in all applications)

Kerosene: 46 MJ/kg or 38 MJ/liter (70% efficient for heating)
(10% efficient for lighting)

Electricity: 36 MJ/kWh (100% efficiency in all applications)
38 MJ/m³ (80% efficiency for heating)

Therefore: 1 MT butagas @ 80% efficiency has
 $(45 \times 10^9 \text{ J}) (.80) = 36 \times 10^9 \text{ J}$ energy output

1 MT kerosene @ 70% efficiency has
 $(46 \times 10^9 \text{ J}) (.80) = 32.2 \times 10^9 \text{ J}$ energy output

1 Kwh electricity @ 100 % efficiency has
 $(3.6 \times 10^6 \text{ J}) (.80) = 3.6 \times 10^6 \text{ J}$ energy output

<u>To displace</u>	<u>Requires</u>
10^3 MT butagas	$1.18 \times 10^6 \text{ m}^3$ natural gas
10^3 MT kerosene	$1.06 \times 10^6 \text{ m}^3$ natural gas
10^6 kWh electricity	$0.12 \times 10^6 \text{ m}^3$ natural gas

EXHIBIT 18-a: CALCULATION OF FUEL SAVINGS THROUGH SOLAR WATER HEATING
FOR BATHING AND WASHING

<u>Level One</u>		<u>Fuel Savings</u>	
Electric	1985: 96x10 ³ households x .05 x 1,500 kWh/household	=	7x10 ⁶ kWh
	2000: 480x10 ³ households x .20 x 1,500 kWh/household	=	144x10 ⁶ kWh
Butagas	1985: 96x10 ³ households x .20 x 120 kg/year	=	2x10 ³ MT butagas
	2000: 480x10 ³ households x .45 x 120 kg/year	=	26x10 ³ MT butagas
Butagas on stove	1985: 96x10 ³ households x .32 x 41 kg/year	=	1x10 ³ MT butagas
	2000: 480x10 ³ households x .20 x 55 kg/year	=	5x10 ³ MT butagas
Kerosene on stove	1985: 96x10 ³ households x .43 x 56 (.82)	=	2x10 ³ MT kerosene
	2000: 480x10 ³ households x .15 x 75 (.82)	=	4x10 ³ MT kerosene

<u>Level Two</u>			
Electric	1985: 892x10 ³ households x .05 x 1,500 kWh/year	=	67x10 ⁶ kWh
	2000: 2,665x10 ³ households x .20 x 1,500 kWh/year	=	799x10 ⁶ kWh
Butagas	1985: 892x10 ³ households x .20 x 120 kg/year	=	21x10 ³ MT
	2000: 2,665x10 ³ households x .45 x 120 kg/year	=	144x10 ³ MT
Butagas on stove	1985: 892x10 ³ households x .32 x 41 kg/year	=	12x10 ³ MT
	2000: 2,665x10 ³ households x .20 x 55 kg/year	=	29x10 ³ MT
Kerosene on stove	1985: 892x10 ³ households x .43 x 56 (.82) kg/year	=	18x10 ³ MT
	2000: 2,665x10 ³ households x .15 x 75 (.82) kg/year	=	25x10 ³ MT

EXHIBIT 18-a: (CONTINUED)

<u>Level Three</u>		<u>Fuel Savings</u>	
Electric	1985: 3,215,000 households x .05 x 1500 kWh	=	241x10 ⁶ kWh
	2000: 3,215,000 households x .20 x 1500 kWh	=	964x10 ⁶ kWh
Butagas	1985: 3,215,000 households x .20 x 120 kg	=	77x10 ³ MT
	2000: 3,215,000 households x .45 x 120 kg	=	174x10 ³ MT
Butagas on stove	1985: 3,215,000 households x .32 x 41 kg	=	42x10 ³ MT
	2000: 3,215,000 households x .20 x 55 kg	=	35x10 ³ MT
Kerosene on stove	1985: 3,215,000 households x .43 x 56(.82) kg	=	63x10 ³ MT
	2000: 3,215,000 households x .15 x 75(.82) kg	=	30x10 ³ MT
<u>Level Four</u>			
Electric	1985: 745,000 households x 0	=	0
	2000: 2,270,000 " x 0	=	0
Butagas	1985: 745,000 " x .02 x 120 kg	=	2x10 ³ MT
	2000: 2,270,000 " x .10 x 120 kg	=	27x10 ³ MT
Butagas on stove	1985: 745,000 " x .06 x 33	=	1x10 ³ MT
	2000: 2,270,000 " x .09 x 42 Kg	=	8x10 ³ MT
Kerosene on stove	1985: 745,000 " x .68 x 45(.82) kg	=	19x10 ³ MT
	2000: 2,270,000 " x .75 x 57(.82) kg	=	80x10 ³ MT
<u>Level Five</u>			
Electric	1985: 4,093,000 households x 0	=	0
	2000: 4,093,000 households x .0	=	0
Butagas	1985: 4,093,000 households x .02 x 120 kg	=	10x10 ³ MT
	2000: 4,093,000 households x .10 x 120 kg	=	49x10 ³ MT

EXHIBIT 18-a: (CONTINUED)

Level Five ContinuedFuel Savings

Butagas	1985:	x .06 x 33 kg	=	8x10 ³ MT
on				
stove	2000:	x .09 x 42 kg	=	15x10 ³ MT
Kerosene	1985:	x .68 x 45(.82) kg	=	103x10 ³ MT
on				
stove	2000:	x .75 x 57(.82) kg	=	143x10 ³ MT

EXHIBIT 18-b: CALCULATION OF FUEL SAVINGS THROUGH SOLAR WATER HEATING
FOR COOKINGLevel One

	1985:	96x10 ³ households	.55 145 kg x 50% savings	4 x 10 ³ MT
Butagas	2000:	480	.75 145 kg	26
	1985:	96	.43 194 (.82) kg	3
Kerosene	2000:	480	.15 "	6

Level Two

	1985:	892	.55 145 kg	32
Butagas	2000:	2,665	.75 145 kg	145
	1985:	892	.43 194 (.82) kg	31
Kerosene	2000:	2,665	.15 "	31

Level Three

	1985:	3,215	.55 145 kg	128
Butagas	2000:		.75	175
	1985:		.43 194 (.82) kg	110
Kerosene	2000:		.15 "	38

EXHIBIT 18-b: (CONTINUED)

<u>Level Four</u>			<u>Fuel Savings</u>	
Butagas	1985:	745	.08 145 kg	4
	2000:	2,270	.20	33
Kerosene	1985:	745	.68 194 (.82) kg	40
	2000:	2,270	.75	135
<u>Level Five</u>				
Butagas	1985:	4,093	.08 145 kg	24
	2000:		.20	59
Kerosene	1985:		.68 194 (.82) kg	221
	2000:		.75	224

EXHIBIT 19: CALCULATION OF FUEL SAVINGS THROUGH NATURAL GAS SUBSTITUTION
FOR COOKING AND WATER HEATING

<u>Level One</u>				<u>Fuel Savings</u>	<u>Requirements for Natural Gas</u>
Electric Ovens	1985:	96x10 ³ households	.02 1,200 kWh	2x10 ⁶ kWh	-
	2000:	480	.10 1,200 kWh	58x10 ⁶ kWh	7x10 ⁶ m ³ Nat. Gas
Butagas stoves	1985:	96	.55 170 kg	8x10 ³ MT	9
	2000:	480	.75 "	52 "	61
Kerosene stoves	1985:	96	.43 194 liters(.82)	6 "	6
	2000:	480	.15 "	12 "	13
Electric H ₂ O	1985:			7x10 ⁶ kWh	1
	2000:		SEE EXHIBIT 18a	144x10 ⁶ kWh	17
Butagas H ₂ O	1985:		FOR CALCULATIONS	2x10 ³ MT	2
	2000:			26x10 ³ MT	31

[BIT 19: (CONTINUED)]

SEE EXHIBIT 18a

FOR CALCULATIONS

					<u>Fuel Savings</u>	<u>Requirements For Natural Gas</u>
Butagas stoves H_2O	1985:				1×10^3 MT	1
	2000:				5×10^3 MT	6
Kerosene stove H_2O	1985:				2×10^3 MT	2
	2000:				4×10^3 MT	5
Butagas space	1985:	96	.05	40 kg	-	-
	2000:	480	.10	40 kg	2×10^3 MT	-
					<u>TOTALS</u>	
					1985	$21 \times 10^6 m^3$
					2000	$140 \times 10^6 m^3$

Level Two

Electric ovens	1985:	892×10^3 households	.02	1,200 kWh	21×10^6 kWh	$3 \times 10^6 m^3$
	2000:	2,665	.10	"	320 "	38
Butagas stoves	1985:	892	.55	170 kg	64×10^3 MT	76
	2000:	2,665	.75	"	290	342
Kerosene stoves	1985:	892	.43	194 liters(.82)	62	66
	2000:	2,665	.15	"	63	66
Electric H_2O	1985:				67×10^6 kWh	8
	2000:				799×10^6 kWh	96
Butagas H_2O	1985:				21×10^3 MT	25
	2000:				144 "	170
					SEE EXHIBIT 18a FOR CALCULATIONS	
Butagas stove H_2O	1985:				12 "	14
	2000:				30	35

EXHIBIT 19: (CONTINUED)

				<u>Fuel Savings</u>		<u>Requirement For Natural Gas</u>
Kerosene stove H ₂ O	1985:			18	"	19
	2000:			25	"	26
Butagas space	1985:	892	.05 40 kg	2x10 ³ MT		2
	2000:	2,665	.1 "	10	"	12
				<u>TOTALS</u>		
				1985		213x10 ⁶ m ³
				2000		785x10 ⁶ m ³
<u>Level Three</u>						
Electric ovens	1985:	3,215x10 ³	.02 1,200 kWh	77x10 ⁶ kWh		9x10 ⁶ m ³
	2000:		.10 "	386	"	46
Butagas stoves	1985:		.55 170 kg	256x10 ³ MT		302
	2000:		.75 "	350	"	413
Kerosene stoves	1985:		.43 194 (.82)	220	"	233
	2000:		.15 "	76	"	81
Electric H ₂ O	1985			241x10 ⁶ kWh		29
	2000:			946	"	116
Butagas H ₂ O	1985:			77x10 ³ MT		91
	2000:			174		205
Butagas stoves H ₂ O	1985:			42		50
	2000:			35		41
Kerosene stove H ₂ O	1985:			63		67
	2000:			30		32
Butagas space	1985:		.05 40 kg	6x10 ³ MT		7
	2000:		.1 40 kg	13	"	15
				<u>TOTALS</u>		
				1985		788 X 10 ⁶ m ³
				2000		949 X 10 ⁶ m ³

SEE EXHIBIT 18a
FOR CALCULATIONS

EXHIBIT 20: CALCULATION OF BUTAGAS SAVINGS THROUGH REINTRODUCTION OF KEROSENE
FOR WATER HEATING

<u>Level One</u>		<u>Butagas Saved</u>	<u>Kerosene needed (at 1.11 M.T. kerosene per M.T. of butane)</u>
	1985:	2×10^3 MT	2×10^3 MT
Butagas	2000:	26	29
	1985:	1	1
Butagas on stove	2000:	5	6
<u>Level Two</u>			
	1985:	21	23
Butagas	2000:	144	160
	1985:	12	13
Butagas on stove	2000:	30	33
<u>Level Three</u>			
	1985:	77	85
Butagas	2000:	174	193
	1985:	42	47
Butagas on stove	2000:	35	39
<u>Level Four</u>			
	1985:	2	2
Butagas	2000:	27	30
	1985:	1	1
Butagas on stove	2000:	8	9
<u>Level Five</u>			
	1985:	10	11
Butagas	2000:	49	54
	1985:	8	9
Butagas on stove	2000:	15	17

TRANSPORTATION

BY

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U.S.-EGYPT COOPERATIVE ENERGY ASSESSMENT

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1.0 SUMMARY AND INTRODUCTION

1.1 Objectives

The principal objectives of the transportation segment of the U.S.-Egypt Cooperative Energy Assessment were:

1. To develop an understanding of the current status of the principal energy users in Egypt's transportation sector.
2. To estimate the energy demand and efficiency for each transport mode within the sector.
3. To identify opportunities for fuel type changes, technology switches, or utilization pattern changes which might increase the efficiency with which Egypt's energy is used, both now and in the future, within the transportation sector.
4. Based on options identified, to forecast energy demands by various modes within the transportation sector.

To realize these objectives, discussion was carried out with a wide cross-section of Egyptian experts on energy, technical, and planning aspects of transportation. Projections of fuel use for transportation in 1985 and 2000 were those of the Egyptian General Petroleum Corporation (EGPC). It was agreed that these projections would be used in the analysis and that the U.S. transportation specialist would classify the projections for each fuel type by mode of transport. The specialist would then use these classifications to estimate the associated activity levels. The data collected in Egypt were then used, together with published U.S. and international data, to estimate energy use and efficiency figures.

1.2 Principal Options and Observations

During the study, an option was developed which might reduce the energy demand of the transportation sector. In summary, the option emphasizes the use of waterways and electrified rails in lieu of the highways. Table 1 shows the fuel consumption under this conservation option, the EGPC projections of transportation fuel use (also called Comparison Case), and fuel use suggested by a projection of trends in current fuel use patterns.

Over and above this option, a number of general observations were made, all of which relate to energy demand in the transportation sector. These observations are as follows:

1.2.1 The Comparison Case: The Comparison Case, developed from EGPC fuel projections, represents a substantial break with recent trends. A key element in achieving the Comparison Case for 1985 and

TABLE 1

TOTAL TRANSPORT FUEL REQUIREMENTS BY TYPE (QUADRILLION JOULES)

	Comparison Case ¹			Option Case ²		Trend Case ²	
	1975	1985	2000	1985	2000	1985	2000
Electricity	0.67	4.56	23.12	6.96	26.10	1.72	21.05
Jet Fuel	8.60	14.00	20.00	14.00	20.00	19.00	30.00
Gasoline	30.28	48.02	91.42	37.25	68.62	66.88	137.46
Diesel (solar)	19.47	33.10	66.35	29.48	58.98	51.34	101.07
Mazout	<u>1.48</u>	<u>2.55</u>	<u>7.33</u>	<u>3.21</u>	<u>8.44</u>	<u>1.65</u>	<u>2.55</u>
Total	60.50	102.23	208.22	87.90	182.14	140.59	292.13

¹ Source: Egyptian General Petroleum Corporation

² Source: Anthony Tomazinis, University of Pennsylvania

2000 is the utilization of energy-effective modes in urban personal travel and intercity freight movement and personal travel. Only through (a) a significant expansion of urban mass transit systems by 2000, and (b) a major expansion of intercity freight movement services by railroads and waterways can the Comparison Case be achieved.

1.2.2 Development areas: There is a need for policy initiatives and investment priorities that foster improvements in urban mass transit, intercity personal travel, and intercity freight movement by inland waterways and the railroad systems. Only when these systems are able to provide, on a regional and national scale, the transportation services that the country crucially needs, would it be prudent to initiate measures for reducing relatively the use of, and dependency on, the intercity truck fleet and the passenger car.

Several things could be done to improve the railroads and the inland waterways other than increasing fleets and the size of the current network. First, the serviceability of the Nile river waterway can be improved by establishing and equipping frequent depots (ports) at strategic locations along the river and by integrating them with the local highway network and with the railroad system of the region. Second, the rail system can be connected with all new industrial enterprises and integrated with the inland waterways. The two systems must be planned to supplement and complement each other and, in fact, work as one integrated system. It is understood that the development of the waterways may be limited due to environmental considerations. Planning should specifically consider this constraint.

1.2.3 The need for comprehensive transportation planning: Egypt, still in the early stages of economic development, has a unique opportunity to direct its efforts towards a more sound, efficient, and effective developmental pattern, including an efficient transportation system. The assessment of energy requirements in the transportation sector of Egypt has revealed only limited regional and national transportation planning. The most comprehensive completed transportation studies that could be located are the SOFRETU study for the metropolis of Cairo, 1973¹, and the Phase I Egypt National Transport Study². These, however, do not explicitly take into account the transportation requirements of the planned cities. The remaining completed studies are quite limited in their focus on specific projects, or are part of other studies, addressed to objectives other than the comprehensive planning of the transportation system.

¹ Transportation Study for the Cairo Metropolitan Area, SOFRETU, 1973, prepared for the Egyptian Ministry of Transportation.

² Egypt National Transport Study, Phase I, Louis Berger International, Inc., January 1977.

Phase II of the Egypt National Transport Study, when completed, should expand considerably the planning base for Egypt's transport sector. According to the Terms of Reference, the objectives of the study are "to assist the Government to develop technical and organizational capacity to undertake comprehensive transport planning activities on a continuous basis. . ." The scope of work for this project details an ambitious, comprehensive planning and training study. The study will be limited in that it will not explicitly consider the urban areas except as they impact intercity activity. Hopefully, further studies will address the transport needs of the new and existing cities. Within the Phase II study, it is suggested that energy requirements be specifically considered as well as coordination between the Ministry of Transport and the other Ministries.

1.2.4 Coordination of transportation planning with comprehensive developmental plans: Fuel consumption patterns within the transportation sector depend on developments and plans in other sectors of the economy. Deliberate planning of transportation to meet these developmentally determined needs would lead to more efficient and less haphazard transport system planning as well as lead to the more effective implementation of general development plans. Some areas where coordinated developmental planning could be improved are:

Urbanization Policy and Planning for New Cities. Egyptian urbanization policy has several explicit objectives with regard to population, industrial decentralization, and conservation of agricultural land, but it does not state clearly any objectives with regard to national transportation efficiency and energy effectiveness. For example, it appears that when the major decisions concerning the three new major cities (Sadat City, Tenth of Ramadan, and King Khalid City) were made, minor attention was paid to the national transportation policies and requirements. As a result, all three cities are placed outside the networks of inland waterways and the railroad. Although Sadat City is expected to be a center for export, only a dead-end branch railroad line and a branch of the Noburia Canal with a minimal basin for maneuvers are planned as part of the industrial district of the city. These two systems are not integrated. Obviously, corrective actions need to be planned as soon as possible, and proper initiatives exercised concerning the desirable development of the three major new cities and all other urbanization plans and programs of the country. The Phase II study may address these questions.

Industrialization Policy. In integrating industrial and transportation activities, it is important to review all major new enterprises to see if they could be serviced primarily and effectively by either the

inland waterways or the railroad system; wherever possible, by both systems. It would be advantageous for all major and long distance industrial freight to be carried by the waterways or the railroads by 1985 or shortly thereafter. The present situation of heavy dependence on trucks for intercity transport should be reversed. It is economically important to an exporting industry to minimize switches from one mode of movement to another (transshipment) of any commodity between its origin and its destination. A single transshipment usually costs as much as all the other transport costs of the commodity, and involves added risks and losses. Such cost factors may make a commodity noncompetitive in the international market.

Land Use Policy Planning. Land use planning should take into account two major transport related considerations. First, it is extremely important to promote, within urban regions, a developmental pattern serviceable by mass transit, particularly during the developmental stages of Egyptian urban regions. Once the urban areas are built, it will be difficult to alter their density and land use patterns to permit effective mass transit service. Second, it is important to require and plan for the major industrial enterprises within metropolitan regions to have immediate and high quality connections with the railroad system of the country and, if possible, with the inland waterways. In fact, one of the primary criteria in selection of sites and the development of new industrial districts within metropolitan regions should be railroad and waterway serviceability.

1.3 Next Steps

Certain studies on aspects of the Egyptian transportation system are fruitful "next steps" in building a transportation planning data base. These are:

1.3.1 Energy assessment of the railroad system: Specific studies of the energy operating characteristics of the railroad system are lacking. From the available evidence it seems that there is a simultaneous coexistence of extreme over-use of certain parts of the fleet and major inefficiencies in the service offered. A detailed review of energy effectiveness in the railroad system would aid in identifying problem areas and in providing solutions.

1.3.2 Energy effectiveness of pipelines: The statistics available on the pipelines system (and storage operations) in Egypt are very sketchy. An assessment of the system requires information on lengths, pressure, diameters, products, operations, etc. Pipelines are an important component of the transportation system, and improvements in their operation can produce significant dividends for the country.

1.3.3 Operating arrangements of inland waterways: Understanding of the organization of the present fleet as the system affects energy consumption should be acquired. In particular, several observations and comments made by the "National Transportation Study" report need to be checked out and pursued to their conclusion if this has not been done in Phase II.

1.3.4 Review of major plans on urbanization and industrialization: Initial review has shown lack of coordination between general development plans and the national transportation system. It is particularly important to carry out in the near future a detailed and complete review of all the non-transportation plans currently under consideration in the country, placing emphasis on their transportation assumptions and energy requirements.

1.3.5 Future national freight movement needs: The material included in the "National Transportation Study" is sketchy and is more explanatory of past practices than of future needs. A comprehensive study of the freight movement needs of the country for 1980, 1990, and 2000, emphasizing energy implications and policy directions, is one of the first steps that needs to be taken in Egypt. Some of this may be done in the Phase II transport study.

1.3.6 Railroads improvement study: Egypt is in need of a comprehensive study that focuses on all that needs to be, and can be done to improve the railroad service in the country (including passenger and more importantly, freight). It should review the role and the potentialities of the railroad system and recommend all the steps needed (policies, projects, organization) to place the railroad in a prominent position in the country by 1990, and retain that position beyond 2000.

1.3.7 Inland waterways potential in Egypt: Also recommended is a comprehensive policy analysis study that reviews and explores the present and future of inland waterways. Initial indications suggest that waterway services could be increased but it is important to make specific recommendations of the steps and actions that should be undertaken.

1.3.8 Comprehensive urban transportation studies: A series of comprehensive urban transportation studies should be undertaken for the major urban areas of the country. It is understood that studies have been completed for Greater Cairo. These should be reviewed and the recommendations reconsidered. The extent to which the future cities of Egypt will experience uncontrolled sprawl, extensive dependence on the automobile, environmental degradation, malfunctioning mass transit with unbalanced distribution of transit services, and enlarged consumption of energy depend, to a large extent, on policies that should materialize in the near future.

1.4 Plan of the Report

The remaining material in this report is divided essentially into five major parts. First, a description is given in Section 2 of the methodology and assumptions used in the analysis. An overview is presented in Section 3 of the transportation system of Egypt in 1975, with emphasis on energy implications. This overview of the 1975 situation is then augmented with discussions of the evolution of the system between 1975 and 1978, and by known plans for development.

Section 4 assesses the energy needs for transportation described in the Comparison Case for 1985 and 2000. The discussion is divided into four parts: the description of the case; its energy implications; the associated activity levels; and the implied constraints and conditions associated with implementing those measures.

Section 5 analyzes a transportation option characterized by conservation and more intensive use of rail and waterways.

Section 6 presents a number of observations which appear significant enough to deserve special mention and individual attention from the proper authorities. The report concludes with a brief discussion of the importance of transportation to development efforts and to the achievement of high living standards in any country. It also refers to the dynamic effects of transportation in developing old or new urban regions and industrial districts and notes that, presently, transportation throughout the world depends heavily on fossil fuels and thus is subject to all the implications of a potential scarcity of such fuels.

The report has two appendices. These contain summary tables with energy efficiency measures for all transport modes under different conditions, and a discussion of the environmental considerations of more intensive use of waterways for transport.

2.0 METHODOLOGY AND ASSUMPTIONS OF THE ANALYSIS

2.1 Introduction

The projection of the transport-related energy requirements of a country can be approached in two ways. First, if an approximation is desired only for comparative reasons, and if there is reason to expect the continuation of already established relationships, then surrogate measures of growth may be used to project future rates of transportation growth. Three such measures of growth frequently used because of their availability and pertinence are population growth, gross national income growth, and the growth in demand by all sectors for all forms of energy. These measures are obviously related to the level of transportation activities in a country, and, of course, to energy demand by the transportation sector.

However, when major shifts of sectoral growth are expected within the country, the utilization of these surrogate measures of growth can be misleading. In such cases, a second approach to the projection of energy consumption by the transport sector is recommended. This approach is characterized by a sequential process, which segments transport demand and determines the factors that influence the level of each type of transport activity.

Egypt clearly belongs within the group of countries that requires the second approach to the projection of transport activities. Although Egypt has experienced railroad activities for many decades and water transport activities for many centuries, it is only recently that Egypt has experienced the impacts of growth in all forms of road transportation. The major shifts expected between the sectors of the country, and the impacts of the anticipated higher future income levels, impose the need for an analytical step-by-step and mode-by-mode projection of the transport activities of the country.

2.2 Analytical Projections of Transport Activities (Unrestrained Growth)

The starting point for the analysis is the estimation of person trips and tons of freight to be transported for 1985 and 2000 disaggregated for urban and inter-urban areas.

To accomplish this first step, six factors are considered: (1) the population growth in the country with special reference to the growth of urban population; (2) growth of the economy in terms of the gross national product and its distribution among the population and the several sectors of the economy; (3) the expected growth of the transportation fleet including automobiles and trucks; (4) locational factors including the distribution and locational spread of both the population and the economic activities of the country; (5) the cost of transportation in the country, per unit of transport activity; and (6) the quality of alternative transportation modes.

On the basis of these factors, an "unrestrained" or "trend" projection was made for Egypt for 1985 and 2000 for both person trips and tons of freight. Urban person trips were projected assuming 24 and 41 million urban population in 1985 and 2000 respectively. One trip per person per day was used for 1985 and 1.2 trips per person per day in 2000 with a normal travel estimate of 300 days per year. These rates are quite conservative as compared to 0.81 trips per person estimated by SOFRETU in 1969, and 1.9 to 2.0 trips per person found in urban areas of more advanced countries.

*The growth of the automobile and truck fleet, although it appears to be dependent upon the previous factors, is, in fact, moving quite independently in some developing countries.

**This factor is particularly important when a major change (reduction or increase) in the cost of transportation is expected in the country.

Total inter-urban person trips are derived by projecting the person trips that the railroad and bus systems are likely to service in 1985 and 2000 plus the number of person trips that the automobile fleet is likely to service. For the trend projections it was postulated that both the railroad and the bus fleet will not be able to increase the absolute number of passengers carried any time in the future. Auto inter-urban person trips, however, will increase in a proportion similar to the increase of the available auto fleet. Due to expected increases in transport cost, however, the trip increase is estimated to be about 30 percent less in 1985 and about half as much as the total fleet increase in 2000.*

Urban freight is projected based on its relationship to inter-city freight. It is usually found to be 1.5 to 2.0 times inter-city freight depending on where the borders of the urban region are drawn. An average co-efficient of 1.75 is, therefore, postulated for Egypt for 1985 and 2000.

Inter-city freight was projected which was accepted as reasonable in the 1985 projection of the Louis Berger Transportation Study. For the year 2000, total inter-city freight tonnage was projected assuming a 50 percent increase over 1985 tonnage by 1990 and then a 30 percent increase for each five-year period over the total at the end of the previous period. This pattern of growth is similar to that accepted by the Egyptian Authorities for projections in the Louis Berger Transportation Study, and it is similar to anticipated growth rates for the Egyptian economy until the year 2000.

The second step in the projection process is to estimate modal characteristics and mileage traveled by persons and freight. The modal split of urban person trips proceeds taking into account the maximum capacity of the expected mass transit systems in 1985 and 2000, plus the amount of pedestrian travel. For 1985 it is assumed that no subway line will be in place, but there will be some noticeable expansion of surface lines to the level of 0.85×10^9 additional transit trips. For 2000, one subway line is also assumed to be in place carrying 1.4×10^9 trips. Pedestrians will continue to be significant for 1985 and 2000, but are assumed at the level of 25 percent of total trips instead of 30 percent in 1975, a rather conservative assumption for this case too.

The lengths of urban trips are expected to grow reflecting the anticipated major expansion of the urban areas. For 1985 the average length of auto person trips is expected to grow from 3.0 km to at least 5.0 km. For 2000 the average length is expected to be at least 5.5 km (as against an average auto trip length in the Philadelphia region in 1960 of 7.2 km--an area of 4.8 million people and 1250 square miles coverage).

* The underlying price elasticity of demand assumption represents a 0.3 percent decrease in passenger trips for every 1 percent increase in the cost of a passenger trip.

For inter-urban personal travel, the modal disaggregation is already complete; but the trip length assumptions are needed. It is assumed for railroad trips that the trip lengths prevailing in 1975 will remain in effect for 1985 and 2000. For bus trips, the assumed trip length is 75 km for 1985 and 100 km for 2000. This trip length is less than that reported in the Louis Berger Transportation Study because that study is believed to underestimate the number of short trips by not including bus travel between neighboring cities (the screen lines were too far apart) and because it is expected that longer trips will tend to be made by car or train in the future. Auto person inter-city trip length is expected to grow substantially in the future. The assumed trip length in 1975 was approximately 100 km (well below the 131 reported in the Louis Berger Study because of the believed underestimation of short trips due to the size of their traffic data zones and the location of their screen lines). By 1985, auto person inter-city trip length is assumed to grow to 165 km and by 2000 to be approximately 190 km. This is assumed because of the trend in the locational distribution of urban areas in Egypt. Tendencies are to develop new cities, and to increase the size of those cities outside the Nile Delta. Of particular significance in projecting future increases in auto person trip lengths is the creation of urban concentration in two southern parts of the country, nearly 800 km away from the center of gravity of the current population in the Delta. The result is the increase of the present average distance of population dispersion from approximately 115 km to approximately 185 for 1985 and 195 for 2000. Additionally, the creation of attraction points around the High Dam, the Nasser Lake, the New Valley, the Red Sea and the Sinai Peninsula will tend to multiply the long auto trips of the country.

Urban freight is almost exclusively served by trucks (assumed to serve 96 percent of the total freight in 1985 and 97 percent in 2000). The mileage for each ton of freight is assumed to average 6.0 km for both 1985 and 2000 reflecting both the fact that factories will tend to be at the outskirts of the cities and that once established, an industrial district will tend to have stabilized relationships.

Inter-urban freight movement is first assigned to specific modes, then an average distance of movement is assumed. The modal assignment starts first with the determination of the expected capacities of the critical modes, e.g., the railroads and the waterways. In both cases a technical judgment was necessary in reaching an assumption as to how much freight the railroads and waterways can service in 1985 and 2000 without dramatic improvements in the two systems. The conclusions reached were used as assumptions; they state that for 1985 a marginal increase of 10 percent for waterways and a slightly greater increase for the railroads should be expected. For the year 2000 an increase of 50 percent for the waterways and an increase of 100 percent for the railways over 1975 loads was assumed. These assumptions are based primarily on what is included in the Five-Year Plan for Egypt and the aspirations expressed orally by certain Egyptian authorities in the Spring of 1978. On that basis, the bulk of the future freight should be assumed to be serviceable primarily by the truck fleet of the country.

The projection of the average trip length of inter-urban freight for each mode was made accepting the conservative assumption that the 1975 average trip lengths will remain in effect for all three modes until 1985. This assumption is supported by the Louis Berger Transportation Study. A similar assumption was made for 2000 for the waterways and railroad freight. For truck freight a small reduction of the average length was introduced (from 210 km to 200 km). The basic reasoning for this reduction is that an increased self-sufficiency will be seen within each region of the country as it matures. Also, there is the expectation that long hauls will tend to be made by rail and water, thus the slight reduction of truck freight lengths. Obviously, any relaxation of these assumptions will tend to produce major increases in inter-urban freight trip length, especially for trucks, and therefore, will have major implications on the amount of energy consumed by this type of transport activity.

The concluding step in projecting the energy required by the transport sector includes the determination of intensities of use of each mode and the efficiency of energy utilization of each assumed set of transport equipment. Assumptions are made concerning car occupancy coefficients for all types of person trips, loading factors for truck trips, proportion of loaded trucks, coefficients for rail freight and passenger travel, proportions of empty wagons on the railroads, loading coefficients on all forms of mass transit, coefficients of water barges, as well as operating coefficients for pipelines and airlines.

The Louis Berger Study suggests a car occupancy rate for 1975 of 3.6 for urban auto person trips. For inter-urban auto person trips it reports a rate of 3.9. Car occupancy will be one of the first coefficients of intensity of use that will be affected as the fleet of cars increases, as personal income rises, and as the diversity of origins and destinations grows. As a result, it is assumed that it will decrease for 1985 to 2.75 for urban trips and 2.9 for inter-urban trips. For 2000 the assumed reduction will bring this coefficient to about 2.6 for urban trips and 2.8 for inter-urban trips. These assumptions are quite conservative in spite of the sizable reductions they involve. For comparison, car occupancy in the Philadelphia region in 1960 was 1.6 persons per car. Currently, estimates in other countries are made with car occupancy rates varying from 1.5 to 2.4 for urban and inter-urban trips, correspondingly. Figure 1 graphically indicates the utilized assumptions for urban and inter-urban auto trip lengths and car occupancy rates.

The assumed loads for trucks are also quite conservative. For the average Egyptian inter-urban 9 tonne truck in 1975, the load reported in the Louis Berger Study was 7.9 tonnes. This high load coefficient was measured by Louis Berger because their sample was taken primarily from governmental companies which move their trucks in a highly organized, convoy-line manner. Therefore, it is assumed for 1985 that with the growth of the trucking industry a lower average load will be realized. It is assumed for the year 2000 that efforts will be made to increase efficiency. The result is an assumed load of 7.0 tons for 1985 and an assumed load of 8.0 tons for 2000.

Fig. 1a Auto Person Trip Lengths

Fig. 1b Car Occupancy Rates

Similarly detailed assumptions were made for each of the other modes indicating type of equipment assumed, operating conditions assumed, etc., so that the activity levels could be translated into exact energy consumption estimates. Table 2 presents the set of assumptions utilized defining the intensity of energy use assumed for each mode.

The next step is, of course, the comparison of the "trends" projection with the Comparison Case projection estimates by fuel type. In spite of the several conservative assumptions included in the trends projections of transport activity, another still more conservative set of assumptions is required that will tend to reduce auto and truck transport activities by either eliminating these trips altogether or shifting them to railroad, buses, and waterways--the three modes that consume less energy per unit of activity than autos and trucks. The new set of assumptions also need to be within the realm of reasonableness and plausibility for Egypt. This has been done, and forms the second round of transport activity projections.

2.3 Comparison Case Transport Activity Levels Projections

The analytical determination of the activity levels that can correspond to the levels of energy consumption by type of fuel included in the Comparison Case starts from the determination of the primary type of transport activities, continues with the "second level" of transport activities (passenger km and ton km) and concludes with the determination of a consistent set of detailed assumptions which indicates the intensity of use of each mode and the efficiency of energy utilization of each set of transport equipment.

On the primary level, urban and inter-urban freight are assumed to remain the same as in the unrestrained case. However, new assumptions are introduced for urban and inter-urban person trips. For urban person trips the conservative assumption is made that the urban people in Egypt will make only 0.10 trips/day more by 1985 than they are making in 1975, and just another 0.10 trips/day more by 2000. Thus, the daily trip rate is assumed reduced from 1.00 to 0.90 for 1985 and from 1.20 to 1.10 for 2000. Further, it is assumed that for the year 2000 there will be in place not one but three major subway lines with a capacity of 3.4×10^9 trips per year. The result of these two assumptions is the reduction of urban person trips from 7.2 billion in 1985 and 14.74 billion in 2000 to 6.48 billion and 13.53 respectively, and that of auto person trips from 2.85 to 2.31 billion for 1985, and from 7.12 billion to 4.87 billion for 2000. Both assumptions are obviously replete with implications with regard to the mobility of the urban Egyptian in 1985 and 2000, and with regard to the commitment of the government to have in place three major subway lines in Cairo by the year 2000.

For inter-urban person trips in 1985 it is assumed that individuals will be making fewer auto intercity trips than in the trends projections in spite of the increased availability of the vehicle fleet. While the trend projection assumes a 171 percent increase over 1975 levels, the

TABLE 2

ADDITIONAL ASSUMPTIONS: INTENSITY OF USE BY MODE

	Person Trips/ person/day	Truck Loading Rate (tons)		% Live Truck km		Freight Trip Distance (haul) km			RR Sys. % of Emty	RR Sys. Occup. Rates	Waterway % of Emty	Pipelines: Assumed	Airlines Load
		Urban	Interurban	Urban	Interurban	Truck Fr.	RR Fr.	Waterways Fr.	+ Manure +Waste		+Manure +Waste	Trans. Length: km	Factor
1975	0.8	7.9	7.9	0.8	0.5	210	280	444	33%	n.or.	45%	250	0.74
1 Trends	1.0	7.9	7.0	0.8	0.5	210	280	444	40%	1.49	45%	250	0.87
9 Referen.	0.9	7.9	9.0	0.8	0.5	200	280	444	40%	1.00	45%	250	0.87
8 Option	0.9	7.9	9.5	0.8	0.5	200	280	444	40%	1.08	21	250	0.87
5													
2 Trends	1.2	7.9	8.0	0.8	0.5	200	280	444	40%	0.65	45%	350	0.80
0 Referen.	1.1	7.9	9.0	0.8	0.5	150	350	400	33%	1.00	25%	350	0.80
0 Option	1.1	7.9	9.0	0.8	0.5	150	350	400	33%	1.25	25	350	0.80
0													

Comparison Case assumes only a 134 percent increase over 1975 levels. In 2000 the need for further reductions in auto person trips necessitates the assumption of improvements in the railroad system and bus lines. Thus, not only a portion of "auto" person trips will become railroad and bus trips (reducing the trends estimates from 201.00 to 163.75 billion) but a number of additional trips will be induced by the two improved systems. Therefore, total inter-city person trips will be greater in the Comparison Case than in the Trends Case.

Freight movement projections for the Comparison Case assume an average urban truck trip length of 4.0 km for 1985, the same as in Egypt in 1975. The estimates of inter-urban freight truck ton km in the Comparison Case are 22.1 billion and 42.6 billion for 1985 and 2000, respectively. This estimate assumes that highway freight will be reduced below the Trends Case, and waterway freight and railroad freight will be increased by a total of 8.5×10^6 tons for 1985 and 36×10^6 tons for 2000. The average truck trip length is assumed to be 200 km in 1985 and 150 km in 2000. This assumption implies that the longest potential truck loads will switch to railroads and waterways; a switch that involves a reduction in the truck loads' average trip length and an increase of the average trip length of the railroad and waterway tonnage. Indeed this assumption forces an increase of the average trip length of the railroad tonnage from 280 in 1975 to 350 for the Comparison Case in 2000. For 1985 the shift is minor and no increases of trip length are assumed for the railroads or the waterways tonnage.

With regard to the passenger km changes, major departures from the Trends Case are assumed for both urban and inter-urban person km. For urban person km the Comparison Case estimates are 65 percent of the Trends Case estimates for 1985 and 62 percent for 2000. For inter-urban auto person km the reductions are equally significant, and again involve switches from autos to buses and trains. The Comparison Case estimates of auto person km are 78 percent of the Trends Case in 1985 and 71 percent in 2000. Inter-urban auto person trip length is assumed to stay the same for 1985 and 2000 at the level of 165 km (instead of the 190 km assumed for the Trends Case). This assumption implies that in spite of the widespread expansion of urbanization and industrial activity in Egypt outside the Nile Delta the average trip length for inter-urban personal travel will not increase. Obviously, this is a conservative assumption made necessary by the requirement to reduce the estimated level of transport activities to a level serviceable by the energy levels included in the Comparison Case.

The concluding step is to determine the specific assumptions concerning the intensity of use by each mode; and the energy efficiency of each mode for 1985 and 2000. For urban autos, the car occupancy rate is assumed for the Comparison Case to remain as high as 2.90 for 1985, and 2.80 for 2000. Both measures are obviously quite high. For inter-urban autos the car occupancy rate is assumed to remain as high as 3.0 for 1985 and 2.9 for 2000. The loading factors for urban freight are assumed to be the same as in the Trends Case since there is little that can be done to influence that factor. For inter-urban freight the

truck loading factors, however, are assumed to increase from 7.0 and 8.0 (1985 and 2000) to 9.0 ton per truck, or in other words, to achieve an almost perfect matching between loads and truck capacity. This is, of course, another of the necessary but very conservative assumptions that need to be included to meet the energy restrictions of the Comparison Case.

2.4 Conservation Option Projections

A third projection of transport activities was undertaken utilizing a set of assumptions representing maximum effort for energy conservation on behalf of the Egyptian Government, the private sector, and the individual users of the system. These then were the most optimistic assumptions in terms of high intensity of use of all modes. The specific assumptions are shown in figure 1 and table 2.

2.5 The Process

As can be seen from the preceding discussion, the projection process was cyclical, starting from an initial assumption of "natural," "unrestrained" growth of transport activities and levels of intensity of use of each mode, called the "trends" projection. The resultant energy consumption levels were then compared with the a priori, generalized energy consumption projections by fuel type of the Comparison Case. This comparison led to a new, more energy conservative set of assumptions for all auto and truck based transport activities, which in turn were matched with the Comparison Case projection in a disaggregated form, by mode and fuel type. A second assessment was made at that point which resulted in another set of assumptions, reflecting maximum plausible and reasonable potential for energy conservation. This set of assumptions led to the Conservation Option energy projections.

This cyclical process is shown in figure 2.

3.0 THE TRANSPORTATION SYSTEM IN 1975

3.1 An Overview

The transportation sector of Egypt in 1975 included an extensive highway system, an integrated railroad system, a significant number of inland canals connected to a system of ports and harbors for shipping, and a network of air transport lines. These systems served the urban regions of the country as well as interregional transport needs. Table 3 shows statistics describing the transportation system of Egypt in 1975, and table 4 reports on the estimated composition of the highway fleet in 1975 and 1978.

During the last three years, more than 100,000 new private cars were added to the fleet, compared to small increases in the number of buses. The fleet of trucks for urban use also grew significantly. The highway fleet amounted to 8.18 vehicles per 1,000 people in 1975,

The Projection Process

Fig. 2

TABLE 3

EGYPT'S TRANSPORT NETWORKS AND NONAUTOMOTIVE VEHICLES, 1975

<u>Highways:</u>	Paved Roads:	12,000 kilometers
	Unpaved Roads:	14,000 km
	Total National Roads:	26,000 km
<u>Railroads:</u>	Total length of lines:	3,905 km
	Double tracks:	951 km
	Freight cars:	17,600
	Passenger coaches:	1,633
	Locomotives:	752
<u>Inland Waterways:</u>	Total length of canals:	3,350 km
	Class I canals:	1,500 km
	Class II canals:	1,850 km
	Barges, public units:	764
	Private use units:	200
	Sailing boats:	5,800
<u>Aviation:</u>	Domestic lines:	3
	Domestic flights:	42 (weekly)
	Foreign lines:	31 (weekly)
	Foreign flights:	71 (weekly)
<u>Pipelines:</u>	Length of lines:	1,600 km
<u>Shipping Ports:</u>	Major ports:	4
	Minor ports:	8

Source: Egypt National Transport Study.

TABLE 4
EGYPT'S HIGHWAY FLEET (THOUSANDS OF UNITS)

Type of Vehicle	1975 ¹	1978 ² (estimated)	1975 Vehicles Per 1,000 Persons
Automobiles	170.5	275	4.48
Taxis	45.0	60	1.18
Buses	9.3	11	
Trucks	38.0	60	
	<hr/>	<hr/>	<hr/>
TOTAL VEHICLES	261.8	404	7.05
Motorcycles	41.0	60	
	<hr/>	<hr/>	<hr/>
INCLUDING MOTOR- CYCLES	302.8	464	8.18

¹ Egypt National Transport Study.

² Anthony Tomazinis, University of Pennsylvania

but grew to about 11.96 vehicles per 1,000 people in 1978.* The rapid increase of domestic and international flights (see table 5) adds to the picture of the rapid and dynamic changes in transportation which are currently taking place within Egypt.

3.2 Transportation Activities

The activities carried out by the transportation system in 1975 are shown in table 6. Urban mass transit is the dominant passenger transportation activity in urban areas, while intercity highway freight traffic is the dominant transportation activity on the national networks of the country.

In terms of trends, urban mass transit has long been a dominant activity within urban areas, operating at its capacity levels (with considerable overuse of the fleet). In contrast, intercity freight movement on Egypt's highway network has been increasing dramatically in recent years and satisfying all the new freight movement needs. The growth of highway freight (trucks) has been accompanied by a decline of railroad freight movement by about 20 percent in recent years, and by almost 50 percent from the peak period of railroad freight operations. The figures of table 4 indicate that in 1975, trucks accounted for 14.5 percent of the highway fleet, well above the average of about 10 percent that is characteristic of highway rolling stock in countries with more extensive private car fleets. In 1975, the country had a truck fleet dominated by 6,500 trailers and heavy trucks (21.6 percent of the truck fleet was of 10 tons or more) to handle the intercity freight problem. The extent of the dominance of intercity truck freight is also revealed in the percentage distribution of activity. In 1975, trucks carried about 75 percent of ton-kilometers, railroads 13.4 percent, and waterways 11.6 percent. By way of contrast, corresponding statistics for the United States show that, in 1975, intercity trucks carried only 33.3 percent of ton-miles, the waterways (barges) 22.2 percent, and the railroads 44.5 percent of the total.

Egypt is a large, almost square country, 386,160 mi² in area. However, Egypt is characterized by linear development along the Nile Valley. This characteristic suggests an appropriate physical setup for extensive railroad use for long-distance freight movement. It is reasonable to characterize the 1975 distribution of ton-kilometer (75 percent- truck; 13.4 percent- railroad; and 11.6 percent- waterways) as extremely inefficient with respect to energy and other transport costs. The movement of freight by truck is usually three to five times more energy-consuming than its movement by railroads and six to ten times

* This estimate was made by Anthony Tomazinis. Since the completion of the analysis, new estimates were given to the U.S. team by the Egyptian Transport Planning Authority. They estimate a total of 344,000 motor vehicles in Egypt at the end of 1973.

¹ Transportation Association of America.

TABLE 5

TREND IN AIR TRAFFIC (THOUSANDS OF PASSENGERS)

Type and Origin of Flights	1971	1972	1973	1974	1975	Annual Growth 71/75 (%)
International	1,341.0	1,649.6	1,535.9	1,999.5	2,359.8	15.2
Domestic	192.0	401.6	404.6	381.2	518.1	28.0
Total	1,533.0	2,051.2	1,940.5	2,380.7	2,877.9	16.2
Cairo- International	1,333.8	1,648.2	1,535.9	1,999.0	2,359.7	15.3
Cairo- Domestic	98.4	160.3	159.3	149.5	195.4	18.7
Other- International	7.1	1.4	---	0.5	0.3	--
Other- Domestic	94.3	241.3	245.4	231.7	322.7	35.9

Source: Egyptian Civil Aviation Organization, 1975 Statistical Report. (Cited in Egypt National Transportation Study report.)

TABLE 6

EGYPT'S TRANSPORTATION ACTIVITIES (1975)

Transport Method	Passengers (Millions)	Passenger Kilometers (Billions)	Freight Tonnage (Millions)	% Total Freight Tonnage	Ton-Kilometers (Billions)	% Total Ton-Kilometers
<u>Highways</u>						
Urban Passengers	1220.0	3.6				
Intercity Passengers	161.0	21.3				
Urban Trucks			122.0		0.5	
Intercity Trucks			58.3	82.9	12.2	75
<u>Railroads</u>						
Passenger	126.0	7.0				
Freight			7.8	11.1	2.2	13.4
Waterways			4.2	6.0	1.9	11.6
Airways	2.8	n.a.	minor			
Pipelines			13.4		n.a.	
Shipping			13.5			
Urban Transit	1700.0	11.9				

Source: Estimates by Tomazinis.

more energy consuming than its movement by barges (depending on the particular efficiency achieved in each mode, i.e., size of barges, length of trains, size of trucks, size of freight wagons, mix of loads, etc.).

3.3 Energy Requirements: 1975

In spite of the extensive use of trucks for intercity freight, transportation was not a heavy user of energy sources in Egypt in 1975. For instance, transportation's share of all direct uses of petroleum products was only 24 percent; if all petroleum uses, including electrical production, are taken into account, its share was only 14.4 percent. This can be contrasted with U.S. transportation share of 53 percent of all domestic petroleum users in 1976. Obviously the limited use of private cars in Egypt is the primary reason for such a low share in petroleum products consumption. As table 7 shows, automobile fuel consumes only 23.6 percent of all petroleum products, while trucks consume 43.4 percent. In contrast, in the U.S., the automobile absorbed 53.7 percent in 1976, and trucks only 21.5 percent.

Another important observation concerning transport fuels consumption in 1975 is that the ship transport system of Egypt consumes much less energy proportionally than the U.S. system, reflecting its limited share in interregional freight transport.

3.4 Transportation Planning in 1978

Several plans currently under consideration by the government of Egypt affect the transportation sector. For example, there are plans to increase the domestic production of highway vehicles in 1985 to 40,000 vehicles annually (5,000 trucks and buses, 35,000 passenger cars), from a current level of about 15,500 vehicles (13,000 passenger cars; 1700 trucks; and 500 buses), according to the Five-Year Development Plan, 1978-82, which affects all of Egypt's transportation system components. Table 8 summarizes the items included in the Five-Year Plan. Improvements of the urban transit systems in Cairo, Alexandria, and other urban areas are proposed which aim to increase the capacity of these systems by 62.5 percent, 28 percent, and 57 percent, respectively. Similarly, improvements are proposed for the railroad system to permit an increase of ton-kilometers and passenger-kilometers of certain sections by 165 percent and 32 percent. Additional heavy trucks are planned to achieve a 79 percent improvement in ton-kilometers. In river transport, the Plan proposes 120 new barge units, establishment of direct navigation lines linking Alexandria-Cairo-Aswan, and preliminary activities to prepare Lake Nasser for major navigation. The Plan also calls for improvements of the Alexandria port to increase its capacity by 50 percent (from 10 to 15 million tons per year). It is significant that the achievement of the goals of the Five-Year plan is not certain and will represent some breaks from past trends.

A major analysis of the transportation system of Egypt is the Egypt National Transport Study, completed in draft form in the middle of 1977.

TABLE 7
COMPARISON CASE ENERGY DISTRIBUTION (1975)¹

	Gasoline	Diesel	Mazout	Jet Fuel	Electr.	Lubr. Oil	Total Energy	Egypt % Dist. By Mode	U.S. % Dist. ² By Mode
Automobile	15.31	0.04					15.35	23.45%	53.76%
Buses	0.03	0.89			0.05		0.97	1.48	1.07
Railways		4.89			0.43		5.32	8.13	5.38
Air Transport				8.60			8.60	13.13	7.53
Ship Transport			1.48				1.48	2.26	5.38
Trucks	14.94	13.28					28.22	43.13	21.50
Pipeline Storage		0.37			0.19		0.56	0.86	5.38
Lubr. Oil						4.95	4.95	7.56	—
Total ³	30.28	19.47	1.48	8.60	0.67	4.95	65.45	100.00	100.00
% Dist. by Fuel	46.26	29.77	2.26	13.13	1.02	7.56	100.00		

¹ Disaggregations of fuel type by modes done by Anthony Tomazinis.

² U.S. distribution from Transportation Energy Conservation Data Book: Supplement III, Oak Ridge National Laboratory, May 1977.

TABLE 8

TARGET SYSTEM IMPROVEMENTS AND ACTIVITY LEVELS OF THE 1978-82 TRANSPORTATION PLAN
(ANNUAL COST LE 440 MILLION, TOTAL COST LE 2,198 MILLION)

Sector	Cost (LE millions)	1978 Capacity	1982 Capacity	Percent Increase
<u>Urban Transportation</u>				
Cairo: Additional 1,900 buses 30 river units	168	From 1,800 to 1,977	2,200	22.0
200 trolley cars (replacement)		3,200 million	5,200 million	62.5
100 trolley cars (increase in fleet)		passengers 1976	passengers	
Extended trolley lines 34 km Additional complementary projects				
Alexandria: Additional 200 buses and 10 trolley cars	16.9	430 (1976)	550 million passengers	28.0
Other Urban Areas: Additional 4,000 buses (for expansion replacement) Supplementary projects	100	5,000 (1975)	7,850 million passengers- kilometer	57.0
<u>Intercity Transportation</u>				
Railroads: - Repair 1,000 kilometers	310			
- Additional 120 locomotives				
- Additional 1,600 freight cars				
- Additional 1,180 passenger cars				
- Additional supplementary projects				
- Freight line Alexandria-Etar-el Baroud				
- Completion of Port Said- Ismailia- El Mansura line		1,246 million tons-kilometer 8,610 million/passengers- kilometer (1975)	3,300 million tons-kilometer 11,365	165.0 32.0
Trucks: Add more 24-ton trucks	25	2,231 million tons-kilometer (1975)	4,000	79.0

TABLE 8 (Continued)

Sector	Cost (LE millions)	1978 Capacity	1982 Capacity	Percent Increase
<u>Intercity Transportation</u> (cont'd)				
River Transport: Maintenance of bodies and engines Add 120 new units	25			
Roads: Add 1,260 kilometers paved roads Repair 180 kilometers Three bridges over Nile River	100			
Navigation: Establish navigation line between Cairo and Alexandria Establish navigation line between Cairo and Aswan Preparation of Lake Nasser for navigation (plus floating base) (river and lock units)	100			
<u>Ocean Transport and Alexandria Port:</u> additional equipment, boats, tractors, lifters, etc. Add 14 merchant ships (replace unserviceable) Ports and lighthouse authority. Port Said, Suez, Uadabia, Mersa Matruh, Safaja Ports Continue studies of the new Damietta Port Add ocean transport companies	213.2	10 million tons (1975)	15 million tons	

TABLE 8 (Continued)

Sector	Cost (LE millions)	1978 Capacity	1982 Capacity	Percent Increase
Air Transport: New places, hangers, servicing, etc. Air control Prepare Luxor Airport to be an international airport Starting the new Alexandria international airport Developing the Mersa Matruh port (for large planes) Improve Cairo airport services Improve meteorological services Civil aviation training	168.3	3 million passengers	5 million passengers	66.0

Source: Egypt Five-Year Plan, 1978-1982.

According to this study, which focuses only on intercity transport systems and needs, it is proposed that the transport system of Egypt be developed to meet the objectives shown in Table 9. Basically, these recommendations represent a 3-fold increase in waterway ton-kilometers and a 3.6-fold increase in railway ton-kilometers, but only a 1.4-fold increase in truck ton-kilometers. The Berger study is important because it is essentially the first and only comprehensive review of the entire intercity transportation system of the country. However, it ignores the demands to be placed on the system by planned industrial and residential development in the new cities.

The Terms of Reference for the Phase II National Egypt Transport Study are now available. This study, when completed, should expand considerably the planning base for Egypt's transport sector. According to the Terms of Reference, the objectives of the study are "to assist the Government to develop technical and organizational capacity to undertake comprehensive transport planning activities on a continuous basis . . ." The scope of work for this project details an ambitious comprehensive planning and training study. The study will be limited in that it will not explicitly consider the urban areas except as they impact intercity activity. Hopefully, further studies will address the transport needs of the new and existing cities. Within the Phase II study, it is suggested that energy requirements be specifically considered as well as coordination between the Ministry of Transport and the other Ministries.

There is no comprehensive study, comparable to the Berger report, concerning the urban transportation systems of the country. The few ad hoc reports for Cairo can provide only partial answers to specific problems; they hardly become the basis for future regional projections in the areas of interface between transportation and energy.

Other sources of Egyptian transportation plans are studies of specific development projects. Examples are the studies of four new cities (Sadat City, Tenth of Ramadan, King Khalid City, and Ameriya). In addition, there are the developmental studies that deal with the Suez Canal-Ismailia, Port Said Zone, the studies on the New Valley, the Lake Nasser-Aswan studies, and the studies concerning the eastern desert in upper Egypt. These are in varying levels of completion, ranging from complete studies (i.e., Sadat city), to simple reports, or even just terms of reference reports for future detailed studies. In most of these studies the transportation sector, or the main transportation implications of the proposed actions, can be distinguished. In some cases, however, transportation received only passing attention (especially in terms of its regional and national implications).

In reviewing the complete set of plans and studies it was difficult to find comprehensive transportation planning studies. As of April 1978, there seemed to be very little evidence of comprehensive transportation planning on the urban, the regional, or the national scale. Similarly, it was impossible to locate modal studies and planning analyses concerning any of the major transportation modes (highways,

TABLE 9

RECOMMENDATIONS FOR THE TRANSPORTATION SYSTEM OF EGYPT (JANUARY 1977)

Transport Component	1975		1985	
	Passengers or Tons (Millions)	Passenger-or Ton-Kilometers (Billions)	Passengers or Tons (Millions)	Passenger or Ton-Kilometers (Billions)
Highway				
Trucks	58.3	12.2	94.0	16.8
Buses	161.0	21.3	287.0	37.1
Railroads				
Freight	7.8	2.2	22.9	7.9
Passengers	126.0	7.0	200.0	11.2
Waterways (freight)	4.2	1.9	18.1	5.7
Airways (passengers)	2.8		7.0	
Ports				
Without phosphate exports	15.0		28.0	
With phosphate exports	15.0		36.0	

Source: Egypt National Transport Study, Phase I.

railroads, urban transit, inland waterways, pipelines, aviation, and ports). Even the SOFRETU study concerning the future subway system of Cairo is rapidly becoming obsolete.

Therefore, any complete assessment of energy needs for the years 1985 and 2000 must proceed carefully and construct most of the planning steps that are normally included in comprehensive transportation studies. Hopefully, the Phase II study will fill in many of these steps.

3.5 The Efficiency of Egyptian Transport Modes

Assessment of the energy requirements of Egyptian transportation necessitated assumptions about the energy intensities of the various modes of transport. Figure 3 shows the subdivisions within transport that were considered. It also gives estimates of the energy consumption of each transport mode in Btu's per unit of activity. These estimates were established, theoretically and operationally, in the United States. Since Egypt-specific estimates were not available, and time did not permit such estimates to be made, U.S. and international measures were adjusted to reflect the Egyptian case. For example, the average Egyptian automobile is smaller than the average U.S. automobile. Therefore, its energy consumption is less. Table 10 shows the energy consumption estimates, by mode, which were used in the analysis. Appendix A contains additional statistics on U.S. and international energy intensities of alternative transport modes.

4.0 THE COMPARISON CASE: 1985 and 2000

The Comparison Case for 1985 and 2000 is based upon projections for each type of fuel used in transportation. These projections were supplied by the Egyptian General Petroleum Corporation during the team visit to Egypt. It was agreed that these projections would be used in the Comparison Case even though they might be contrary to projections generated by the transportation specialist. The specialist was to disaggregate the EGPC projections by mode of transport. From this breakdown implied activity levels were calculated.

The energy apportionment among transport modes and the shares of each fuel type are shown in table 11. A number of important observations can be made concerning the distribution of energy among modes and fuel types in 1985 and 2000. Total energy consumption rises from 65.45 quads* to 111.12 quads in 1985, and to 227.6 quads in 2000. In 1985 the energy used by the transport sector is assumed to be only 25 percent of all direct petroleum usage, and to drop dramatically between 1975 and 1985 from 14 percent to only 5 percent of all energy (petroleum plus other) use in the country (including production of electricity). Use of electricity in transportation is expected to increase from 0.67

* One quad equals 1 quadrillion (10^{15}) joules or approximately 10^{12} Btu.

Notes:

aAssuming 50 mpg, 2 seats.

bInsufficient data

cHighly system dependent

d1973 figure

eRange from small passenger planes to high density wide body aircraft as used in charter service

fSize and commodity dependent

gAll cargo configuration

hUpstream and downstream values account for additional variation

iAdditional variation due to flow rates

Fig. 3 Energy intensity by transportation mode (theoretical in Btu's 1972 operational)

TABLE 10
URBAN AND INTERCITY ENERGY MEASURES

Transport Mode	Activity	1975	1985			2000		
			Comparison Case	Option Case	Trends Case	Comparison Case	Option Case	Trends Case
Automobiles								
Urban	litres/100 km		7.7	7.7	7.7	7.7	7.7	7.7
Intercity	litres/100 km	7.15	6.65	6.65	6.65	6.65	6.65	6.55
Trucks								
Urban	litres/10 km	3.6	3.2	3.2	3.6	3.2	3.2	3.2
Intercity	litres/10 km	2.1	1.9	1.9	2.1	2.15	2.05	2.30
Railroads								
Suburban	Btu/pass-km	165.0	165.0	165.0	165.0	270.0	270.0	360.0
Nat. Pass.	Btu/pass-km	363.0	810.0	750.0	544.0	810.0	650.0	1,250.0
Freight	Btu/ton-km	450.0	450.0	450.0	450.0	450.0	450.0	450.0
ER + M + W*	Btu/car-km	350.0	350.0	350.0	350.0	350.0	350.0	350.0
Subway	Btu/pass-km	-----	-----	-----	-----	405.0	300.0	527.0
Buses								
Trolleys	Btu/pass-km	40.0	110.0	110.0	110.0	110.0	110.0	110.0
Urban	Btu/pass-km	30.0	92.0	130.0	200.0	174.0	174.0	275.0
Intercity	Btu/pass-km	40.0	75.0	100.0	175.0	130.0	130.0	195.0
Pipelines	Btu/ton-km	250.0	190.0	190.0	190.0	168.0	168.0	168.0
Air Transport								
Domestic	Btu/pass-km	6,500.0	5,500.0	5,500.0	5,500.0	4,400.0	4,400.0	4,400.0
International	Btu/pass-km		5,500.0	5,500.0	5,500.0	4,400.0	4,400.0	4,400.0
Inland Waterways	Btu/ton-km	400.0	325.0	300.0	415.0	374.0	374.0	500.0

TABLE 11

ENERGY APPORTIONMENT AMONG TRANSPORT MODES:
COMPARISON CASES, 1985 AND 2000 (QUADRILLION JOULES)

1985 Comparison Case								
Transport Mode	Gasoline	Diesel	Mazout	Jet Fuel	Electr.	Lubr. Oil	Total Energy	% Dist. By Mode
Automobiles	33.79	0.26					34.05	30.65
Buses	0.03	0.89			0.19		1.11	1.00
Railways		7.82			4.70		12.52	11.37
Air Transport				14.00			14.00	12.60
Ship Transport			2.55				2.55	2.29
Trucks	14.20	24.13					38.33	34.49
Pipeline Storage					0.67		0.67	0.60
Lubr. Oil						8.89	8.89	8.00
Total	48.02	33.10	2.55	14.00	5.56	8.89	112.12	100.00
% Dist. by Fuel Type	43.21	29.79	2.29	12.60	4.10	8.00	100.00	
2000 Comparison Case								
Transport Mode	Gasoline	Diesel	Mazout	Jet Fuel	Electr.	Lubr. Oil	Total Energy	% Dist. By Mode
Automobiles	66.21	0.65					66.86	29.38
Buses		2.32			0.19		2.51	1.10
Railways		3.67			21.64		25.31	11.12
Air Transport				20.00			20.00	8.79
Ship Transport			7.33				7.33	3.22
Trucks	25.21	59.71					84.92	37.31
Pipeline Storage					1.30		1.30	0.57
Lubr. Oil						19.37	19.37	
Total	91.42	66.35	7.33	20.00	23.13	19.37	227.60	100.00
% Dist. by Fuel Type	40.17	29.15	3.22	8.79	10.16	8.50	100.00	

Source: EGPC (total) and Tomazinis (disaggregation).

quads in 1975 to 4.56 quads in 1985, and 23.13 quads in 2000. Transportation's percentage is assumed to increase from 2.24 percent of total electricity in 1975 to 4.15 percent in 1985. Of petroleum product use, gasoline consumption is assumed to increase by 58 percent in 1985, while diesel will increase by 70 percent, and mazout by 72 percent. Of course, use of electricity is assumed to show the largest increase: 680 percent over 1975 levels.

In terms of distribution of each fuel type to the various modes in the Comparison Case, observations can be made for gasoline, diesel, and electricity. While in 1975 gasoline was about evenly distributed between passenger cars and trucks, its distribution in 1985 is expected, in the Comparison Case, to be 70 percent for passenger cars. The truck fleet and the railroads share the use of the diesel in similar proportions in 1975 and 1985. Electricity use in 1985 is committed to the initiation of railroad electrification and automation of classification yards and signal installation.

Total transportation consumption of energy in 2000 is expected to include 91.42 quads of gasoline (40.17 percent of transportation's total energy consumption) and 66.33 quads of diesel (29.15 percent of the total). Of these two fuel types the automobile will receive, in 2000, 66.86 quads (29.38 percent of the total) and the truck fleet 84.92 quads (37.31 percent of the total). Between 1985 and 2000, the use of gasoline is expected to decrease from 43.21 percent to 40.17 percent of total energy consumed in the transportation sector. Diesel will remain at approximately the same relative level (from 29.80 percent in 1985 to 29.15 percent in 2000).

The Comparison Case appears to underestimate energy use. The extent of this underestimation can be seen by tracing present trends in energy consumption and projecting them to the year 2000. Table 12 presents the augmentation of the highway fleet for 1985 and 2000 under two sets of assumptions. The most consistent with present trends (but still on the conservative side) are the upper level projections. These suggest that by 2000, two million motorized vehicles will be in the civilian registry in Egypt. If these trends continue, together with the trends toward the intensive use of passenger cars in the urban regions and of truck fleets for intercity freight, the expectations are that Egypt could need approximately 150 quads in gasoline and 104 quads in diesel. The difference between the trend-based projections and the Comparison Case-based projections of motor vehicles and their concomitant consumption of fuels represents the extent to which underestimates may have been made in the Comparison Case.

Constraints on gasoline and diesel fuel use can be the reasons behind the significant increase in projected energy utilization by the railroads (from 11.52 quads in 1985 to 25.31 quads in 2000) and by waterways transport (from 2.55 to 7.33 quads). Behind these shifts in energy utilization is an equally significant shift in transport activities from personal travel to group travel, and from truck fleets to the railroad system and the waterways, i.e., from the less energy-effective

TABLE 12

CIVILIAN REGISTRY HIGHWAY FLEET POSTULATIONS, 1985 and 2000

(THOUSANDS OF UNITS)

Vehicle Type	1985		2000	
	High Expectation ¹	Low Expectation ²	High Expectation ³	Low Expectation ⁴
Automobiles	480	350	1,320	840
Taxis	75	75	80	80
Buses	20	20	25	25
Trucks	125	100	325	255
Total	700	600	1,750	1,200
Motorcycles	150	150	250	200
Total Vehicles	850	750	2,000	1,400

¹ With 10.4 percent annual increase 1975-85 (as compared to 10.8 percent increase suggested by the L. Berger Report, and 17.8 percent increase experienced in 1975-78).

² With only 6.85 percent annual increase.

³ With 10 percent annual increase from high 1985 projections.

⁴ With 4.76 percent annual increase from high 1985 projections or 6.66 percent annual increase from low 1985 projections.

to the more energy-effective modes. The difference of 97 quads in energy utilization between the trend-based projection and the Comparison Case-projection for cars and trucks should be compared with the added energy used by buses, trains, and waterborne shipping.

The major policy questions focus on the extent of private car utilization and on the relative role that the truck fleet, the railroads, and the inland waterways will play in moving freight. For instance, if present trends continue, by 1985 Egypt may have about 555,000 passenger cars. At an average annual distance of 22,300 kilometers per car (as in 1975) and fuel consumption of 6.55 liters per 100 kilometers (economy cars), plus 150,000 motorcycles, private transport will consume more than 42.38 quads of gasoline. Adding the gasoline that trucks use, the present trends in the growth of passenger car possession and use will mean about 73.00 quads of gasoline devoted to transportation instead of the 48.02 quads that the Comparison Case suggests. Similarly, the present trends of truck fleet growth and use for long distance freight movement would require about 46.00 quads of diesel fuel instead of the 33.10 quads allowed in the Comparison Case. Resolving these differences depends upon the extent to which urban and interurban public transit can be improved, between 1975 and 1985, to serve personal travel needs, and the extent to which the inland waterways and the railroad system can be improved, between 1975 and 1985, to serve the intercity freight movement needs. Even the large trucks of the Egyptian public companies require about 20 tons of fuel to serve 1 million ton-kilometers as opposed to only 4.2 tons needed for railroad service and even less (by half) for inland waterways service. The energy efficiency of urban mass transit (in the form of urban bus, street car or trolley car or suburban commuter train) is ten to twenty times that of the passenger car, depending on load factors. Obviously, greater use of the more energy-efficient modes of freight movement and personal travel will require a smaller total amount of energy for a given level of transportation activity.

Activity Levels Projection. The Comparison Case projections of fuel use imply certain levels of transportation activity. Table 13 indicates the levels of transportation activities by transport modes, for urban and interurban needs, as implied by the Comparison Case. Two major points can be made on the basis of table 13.

First, between 1978 and 1985, urban transit throughout the country, and especially in Cairo, must be expanded sufficiently to serve at least 2.55 billion trips per year without the introduction of any subway facilities. The Five-Year Development Plan for Egypt includes a similar expectation (stating a desired 62.5 percent increase in Cairo). The expectations are based on the addition of 400 buses, 100 trolleys, and 34 kilometers of trolley lines. These projects, plus the planned extensive improvements and replacement of the present fleet and services, can be expected to achieve this objective in Cairo. Similar improvements are included in the Five-Year Plan for Alexandria and intercity passenger

TABLE 13

ACTIVITY LEVELS: COMPARISON CASES, 1985 and 2000

Transport Item	1985	2000
URBAN		
Total Urban Person Trips (Billion)	6.48	13.53
Total Transit Trips (Billion)	2.55	5.95
Buses + Trolleys + Suburb Trains (Billions)	2.55	2.55
Subway (Billion)	----	3.40
Auto Passenger Trips (Billion)	2.31	4.87
Auto Vehicle-km (Billion)	3.16	8.70
Auto Passenger-km (Billion)	9.24	24.35
Total Freight (Million Tons)	234.00	404.00
Highway (Million Tons)	225.00	392.00
Freight Ton-km (Million)	936.00	2,350.00
Truck Vehicle-km (Million)	148.10	371.87
INTERCITY		
Total Person Trips (Million)	397.70	661.55
Auto Passenger Trips (Million)	107.5	163.75
Railroad Trips (Million)	126.00	200.00
Bus Trips (Million)	161.00	287.00
Airline Person Trips (Million)	3.20	10.80
Total Freight (Million Tons)	135.00	342.00
Waterways (Million Tons)	7.00	35.00
Railroads (Million Tons)	17.50	23.00
Highways (Million Tons)	110.50	284.00
Total Freight Ton-km (Billion)	31.10	64.65
Water Ton-km (Billion)	3.10	14.00
Railroad Ton-km (Billion)	4.90	8.05
Highway Ton-km (Billion)	22.10	42.60
Auto Passenger-km (Billion)	17.73	27.02
Auto Vehicle-km (Billion)	5.91	9.32
Truck Vehicle-km (Billion)	5.60	9.46
Pipelines (Million Tons)	13.40	21.10

travel, which adds 400 new buses, 1,180 new passenger coaches, and 120 new locomotives in the railroad rolling stock. If the Five-Year Plan of 1978 to 1982 is fully operative by 1985, the capacity of the system to serve the passenger travel needs of the country will indeed increase to the appropriate level. However, it is questionable whether the additional capacity will be used to divert automobile travel (and possession) or will be used to further increase population mobility (and add some travel amenity). Neither the passenger railroad improvements nor the intercity bus fleet included in the Comparison Case are really expected (as mentioned in the Five-Year Plan) to increase intercity passenger load. The purpose is essentially to improve the conditions and quality of travel for users so that the pressure to acquire and operate a private car is reduced, and economies in energy consumption by passenger cars are realized. Increased capacity of intercity passenger travel facilities is needed to support actual increases in traffic loads.

Another question is whether inland waterways and railroads can be enlarged and coordinated sufficiently to serve 24.5 million tons of freight, or 18.16 percent of the total expected load. The two systems (rail and waterways) were carrying only 12 million tons (17 percent) in 1975. At that time the barge fleet was used at about its operating capacity (imposed by its work rules), while the railroad network could have carried some additional freight, if there had been more demand. By 1985 the two systems must double their capacity from 12 million to 24.5 million tons, while retaining their proportional shares of intercity freight movement. The Comparison Case estimates are based on that expectation and its achievement will crucially affect Egypt's ability to retain the present level of energy efficiency in freight movement. Otherwise, another 22 quads will be needed to service the freight needs.

The Comparison Case demands rapid developments in railroad systems, the inland waterway system, and the land use evolution of the country. The Five-Year Plan does include 1,600 freight cars and 120 new locomotives, a freight line linking Alexandria-Etay-el Baroud and completion of the Port Said-Ismailia-El Mansura line. It also includes 120 new barge units and the establishment of regular navigation lines between Alexandria-Cairo, and Cairo-Aswan. In addition, it includes provisions for navigation in Lake Nasser. All these planned projects should be completed by 1985, if the Comparison Case energy allocations are to be workable. Additionally, the road beds of most main lines of the railroad network will need strengthening, and high quality connections between the railroad system and all new industrial plants will need to be established. Finally, reliability of the railroad operations must be improved. Better, more efficient, work rules in the waterway system are needed so that the system can carry more freight, up to 7 million tons per year. Increases in the daily working hours and the actual working days per month are indicated.

As table 11 reveals, the Comparison Case projections for 2000 require that additional emphasis be placed, first, on urban mass transit. The Comparison Case assumes that a fully operational subway system will

be available by 2000 in Cairo. Such a system would have at least three lines intersecting the region and could carry twice as much traffic load as all the transit means in Cairo in 1975. In addition, the improvement of surface transit, assumed by the Comparison Case of 1985, would also be in place. It could reasonably be expected to reduce passenger car use for most trips in the Cairo region. Additional improvements in the surface transit of the other major urban areas of the country are also included in the Comparison Case. Thus, of 13.53 billion person trips expected in the urban regions in 2000, approximately 4.87 billion would be made by passenger car, 5.95 billion by mass transit, and the remaining by foot.

Urban freight growth will be significant and its dependency on small and medium trucks almost total. By 2000, approximately 404 million tons of freight will have to be moved within urbanized regions, about 97 percent of it by distribution trucks, and the remaining 3 percent by passenger cars, station wagons, animals, and individuals.

Intercity personal travel is also expected to be strongly influenced by the assumptions included in the Comparison Case. Railroad person trips are expected to rise to the level of 200 million. The implications is that the fleet and line improvements suggested by the Egypt National Transport Study for 1985 must be in place by 2000 at least, if the Comparison Case is to be realized. Both the bus and railroad systems would help to limit the use of passenger cars for intercity travel to only one trip every two weeks per car, instead of one trip per week as otherwise expected.

The situation for intercity freight is also replete with clear requirements. The present trend places increased emphasis on the highway truck fleets, since the waterways and the railroad systems operated near their present capacity for years and allowed the highway system to absorb the additional needs for freight movement. Egypt's underutilized highways still have additional capacity, and the truck fleets are relatively easy to expand. Thus, in 1975, the highways were serving 82.9 percent of the tonnage and 75 percent of ton-kilometers in the country, and were trending toward an increased share by 1985. This trend would need to be reversed, to allocate 35 million tons of freight to the waterways, and 23 million tons to the railroads, leaving only 284 million tons for the highway-truck. In terms of ton-kilometers the trend would need to change so that the waterways would carry 21.65 percent, the railroads 12.45 percent, and the highways only 65.90 percent of the total ton-kilometers.

Although no technical study assesses the maximum possibilities of the waterways and the railroad system of Egypt, inspection of the systems, and review of the available reports, suggest that it is technically possible to expand these two systems so that they can provide the services presumed by the Comparison Case. The canals, and especially the Nile river, are utilized presently at a very low level. The barge fleet is at a minimal level. Nile working arrangements are very restrictive and the physical facilities are minimal. In particular, the

Cairo-Aswan section of the Nile can carry vastly more freight than it currently does, given a much expanded barge fleet and well-developed and well-integrated docking spots, ports, and transshipment points in frequent and well selected locations. As Upper Egypt develops, the opportunities for river and canal shipment will also increase, as will coastal freight from Alexandria and the Mediterranean coast to the ports of Safaga and Berenice.

Concerning the railroad system of the country, the assumed 23 million tons for the Comparison Case for the year 2000 is the 1985 freight expectation of the Egypt National Transport Study. For its realization, all the system improvements suggested by that study should be in place by the year 2000, at least. (The improvements in the railroad system included in the Five-Year Development Plan closely approximate the suggestions of the Egypt National Transport Study.)

Table 13 reveals two more points, one concerning the railroad system and another concerning the network of pipeline and storage facilities for petroleum products. The Comparison Case railroad system is expected to be extensively electrified by the year 2000. The electrification should cover the main lines of the system (i.e., all the double-track lines) and the major classification yards. This change will strengthen the main lines as well as the diesel locomotives on the rest of the system. A reasonable expectation is to have in place a well-functioning system capable of competing with all the other transport modes for median and long passenger and freight trips. Additional electrified units can also be used throughout the system for good quality, frequent, passenger services. The anticipated level of quality includes air conditioning and automated signals.

Finally, jet fuel provisions are predicted to increase by only 42.8 percent from 1985 while the air transport activity is expected to more than triple. This prediction reflects an assumption of substantial improvements in air travel over the 1975 situation. At that time, the passenger efficiency of Egypt Air had much room for improvement, averaging only 51 percent seat utilization and a 44 percent load factor. Improvements in scheduling and utilization plus the introduction of wide body aircraft can reduce energy consumption per passenger by a factor of 3 to 4.

5.0 ASSESSMENT OF THE OPTION CASE

A major objective of the transportation assessment was to identify opportunities for fuel switching and/or energy conservation within the sector. The option identified increases utilization of the waterways and electrified rail and decreases emphasis upon highway movement of freight and passengers. Table 14 shows the use of fuels by mode in the Option Case. In summary, the Option Case in 1985 involves an increase of total energy consumption of 52 percent over 1975 levels, as compared to a 70 percent increase in the Comparison Case. In 2000, the Option Case consumes about 30 quads less than the Comparison Case. This is 2.5

TABLE 14

ENERGY APPORTIONMENT AMONG TRANSPORT MODES:
OPTION CASES, 1985 and 2000 (QUADRILLION JOULES)

1985 Option Case								
Transport Mode	Gasoline	Diesel	Mazout	Jet Fuel	Electr.	Lubr. Oil	Total Energy	% Dist. By Mode
Automobiles	23.02	0.33					23.35	23.40
Buses		1.67					1.67	1.67
Railways		11.32			6.29		17.61	17.65
Air Transport				14.00			14.00	14.03
Ship Transport			3.21				3.21	3.22
Trucks	14.23	16.16					30.39	30.45
Pipeline Storage					0.67		0.67	0.67
Lubr. Oil						8.89	8.89	8.91
TOTAL	37.25	29.48	3.21	14.00	6.96	8.89	99.79	100.00
% Dist. By Fuel Type	37.33	29.54	3.22	14.03	6.97	8.91	100.00	

2000 Option Case								
Transport Mode	Gasoline	Diesel	Mazout	Jet Fuel	Electr.	Lubr. Oil	Total Energy	% Dist. By Mode
Automobiles	45.93	1.65					47.58	23.98
Buses		2.92					2.92	1.47
Railways		4.97			25.80		30.77	15.51
Air Transport				20.00			20.00	10.08
Ship Transport			8.44				8.44	4.25
Trucks	22.69	49.44					72.13	36.35
Pipeline Storage					1.30		1.30	0.65
Lubr. Oil						16.27	16.27	
Total	68.62	58.98	8.44	20.00	27.10	16.27	198.41	100.00
% Dist. by Fuel Type	34.55	29.72	4.25	10.08	13.15	8.20	100.00	

times the 1985 savings of the Option over the Comparison Case. The essential difference is in further increases in the use of the energy-efficient modes for intercity personal travel and intercity freight movement. The two changes are reflected in the additional increase in the use of mazout (shipping and inland waterways) and electricity (railroad use).

Since the Comparison Case also implies some moves toward conservation and increased use of the waterways and railways, a more striking comparison is with the Trends Case. In 2000, the Trends Case would use 126 quads more than the Option Case.

In 1985, fuel use by automobiles under the Option is 23.35 quads versus 34.05 quads in the Comparison Case. For trucks, the anticipated use in 1985 is 30.39 quads as compared to 38.33 quads for the Comparison Case and 28.22 quads in 1975. In contrast to these two reductions in fuel consumption, the Option Case anticipated 3.21 quads energy use for shipping and inland waterways instead of 2.55 quads in the Comparison Case and 1.48 quad in 1975. The 1985 Option Case also anticipates energy use of 17.61 quads for railroads, instead of 11.52 quads under the Comparison Case and 5.38 quads in 1975; and 1.67 quad for the bus fleets instead of 1.11 quad in the Comparison and 0.97 quad in 1975.

In 2000, the Option Case is characterized by a reduction in gasoline consumption, as compared to the Comparison Case, from 91.42 to 68.62 quads, or from 40.1 to 34.55 percent of the total transport energy consumption. A similar reduction is observable in diesel fuel consumption, from 66.35 quads in the Comparison Case in 2000, to 58.98 quads in the Option Case. Since this decrease in diesel usage is proportional to the total decrease of energy consumption in the Comparison versus the Option Case, diesel fuel consumption remains at approximately the same relative level of total energy consumption for both Cases.

In terms of energy consumption by transport mode, in 2000, the Option Case is characterized by reductions in the consumption of fuels by passenger cars, from 66.86 quads to 47.58 quads or from 29.38 percent to 23.98 percent of the total. A second important reduction can be noted in the consumption levels of trucks, from 84.92 quads to 72.13 quads, or from 37.31 percent to 36.35 percent of total transport energy consumption. The other transport modes are characterized by increases in their levels of energy consumption. For instance, in 2000, the railroad system increases its consumption from 25.31 quads (Comparison Case) to 30.77 quads (Option Case), or from 11.12 percent to 15.51 percent of the total fuels in transport. Similarly, ship transport registers an increase from 7.33 quads, in the 2000 Comparison Case, to 8.44 quads, in the 2000 Option Case. Finally, the bus fleet also shows greater consumption for the Option Case, 2.92 quads as compared to 2.51 quads.

Increases in energy use by the waterway, railroad, and bus modes imply specific levels of transportation activities carried out by each mode, as well as specific transportation projects and national policies in transportation, land use, urbanization, and industrialization.

The level of transportation activities expected in the Option Case is shown in table 15. The table reflects the increase in transportation activity levels over the Comparison Case levels for mass transit, intercity personal travel, and freight movement by the waterways and the railway system. The Option Case suggests additional support for urban mass transit, in the form of either a fourth line of the subway system in Cairo, or a number of additional bus lines, and light rail lines of several types in Cairo, Alexandria, and other large urban areas of the year 2000.* The extent of these additional improvements would have to equal the total urban transit use in Egypt in 1975. The shift of urban personal travel from passenger car trips to bus trips, subway trips, or light rail trips involves substantial and obvious economies in energy consumption.

The technical question is whether such a shift can be accomplished. A review of the SOFRETU study of 1973 does not indicate any serious technical problems in designing a fourth line into the subway system. In fact, the three lines proposed by that plan leave major and densely developed areas of the Cairo region completely unserved. Similar opportunities to add bus lines and light rail lines exist in Cairo, Alexandria, Manura, and other major cities of Egypt.

In terms of urban mass transit the activity level included in the Option Case for 1985 is 3.40 billion transit trips annually, compared with 2.55 billion in the Comparison Case and 1.70 billion in 1975. It is apparent that the bus system of the Egyptian metropolitan areas could be expanded dramatically, well beyond the provisions of the Five-Year National Plan, based upon anticipated demand. For instance, a metropolitan area of 8.5 million people in 1978 (or 12 million in 1985) needs more nearly 3,500 to 4,500 buses (and twice as many lines) to be served properly. This number far exceeds the 2,000 included in the Five-Year National Plan. An increase of this scale, plus the improvements called for by the Comparison Case, can be expected to serve, at an acceptable quality level, 3.40 billion trips and in turn hold automobile trips to 1.46 billion instead of the 2.31 billion of the Comparison Case.

For intercity personal travel, the activity levels expected under the Option Case, for 1985, are 200 million trips for the railroad system, and 287 million trips for the bus system compared with 126 million and 161 million for the Comparison Case and 1975. These increases will result from implementation of the Egypt National Transport Study recommendations: substantial improvement of the railroad services (especially passenger coaches), additional trains, and electrified units. For intercity buses, an approximate doubling by 1985 of the number of buses and lines operating in 1975 is included in the Option Case. This anticipates an increase of more than 100 percent (from 9,300 in 1975 to about 20,000).

*For the purposes of this report, light rail lines, subway lines, and commuter rail lines are included in the classification of railroads.

TABLE 15

ACTIVITY LEVELS: OPTION CASES, 1985 and 2000

Transport Item	1985	2000
URBAN		
Total Urban Person Trips (Billion)	6.48	13.53
Total Transit Trips (Billion)	3.40	7.65
Buses + Trolleys + Suburb Trains (Billions)	3.40	2.55
Subway (Billion)	---	5.10
Auto Passenger Trips (Billion)-Highway	1.46	3.17
Auto Vehicle-km (Billion)	2.98	5.66
Auto Passenger-km (Billion)	8.76	19.02
Total Freight (Million Tons)	234.00	404.00
Highway (Million Tons)	225.00	392.00
Freight Ton-km (Million)	936.00	1,960.00
Truck Vehicle-km (Million)	148.10	310.10
INTERCITY		
Total Person Trips (Million)	540.00	765.40
Auto Passenger Trips	47.00	145.60
Railroad Trips (Million)	200.00	250.00
Bus Trips (Million)	287.00	358.00
Airline Person Trips (Million)	3.20	10.80
Total Freight (Million Tons)	135.00	342.00
Waterways (Million Tons)	18.00	40.00
Railroads (Million Tons)	23.00	45.00
Highways (Million Tons)	94.00	257.00
Total Freight Ton-km (Billion)	33.23	70.30
Water Ton-km (Billion)	7.99	16.00
Railroad Ton-km (Billion)	6.44	15.75
Highway Ton-km (Billion)	18.80	38.55
Auto Passenger-km (Billion)	7.75	25.48
Auto Vehicle-km (Billion)	2.44	7.82
Truck Vehicle-km (Billion)	3.96	8.56
Pipelines (Million Tons)	13.40	21.10

In 2000, the shift in mode involves 18 million trips diverted from passenger cars to railroads and buses. It also involves approximately 100 additional induced trips that should be expected to be generated due to the assumed future higher quality of the two modes. The energy efficiency of an intercity bus is about three times the efficiency of a fully loaded passenger car; that of railroads, about two and one-half times. In combination with freight travel, that efficiency increases significantly. On that basis the Option Case for 2000 implies further strengthening of the intercity bus lines of the country and added railroad passenger units for personal travel within the Delta and along the Nile to Upper Egypt. Both shifts are technically feasible within the Egyptian network of highways and railroad lines.

In terms of freight movement, the Option Case postulates that all growth of freight movement by railroad and waterways, projected by the Egypt National Transport Study, will be achieved by 1985, both in terms of tons and ton-kilometers. As table 15 indicates, the railroad will, in this case, carry 23 million tons and 6.44 billion ton-kilometers (19.4 percent of the total activity) in 1985, while the waterways will carry 18 million tons or 7.99 billion ton-kilometers (24 percent of the total activity). The two modes will carry 43.4 percent of the total activity, while the truck fleet will carry 56.6 percent, as compared with 73.7 percent in the Comparison Case and 74.9 percent in 1975. Thus, only the Option Case reverses the current trend, which places major emphasis on the truck fleet. The Comparison Case succeeds only in maintaining the haulage shares at the 1975 levels (an important accomplishment in itself, since otherwise the share of the truck fleet would grow to 91 percent, if no improvements take place in the railroads and waterways).

The Option Case in 2000 suggests a modest increase of river freight movement, from 35 million to 40 million tons, and a major increase of railroad freight from 23 million to 45 million tons. The first shift is only a small proportional increase over the Comparison Case for 2000 and appears possible by only small increments in industrial production and in general Nile cargo destined for Upper Egypt. The only technical* requirements are an extension of the fleet of barges, adjustments of several locks on the major canals, increases in the fleet operating hours per month, raising several low bridges, and building docks and ports at strategic points along the Nile.

The railroad system needs, first of all, to significantly improve the railroad service available at the Alexandria Port. Additionally, it needs to add freight cars of different types, add additional locomotives, strengthen the roadbed of all main lines, extend double tracks in several cases, and establish (or reestablish) the connection between the railroad system and the new industrial developments of the country. This effort will be instrumental in raising the ton-kilometers carried by railroads, from 13 percent to 22.4 percent of the total.

*Appendix B discusses environmental problems associated with utilization of the waterways and potential solutions to them.

By 2000, the railroad system is also expected to be largely electrified. Electrification is not necessarily energy conserving and should be limited to heavily or frequently traveled lines of the Egyptian railroad system. However, there are three other advantages of electrification, which raise the quality of the system far above comparable systems and improve its competitive ability to attract passengers and freight. The three advantages are:

- o it reduces downtime of locomotives to less than half of the most reliable diesel locomotives;
- o it requires less than one-third the maintenance cost of the most streamlined diesel locomotives; and
- o it doubles the economic life of the locomotives.

The Egyptian railroad system has been plagued with locomotive maintenance problems to the extent of being forced to cancel or eliminate several thousand trains in 1975-1977. This lack of system reliability produces multifarious effects in its serviceability and appeal. To raise the system to the point of servicing 45 million tons, electrification of the main lines is imperative. From a long-range point of view, electrification is also necessary because of the expectation of greater electric than petroleum product energy availability after 2000.

The effort to improve the waterway and railway systems will depend upon national policies supporting these two modes by:

- o making certain that when major industrial enterprises choose their location and determine operations, they consider the railroads and/or the waterways as their central service system;
- o making certain that any new urban development between now and 1985 is located on a site that is easily serviceable by railroads and/or waterways; and
- o encouraging the two systems to start planning complementary integrated services.

Observations. Some observations can be made at this time concerning the 1985 and 2000 Comparison and Option Cases. First, the difference between the Comparison Case and the Option Case is rather small (in 1985 only 12.33 quads) for two reasons. One reason is that the Comparison Case is clearly limited, not reflecting the projection reached by extending present trends to predict the increased role of the intercity truck fleet and the growth of passenger car ownership and utilization (a difference of more than 30 quads). Another reason is that the time between 1978 and 1985 is too short to implement major land use and development policy, such as development of new cities and major industrial districts.

A second observation is that achieving the Comparison Case will not be easy. Coordinated planning and action by several ministries, authorities, and agencies would be required before the Comparison Case could be ensured and much more effort would be required to achieve the Option Case. Although both projections are considered technically feasible, significant planning and investment in the field of transportation would be necessary before results would begin to be felt. The first activity along these lines is the need for comprehensive planning in the field of transportation, starting from policy studies for each transport mode, including policies on urbanization and industrialization, and concluding with alternative analyses that consider energy requirements, unit costs of operations, environmental effects, and land use implications.

6.0 OBSERVATIONS AND CONCLUSIONS

6.1 Significance of the Cases

Table 16 summarizes the transportation fuel use for 1975 as well as the Comparison Case and Option Case totals for 1985 and 2000. The energy consumed by transportation in Egypt in 1975 was modest, only 24.52 percent of that used by all direct users. A similar proportion is maintained for the Comparison cases for 1985 and 2000. The Comparison for both 1985 and 2000 falls between the Trends and the Option Case. In particular, for 1985 the Comparison Case is a departure from the Trends Case projection, showing a reduction of almost 45 quads. This represents an effort toward more energy-effective transport modes. Any conservation effort beyond this level might be hard to achieve by 1985, primarily because of the short time period.

A similar situation prevails for the 2000 projections, but with greater consumption quantities involved. By then, the Trends Case projection would require 324 quads and consume 36.51 percent of direct petroleum products. Instead, the Comparison Case calls for 96.4 quads less consumption and represents 24.8 percent of direct petroleum products utilization. The Option Case calls for even less consumption: 29.29 quads, which corresponds to only a 20.11 percent share of direct use of petroleum products. In both cases, in 2000, electricity will contribute substantially to transportation needs, supplying 23.13 quads (Comparison Case) and 26.10 quads (Option Case). Thus, both cases depend on important conservation efforts, demanding significant efforts for the achievement of either. The important point, however, is that changes in energy consumption patterns are included in the energy projections of both the Comparison and the Option Cases. Table 17 presents these changes and reveals the emphasis placed by the projections on the energy-efficient transport modes, i.e., the railroad system, the inland waterways, the intercity bus system, and urban mass transit.

The energy distribution shown in table 17 represents the entire energy demand in the transportation sector of the country, and includes civilian as well as government use requirements; the latter is assumed to be approximately 22.02 quads in 1975 and to remain constant for the years 1985 and 2000.

*U.S. transportation consumed about 53.6 percent of all direct uses of petroleum products in 1976.

TABLE 16

SUMMARY OF ENERGY CONSUMPTION FOR THREE STUDY
CASES (QUADRILLION JOULES)

Case	Amount	Percent*
1975 Actual	65.45	24.52
1985 Comparison	112.12	25.04
Option	99.78	21.97
Trends	156.00	35.99
2000 Comparison	227.60	24.81
Option	198.41	20.11
Trends	324.00	36.51

*Percentage of petroleum products used in transportation as opposed to total direct usage of petroleum products.

TABLE 17
DISTRIBUTION OF ENERGY REQUIREMENTS BY TRANSPORT MODE AND FUEL TYPE
(QUADRILLION JOULES)

Transport Mode	ELECTRICITY			JET FUEL			GASOLINE			DIESEL			MAZOUT		
	1975	1985	2000	1975	1985	2000	1975	1985	2000	1975	1985	2000	1975	1985	2000
<u>COMPARISON CASE</u>															
Automobiles							15.31	33.79	66.21	0.04	0.26	0.65			
Buses	0.05	0.19	0.19				6.03	0.03		0.89	0.89	2.32			
Railways	0.43	4.70	21.64							4.89	7.82	3.67			
Airways				8.60	14.00	20.00									
Waterways													1.48	2.55	7.33
Trucks							14.94	14.20	25.21	13.28	24.13	59.71			
Pipes and storage	0.19	0.67	1.30							0.37					
TOTALS	0.67	5.56	23.13	8.60	14.00	20.00	36.28	48.02	91.42	19.47	33.10	66.35	1.48	2.55	7.33
<u>OPTION CASE</u>															
Automobiles								23.02	45.93		0.33	1.65			
Buses											1.67	2.92			
Railways		6.29	25.80								11.32	4.97			
Airways					14.00	20.00									
Waterways														3.21	8.44
Trucks								14.23	22.69		16.16	49.44			
Pipes and storage		0.67	1.30												
TOTALS		6.96	27.10		14.00	20.00		37.25	68.62		29.48	58.98		3.21	8.44

TABLE 17 (CONTINUED)

Transport Mode	ELECTRICITY			JET FUEL			GASOLINE			DIESEL			MAZOUT		
	1975	1985	2000	1975	1985	2000	1975	1985	2000	1975	1985	2000	1975	1985	2000
<u>TRENDS CASE</u>															
Automobiles							46.26	93.71		0.04	2.90				
Buses		0.19	0.19				0.22			3.08	4.76				
Railways		0.86	19.56							7.82	3.67				
Airways					19.00	30.00									
Waterways													1.65	2.55	
Trucks							20.40	43.75		46.40	89.74				
Pipes and storage		0.67	1.30												
TOTALS		1.72	21.05		19.00	30.00	66.88	137.46		51.34	101.07		1.65	2.55	

6.2 Available Courses of Action

Egypt has at least three courses of action and three targets for 1985 and 2000 among which to choose. The situation could continue the pattern of the Trends Case, so that by 1985 a transportation system and a land use pattern (on the regional and national level) could result that would require much more energy than the Comparison Case allocates. Alternatively, concentrated effort can be made in the years between 1978 and 1985, in both the transportation system and the associated development policies of the country, toward a more energy-effective system. Still further, a determined commitment to energy efficiency may be followed by appropriate projects and policies in pursuit of achieving the Option Case by 1985. Similarly, for the year 2000, there are at least three courses of action corresponding to the ones faced for 1985. However, it is highly unlikely unless conservation efforts are begun immediately, that Egypt will be able to reach the Option Case projections or even the Comparison Case projections for 2000.

6.3 Need for Associated Policies

It is difficult to deal with the energy requirements of Egypt's transportation sector and project them to the future without taking into account specific policies that crucially affect the consumption patterns of the transportation system. It is likewise difficult to determine such patterns within the transportation sector without making basic assumptions about the desired objectives of other sectors of the economy.

Increased participation of the energy-effective transport modes in the transportation activities of the country requires an immediate policy of support and development of such modes. First on the list of priorities for making the transport system of Egypt energy-effective is improvement and extension of the railroad system, the bus fleet, and urban transit. All other energy conserving steps in the area of transportation depend on this. Only if and when these systems are able to provide the transportation services on a regional and national scale, which the country crucially needs, will it be prudent to initiate measures to reduce the use of and dependency on the intercity truck fleet and the passenger car.

Many things could be done to improve the railroads and the inland waterways. Beyond improving their fleets and the current network, it is particularly important to study and undertake measures to improve these systems in two other ways:

1. The serviceability of the Nile River waterway would be improved by establishing and equipping closely spaced depots on strategic locations along the river and by integrating them with the local highway network and with the railroad system of the region.
2. Methods of connecting the railroad system with all new industrial enterprises and integrating it with the inland waterways should be studied and initiated. The two systems should be planned to supplement and complement each other and, in fact, work as one integrated system.

The next important policy orientation in the transportation field involves land use developments within existing urban areas, and has two specific objectives. First, it is important to promote, within urban regions, a developmental pattern that can be serviced effectively by mass transit. This is extremely important during the developmental period of Egyptian urban regions, when they are in the initial stages of expansion. Once built, it will be difficult, if not impossible, to improve their density and land use patterns to permit effective mass transit service. Currently, the tendency is to develop solutions that are automobile-dependent. If this trend continues, even the building of a subway system may not be able to reverse the trends, as other major urban regions of the world have proven, e.g., Mexico City and Sao Paulo; Cairo may present a similar future example. Immediate and high quality connections should be planned with the railroad system of the country and, if possible, with the inland waterways of the country. In fact, for each large industrial enterprise within metropolitan regions, site selection and development of new industrial districts should consider railroad and waterway serviceability.

The third important policy orientation concerns the contributions or impediments of transportation to the industrialization of the country. In integrating industrial and transportation activities, all significant new enterprises must be assured of primary and effective service by either the inland waterways or the railroad system; wherever possible by both systems. Most industrial freight must be carried by the waterways or the railroads by 1985. The present situation must be reversed. It is undesirable to have, as in 1975, 85 percent of cereals tonnage, 94 percent of sand, gravel, clay, and limestone, 95 percent of steel, 98 percent of construction materials, 91 percent of manufactured fertilizers, and 28 percent of mineral ores transported in intercity travel by highway. In addition, it is economically important to minimize change from one mode of transport to another for any commodity between its origin and its destination. This is particularly true for the export industry. A single transshipment usually costs as much as all the other transport costs of the commodity, and involves added risks. The transport cost of such commodities may make them noncompetitive in the international market.

The fourth important policy orientation for transportation is the urbanization policy of the country, especially as it affects the establishment of new cities. Decisions concerning the three new large cities (Sadat City, Tenth of Ramadan, and King Khalid City) appear to have been made without giving sufficient attention to national transportation policies and requirements. As a result, all three cities are placed outside the inland waterway and railroad networks. For instance, only a dead-end branch railroad line serves Sadat City, and only a branch of the Noburia Canal, with a minimal basin for maneuvers, is part of the industrial district of the city. Nor are the two systems integrated; yet, the expectations are for a major export industrial base in Sadat City. The plans of the other two cities (plus the smaller one, Ameriya, proposed for development near Alexandria) reveal only marginal consideration, if any, of national transportation policies. For instance, there is no evidence of plans for major railroad service for either city, nor for any major or minor canal connection and port facility.

There is still much to be desired in the coordination of plans and policies between the various sectors of governmental activity. As for the new cities, the problem seems to be determining responsibility for implementing national objectives, where responsibilities for projects overlap. Which ministry, in fact, determines the optimum location and the required transportation facilities of the new cities, and bears the responsibility for the decision, does not seem to be clearly defined. The urbanization policy includes several explicit objectives for population and industrial decentralization, as well as for conservation of agricultural land, but it does not state definite objectives for national transportation efficiency and energy effectiveness. Corrective actions need to be planned as soon as possible, and initiatives exercised by the proper authorities on the desired development of the three new cities and all other urbanization plans and programs of the country.

The fifth important extension of national policies for transportation is the application of development policies to efforts to develop whole new regions. This particularly complicated and demanding problem is crucial to the proper development of the transportation system. Essentially, the concerns are:

- o the need to assign priorities to regions with greater serviceability, where choices are possible and reasonable; and
- o to plan for an integrated and comprehensively designed system to serve all the needs of the new regions effectively and energy-efficiently.

Both concerns are particularly important because their disregard may produce artificial, short-lived successes which cannot survive without excessive subsidies. Thus, regional development should be planned with the complete set of regional transportation needs in each case, so that complementary economies can be developed. Problems of initiative, comprehensiveness, and coordination may arise among agencies over responsibilities for the implementation of transportation policy. Nevertheless, the regional developmental policy of Egypt must be based on a sound transportation system which can both serve the transportation needs of the region and promote the national objectives.

6.4 Need for Comprehensive Transportation Planning

The assessment of energy requirements and prospects in the transportation sector of Egypt has revealed limited comprehensive transportation planning for both the regional and the national transportation systems. The only two transportation studies that were located were the SOFRETU study for the metropolis of Cairo, 1973, and the Egypt National Transport System Study of 1977. The remaining studies were limited in scope, focused on specific projects, or were part of studies addressed to objectives other than the comprehensive planning of the transportation system.

One of the most critical current needs for Egypt, in the field of transportation, is comprehensive planning on a national scale for each mode and for each major region. Egypt has a unique opportunity to capitalize on the initial steps of economic development and to direct its efforts towards a more sound, efficient, and effective development pattern that will include an efficient transportation system.

7.0 APPENDICES

7.1 Appendix A: Energy Efficiency Tables and Figures

TABLE A-1

SHARE OF PASSENGER AND FREIGHT TRANSPORTATION ENERGY
USE FOR SEVEN WORLD REGIONS, 1975, 1985 and 2000

	Passenger			Freight		
	1975	1985	2000	1975	1985	2000
World	62.5		55.7	37.5		44.3
United States	81.0		75.7	19.0		24.3
Western Europe	63.2		62.4	36.8		37.6
Japan	29.9		39.2	70.1		60.8
U.S.S.R.	26.4		48.2	73.6		51.8
Eastern Europe	42.5		59.7	57.5		40.3
Advanced Developing	53.2		47.5	46.8		52.5
Less Developed	38.0		28.5	62.0		71.5
Egypt (Comparison)*	35	47	44	65	53	56
(Trends)**	-	43	42	-	57	58

Source: Robert U. Ayres, Worldwide Transportation/Energy Demand Forecasts: 1975-2000, Vol. 1, Delta Research Corp., Arlington, Virginia, March 1978.

*Egypt/U.S. Cooperative Energy Assessment, Main Report-Comparison Case

**Dr. Anthony Tomazinis, University of Pennsylvania

TABLE A-2

TRANSPORTATION ENERGY AS A PERCENT OF TOTAL ENERGY
IN TWELVE COUNTRIES, 1972 and 1985

	1972	1985	% Change in Shares	% Change energy
United States	23.8	20.8	-12.6	8.9
Canada	18.8	17.7	-5.9	40.9
Denmark	17.3	20.2	16.8	30.5
Finland	12.4	13.1	5.6	59.2
France	18.7	17.6	-5.9	15.9
Germany	13.7	13.1	-4.4	17.0
Italy	14.8	10.5	-29.1	-22.0
Japan	12.4	12.9	4.0	63.0
Mexico	27.5	27.1	-1.5	120.0
Norway	11.1	14.0	26.1	76.9
Sweden	13.0	10.5	-19.2	11.5
United Kingdom	13.4	14.0	4.5	17.6
Egypt (1975)*	19.0	17.0		

Source: Paul S. Basil, editor, First Technical Report of the Workshop on Alternative Energy Strategies (WAES): Analysis of 1972 Demand and Projections of 1985 Demand, 1977.

*Egypt/U.S. Cooperative Energy Assessment, Main Report-Comparison Case

Fig. A-1 Total Annual Fuel Consumption by Type of Vehicle

Source: U.S. Department of Transportation, Federal Highway Administration, Highway Statistics, table Vm-1, annual.

Fig. A-2 Average Annual Fuel Consumption by Type of Vehicle

Source: U.S. Department of Transportation, Federal Highway Administration, Highway Statistics, table Vm-1, annual.

TABLE A-3

ENERGY INTENSITY FOR TRUCKS, 1974 to 1980

Use	Cargo Density (lb/ft ³)	Maximum Payload (in tons)	Trip Length (statute miles)	Average Trip Time (hr at mph)	Type of Fuel	Vehicle Statute Miles/ Gal	Specific Energy Stop/Start Cycle	
							Ton-Miles/Gal.	Btu/Ton- Mile
Urban	20-100	9.0	10	0.4/25	Gas	8.0	64	1,953
Urban	20-100	8.0	10	0.4/25	Diesel	12.0	96	1,446
Urban	10-30	3.1	10	0.4/25	Gas	8.0	25	5,040
Intercity	20-100	25.0	100	1.8/55	Diesel	5.0	125	1,110
Intercity	15	14.3	100	1.8/55	Diesel	4.8	69	2,023

Source: W. F. Gay, U.S. Department of Transportation, Transportation Systems Center, Energy Statistics, Cambridge, Mass., 1975, p. 139.

TABLE A-4

TRUCK OPERATING ENERGY EFFICIENCY AND INTENSITY
BY WEIGHT CLASS, 1972 (POUNDS)

		10,000 to 14,000	14,000 to 16,000	16,000 to 19,500	19,501 to 26,000	26,000 to 33,000	Over 33,000
Gas	Btu/ton-mile	7,353	7,764	6,944	3,079	2,129	1,701
	Ton-miles/gal	17	16.1	18	40.6	58.7	73.5
Diesel	Btu/ton-mile				2,872	2,102	1,622
	Ton-miles/gal				48.3	66	85.5

Source: D.A. Hurter and W.D. Lee, Arthur D. Little Inc., A Study of Technological Improvements to Optimize Truck Configurations for Fuel Economy, Washington, D.C., Sept. 1975, pp. 3-4 through 3-6.

TABLE A-5

ENERGY INTENSITY OF PASSENGER TRAINS, 1974 TO 1980

Vehicle Type	Gross Weight (10 ³ lb)	Trip Length (statute miles)	Average Trip Time (hr)	Fuel Type	Vehicle Statute Miles/Gal	Number of Seats	Specific Energy, Stop/Start Cycle	
							Seat-Miles/ Gal	Btu/ Seat-Mile
Urban train	79	0.75	0.02	Electric	(57,600 Btu/mi)	50-60	106	1,320
New Tokaido line	2,000	140.00	1.40	Electric	0.4	1,400	305	427
Standard diesel	1,200	50.00	0.75	Diesel	0.66	360	240	583

Source: W. F. Gay, U.S. Department of Transportation, Transportation System Center, Energy Statistics, Cambridge, Mass., 1975, p. 139.

TABLE A-6

OPERATING ENERGY INTENSITY OF PASSENGER TRAINS,
1970 THROUGH 1974

PASSENGER TRAINS WITH LOCOMOTIVES				RAIL MOTOR TRAINS		
Year	Total Energy (10 ¹² Btu)	Btu/ Car-Mile ¹	Btu/ Passenger- Mile ²	Total Energy (10 ¹² Btu)	Btu/ Car-Mile ³	Btu/ Passenger- Mile ⁴
1970	34.8	61,152	5,632	8.73	93,994	1,901
1971	22.0	57,419	4,996	8.11	82,365	1,803
1972				7.62	76,323	1,801
1973	22.4	67,419	4,433	8.23	79,118	1,938
1974	22.8	64,607	3,931	9.08	80,473	2,003

¹ Total Energy used by passenger trains with locomotive divided by car-miles.

² Total energy used by passenger trains with locomotive divided by passenger-miles.

³ Total energy used by rail motor cars divided by commuter car-miles.

⁴ Total energy used by rail motor cars divided by commuter passenger-miles.

Source: The Aerospace Corporation, Characterization of the U.S. Transportation Systems, vol. 4 - Railroads (Freight and Passenger), Los Angeles, Calif., March 1977, pp. 5-17.

TABLE A-7

BTU PER TON-MILE ESTIMATES FOR RAILROAD FREIGHT (LOADED MOVEMENTS)

COMMODITY	CAR TYPE						
	Boxcar	Covered Hopper	Flat Car ¹	Gondola	Open-top Hopper	Tank Car	Misc. Cars ²
Agricultural products	335	235	725	290	380		715
Metallic ores	265	225		195	180		
Coal, coke produced from coal				195	210		
Crude oil, petroleum	440		725			275	415
Nonmetallic minerals	310	225		280	180	195	315
Food, kindred products, and tobacco	420	310	750			266	410
Textiles, apparel, and leather	775		725				
Lumber, wood products, and furniture	475	300	600	340	360		380
Pulp, paper, and allied products	395		700			270	410
Chemicals, allied products	390	240	725			257	380
Rubber, plastic products	875		730				610
Clay, concrete, glass, and stone	350	225	600	295	225		380
Primary metal products	290	175	295	285	185		320
Fabricated metal products	820		725	370			530
Nonelectrical machinery	675		730	425			
Electrical machinery	1,050		750	340			725
Transportation equipment	650	480	846	400		570	
Instruments, photo goods	1,020		770				
Waste, scrap materials	420	300	725	300	190	252	400
Empty movements (distance weighted)	390	420	796	420	320	399	390-450

TABLE A-8

CALCULATED ENERGY INTENSITY OF URBAN RAIL SYSTEMS,
HEAVY RAIL

Distance Between Stops (miles)	Btu VEHICLE MILE		Btu PASSENGER MILE		
	Maximum Occupancy Including Standeers	All Seats Occupied	Maximum Occupancy Including Standeers	All Seats Occupied	30% Seats Occupied
.5	93,000	84,000	669	1,040	3,130
1.0	66,000	60,000	472	750	2,250
1.5	50,000	45,000	351	560	1,670
2.0	39,000	36,000	284	450	1,350
2.5	34,000	30,500	246	390	1,170

Total Load: 140 passengers; seats: 80
 Maximum Load weight: 122,100 lbs
 Empty weight: 91,920 lbs
 Maximum speed: 55 MPh

Source: The Aerospace Corporation, Characterization of the U.S. Transportation System - Urban Rail Transit, Los Angeles, California, July 1976, p. 21. (Draft)

TABLE A-9
CALCULATED ENERGY INTENSITY OF URBAN RAIL SYSTEMS,
LIGHT RAIL

Btu VEHICLE MILE			Btu PASSENGER MILE		
Distance Between Stops (miles)	Maximum Occupancy Including Standeers	All Seats Occupied	Maximum Occupancy Including Standeers	All Seats Occupied	30% Seats Occupied
.5	90,000	67,000	309	883	2,652
1.0	61,000	43,000	192	558	1,696
1.5	45,000	32,500	140	429	1,304
2.0	37,500	26,000	114	351	1,087
2.5	31,500	23,500	98	299	913

Total Load: 320 passengers; seats: 77

Maximum Load weight: 109,400 lbs

Empty weight: 55,815 lbs

Maximum speed: 55 MPH

Source: The Aerospace Corporation, Characterization of the U.S. Transportation System - Urban Rail Transit, Los Angeles, California, July 1976, p. 21. (Draft)

TABLE A-10

BARGE ENERGY INTENSITY BY WATERWAY

Waterway	Upstream Btu/ton-mile	Downstream Btu/ton-mile
Ohio River System	456	173
Upper Mississippi River System	495	182
Lower Mississippi River System	276	103
Gulf Intracoastal Waterway	475	475
Atlantic Intracoastal Waterway	330	330
Pacific Coast Waterway	242	242

*Weighted average values; the energy intensity is influenced by tow size, commodity shipped, tow velocity, river current, and other such factors.

Source: R.H. Leilich, R.D. Cohen, A. Green, and M.J. Kendrick, Peat, Marwick, Mitchell and Co., Energy and Economic Impacts of Projected Freight Transportation Improvements, Washington, D.C., May 1977, pp. 2-28 and 2-29.

TABLE A-11

BARGE ENERGY INTENSITY BY COMMODITY TYPE

Commodity	Btu/ton-mile
Agriculture	172
Metallic Ores	263
Coal and coke	296
Petroleum	321
Nonmet mineral	339
Food products	201
Textiles	306
Lumber and furniture	226
Pulp and paper	221
Chemicals	290
Rubber and plastic	169
Stone and glass	230
Primary metal	240
Fabrication metal	231
Non-electric machine	284
Electric machine	265
Transport equipment	270
Instruments	373
Scrap	310
Average	272

Source: R.H. Leilich, R.D. Cohen, A. Green, and M.J. Kendrick, Peat, Marwick, Mitchell and Co., Energy and Economic Impacts of Projected Freight Transportation Improvements, Washington, D.C., May 1977, pp. 2-28 and 2-29.

TABLE A-12

ENERGY INTENSITY FOR CARGO AIRCRAFT, 1974-1980

Aircraft	Maximum Payload (tons)	Payload Gross Density (lb/ft ³)	Specific Trip Length Statute Miles	Average Trip Time ² (hr)	Vehicle Statute Mile/Gal	Specific Energy, Stop/Start Cycle		Fuel Type
						Ton-Miles/Gal	Btu/Ton-Miles ³ (X1000)	
Turbofan, narrow body	20.6-58.7	8.3-11.6	500	1.3	0.19-0.44	8.4-11.1	11.1-14.7	Kerosene
Turbofan, narrow body	20.6-58.7	8.3-11.6	1,000	2.3	0.22-0.53	9.6-12.8	9.6-12.9	Kerosene
Turbofan, narrow body	46.8-58.7	10.9-11.6	2,000	4.4	0.23-0.27	12.6-13.6	9.1- 9.8	Kerosene
Turbofan, wide body	77.9-126.0	10.0	1,000	2.3	0.12-0.23	13.7-15.0	8.2- 9.0	Kerosene
Turbofan, wide body	77.9-126.0	10.0	2,000	4.4	0.13-0.24	14.2-16.0	7.7- 8.7	Kerosene

¹ All fuel consumption data obtained directly from aircraft manufacturers for all-freighter or convertible-freighter aircraft models.

² Trip times assumed same as passenger schedules obtained from "Official Airline Guide," Jan. 15, 1974, schedule times plotted against trip distance.

³ Kerosene at 18,400 Btu/lb and 6.7 lb/gallon.

Source: W.F. Gay, U.S. Department of Transportation, Transportation Systems Center, Energy Statistics, Cambridge, Mass., 1975, p. 140.

TABLE A-13

CITY PAIR AIRPLANE ENERGY EFFICIENCIES, INCLUDING CIRCUITRY.¹

City Pair	Great Circle Distance (miles, airport to airport)	Air ATA ² (range, miles)	Circuitry	Btu/Great Circle (statute sm)	Btu/sm
Los Angeles-San Diego	109	190	1.74	14-24	24-42
New York-Washington	213	296	1.39	21-32	29-44
Chicago-St. Louis	251	334	1.33	24-32	32-43
Portland-San Francisco	550	638	1.16	30-42	35-49
New York-Chicago	738	828	1.12	32-46	36-52
New York-Miami	1,092	1,188	1.09	36-51	39-56
Seattle-Denver	1,019	1,114	1.09	35-42	38-46
Minneapolis-San Francisco	1,586	1,690	1.07	36-42	39-45
Atlanta-Los Angeles	1,942	2,053	1.06	36-53	38-56
Miami-Los Angeles	2,338	2,457	1.05	54	57

¹ Efficiency figures were calculated assuming a 100 percent load factor and taking the actual aircraft mix for the route in 1974 into account.

² These air distances were calculated using Air Transport Association (ATA) fuel allowance formulas.

Source: Boeing Commercial Airplane Company, Intercity Passenger Transportation Data Energy Comparisons, Vol. 2, Seattle, Wash., May 1975.

TABLE A-14
ENERGY INTENSITY BY MODE

Btu Per Kilometer	U.S.	Less Developed Countries
Truck	2,200	2,500
Waterways	340	250
Rail	450	350

Source: Robert U. Ayres, Worldwide Transportation Energy Demand Forecast: 1975-2000, Vol. I., Delta Research Corp., Arlington, Virginia, March 1978.

TABLE A-15
TRANSPORTATION ENERGY PROJECTIONS

	U.S.	Advanced Developed Nations	Less Developed Nations	Egypt
Total Transportation 1975/2000	33%	456	359	347
Passenger Transportation 1975/2000	24%	600	267	425
Freight Transportation 1975/2000	71%	388	409	321

Source: Joel Darmstadter, Joy Dunkerley, and Jack Alterman, How Industrial Societies Use Energy: a Comparative Analysis, Resources for the Future, Johns Hopkins Press, 1977.

Fig. A-3 Energy Intensity for Oil Pipelines

Source: The Aerospace Corporation, Characterization of the U.S. Transportation System - Pipeline Transportation Systems, Los Angeles, California, March 1977, p. 1-25. (Draft)

Fig. A- 4 Energy Intensity of Natural Gas Pipelines

Source: The Aerospace Corporation, Characterization of the U.S. Transportation System - Pipeline Transportation Systems, Los Angeles, California, March 1977. (Draft)

7.2 Appendix B: Waterways and Environmental Problems

The waterways face three technical problems in the case of increased traffic on them:

- o dredging, especially the Nile River between Cairo and Aswan;
- o bank protection of the canals, especially the narrow ones (or the narrow parts of the wider, Class I canals); and
- o water pollution of the canals.

Since the building of the High Dam the velocity of the river has been reduced, a change which produced an increased siltation of entrained matter. Presently there are only two dredges above Cairo in the Nile River. This number would need to be increased five-fold to maintain a constant 1.8 meter draft. However, the real and final solution of the dredging problem is the total regulation of the river with barges and locks that regulate flow and traffic.

The problem of bank protection is a bit more delicate, but easier to face incrementally. Bank erosion occurs in narrow canals when barge traffic is frequent and heavy. One such case is a portion of the Beheiri Canal just outside of Alexandria, about 200 meters in front of the last two locks of the canal. The canal, which is planned to be widened to 32 meters in the immediate future, is only 25 meters wide at this point. The Ministry of Irrigation has not yet agreed to widening the canal to 40 meters, which would reduce bank erosion. Two crossing barges, of two or three units each, at full speed, will produce wakes that cause bank erosion. Both the Beheiri Canal and the continuation towards Cairo, the Noburia Canal, have no bank protection. The problem is created by the backwash waves of passing barges and aggravated by the fine-sand subsoil by the canals. The current (even as slow as 0.5 meter/second) and the propeller screws of the vessels suck up the sand under the bank, even where the bank is partially protected. Typical and effective protection against erosion is a layer of rip-rap net placed on a layer of gravel and small stones. In cases of localized damage, the gaps in the bank can be filled with slightly larger stone material. Planting additional reeds could also add to bank protection in less demanding circumstances.

The environmental problems of inland waterways are those of noise pollution in the immediate vicinity of the canal, and oil pollution from motor craft. The first problem can be resolved by adopting proper construction standards as well as operating standards for barges which will reduce the effective noise in the immediate vicinity of the canals. The problem of oil pollution of the inland waterways stems from water entering the vessels through the bearing of the tail shaft, and accumulations of waste oil products at the bottom of the vessels due to random leaks of pumps, cleaning of the engines, oil changes, etc.

In typical European barge operations one may expect up to 1.5 tons of waste petroleum products annually. A similar amount should be expected for future Egyptian operations. The most effective solution to this problem is control at its source. This is done with the construction of properly designed and located stations, within the network of canals, where barges can conveniently and economically be cleaned and their waste petroleum products disposed of. Regulations requiring such operations and annual inspections are also needed. Such environmental control stations are relatively simple to construct and operate, consisting of two settling tanks and one or two pumps to draw the waste materials from all parts of the vessel to the settling tanks.

FOSSIL FUELS SUPPLY OPTIONS

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U.S. - EGYPT COOPERATIVE ENERGY ASSESSMENT

SEPTEMBER, 1978

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1.0 OVERVIEW

Egypt's fossil energy resources are essentially those of petroleum and natural gas, but coal deposits exist, one of which has a potential for development. Inconclusive evidences of bituminous shales have been noted. Tar sands so far have not been discovered. Petroleum reservoirs have been delineated in the Gulf of Suez and in the Western Desert. The major production of natural gas is that associated with Gulf of Suez oil production. Gas production in the Western Desert and in the Delta regions is non-associated with oil production.

This investigation of Egypt's fossil energy supply options was carried out over the two month period from March/April, 1978, and included a period of visits and interviews in Egypt. A number of options have been identified and evaluated in terms of their applicability toward supplying Egypt's energy needs for the balance of the century. The limited time available for investigation compels the findings to be qualitative in their impacts, particularly with respect to the financial impacts. Useful work to develop these options further should include cost estimations for the more promising.

1.1 Coal

The most significant market for coal is a potential one. It would exist in the supply of metallurgical coke for the iron and steel industry at Helwan. By 1982, Egypt should be importing 1.5 million metric tons of metallurgical coal per year for coke making. Other markets could be the thermal generation of electricity, steam raising, and other industrial heat applications. Future demand for electricity will exceed the hydroelectric generation capacity, and deficiencies will have to be met from other energy sources.

1.1.1 Reserves: The coal reserves so far exist at Maghara in the Sinai, about 150 kilometers (km) east of Ismailia. Recoverable resources are estimated to be 35.6 million metric tons with prospects that this quantity might double if exploration were carried further. Coal exists in the deposit in two separated mineable seams, the upper 0.80 meter (m) thick (2.6 feet) and the lower main seam 1.9 m (6.25 feet). The two seams lie an unknown distance apart within a zone of coal bearing sequences 90-100 m thick (300-350 feet). Coal quality is equivalent to subbituminous with characteristics ranging as follows:

	<u>Upper Seam</u>	<u>Lower (Main) Seam</u>
Moisture, wt. %	3.5 - 5.0	2.8 - 11.9
Ash, wt. %	3.6 - 27.3	4.4 - 34.2
Sulfur, wt. % (combustible)	1.1 - 3.9	1.6 - 4.3
Gross Heating Value		
Kg-Cal/Kg	7,215	6,855
Btu/lb	13,000	12,400

The known reserves at Maghara can support a maximum production extraction rate of 1.2 million metric tons per year and will provide an adequately long period (30 years) for amortization of capital investments.

1.1.2 Production/Extraction: The extraction option is conventional underground mining by either the room and pillar method or the longwall mining method. The precise method for extraction requires a better physical knowledge of the deposit. For example, the longwall method may not be applicable when two seams are to be extracted in the same zone. However, if the room and pillar method is selected, recovery of coal may be reduced, thereby dropping the reserves to about 25 million tons. Extraction rates may be either 300,000 or 1,200,000 metric tons per year depending on the utilization of the coal.

1.1.3 Transportation: The closest point of access to the market from the mine site is Ismailia, about 150 km to the west. The options for transport are truck and highway at any capacity of extraction, and for maximum capacity the construction of a rail line or a slurry pipeline. In all options a crossing of the Suez Canal is required, either by bridge or tunnel. The highway option will require infrastructure improvement of the Ismailia/El Arish road and of the branch road to the minesite. The present condition of these roads is unknown.

1.1.4 Conversion: The most attractive option appears to be the blending of the Maghara coal with imported metallurgical coal at Helwan. By 1982, about 300,000 metric tons could be blended with about 1,200,000 metric tons of imported coking coal to produce the coke required at Helwan. Early work before 1967 indicated that a satisfactory coke could be made this way, and the facility to test coke blends on a laboratory scale is being installed. The small blast furnace (450 T/D) at Helwan can be utilized to test the acceptability of large samples of coke produced from blends of Maghara coal and imported coal.

Other options oriented toward the iron and steel industry involve the potential increase in the consumption of Maghara coal by, for example, first carbonizing and then blending the char. Presuming successful experimentation, the quantity of Maghara coal might be increased to 1.2 million metric tons per year with concomitant production of coal tar products. The production of formed coke could also be considered to replace all imported coal provided experimentation is successful and coal reserves can be at least tripled through further exploration.

An extraction of 300,000 metric tons per year could support, at the mine site, the generation of about 80 megawatts (MWe) of electricity. This would be a localized supply designed to support regional development. A transmission line from Ismailia would be required to secure the supply, or to provide an outlet for any surplus generation. Another option is the construction of generation capacity at Ismailia at the full mine output to provide 375 MWe to Egypt's Unified Power System. This would be a base-loaded station, and could avoid the use of residual fuel oil, thereby releasing a corresponding quantity (15,100 B/D) of fuel oil for export.

Other possibilities include steam raising and industrial heat applications (e.g., cement kilns).

1.1.5 Impacts: Open mining operations at Maghara at the low extraction rate could provide employment, according to a recent (1977) estimate, for about 1,325 miners. Accordingly, a gross forecast of the size of the mining community might be the following:

	<u>Low Rate</u>	<u>High Rate</u>
Output, MTY	300,000	1,200,000
Employment, Direct	1,325	5,300
Indirect	175	200
Total	1,500	5,500
Community Population	9,000	33,000

Therefore, investments would be required for the opening of the mine and the construction of the community facilities, including housing, markets, schools, hospital, mosques, electricity supply, water supply, and roads. Part of these investments, perhaps 40 to 50 percent, could be expended in foreign exchange.

Mining operations at Maghara, on the other hand, could provide savings or earnings in current or projected foreign exchange as follows:

<u>Option</u>	<u>Prospective Foreign Exchange Without Option</u> <u>Million U.S. \$/YR</u>	<u>Earning (E) or Savings (S) With Option</u> <u>Million U.S. \$/YR</u>
Blend Coal with Imported Metallurgical Coal	113	22.5(S)
Power Generation 375 MWe	-	60.6(E)

1.1.6 Policy implications: The development of the Sinai coal resource is consistent with Government policy to disperse population. Depending on the extent of the resource, a new permanent community can be established of 9,000 to 33,000 population solely to support mining activities. If the project to develop agricultural land in the Sinai through the extension of the Ismailia canal is implemented, the farming community thus established and the mining community can be mutually supportive.

1.1.7 Key initiating actions: No action is practical until the nation is physically in possession of the territory in which the coal deposit occurs. At such a time, the information on the deposit would

have to be supplemented, probably with further drilling, to enable a mining plan to be established and cost estimates to be prepared. This plan would be prerequisite to financing the capital cost and to training the managerial and operating personnel. Coincidental with the planning of the mine, large samples of the coal would be shipped to the coke works at Helwan to enable them to experiment with blends, to produce coke experimentally for quality evaluation, and, eventually, to produce large samples of coke for evaluation in the small blast furnace of the steel works. The results would enable a price to be set for the coke, and, in turn, a price to be paid at the coke works for the Maghara coal.

Finally, as the mining project begins to be implemented, and a cash flow occurs, some funds can be allocated to further exploration aimed at establishing the ultimate extent of, and the reserves in, the coal deposit. Then the desirability and attractiveness of exercising the other options can be assessed.

1.2 Petroleum

The markets for Egyptian petroleum already exist, both domestically for petroleum products, and internationally for the export of crude oil and selected petroleum products such as residual fuel oil and light naphtha.

1.2.1 Reserves: Egypt's petroleum reserves are estimated to range between 2.1 and 5.1 billion barrels. The Egyptian General Petroleum Corporation has estimated reserves at the end of 1977 at 2.1 billion barrels, with a corresponding production of 414,000 barrels per day. Known reserves correspond to 13.9 years of production at this rate. Most of the reserves are located in the Gulf of Suez where the reserves range is estimated to be 2.4 to 3.3 billion barrels in 20 fields not producing oil. Other reserves occur in the Western Desert.

A national goal is to attain production of oil (including the oil equivalent of natural gas) in 1982 of 1,000,000 B/D. This would require the doubling of reserves as estimated by EGPC to 4.2 billion barrels, a level which is within the range estimated by others.

Only 40 percent of the promising oil prospecting areas of Egypt have been addressed with more than a cursory examination. The Gulf of Suez holds the most immediate prospects for replacing or increasing the reserves, but with diminishing results as medium depth structures are drilled. Masking salt beds in the Gulf have prevented interpretation of the lower structure.

1.2.2 Production: Petroleum production in Egypt occurs mainly in the primary mode, i.e., through the movement of oil into wells because of the native energy present in the reservoir. No activity is occurring to maintain the reservoir pressure through gas or water injection, and little to increase recovery through waterflooding or to improve recovery through reservoir stimulation. One experience in waterflooding took

place at the El Morgan field, which was flooded only after reservoir pressure had decreased to one-third of the initial level. A second waterflooding project is scheduled for the July field in the Gulf of Suez later in 1978.

Separately from this assessment, the Egyptian Government and the U.S. Department of Energy are cooperating in a prospective enhanced oil recovery project in the Ras Gharib field. These results can provide a basis for projects in other producing fields.

1.2.3 Transportation: By 1982, all Egyptian refineries except those in Alexandria will be able to receive crude oil from the Gulf of Suez by pipeline. The Alexandria refineries will receive crude oil by tanker. This pattern seems adequate for the future delivery of crude oil to refineries.

1.2.4 Refining: The two options for meeting demand for refined petroleum products are the construction of low-gasoline refineries and high-gasoline refineries. The option of no refineries with exports of crude oil and import of products is rejected as unresponsive to Egyptian national policy. The indication is that the demand pattern can be fulfilled by the low-gasoline type refinery.

Throughput capacity for each refinery project would reasonably be 100,000 B/D, which is the capacity for the current project at Suez. Refinery locations should suit the market centers, and likely locations in the future appear to be El Shukheir (a new refinery at the location of the projected on-shore terminal of the gathering system for the off-shore production in the Gulf of Suez) and additions to the refineries at Cairo (Mostorod) and Alexandria (El Almeriya). According to Egyptian government views, one new refinery would be constructed during each five-year-plan period. Thus, two or three refineries, plus the Suez unit already planned, should cover increases in demand for petroleum products through the year 2000.

1.2.5 Suez coke production: A contractual agreement between the Suez Oil Processing Company and the Aluminum Company of Egypt covers the supply of petroleum coke from a refinery at Suez for electrode manufacture at the smelter at Nag Hammadi. A major investment is underway to reconstruct the coking unit at the Suez refinery. It appears that a major technical problem will exist in the vanadium and nickel content of the coke which will be too high by a factor of two. Despite contractual obligations to accept, the smelter may be forced to reject Suez coke and continue to import a satisfactory material. In this event, an option exists to divert Suez petroleum coke to Helwan for blending with imported metallurgical coal for coke making. However, this would exclude the option to utilize Maghara coal in the same fashion.

1.2.6 Electricity generation: About 50 percent of the refinery product mix, currently and for the future, is residual fuel oil. The two options for the disposal of this product are (a) export and (b) the

generation of electric power. Egypt is advantageously located with respect to export markets for fuel oil, since ships in transit in the Suez Canal often need rebunkering and payments made benefit the foreign exchange balance. Thus, diversion of fuel oil to electricity generation can be thought of as a loss in foreign exchange revenue, depending upon the quantities involved.

New construction of residual-oil fueled power stations should be of modern low heat-rate design sized to the capacity of Egypt's Unified Power System, namely about 450 MWe. Stations would be constructed as required by load growth at sites suited to the load centers, as permitted by the availability of cooling water. Designs may be chosen to minimize cooling water consumption through recirculation. As the total capacity of the Unified Power System increases, new generating unit capacities would likewise increase so that each new unit is about 10 percent of system capacity.

Peak power generation is likely to be fueled with natural gas, but standby distillate fuel would be needed in the event of interruptions in the natural gas supply. As new larger capacity is constructed, the older, smaller, less efficient units should be reevaluated for peaking service.

1.2.7 Impacts: The most important effect of Egypt's activities in the petroleum sector is the foreign exchange that can be earned from the export of crude oil. Given the achievement of the stated goal of production of crude oil in 1982 of 1 million barrels per day, including the crude oil equivalent of natural gas, the disposition would be the following:

1.	Production of Natural Gas (580 million SCFD)	100,000 B/D
2.	Exploration and Production Companies' Share	270,000
3.	Egyptian Government Share	630,000
	(a) To refinery	316,000
	(b) To export	314,000
	Total	1,000,000 B/D

The export of 316,000 B/D for a year at a U.S. \$12 per barrel price represents a foreign exchange earning of U.S. \$1,390 million. In addition, some of the refined production is likewise exportable, namely, the fuel oil and light naphtha fractions.

If markets justify it, the construction of a refinery at El Shukheir, where the off-shore production will be collected for transmission by pipeline to Suez, can provide a base for industrial development and concomitant employment. This location may be a good base for the supply

of future market growth southward along the coast to the alumina port at Safaga and thence inland to the Oena-Aswan area. The other prospective locations for new refineries involve additions to existing refineries and would have only a marginal effect on employment.

The El Shukheir site could provide employment for perhaps 1,000 persons and add 6,000 persons to the local area. A refinery addition in an already developed area could have about half the employment results.

1.2.8 Policy implications: To assure that the goal of a million barrels per day production can be achieved, government policy may need reconsideration in two ways. One apparent policy seems to be secrecy with respect to the exchange of geologic data of a regional nature. Accordingly, no benefit is gained through discussions of interpretations of technical information that normally does not impact on the private interests of concessionaires but rather enables each of them to be more effective in achieving successful exploration of his concession.

A second example is the apparent lack of a concerted policy to consider comprehensive secondary and tertiary recovery of the known petroleum reservoirs, although some activity in secondary recovery of an ad-hoc nature is noted. A concerted policy in this respect is needed in order to protect the government interests in maximizing recovery which may not coincide with the interests of concessionaires who oftentimes have other non-Egyptian alternatives for investment and production which are of no benefit to Egypt.

With respect to consumption of residual fuel oil, a policy of encouraging more efficient combustion, particularly in industrial furnaces and power boilers, and of converting older, low-efficiency, generation stations to peaking use through replacement by larger high efficiency units, will release quantities of fuel for export. These quantities may be significant enough to warrant the foreign exchange costs of the new investments.

1.2.9 Key initiating actions: Three actions appear warranted. First, geological and geophysical communication should be facilitated through standardization of subsurface sections with standard nomenclature. This would entail the services of experts in a thoroughly planned program of data evaluation from the stratigraphically deepest wells throughout the oil provinces. Second, basic regional framework, beginning with basement tectonics and paleozoic rock distributions, needs to be better understood. This could involve new field work to establish reference seismic refraction lines to which available data can be related for better interpretation. Stratigraphic analysis would follow, through drilling a number of test holes and performing seismic stratigraphy. Third, the situation regarding the position of secondary and tertiary recovery of reservoirs should be reviewed at the appropriate level in government in terms of national interest to undertake this type of oil production. Concession policies should be modified to encourage such recovery to the extent national interest dictates.

Finally, an institutional effort to promote efficiency in the combustion of residual fuel oil, especially among the larger consumers, should be launched as a government service. The scope of this effort could involve the installation and reconditioning of devices to measure efficiency and the determination of both design and operational modifications to combustion devices to increase efficiency.

1.3 Natural Gas

The markets for Egyptian natural gas are essentially domestic. Quantities of reserves do not appear to warrant export.

1.3.1 Reserves/Production: Egypt's natural gas reserves are estimated to range from 2.5 to 4.0 trillion cubic feet. An estimate by the Egyptian General Petroleum Corporation of reserves at the beginning of 1978 is 3.9 trillion cubic feet (74 million tons). The 1977 production was 88.3 billion cubic feet, of which 70.6 billion cubic feet was associated gas and 17.7 cubic feet non-associated. The projection for 1978 production is 678 million cubic feet per day (240 billion cubic feet per year). Of the 1977 production, 53.0 billion cubic feet is estimated to have been associated gas that was flared in the Gulf of Suez. This is equivalent in heating value to 23,200 barrels per day of residual fuel oil.

1.3.2 Utilization: The option is to provide for total utilization of the gas and the elimination of waste in flaring by creating a national pipeline grid to connect all consuming locations. The grid can be supplied from all sources of associated gas; deficiencies can be made up by the non-associated gas production. Some elements of such a grid are already in existence, e.g., the 24-inch line from Abu Gharadig to Helwan. A 16-inch line is under study to bring the associated gas from the Gulf of Suez to Suez and Cairo. Smaller lines connect non-associated gas production in the Delta to specific consumers. The option requires that all existing and new pipeline projects be integrated into one national pipeline system ultimately reaching all significant population centers. The system would operate so that the priority source of gas would be any associated gas production. The pricing formula for the pipeline gas can be designed to assure the consumption of all associated gas produced. The candidate pricing categories appear to be the following:

- o Urban distribution for water heating and cooking;
- o Utilization as a chemical feedstock;
- o Peak electricity production; and
- o Baseload electricity generation.

The pricing formula adopted should recognize the use pattern that best serves the national interest.

1.3.3 Urban Distribution: An urban distribution system is already under way, intended for completion by 1983. It will distribute gas from Helwan to the Helwan, Maadi, Nasr City, and Heliopolis suburbs of Cairo. A recently formed National Gas Company will undertake the marketing and public relations efforts to "sell" the merits of natural gas vis-a-vis butagas. Burner orifices will be altered gratis.

Expansion could be considered to Cairo itself, through a separate system to Alexandria, and to the locations where new cities are planned.

1.3.4 Chemical feedstock: The two significant consumers in the future can be ammonia-based fertilizer producers and companies associated with the iron and steel industry, doing direct reduction of iron ore.

The two ammonia-based fertilizers manufactured in Egypt are calcium ammonium nitrate (CAN) for which about 340 cubic meters (M^3) (12,000 SCF) of natural gas would be consumed per metric ton of CAN produced; and urea, for which the natural gas consumption is about 500 M^3 (18,000 SCF) per metric ton of urea.

The direct reduction of iron ore consumes, depending on the ore and the reduction process, between 400 and 600 M^3 (15,000-20,000 SCF) per metric ton of steel produced. Additional fuel (electricity or fuel oil) would be required for the steel making process.

1.3.5 Peak-load electricity production: Natural gas is an ideal fuel for generation of electricity to meet peaks in demands. The gas turbine is the key equipment item and such stations already exist in Egypt. One option is to continue on this path and to site new peaking stations conveniently near the national pipeline grid. Distillate petroleum fuel would be the standby. Another option is to retire the older, smaller, inefficient steam cycle stations from baseload service, and convert them to peaking service with natural gas and/or distillate fuels. This option would not be as convenient to operate as the gas turbine, but it could reduce capital needs and conserve residual fuel oil. New peaking stations would probably have a capacity of about 50 MWe and would be installed as near as practical to load centers.

1.3.6 Base-load electricity generation: The cycle gas turbine and steam turbine could be combined to generate base load electricity on the scale of about 450 MWe. Such a station could comprise four standardized 77 MWe gas turbines, each with an electricity generator and waste-heat boiler. The combined steam generation would operate one 154 MWe steam turbine. The total cycle would have an efficiency of 42 percent, which corresponds to a heat rate of about 2,040 Kcal/kWh (8,100 Btu/kWh), or a gas consumption of 0.23 nM^3 (8.05 SCF) per kWh.

Alternatively, natural gas could be used in more conventional cycles by providing existing or new installations with dual firing capability. Each steam generator could be fired with either residual fuel oil or natural gas, or a combination of both. This is an option already under consideration.

1.3.7 Impact: The establishment of a national pipeline grid will have two results, both affecting foreign exchange. If the natural gas is further distributed for urban use, a major decrease in the foreign exchange expenditures for imported LPG (butagas) can occur which can help offset the foreign exchange component in the pipeline investments. If the pattern of use for the natural gas is controlled in an appropriate manner, two benefits may be achieved:

- o The foreseeable associated gas production can be consumed domestically in Egypt, thereby releasing exportable fuels (e.g., residual fuel oil) or reducing the importation of metallurgical coals for steel making.
- o Non-associated gas reserves can be conserved for the future by producing only enough to meet deficiencies in supply for prevailing demands.

1.3.8 Policy implications: No current formal policy encourages the formation of a national natural gas pipeline grid or sets priorities for the utilization of the natural gas reserves. The general thinking, however, seeks to give priority to (1) industrial process use, (2) domestic use, and (3) electricity generation. The markets in these areas are not firmly established yet.

1.3.9 Key initiating actions: Two separate actions are indicated. The first is to extend the scope of the present study of the El Shukheir/Suez/Cairo natural gas pipeline to include the problems of integrating such a line with the existing lines and with the lines under construction. The second is to assess in some depth the role desired for natural gas in meeting future demands for energy. This assessment should include a priority system (i.e., a system of superior/inferior uses) and a pricing policy that would assure the consumption of future associated-gas production in a manner that most benefits the national economy.

1.4 Observations

The key supply options that emerge are petroleum exploration and production and the utilization of the associated natural gas production. Also of primary importance is the potential costly impasse regarding the supply of petroleum coke for electrode manufacture at the Nag Hammadi aluminum smelter, the need for more efficient utilization of fuel oil, and the priority use for the Maghara coal when it becomes available. Other significant energy supply options are the construction of petroleum refining capacity as the need arises and the construction of thermal electric generating stations to suit rising demand for electricity. These straightforward supply options do not appear to conflict with existing policies or require any unusual initiating actions to enable implementation.

1.4.1 Petroleum exploration: The exploration and production records of all oil companies in Egypt need analysis. Summaries need to

be prepared of regional reports customarily available, and these made public to assist in private exploration activities. A specialized field exploration program is also required. This is vital if Egypt's stated goal of 1 million barrels per day production of crude oil (including crude oil equivalent of natural gas) is to be achieved. There is uncertainty that these needs can be fulfilled by 1982.

1.4.2 Petroleum production stimulation: Petroleum production stimulation is distinct from primary production that depends on the native energy present in the reservoir. The techniques of production stimulation include reservoir pressure maintenance through gas or water injection, waterflooding, or enhanced oil recovery methods. The use of these techniques can increase recovery of oil from known fields, permitting achievement of the production goal earlier than by the exploration activities noted above. But, recovery attractive to the concessionaire, in terms of profit and flexibility to operate worldwide in his own interest, would not necessarily be attractive to a government acting in the national interest. National interests would probably dictate a higher recovery than a concessionaire is willing to achieve.

The first production results available from waterflooding in the El Morgan field are encouraging in terms of striking the balance between public and private interests. The present 70/30 formula for dividing production between the government and private interests needs to be reevaluated. The division formula, with respect to incremental production obtained from reservoir pressure maintenance, waterflooding, and enhanced oil recovery, needs to be reconsidered. The extent of change, namely the reduction in the Government's share of oil produced by stimulation methods, should be the minimum that would still make use of such methods attractive to the concessionaire.

1.4.3 Utilization of associated natural gas: Gas produced in association with oil in the Gulf of Suez is now being flared for lack of collection, transmission, distribution facilities, and developed markets for natural gas. Industrial development plans and growing electricity demand will ultimately generate markets probably exceeding Egypt's production capacity for all natural gas.

The current study of the collection of the Gulf of Suez associated natural gas appears unrelated to other natural gas activities in the country. A policy that (a) integrates all natural gas pipelines into a national interconnected system that can be supplied from all production locations and reaches all significant consuming locations and (b) establishes a pricing schedule that at least assures the consumption of all associated gas production, should be in the national interest. This national grid concept offers the facility to absorb all foreseeable production of associated natural gas and thereby avoid waste. This gas production can serve distinct markets, and to the extent it does so, can liberate equivalent liquid oil fuels for export.

1.4.4 Petroleum coke impasse: A situation seems to be developing in which a major investment being made in the restoration of petroleum coking capacity at Suez may have little or no return on the capital, because the excessive vanadium content in the coke product makes it unuseable by the aluminum smelter at Nag Hammadi. The smelter has contracted for the coke output and will be subject to a penalty if they eventually do not accept the product. If the aluminum is to be salable on the world market (70 percent of the smelter output in 1982 is to be exported), the smelter may have no choice but to reject the coke product. The situation should be reviewed promptly at the appropriate level in government to ascertain (a) whether in fact an impasse will exist, and (b) if so, what remedial steps are now in order.

1.4.5 Fuel oil utilization efficiency: Observations made during the sample of field visits to power stations and refineries showed a lack of knowledge as to the efficiency with which fuel oil was being consumed. Measuring instruments were either lacking or inappropriate. Gross observations of furnace conditions and discussions with operating personnel point to the prospects that combustion conditions could be improved with minimal investment and effort. The fuel oil quantity thus liberated becomes available to support new industrial expansion or for export. The situation warrants a quantitative analysis based on actual efficiency measurements of major fuel oil consumers.

1.4.6 Maghara coal utilization: When the coal deposits at Maghara become available, the best option is to follow the original intention to use this coal as a component of the coal blend to the metallurgical coke-ovens at Helwan. This use could lead to a mining operation on the scale of 300,000 metric tons per year and the generation of a cash flow. Then further exploration to discover additional coal reserves can be undertaken. If reserves increase substantially, consideration could then be given to the other options for coal which could further reduce the import of metallurgical coal or provide an alternative fuel for the generation of electricity or industrial heat.

2.0 ASSESSMENT OF FOSSIL ENERGY RESOURCES

The records and reports on file in the offices of the Egyptian General Petroleum Corporation and the Geological Survey of Egypt were the basis for assessing the fossil energy resources of Egypt. Accordingly, no new data acquisition activities were involved. A detailed assessment of resources is contained in a separate Annex. A brief summary of the findings relevant to the discussion of supply options is presented here for convenience.

The extent of Egypt's carbonaceous and oil shale resource appears to be marginal in comparison with the presently known coal, petroleum, and natural gas resources. Accordingly, carbonaceous and oil shales are excluded as a resource and no supply options are identified in this Annex. No reference to the occurrence of tar sands in Egypt was found. Accordingly, tar sands are also excluded and no supply options are identified.

2.1 Coal

Numerous occurrences of coal in Egypt are known. In most areas, the knowledge is derived largely from well cuttings, electric logs, and a small number of cores from wells drilled in search of oil in recent years. In the Sinai Peninsula and at a few localities west of the Gulf of Suez, the coal-bearing sequences are exposed and close to the surface. In these areas the coal measures have been investigated by geologic mapping, drilling and tunneling.

Coal deposits are of different geologic ages and are thin, impure, lenticular, and/or too deep (more than 1,000 meters below the surface). Hence, they are not attractive for recovery by conventional extraction methods. The only coal with an apparent economic potential occurs in a sedimentary sequence exposed on the northwestern flank of the Maghara anticline, a northeasterly trending structure in the north-central Sinai Peninsula.

Exploration for coal in the area of the Maghara anticline began during 1958. An intensive geologic mapping and exploration program was instituted, which resulted in delineating reserves sufficient to justify opening the Safa Mine, about 150 km northeast of Ismailia on the Suez Canal and 70 km southeast of El Arish, a port on the Mediterranean Sea. A railway between the two towns (which may have been dismantled) passes within 42 km of the Safa mine, and an asphalt road (in an unknown condition) connecting the two towns is 11 km to the south. The area is surrounded by drifting sand which encroaches in all directions, particularly from the north and west. Elevations in the area range from 300 to 560 meters above sea level.

The coal-bearing sequence is 90 to 100 m thick and contains as many as 10 coal seams; however, only two attain a mineable thickness (greater than 0.65 m thick). The two mineable beds, referred to as the Main and Upper seams, are separated by 10 to 13 m of shale, sandstone and limestone. The main seam attains a maximum thickness of approximately 1.90 m, and the upper seam, 0.80 m. The beds dip 8-1/2 to 11 degrees north-westerly and are, at places, offset by faults.

Both beds have been explored by adits and by drilling on a grid pattern with a 400-m spacing between holes in the area of the Safa mine and a 1,000-m spacing in adjacent areas. Coal reserves, in beds thicker than 0.65 m and as thick as 1.9 m (including coal of main and upper seams), are reported as follows:

Gross proved	39,900,000 tons
Probable	<u>11,900,000 tons</u>
Total	51,800,000 tons

Workable (recoverable) reserves:

Net proved coal	27,800,000 tons
Probable	<u>7,800,000 tons</u>
Total	35,600,000 tons

The indicated recovery of 70 percent is based on a "longwall" mining technique for extraction.

The coal has a low ash and a high volatile and sulfur content. The average proximate analysis of 23 samples from the main seam is: 5.3 percent moisture, 10.9 percent ash, 49.6 percent volatile matter, 31.0 percent fixed carbon, and 3.35 percent sulfur. The heating value is 6,855 K cal/kg (12,300 Btu/lb). The average of 10 samples from the upper seam is: 4.4 percent moisture, 4.9 percent ash, 52.2 percent volatile matter, 38.5 percent fixed carbon, and 2.43 percent sulfur. The heating value is 7,430 K cal/kg (13,400 Btu/lb).

By ASTM standards the coal is subbituminous C rank, although it contains a higher percentage of volatiles than typical American western subbituminous C coal, with which it can be equated. The coal produces a weak coke. The coal is described as dark brown to black with vitreous to semi-vitreous luster, and conchoidal fracture. Average specific gravity is 1.26.

At the time of the Israeli occupation of the Sinai Peninsula, the Egyptian Geological Survey had opened a shaft and an adit; had extended an incline 360 meters down dip; and had driven a drift 160 meters along a strike on the main seam. Also, an incline had been driven 325 meters down dip along the upper seam. Reserve data obtained subsequent to the opening of the Safa mine indicates that the mine opening should be moved to a new location where mineable reserves are more accessible.

The coal bearing sequence has not been fully explored in areas surrounding the Safa mine. Where the sequence is at or near the surface, it may contain additional economic reserves. A methodical exploration program will be required to discover new deposits. Although large reserves are not anticipated, it may be possible to double the known reserves in the area. Exploratory drilling appears warranted to the northwest and southeast of the presently explored area.

2.2 Petroleum

The Egyptian General Petroleum Corporation is the depository for exploratory and production records of all oil companies in Egypt. The reports and records provided for review were multitudinous and, in some cases, much too detailed. The few summary and regional reports, mainly from different oil companies, used different nomenclature and proved to be contradictory in major interpretations. These made a confusing basis for even a qualitative assessment of the petroleum potential of Egypt. Accordingly, a quantitative assessment of the petroleum resources can be many years away, even if exploration and drilling are intensified.

Estimates of proved recoverable oil reserves in Egypt range from 2.1 to 5.1 billion barrels. Production for 1976 averaged over 320,000 barrels a day, and the Egyptian government hopes to attain a rate of

500,000 barrels a day in 1978 and 1,000,000 barrels a day in 1982.¹ Specifically, EGPC reports reserves at the end of 1977 as 2.1×10^9 barrels and production in 1977 of 151×10^6 barrels, or an average daily production of 414,000 barrels.

Most reserves are in the Gulf of Suez basin (estimated range from 2.4 to 3.3 billion barrels), where 20 fields produce oil. Six commercial oil discoveries have been made in the Western Desert. The reserves discovered are estimated at 220 million barrels of oil and condensate. Six other recent discoveries in this region have not yet been evaluated.

The area of promising petroleum₂ prospects in Egypt total more than 600,000 km² of which only 230,000 km² are reported to have received more than a cursory examination. Prospects appear very favorable for substantial undiscovered reserves in many parts of this large area.

The Gulf of Suez basin holds the most immediate prospects for replacing and increasing the reserves, but will have diminishing results as the larger medium-depth structures are drilled. The development of new seismic techniques that will permit interpretation of structure beneath the masking salt beds in the Gulf of Suez may open new deep exploration programs in the next few years.

The most promising frontier regions are the relatively unexplored broad expanses of the Western Desert, Nile Basin, the Nile Delta Basin, and northern Sinai along with the adjacent offshore tracts. It does seem possible that an intensive exploration and drilling program could double the present reserves in 10 years.

The disparity in the reserve data may be the result of a lack of adequate communication and exchange of technical data of a regional nature. During the review of the data and local reports in the files of the EGPC it became apparent that little communication, and perhaps no discussion, of interpretations of a regional nature takes place between companies, universities, and government agencies. The strict confidentiality imposed on most data both by the companies and by the government tends to prevent this. Even regional data and reports not concerned with local prospects have been little used in the few published papers. Administratively, this is understandable. It is always much simpler to release nothing than to make judgments as to the real need for secrecy in technical data of a regional nature.

Specifically, published geological reports of a regional nature are needed to encourage scientific discussion, such as occurs in the United States, and to permit later workers to build on earlier results.

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The 1982 projection is for the production of crude oil and the crude oil equivalent of natural gas. One barrel of oil has a heating value of 5.8 million Btu.

Examples are (a) an aeromagnetic map, (b) a gravity map, (c) a seismic map, (d) a basement tectonic map, and (e) a Paleozoic isopach map, all on base maps at 1:2,000,000 scale covering all Egypt. These could be attempted with the collaboration of company, university, and government geoscientists in sequence, so that each year one or two products could be available for publication. The establishment of an Egyptian Petroleum Exploration Society affiliated with the American Association of Petroleum Geologists, a worldwide organization of nearly 20,000 members, would be an easy step in the direction of interchange of geological and geophysical information of a theoretical or a regional nature. The availability of reliable data in these areas can establish the third dimension of Egyptian geology, and the basis for maintaining, if not expanding, Egyptian petroleum resources.

Thus, two basic concepts are needed to establish the third dimension in Egyptian geology. First, standard-type subsurface sections with standard nomenclature are necessary for geological and geophysical communications. These could be best established by selection of the stratigraphically deepest wells with complete samples, cores, and electric logs in each basin or province, and the preparation of composite sample logs by experts. These logs would include not only lithology and electrical characteristics but also fossils, oil, gas and water information. These standard logs could then be used to extend correlations along cross sections designed to outline the regional stratigraphy and facies changes. It might suffice to have one or two standard well logs for each province such as the Western Desert and the Nile Delta, and perhaps two cross sections at a vertical scale of 1" = 100' at right angles across each region. Other electric logs could then be tied to them.

The second equally great need is to understand the basic regional framework. This will have to be developed, beginning with the basement tectonics and the Paleozoic rock distribution, now subject to widely different interpretations. One approach that may be suggested is shooting two seismic refraction lines across the Western Desert at about right angles to each other, and each about 100 miles long, to determine the velocity of the seismic interfaces at depth. This could provide needed control to determine the tops of the basement and the Paleozoic rocks for the basic tectonic framework. Reflection seismic, aeromagnetic, and gravity data now at hand can be related to this and better interpreted.

Following this, stratigraphic analysis of basins is needed. In addition, numerous stratigraphic test holes may be required to establish the validity of the geophysical results. Seismic work offshore in the Mediterranean, especially around the Nile Delta, is needed. Seismic stratigraphy, a relatively new approach, may be applied in these areas.

Successful exploration in Egypt might be encouraged by subsidized educational efforts covering modern concepts and techniques. The basic geological education of Egyptian earth scientists is very sound, but

continuing contact with new theory and technique is needed. Topics of special importance include stratigraphic interpretation of seismic data and modern sedimentologic analysis of clastic, carbonate, and evaporite depositional systems.

2.3 Natural Gas

Natural gas production in Egypt began in 1974, and the 1977 production of gas is estimated at 88.3 billion cubic feet (70.6 billion associated, 17.7 non-associated). Estimates of proved gas reserves range from 2.5 to 4 trillion cubic feet; of this, one estimate assigns 1.5 to 2.5 trillion cubic feet to the Delta Basin, 1 to 1.5 trillion cubic feet to the Western Desert, and the remainder, some used for gas lift of oil and some flared, to the El Morgan field in the Gulf of Suez basin. Specifically, the EGPC has estimated 3.9 trillion cubic feet of gas reserves at the end of 1977. Projections for 1978 production are 675 million cubic feet a day.

3.0 SELECTION OF SUPPLY OPTIONS

A supply option is one identified path among several, linking an energy resource with an energy demand. The path serves to help fill the demand from the energy resource, and it is likely to be technological in nature. The path can involve a combination of (a) the extraction of the resource to make it available, (b) the conversion of the extracted resource to another form suited to the consuming device, and (c) the transport of the extracted resource or the energy form before or after conversion.

The ultimate consumption of an extracted resource or the energy form by the consuming device is a separate issue. Analysis of the various ways in which consumption can occur leads to the identification of demand options, which are considered here to be distinct from supply options. The scope of this Annex is limited to discussion and evaluation of supply options only.

3.1 Selection Criteria

The criteria for selecting supply options should assure that each supply option will be attractive, practicable, and implementable during the time frame selected for the assessment, i.e., from the present to the year 2000. The criteria that promise this assurance are accordingly:

The Utilization of Developed and Proven Technologies. This criterion serves to reduce uncertainty to a manageable level with respect to (a) schedules in which implementation of a supply option can be achieved, (b) the costs which will be incurred during the achievement, and (c) the risk that the desired supply results will not be obtained. Thus, this criterion enables realistic forecasts to be made of costs of production, the amount and attractiveness of investments, and the impacts on the economy, environment, and institutions.

The Promotion of Self-Reliance. The extent to which a nation wishes to be self-reliant, i.e., the extent to which upsets to its welfare can be avoided when supply channels suddenly and unexpectedly disappear, is clearly a matter for internal judgment. Nevertheless, supply options which offer local production of energy forms to fill local demands are given particular attention and preference.

Amenability to Local Fabrication. Local fabrication reduces foreign exchange demand, utilizes investments already made, and increases local employment. These are all positive factors that encourage economic growth and promote general welfare.

Adequate Reserves of Energy Resource. The extent of reserves for an energy resource should enable the supply option to be exercised in fulfilling a demand on a significantly large scale. The desire is to avoid an import of that same resource in order to support the contemplated scale of operation.

Superior Usage of the Resource. If a given resource is limited in reserves and if alternative energy resources exist, which may be more plentiful and which can likewise serve to fill a particular demand, the attractiveness of the given scarcer resource in filling that demand should be reduced.

3.2 Supply Options Rejected

The supply options discussed below are rejected through a general application of the criteria enumerated above.

3.2.1 Coal-based options:

In-Situ Gasification. The deep coal finds in the Western Desert of Egypt may be amenable to in-situ gasification with air/steam or oxygen/steam mixtures to produce low or medium heating value fuel gases respectively. The low-Btu gases could be used for baseload electricity generation, and the medium-Btu fuel gases for upgrading to substitute pipeline gas, for conversion to hydrogen for ammonia production, or for methanol production. The development of in-situ gasification technologies has been underway since the 1930's in many countries. The U.S.S.R. is believed to have installations still operating for power production, but it also appears that the U.S.S.R. has largely abandoned the technology in favor of conventional coal extraction for power. The program in the United States is one of research and development with demonstration planned for the mid-1980's.

Given the natural gas resource of Egypt, the lack of an extensive gasoline market which might favor methanol production, the amenability of the coal deposit at Maghara to conventional extraction, and non-availability of well-developed and proven in-situ gasification technology before the late 1980's, consideration of this option should be delayed. It could be reconsidered when future energy demand patterns in Egypt and the extent of energy resources are better known, perhaps before the late 1980's, and when adequately developed and proven technology is available.

Above-Ground Gasification. This path pertains to the production of low, medium, or indirectly derived high Btu fuel gases from mined coal. These gases could have the same uses as the gases from in-situ processing, noted above. First-generation gasification technologies are available which have been in commercial use for many years. Currently, second-generation technologies that should reduce production costs are at various stages of research, development, or demonstration. The second-generation technologies would operate at such a large scale that the known Maghara coal reserves would support operations for only 10-15 years. Demonstration and utilization of these technologies will not occur before the late 1980's.

The first-generation technologies could operate at a smaller scale, but most likely at a high cost of production compared to the alternative fuel gas (natural gas) available in Egypt. The demand situation appears easily supported by available natural gas resources in Egypt.

Accordingly, this supply option should be deferred indefinitely, and reviewed again when it becomes clear that (a) Egypt's coal resources are greater than presently indicated, and (b) the natural gas resource is limited in terms of domestic demand.

Liquefaction. This option pertains to the production of liquid hydrocarbon products obtained through the processing of mined coal by hydrogenation. A 50-year-old technology base reached wartime commercial operation in Germany (1939-1945). The products range from heavy liquids (which may be solid at ordinary temperature), suited for electrode manufacture, to light hydrocarbon distillates suited as transport fuels. Currently, in the United States, considerable process development effort is directed toward liquefaction, aiming at cost reduction via second generation processing. A large distillate fuel demonstration facility is now under construction at Ashland, Kentucky, and process development units are operated in Washington State and Alabama for using solvent refined coal (SRC) as a superior low-sulfur, low-ash boiler fuel.

Liquefaction of coal to produce a transport fuel is a supply option that should be rejected for the reasons (a) the coal resource in Egypt is limited in terms of needed scale of operation and (b) the gasoline demand in Egypt is low. In fact, Egypt exports surplus light distillates produced from petroleum.

The production of SRC, however, appears to be of interest as a feedstock for electrode manufacture that can serve Egypt's aluminum facility at Nag Hammadi, the projected phosphorus reduction facilities in the New Valley, and existing and projected electric furnace steel-making facilities. Consideration of this supply option, however, should be deferred until the supply option discussed below, electrode production from petroleum coke, is resolved.

Coal Importation. A supply option that is practical in many situations worldwide is import of steam coal for power generation. In the case of Egypt, the import of steam coal for new power generation facilities could release equivalent fuel oil for export. Foreign exchange thus earned could support the import of coal. This is not considered here because the analysis would require an evaluation of world coal markets which is beyond the scope of this assessment. Also, it does not meet the self-reliance criterion, even though it is technically feasible to provide a boiler design with a dual firing capability, plus the import of steam coal by an oil-producing nation may not be politically feasible.

3.2.2 Petroleum based options:

Minimal Refinery Construction. With surplus refinery capacity existing in many locations world-wide, Egypt could avoid the investment in new refinery construction by importing products to fit its demand pattern, while exporting the crude oil production not consumed in domestic refineries. This supply option is rejected for the reasons (a) it violates the self-reliance criterion, and (b) the economy would lose the value-added benefits of a complete refining activity.

Intensive Gasoline Production. Gasoline production could be increased without an increase in refinery crude oil throughput by installing catalytic cracking or residue hydrogenation in the existing or future refineries. This supply option is rejected because (a) the current demand pattern requires no new gasoline production other than that produced by catalytic reforming of straight run gasoline, and (b) the future demand pattern is expected to be similar and should require only a proportionate increase in refinery capacity.

3.2.3 Natural gas based options:

Export as LNG. The liquefaction and export of natural gas in specially constructed tankers is a growing worldwide activity between areas of low cost natural gas surpluses and natural gas deficiencies. Such shipments require large-scale liquefaction installations. This supply option is rejected for the reason that no indication exists that natural gas production in Egypt will result in surplus production beyond national needs.

Methanol Synthesis. Natural gas can be utilized conveniently, without major modification to the conventional internal combustion engine, by conversion to methanol and blending with gasoline. In this mode, natural gas can serve to release gasoline supplies and reduce crude oil consumption domestically. This option is rejected. The reasons are (a) the Egyptian transport needs are minimal for gasoline and (b) gasoline fractions of the crude oil are already surplus and available for export as light naphtha. This pattern of consumption is expected to continue through to the year 2000.

3.3 Options Selected

The options selected are summarized in table 1 and evaluated in the following chapter.

4.0 EVALUATION OF OPTIONS

This chapter addresses the supply options selected (table 1). The goal was the quantitative evaluation of each option in terms of its financial, environmental, economic, social and institutional effects, but needed data were not always available, especially the costs and resource consumption associated with the implementation of an option. The major reasons for the lack of data were the accelerated schedule adopted for the energy assessment project and the limited project resources that could be concentrated on cost estimations. Therefore, the evaluations are basically qualitative with quantitative aspects discussed only as far as these could be supported. Environmental aspects are summarized rather than detailed, since the environmental effects of energy supply options are covered in this overall assessment by a separate annex.

4.1 Coal

Egypt's coal resources for the present and through the year 2000 appear to be a single deposit at Maghara in the Sinai, with proven and probable recoverable coal reserves of 35.6 million metric tons. Once

TABLE 1
LIST OF SELECTED SUPPLY OPTIONS

Resource	Objective	Options
1. Coal	Extraction of resource	a. Room and Pillar Mode; 300,000 MTY b. Room and Pillar Mode; 1,200,000 MTY c. Longwall Mode; 1,200,000 MTY
2. Coal	Transportation to place of use	a. Truck and Highway; 300,000 MTY b. Truck and Highway; 1,200,000 MTY c. Railway; 1,200,000 MTY d. Slurry Pipeline; 1,200,000 MTY
3. Coal	Electricity generation	a. Mine Site; 80 MW; 300,000 MTY b. Ismailia; 375 MW; 1,200,000 MTY
4. Coal	Metallurgical coke manufacture	a. Blending Agent; 300,000 MTY b. Blending Agent (Char); 1,200,000 MTY c. Formed Coke Manufacture; 1,200,000 MTY
5. Petroleum	Production	a. Primary b. Reservoir Pressure Maintenance c. Water flooding d. Enhanced Oil Recovery
6. Petroleum	Refining	a. 100,000 B/D (5 million MTY) modules, low gasoline product mix.
7. Petroleum	Alternative utilization of petroleum coke product	a. Manufacture of metallurgical coke by blending with metallurgical coal.
8. Petroleum	Electric power generation	a. 450 MW Module designed for low heat rate and residual oil firing. b. Peak generation needs, combined with similar supply option for natural gas distillate oil fuel standby.
9. Natural Gas	Production	a. No evident option beyond conventional production.
10. Natural Gas	Link associated gas production with non-associated production in a unified supply system	a. Formation of a National Pipeline Grid

TABLE 1 (CONTINUED)

Resource	Objective	Options
11. Natural Gas	Distribute natural gas from the unified supply system to the population centers	a. Construction of urban distribution system
12. Natural Gas	Provide fuel for expansion of selected industries	a. Use as a Chemical Feedstock for ammonia based fertilizer manufacture and for direct reduced iron ore
13. Natural Gas	Peak load electricity	a. 50 MW gas turbine (or surplus older base-loaded units) peaking stations
14. Natural Gas	Base load electricity generation	a. Construct new combined cycle units b. Install dual firing with fuel oil

further exploration can be financed, such as through cash flow generated by exploitation of the known reserves, it is likely that extensions can be found to the Maghara deposit, which could perhaps at least double the recoverable reserves.

The options discussed below are based on a highside limitation of 1.2 million tons per year extraction. This rate will give the known deposit a life of 30 years, sufficient to support the full depreciation of capital investments made to extract and utilize the coal.

4.1.1 Extraction: The option selected is one of conventional extraction by underground mining at rates suited to the utilization options discussed below. The depth of the two coal seams identified appears to eliminate the option of surface mining. Thus, a two-level mining operation underground is required to extract the upper and the lower seams.

The mining methods selected are (a) the room and pillar type, which tends to require a lower capital investment and more labor intensive operation, and (b) the longwall mining type, which tends to require a higher capital investment and less labor intensive operation. The disadvantage of room and pillar mining is its limitation on recovery to about 50 percent of the deposit, thus delivering less coal to the Egyptian economy from the existing deposit. As noted above (section 2.1), recoverable reserves of coal are based on about a 70 percent recovery, which is usual for longwall mining. Room and pillar mining, accordingly, would decrease the Maghara recoverable reserves about 10 million tons. Room and pillar mining is sometimes amenable to enhanced recovery of coal through controlled roof collapse by pillar removal, the pillars yielding the increased coal recovery.

Longwall mining, which is based on control of roof collapse during the extraction of the coal, can have a limited application. Some controlling factors are restrictions imposed on the mining operation (true also of the pillar recovery above) to avoid surface subsidence; the need for fairly continuous rectangular blocks of coal that permit long runs with each equipment setup; the presence of roof structures that are amenable to controlled collapse; the need for a clean coal seam free of abrasive shale or slate intrusions that wear the bits; and avoidance of two or more seams (a noteworthy limitation with respect to the Maghara deposit). The precise selection of mining method can only be made after thorough evaluation of the physical nature of the coal deposit.

The following observations may be relevant when coal mining activity begins.

Construction. Excavation to open the mine would be accomplished by local labor, requiring minimal foreign exchange for tools and equipment. Roof bolts and similar equipment could be locally fabricated once designs are established by consultants. Mining equipment, especially if

machinery is used, would be imported. Coal cleaning equipment probably would involve the procurement of a plant of standardized design from recognized suppliers.

Operation. Coal mining is among the most dangerous occupations in the United States. It is too early to estimate what safety regulations and practices would be instituted in Egyptian mines, when the Maghara deposit would be opened, and no parallels with the U.S. occupational injury rates in coal mining should be drawn. Comments may be made, however, for illustrative purposes.

The seams are relatively thin, and headroom probably would not permit miners to stand full height. Particular attention would need to be paid to safety practices, including instilling awareness of hazards into underground personnel. The effectiveness of modern safety practices may be illustrated by the experience in Pennsylvania in 1975, where one fatality occurred for each 4 million tons of bituminous coal mined and one non-fatal incident occurred for each 26,000 tons of coal mined. About 600 tons per day of water would be needed to produce 300,000 MTY of coal. At a 1.2 million MTY rate, water consumption could rise to 15,000-20,000 tons per day. The mining area appears to have adequate fossil waters.

Supporting Industry. A coal mining industry could be self-sufficient with respect to its own operations. It could perform its own maintenance. However, it would depend on the operation of transport industries to take the coal to the market centers.

Environment. Comparisons can be made with the environmental impacts of coal mining in the United States only in a limited sense. The amount of land disturbance associated with underground mining is generally much less than for strip mining. Disposal of mine water is a problem in both types of U.S. mines due to the contained pollutants. It is not known if mine water would be found or be a problem in an Egyptian mine, but adequate means of disposal could be found in the vast desert wastelands which surround the Maghara deposit.

In addition to the release of aqueous pollutants, atmospheric pollution can accompany mining operations. However, atmospheric pollution release from an Egyptian mine would be of less consequence because of the surrounding desert and the extremely low population densities that characterize desert areas. Settlement areas would have to be protected, however.

The processing of coal (i.e., removal of non-combustibles and size reduction) is another source of residuals for disposal. There should be no difficulty in finding disposal areas compatible with the desert environment.

Manpower. Early plans (1967) to operate the Maghara mine included a labor force of 1,742 miners producing an output of 300,000 MTY. In 1977, a more mechanized operation was proposed that would reduce the

labor force to 1,326 miners. At a 1.2 million MTY extraction rate, the labor force might increase to 5,300. Allowing for 175 and 200 indirect supervisory and administrative personnel and a multiplier of 6 for total population, the mining community population would be 9,000 and 33,000 respectively for the two levels of coal extraction. Because of the uniqueness of the operation in terms of Egyptian experiences, comprehensive training in job practices and safety would be required.

Social/Institutional. The establishment of a mining community would represent a population dispersal and a nucleus for further development of the region surrounding the mining area. The mining operation itself would probably be under the control of a business enterprise charged with producing according to the cost/price conditions established beforehand. The transportation of the coal could be taken over by existing institutions already engaged in transport by conventional means. If the means is a slurry pipeline, the logical action might be to make this a responsibility of the coal organization.

Economic.* Making coal available to the Egyptian economy would affect residual fuel exports and metallurgical coal imports. Both commodities may be valued at about U.S. \$75/metric ton (L.E. 51). About 1.7 tons of coal would be needed to displace 1 ton of residual fuel oil, while metallurgical coal may be displaced at a ton per ton rate in quantities up to the lower mining rate. At the higher mining rate about 2.7 tons of Maghara coal could displace one ton of imported metallurgical coal, meanwhile making available a line of liquid hydrocarbon products. Accordingly, at the lower mining rate, the foreign exchange value of the coal is about U.S. \$13 million (L.E. 8.8 million) annually to replace residual fuel oil for export and about U.S. \$22.5 million (L.E. 15.3 million) annually to reduce metallurgical coal imports. At the higher rate, the value of fuel oil is about U.S. \$52 million (L.E. 35.4 million). A value with respect to imported metallurgical coal is too difficult to determine at this stage. Achieving these results would require new investments which can have a significant foreign exchange component, but, at the same time, gross national product can increase. Analysis requires further study involving the development of realistic estimates of investment and operating cost estimates.

4.1.1.1 Room and pillar mode, 300,000 MTY rate: The capital cost and operating requirements for an underground coal mining operation are logically developed only after establishment of a mining plan that reflects the realities of the coal deposit and the rate of extraction. The variables that control the costs are:

- o The height of the seam, which is reported as 0.6 m for the upper seam and 1.9 m for the main seam;

* Discussion in this section refers to and incorporates aspects of the coal conversion options not yet mentioned but evaluated below.

- o Roof structure, which can affect the sizes of rooms and pillars, and thus the coal recovery;
- o Bottom (floor) quality, which can affect the load bearing capability and hence the type and costs of haulage underground;
- o Methane liberation, which can affect ventilation costs and the provision for hazard control;
- o Hardness of seam, which can affect the selection of mine face equipment and techniques, and hence productivity;
- o Depth of seam below surface, which can help to assess, for example, the quality of the roof structure, and
- o The presence of water, which involves costs for control and removal.

Knowledge of these variables then enables selection of the design factors upon which costs can be based. Examples are the sizes of the pillars, the widths of openings, the depth of cuts, roof support techniques, and the percentage of recovery. The mining plan would include the method of entry, whether by drift (when the deposit outcrops as is the case at Maghara), shaft, or slope; and the method of haulage.

It is noteworthy that, after the opening of the Safa mine, further knowledge of the deposit became available which indicates another more favorable location for opening a mine. The Maghara deposit poses even greater difficulty to proper planning because of the evident lenticular nature of the deposit. A 1964 estimate indicated for a 300,000 ton per year production by the longwall method, a foreign exchange capital cost equivalent to L.E. 4.1 million and a local cost of L.E. 4.8 million. Similar costs in 1978 are perhaps two to three times these estimates. The production costs estimate was L.E. 4.60 per metric ton, which in 1978 is probably inflated to L.E. 9 to 14 per ton.

4.1.1.2 Room and pillar mode, 1.2 million MTY rate: This extraction option is identical with the lower extraction rate of the option above, with the exception that the extraction rate is 1.2 million metric tons per year. The problems of establishing a mining plan are the same, except that the physical activities will occur on a larger scale, and the capital investments will be larger.

4.1.1.3 Longwall mining mode, 1.2 million MTY rate: Longwall mining is attractive when large blocks of coal can be delineated, having dimensions on the order of approximately 90-120 m (300 to 400 feet) wide and perhaps 180-210 m (600 or 700 feet) long. Two entries are driven along the length of the block of coal and extraction occurs along the width by a mining machine. The roof over the excavated area is supported along the width of the face by a system of interconnected jacks. The coal is removed by a haulage system. As coal is mined, the mining machine and jack system advance toward the face, and the roof area that becomes unsupported is allowed to collapse.

Since the mining system is capital intensive, its attractiveness lies in the ability to delineate the large blocks of coal continuously over the life of the equipment. The available knowledge of the Maghara deposit indicates a lenticular deposit, not suited to longwall. Also, with two seams to be mined, at unstated depths, the collapse of the roof for the main (lower) seam may make the upper seam unmineable, in which case substantial reserves would be lost. In this respect, it is noteworthy that the Egyptian mining plan before 1967 contemplated longwall mining.

4.1.2 Transportation: In the event the utilization of the coal is to occur away from the mine site, the option selected is transportation from the mine site to Ismailia. From this location the coal can be moved westward and southward by the transportation infrastructure already installed and in operation. The transportation modes selected are road/highway/trucks, railway, and coal slurry pipeline. For the low-rate extraction option above, because of the relatively small capacity, only the first mode (road/highway/truck) should be considered.

Ismailia is selected because it is the closest location to the coal deposit that represents a well-developed limit of Egypt's transportation infrastructure. Rail, highway and canal-barge facilities should be available.

However, additional infrastructure development would probably be needed to improve the inland Ismailia-El Arish road up to its intersection with the mine road and to provide a tunnel or bridge crossing of the Suez Canal. Estimates of required investments are not feasible, since the present condition of these roads is unknown.

4.1.2.1 Truck and highway, 300,000 MTY rate: The distance from mine site to Ismailia (combination of mine road and highway) is about 190 km. The total transport, mine site to Ismailia, is about 57 million tonne-km annually. If the carrying capacity of each truck is taken as 20 tons of coal, and if the average outward speed is 40 km/hr (the trip to Ismailia is downhill with a total elevation drop of about 700 meters) and inward speed is 30 km/hr, each truck will have an annual transport capacity (24 hour, 5 day operation) of 8,840 tons of coal. Thus, $(300,000)/(8,840) = 34$ trucks would be required. Trucks would be spaced on the road $(24)(60)/(34) =$ about 42 minutes apart.

4.1.2.2 Truck and highway, 1.2 million MTY rate: This option is identical with the option above, except for capacity, which is four times larger. It would appear warranted to use larger, 25-ton capacity trucks with a faster inward speed (40 km/hr). Then each truck would have an annual transport capacity of 12,500 tonnes, and $(1,200,000)/(12,500)$, or 96 trucks would be required. Trucks would be spaced on the road about $(24)(60)/(96)$ about 15 minutes apart.

4.1.2.3 Railway, 1.5 million MTY rate: A new heavy duty (60 Kg/ meter rail) single track railroad in a right-of-way would be

constructed. A right-of-way at the appropriate grade (probably greater than normal because of the downhill slope of the loaded train) would need to be surveyed. Such a line may be found to be 125 km long. Signals, communications, structure, wooden or steel sleepers, grading, and ballast would be involved.

If each car can carry 50 tons and a train of 50 cars is taken, and if the average outbound speed is 30 km/hr and in-bound speed (uphill-unloaded) is likewise 30 km/hr, the annual carrying capacity of a train would be (5 days per week operation) exactly 1.2 million tons. Therefore, only one train would be required. Loading hopper capacity of at least 2,500 tons would be required at the mine.

4.1.2.4 Slurry pipeline, 1.2 million MTY rate: A coal slurry pipeline system would comprise the slurry preparation facilities, the line itself, and the slurry dewatering facilities. The on-stream factor may be 98 percent (357 days per year) with a life expectancy for the system of 40 years. The line could be straight, 100 km long. It would be oversized to permit blocked operation, in which, for part of the time, water from the dewatering operation is returned for use in the slurrying of new coal. Since the difference in elevation between mine site and Ismailia is approximately 700 m, the available head could provide pipeline flow at adequate velocity without pumping--depending on the line size and route selected. For capacity of 1.2 million metric tons of coal per year, the line diameter in blocked operation would be about 14" OD (356 mm). The preparation plant would include the water supply, handling and storage, and agitated slurry storage. The dewatering plant would include the necessary slurry tanks and water treatment.

4.1.3 Electricity generation: The combustion of coal to produce electricity is one option suited to Egypt's future energy needs. The use of a solid fuel would be a unique technological effort, since thermal generation of electricity in Egypt in recent years has utilized only gaseous and liquified hydrocarbon fuels. The new operations would involve the handling of coal (storage, crushing and feeding to the boilers) the disposal of the incombustible ash, and the management of ash accumulations within the boiler itself. Otherwise, all operations (such as in the turboelectric area) are conventional and well known and practiced in Egypt.

Two scales of generation are considered, each corresponding to one of the coal extraction rates discussed above. The 300,000 metric ton per year rate corresponds to an 80 MWe station at a heat rate of about 3,275 Kcal/kWh (13,000 Btu/kWh). The 1.2 million rate corresponds to a 375 MWe station at a heat rate of about 2,770 Kcal/kWh (11,000 Btu/kWh).

The combustion of coal for power generation would effect the environment particularly through the emissions of ash, sulfur oxide, and nitrogen oxides. At 80 MWe generation, the annual emission without control of ash would be approximately 9,600 tons of sulfur oxides, approximately 17,000 tons of nitrogen oxides, and approximately 2,450 tons of particulates. At 375 MWe, the emissions become 38,400 tons, 68,000 tons, and 9,800 tons respectively.

The construction and operation of the power stations would be an incremental activity of the Egyptian Electricity Authority, but would involve new techniques for the combustion of a solid fuel. Training of personnel in handling, crushing, combustion, and waste disposal would be required.

4.1.3.1 80 MWe generation: An 80 MWe coal-fired electricity generation station would be designed to have a life of 30 years, and to be baseloaded. It would be located at the site of the coal mine. The cooling water circuit would be designed for a maximum recycle and tower cooling. On this basis it is believed that adequate water is available at the mine location to provide the make-up quantity. The heat rate would be about 3,275 Kcal/kWh (13,000 Btu per kWh).

The output would provide a local power source for settlements in the vicinity of the coal mine. This energy supply could reinforce development plans to extend the Ismailia Canal, under and across the Suez Canal about 100 km into the Sinai, to provide irrigation water. Construction of an 80 MWe capacity transmission line from the national grid at Ismailia to the main site would assure reliability of the electricity supply. Also, surplus power generation could be fed back to the National Power Grid through this same line. No transport of coal would be required.

The expectations are that considerable coal washing will be required because of the thin coal seams, if the combustion of coal occurs in a conventional steam generator. The use of fluid bed combustion equipment could eliminate the need for washing since it can accommodate almost any combustible material. This technology is in an advanced stage of development and could be available within the time frame of this assessment.

4.1.3.2 375 MWe generation: A 375 MWe coal-fired electricity generation station would be designed to be baseloaded to supply the National Power Grid at a rate that corresponds to the maximum rate of extraction of coal from proven and probable coal reserves. If the reserves should expand through future exploration, the capacity of the station could be increased. The location of the station would be Ismailia, which would require the transport of coal from mine to station, as discussed above. Cooling water could be taken from and returned to the Suez Canal. The heat rate would be about 2,770 Kcal/kWh (11,000 Btu per kWh). Duplicate firing equipment for fuel oil would be included to allow for operation during periods of interrupted coal supply. Because of the transport, coal cleaning facilities would be provided at the mine site. This would require finding a source of water at the site or bringing it from Ismailia on the return trip of the coal transport facilities.

4.1.4 Metallurgical coal manufacture: Egypt's main iron and steel manufacturing industry is located at Helwan, to the south of Cairo, and is based on the blast furnace reduction of domestic iron ore. The coke

needed for the reduction, however, is produced from imported metallurgical coal by a conventional by-product coke oven installation adjacent to the steelworks. A probable realistic price for this coal, delivered at the coke works, is about L.E. 51. When the current expansion at Helwan is completed, about 1982, the quantity of imported coking coal will reach about 1.5 million metric tons annually. Thus, foreign exchange requirements will be about L.E. 76.50 million.

Sufficient technical experience exists worldwide to permit a portion of the Maghara coal to be blended with imported coking coal. In fact, early experiments in Egypt itself indicate that up to 20 percent of the blended coal charged to the coke ovens might be Maghara coal; and if this were demonstrated, the savings in foreign exchange annually could be as much as L.E. 15.30 million.

Other experience indicates that, if the coal were first carbonized, the char might be admixed to the extent of 30 percent of the blend. The foreign exchange savings would rise to L.E. 23 million, but a processing plant would need to be installed, which would require a capital investment. Moreover, a domestic market would be needed for a number of coal tar products, such as BTX (benzene, toluene, and xylene) and creosotes.

Finally, it is likely that all the Maghara coal could be converted entirely to an acceptable reducing agent for the blast furnace, as formed coke. An 85,000 ton per year plant has now operated for many years at Kemmerer, Wyoming, producing a formed coke for phosphorus reduction furnaces from a local Wyoming subbituminous coal, a coal similar to the Maghara coal.

Thus, three options are available for utilization of Egyptian coal as a solid reducing agent; their validity depends on the acceptability of the eventual coke product at the iron and steel works.

The coke works is planning the acquisition of a 100 kg laboratory coke oven by late 1978. This will enable them to produce trial batches of coke and to test varying blends of coal. The promising blends of coal can then be tried in a group of full-sized ovens to produce large samples of coke, whose acceptability can be evaluated by the iron and steel company in its 450 ton per day blast furnace. The evaluation would identify the effects on blast furnace productivity of a possible higher sulfur content (which means possibly greater limestone additions to the burden in the blast furnace and a higher or lower ash content in the coke). From these effects, the transfer price for the coke can be established, and consequently, the price that Maghara coal could earn in this use.

Institutionally, Egypt will be in a good position to explore the attractiveness of domestic coal supplies for metallurgical use and for decreasing imports and generating local employment.

4.1.4.1 Blending agent (coal): The substitution of Maghara coal for part of the coal blend charged to the coke ovens at Helwan does not require significant new investment at the plant itself. The new physical activities involve introducing changes in material handling practices. The coal price that evolves from the tests noted above would have to be netted back to the mine site through subtractions of Ismailia to Helwan transport costs and mine site to Ismailia transport costs. Transport from Ismailia to Helwan is expected to involve the existing transport infrastructure and transport institutions which would charge a customary fee for this transport function. The netback price and the foreign exchange implications would then become the basis for justifying the opening of the coal mine.

Before full implementation, a period of perhaps a year would be needed for the sequence of testing noted above, in the laboratory and commercial coke ovens, and in the steel company's 450 ton per day blast furnace. Associated costs, beyond the value of marketable products made during the tests, should be capitalized and eventually recovered from the ultimate commercial operation. One such cost would be the preliminary mining operation at Maghara to obtain sufficient samples of the coal.

The indications from past experimentation are that a successful testing program is virtually assured, so that the incentive ultimately can exist to exercise this option. The exercise of this option could begin as soon as the coal deposits become available. The period of test, evaluation, opening of mine, and the installation of mine/Ismailia transport facilities should require about a three-year period.

Assuming that the scope of this option begins with the delivery of Maghara coal at Helwan, the following observations may be made:

Construction. Some modification to the material handling facilities at the coke works to permit the blending of Maghara coal with imported coking coal are probably needed. But these appear to be insignificant in terms of money value, especially since it appears that even now imported coals from different sources are being blended.

Operation. The coke plant already blends imported Russian coal with imported U.S. coal. The introduction of a domestic coal into the blending operation should have little or no effect on operations and it could be handled without problems.

Supporting Industry. The supporting industry would be a coal mining operation at the Maghara coal deposit. The existing transportation industry would have to be extended to reach from Ismailia to the mine site.

Environmental Impact. The introduction of Maghara coal would involve the introduction of an additional quantity of sulfur. Since, in the steel making process, the sulfur in coal is discharged in the solid slag in a stable form, there should be no air pollution for this option. No change in plant effluents would be involved.

Social/Economic/Institutional Impact. No changes are likely from the point of view of social and institutional effects. However, the economic effect of a reduction in foreign exchange demand should be significant.

Manpower. Manpower requirements, and levels of skills, will be unchanged.

4.1.4.2 Blending agent (char): As noted above, if the coal is first carbonized and the resultant char is used as the blending agent, the proportion of the blend that is charred could rise to 30 percent, or possibly higher. Considerable definitive experimental work to this end was under way in Yugoslavia at the Boris Kidric coke works at Tuzla in the early 1960's.

From the personal experiences of one of the authors, who visited the operation in early 1964, it is known that the goal at the time was a 50/50 blend of char with imported U.S. coking coal. The char was produced in a suspension of recirculating hot coke fines with fresh fine lignite, i.e., by the Lurgi Ruhrgas Process. Liquid products are coproduced, namely tars which could be used further for the production of electrode coke and a lighter boiling fraction from which phenols, BTX products, and creosotes can be made.

Given a potential of blending of about 30 percent, then 450,000 metric tons per year of char would be needed. From the fixed carbon analysis of Maghara coal of 31 percent (main seam) and 38.5 percent (upper seam), about 1.2 million tons of coal would have to be processed, assuming an average 37 percent yield of char. This is the maximum rate at which the known reserves at Maghara should be extracted. Thus, in this option about 2.7 tons of Maghara coal would be required to replace one ton of imported coking coal. But co-products, coal liquids, would be produced.

The current practices of the Boris Kidric coke works could be transferable to Egypt, but this potential would first need to be identified. The quantitative aspects of this option require further investigation and study to establish the yields, product utilization, and investments involved. In the meantime, some qualitative observations are feasible.

Performance Capabilities. A reasonable expectation is that the quantity of imported metallurgical coal could be reduced by 1982 by about 450,000 metric tons per year. The entire output of the Maghara mine at the high extraction rate would be dedicated to providing the char substitute for the metallurgical coal. The liquid products made in conjunction with the char would be additive to similar products already being made in the coke works at Helwan.

Availability and Timing. The carbonization process to produce the char is available from a reputable commercial supplier. Plants employing

the process exist elsewhere, and the expectation is that conventional commercial arrangements are practical. Samples of Maghara coals could be sent for processing in laboratory coke making, quality testing, and the production of experimental quantities for use in the steel company's small blast furnace. Thus, no commitment to plant construction would be needed until there was total satisfaction that the production was acceptable and marketable. About one or two years of such experimentation would be needed once the Maghara coal became available, after which time, given attractive results, a commitment to plant construction at Helwan could be made. A total of five or six years would probably be required after the coal became available before this option could be fully implemented.

Construction and Operation. Commitment for construction of the plant could be made with reputable and reliable engineering construction firms and process suppliers. The process operates at low pressure and the expectations are that much of the equipment may be manufactured locally. The Maghara coal would be supplied at the plant gate. The operational requirements are on the same technical level as the present coke plant with its fertilizer facilities. The maintenance facilities already in existence should be adequate.

Supporting Industry. The supporting industry would be the industry set up to mine Maghara coal and the transportation industries involved to bring the coal from mine site to the plant gate at Helwan.

Environmental Impact. An analysis of emissions should be based on the system at Helwan, which would comprise the coking facilities and any new carbonization facilities installed for the production of char. Given the blend of essentially a non-volatile char to replace some of the volatile metallurgical coal, the expected effect would be a reduction in emissions. Definitive data in this respect should come, given the feasibility of access, from observation and measurements at the Yugoslav plant.

Social/Institutional Impact. A carbonization plant would probably be installed as one of the facilities at the Helwan coke plant. As such, any social or institutional effects would be marginal and probably of no significance.

Economic Impact. The economic effect could be major, and it relates to the trade-off between the foreign exchange saved through a reduction, by 1985, of metallurgical coal imports to the extent of 450,000 metric tons per year (having a value of approximately L.E. 23 million) and the foreign exchange component of constructing the carbonization facility. The expectations are that the trade-off would have a favorable economic effect.

Manpower. Employment would be increased to meet the operational needs of the carbonization facility. The level of skills should be equivalent to those now needed to run the coking operation and the

fertilizing facilities at Helwan. Any special skills and experience required could be obtained through a mutual agreement, such as with Yugoslavia, to permit training of Egyptian personnel at the Boris Kidric Coke works. This prospect presumes that the experiences in Yugoslavia have been positive.

4.1.4.3 Formed coke manufacture: Technology in various stages of development is currently available which could provide a metallurgical coke product made entirely from local Egyptian coal. If the extent of Egypt's coal resources are found later to be greater than currently indicated, the import of metallurgical coal might be completely eliminated. Organizations engaged in the development of formed coke processes exist worldwide. Perhaps the most advanced is the FMC Corporation of the United States, whose process is now operated in Kemmerer, Wyoming, on a production scale of 85,000 tons of formed coke per year. Other organizations actively engaged in alternative processes are Lurgi (Frankfurt, Germany) and the U.S. Steel Engineers and Consultants (Pittsburgh, USA). Other work is reported in the Union of Soviet Socialist Republics, Japan, Rumania, England, Australia, France, Poland, and Belgium.

The Kemmerer installation might function analogously to the Yugoslav plant noted above in terms of providing a firm and physical basis for quantitative analysis of an Egyptian formed-coke manufacturing installation. This plant has operated for at least 10 years and provides coke for the FMC phosphorus reduction plant in Pocatello, Idaho. At one time its output of formed coke was tested by U.S. Steel Corporation in an experimental blast furnace and found to be technically satisfactory. The Kemmerer facility might function to evaluate the technical and cost potential of producing formed coke from Egyptian coal and provide samples for large scale evaluation in the small blast furnace in the Helwan steel works.

Thus, the quantitative aspects of this option require further investigation and study to establish the yields, product utilization, and the investments. In the meantime, some qualitative observations are feasible.

Performance Capabilities. About 3.75 million tons of Egyptian coal would be required annually to produce 1.5 million tons for formed coke. This extraction rate is about three times the maximum rate economically justifiable by the currently known reserves at Maghara. If adequate new reserves are not found through additional exploration, then importing of metallurgical coal will be needed to satisfy the demand for coke.

Given the necessary period of testing time, the performance of the blast furnace will not be affected, unless the sulfur content of the formed coke is higher than the coke now utilized. The extra limestone addition to the burden could reduce the productivity of the blast furnace somewhat.

Availability and Timing. Whether the manufacturing technology is available without developmental risk needs to be determined. The FMC

process appears to be so available. A required period of testing, large scale sample preparation, and sample evaluation could take about two years. Given the justification for plant construction, another three to four years would be required. Thus, a five to six year lag is likely after the coal becomes available before this option could be fully implemented.

Construction and Operation. The process operates at low pressure at a technological level of complexity that is comparable to the existing coke-solids and gases, an operation that has not, apparently, so far been practiced in Egypt. Much of the equipment should be amenable to local fabrication. The maintenance facilities should be no different from those available for the coke oven equipment.

Supporting Industry. The plant could be installed within the existing coke works. The supporting industry therefore is that which involves the extraction of the coal and its transport to the plant gate.

Environmental Impact. If formed coke manufacture could displace conventional coke-oven production completely, a beneficial environmental effect would result. The formed coke process is entirely contained under nominal pressure so that emissions are readily controlled. The emissions normally encountered in the coke oven during charging, coking, pushing, and quenching are entirely eliminated. The precise emissions from formed-coke manufacture would need to be ascertained through monitoring production. The elimination of liquid products in formed coke manufacture should result in a reduction, if not elimination, of liquid effluents. No solid disposal problems would exist.

Social/Institutional Impact. Since formed coke manufacture would displace the present conventional coke manufacture facilities at the Helwan coke works, the social and institutional effect would be marginal, and probably insignificant.

Economic Impact. The major benefit is the partial or complete elimination of the import of metallurgical coal. Complete elimination would mean foreign exchange savings of approximately E.E. 79 million annually. On the other hand, the investment in the existing coke works at Helwan would have to be written off entirely (except for the scrap value of the steel and equipment) and a foreign exchange component expended for construction of the formed coke facilities. The fertilizer manufacturing facilities at Helwan would be affected by the loss of the coke oven gas supply. Natural gas could be substituted, but an additional processing step to reform this gas to synthesis gas would need to be installed. This would represent an additional foreign exchange expenditure. The indications are, however, that the tradeoffs would be favorable to the economy. This observation needs confirmation through quantitative analysis.

Manpower. Manpower requirements probably would not change significantly. Training for new operating skills would be required, especially

for those skills that involved the operation of fluid bed devices. Such training should be available overseas in an operating plant.

4.1.5 Other coal uses. Several other uses for coal in Egypt have been suggested. These include use in cement kilns, use in Cairo and Alexandria gas works, use in extracting lead and zinc from their ores in the Red Sea coastal areas, and others. These were not evaluated here due to a lack of substantive information.

4.2 Petroleum

In contrast with coal production, petroleum exploration, production, transport, and refining is a well established industry involving participation of foreign countries and having an institutional framework in Egypt for the protection of national interests. Thus, petroleum supply options will tend to be incremental to current activities and involve little or no unfamiliar technologies.

As of November 1977, a total area in Egypt of more than 625,000 km² was subject to exploration agreements, as compared with about 511,000 km² in 1976. Some 47 concessions were involved. Oil and gas fields, concessions, and significant exploratory wells as of March 1978 extend throughout the Egyptian territory and are concentrated in the Western Desert, the Nile Delta, and the Gulf of Suez.

During 1977, exploration activities accelerated at a rate slightly over that of 1976, although a few companies relinquished some of their existing blocks of concessions. Seismic activity in 1977 equalled 95 party months, and 393,000 feet of exploratory holes were drilled, a small increase over the 369,000 feet drilled in 1976. Two new discoveries were made. Reserves reported by the Egyptian General Petroleum Corporation at the end of 1977 were 2.1 billion barrels.

For 1977, production was 151 million barrels of petroleum obtained from 373 producing wells, an average daily production during the year of 414,000 barrels. The daily production at the end of 1977 was 500,000 barrels. About 60 percent came from the El Morgan field in the Gulf of Suez. This is a field which has been waterflooded since 1974. Egyptian authorities estimate that they can achieve a production rate by 1982 of 1 million barrels daily of combined crude oil and crude-oil equivalent of natural gas. Table 2 contains estimates of projected oil and gas reserves. Table 3 gives estimates of projected oil production by producer.

Egypt is a net exporter of petroleum and petroleum products. In 1977, exports in millions of barrels were: petroleum 43.9, products 2.8. Imports were: petroleum 3.6; products 2.8. Table 4 projects exports and imports through 1982. Table 5 summarizes crude-oil exports by destination. Table 6 gives the source of current and projected crude-oil imports. Table 7 summarizes the petroleum sector trade values.

TABLE 2

PROJECTED EGYPTIAN PETROLEUM PRODUCTION AND RESERVES (1978-1982)

	EXISTING FIELDS		NEW DISCOVERIES		TOTAL	
	10 ⁶ Tons	10 ⁶ BBL	10 ⁶ Tons	10 ⁶ BBL	10 ⁶ Tons	10 ⁶ BBL
<u>1978</u>						
Reserves, first of year	297	2,138	41	295	338	2,433
Production	26	187	-	-	26	187
Reserves, end of year	271	1,951	68	490	339	2,441
<u>1979</u>						
Reserves, first of year	271	1,951	68	490	339	2,441
Production	32	229	-	-	32	229
Reserves, end of year	239	1,722	117	842	356	2,564
<u>1980</u>						
Reserves, first of year	239	1,722	117	842	356	2,564
Production	35	255	1	7	36	262
Reserves, end of year	204	1,467	164	1,181	368	2,648
<u>1981</u>						
Reserves, first of year	204	1,467	164	1,181	368	2,648
Production	34	244	8	58	42	302
Reserves, end of year	170	1,223	204	1,469	374	2,692
<u>1982</u>						
Reserves, first of year	170	1,223	204	1,469	374	2,692
Production	30	215	17	122	47	337
Reserves, end of year	140	1,008	228	1,642	368	2,650
<u>5-Year Plan</u>						
Reserves, beginning	297	2,183	41	295	338	2,433
Production	157	1,130	26	187	183	2,317
Reserves, end	140	1,008	228	1,641	368	2,650

SOURCE: Egyptian General Petroleum Corporation, April 1978

TABLE 3

ACTUAL, ESTIMATED, AND PROJECTED PETROLEUM PRODUCTION BY PRODUCING
ORGANIZATION (1977-1982)

COMPANY	ACTUAL 1977		ESTIMATED 1978		PROJECTED							
					1979		1980		1981		1982	
	10 ⁶ Tons	10 ⁶ BBL	10 ⁶ Tons	10 ⁶ BBL	10 ⁶ Tons	10 ⁶ BBL	10 ⁶ Tons	10 ⁶ BBL	10 ⁶ Tons	10 ⁶ BBL	10 ⁶ Tons	10 ⁶ BBL
General Petroleum Company	1.5	10.8	1.2	8.7	1.1	7.9	1.0	7.2	0.95	6.8	0.8	5.8
Oriental Petroleum Company	3.5	25.2	4.4	31.7	4.0	28.8	4.4	31.7	4.2	30.2	3.8	27.4
Gulf of Suez Petroleum Company	14.4	103.7	18.9	136.1	25.1	180.7	28.7	206.6	28.0	201.6	24.75	178.6
Abu Gharadiq Razzak	0.9	6.5	0.8	5.8	0.7	5.0	0.4	2.9	--	--	--	--
Western Desert Petroleum Company	0.6	4.3	0.5	3.6	0.6	4.3	0.5	3.6	0.3	2.2	0.1	0.7
Western Desert Petroleum Company (Moleha)	--	--	--	--	--	--	0.1	0.7	0.15	1.1	0.15	1.1
Dimnex	--	--	--	--	0.3	2.2	0.3	2.2	0.3	2.2	0.3	2.2
New Discoveries	--	--	--	--	--	--	1.0	7.2	8.0	57.6	17.0	122.4
TOTAL	20.9	150.5	25.8	185.8	31.8	229.0	36.4	262.1	41.9	301.7	46.9	338.2

SOURCE: Egyptian General Petroleum Corporation, April 1978.

TABLE 4

PROJECTED EGYPTIAN TRADE IN CRUDE OIL AND PETROLEUM PRODUCTS
(1977-1982)

	ACTUAL		ESTIMATED		PROJECTED							
	1977		1978		1979		1980		1981		1982	
	10 ⁶ Tons	10 ⁶ BBL	10 ⁶ Tons	10 ⁶ BBL	10 ⁶ Tons	10 ⁶ BBL	10 ⁶ Tons	10 ⁶ BBL	10 ⁶ Tons	10 ⁶ BBL	10 ⁶ Tons	10 ⁶ BBL
CRUDE OIL												
Exports ¹	6.1	43.9	9.3	67.0	10.4	74.9	12.1	87.1	14.3	103.0	16.4	118.1
Imports ²	0.5	3.6	1.0	7.2	0.2	1.1	0.2	1.1	-	-	-	-
Net Flow	5.6	40.3	8.3	59.8	10.2	73.8	11.9	86.0	14.3	103.0	16.4	118.1
PRODUCTS												
Exports	1.9	14.0	2.6	19.0	3.0	21.7	3.2	23.0	3.6	25.9	3.8	27.7
Imports	0.3	2.8	0.6	4.4	0.6	4.1	0.4	3.2	0.4	3.2	0.4	3.2
Net Flow	1.6	11.2	2.0	14.6	2.4	17.6	2.8	19.8	3.2	22.7	3.4	24.5

¹ Of Egyptian share of production.

² Including purchases from partner companies.

Source: Egyptian General Petroleum Corporation, April 1978.

TABLE 5
DESTINATION OF EGYPTIAN CRUDE OIL EXPORTS IN 1977

DESTINATION	1977	
	<u>10⁶ Tons</u>	<u>10⁶ BBL</u>
Greece	0.7	5.0
East Germany	0.1	0.7
United States	1.0	7.2
Italy	1.9	13.7
France	0.3	2.2
Yugoslavia	0.3	2.2
India	0.3	2.2
TOTAL	4.5 ¹	32.4

¹ Corresponding figure in Table 4 is 6.1 million tons (43.9 million barrels).

SOURCE: Egyptian General Petroleum Corporation, April 1978.

TABLE 6

ACTUAL AND PROJECTED EGYPTIAN CRUDE OIL IMPORTS BY SOURCE
(1977-1982)

YEAR	IMPORTS		PURCHASES FROM PARTNERS		TOTAL	
	10 ⁶ Tons	10 ⁶ BBL	10 ⁶ Tons	10 ⁶ BBL	10 ⁶ Tons	10 ⁶ BBL
1977 ¹	-	-	0.5	3.6	0.5	3.6
1978	0.8	5.8 ²	0.2	1.6	1.0	7.4
1979	-	-	0.2	1.1	0.2	1.1
1980	-	-	0.2	1.1	0.2	1.1
1981	-	-	-	-	-	-
1982	-	-	-	-	-	-

¹ Actual

² From Iraq

SOURCE: Egyptian General Petroleum Corporation, April 1978.

TABLE 7
EGYPTIAN PETROLEUM SECTOR TRADE VALUES
(Millions U.S. \$)

	ACTUAL	ESTIMATED	PROJECTED			
	1977	1978	1979	1980	1981	1982
EXPORTS	<u>710.4</u>	<u>1,031.5</u>	<u>1,141.4</u>	<u>1,316.2</u>	<u>1,514.0</u>	<u>1,713.0</u>
Crude Oil	487.6	765.5	829.8	968.0	1,140.0	85.0 ⁵
Sumed Company	5.2	32.5	75.0	75.0	80.0	318.2
Petroleum Products	208.3	233.5	236.6	263.2	294.0	150.7
Other	9.3	-	-	-	-	-
IMPORTS	<u>175.8</u>	<u>256.5</u>	<u>191.6</u>	<u>186.3</u>	<u>164.5</u>	<u>150.7</u>
Crude Oil and Natural Gas	43.7	98.0	14.6	16.2	1.6	1.6
Petroleum Products	45.7	77.1	75.7	62.6	59.1	54.1
Other Products and Services ²	86.4	81.4	101.3	101.3	103.8	95.0
BALANCE OF TRADE ³	534.6	775.0	949.8	1,119.9	1,349.5	1,562.3
BALANCE OF TRADE ⁴	534.6	775.0	949.8	1,119.9	1,314.5	1,492.3

¹ L.E. 1 = \$2.50

² Special products, lubes, spare parts, chemicals, and transport costs between fields to refineries.

³ If all new discoveries of petroleum were developed as predicted.

⁴ If 50 percent of new discoveries of petroleum were developed.

⁵ Should be 1,244.1 if data are consistent.

SOURCE: Egyptian General Petroleum Corporation, April 1978.

Accordingly, the supply options for petroleum evaluated below are those which either increase the productivity of existing fields or serve to supply existing or projected domestic markets.

4.2.1 Production: Petroleum production occurs in four modes: (1) primary, (2) reservoir pressure maintenance through gas or water injection, (3) waterflooding, and (4) enhanced oil recovery.

Primary is the production of oil that is moved into producing wells through the native energy present in the reservoir, i.e., through a gas cap, gas in solution, or water drive, or a combination thereof. All of these production modes can be assisted by gravity drainage. Current Egyptian practice includes the use of recirculated associated gas for lifting the crude oil.

Reservoir pressure maintenance is the injection of fluids (gas or water) into the producing reservoir before the initial reservoir pressure has dropped significantly. This mode has been and is being practiced to some extent in the United States. It is also being widely used in the Soviet Union, and this may be one reason why Russia can cite a percentage of recovery of the original oil-in-place considerably higher (up to 60 percent) than the average U.S. percentage (about 32 percent). Reservoir pressure maintenance has not been practiced in Egyptian fields.

Waterflooding is the injection of water into selected wells to force oil to adjacent production wells. Normally waterflooding is begun when the reservoir pressure has declined to the point where efficient and economic primary production no longer is feasible. In the case of the waterflooded El Morgan field, the reservoir pressure had decreased to about one-third the initial reservoir pressure (about 1,000 psi below the bubble point) by the time water injection was started.

Enhanced oil recovery (EOR), sometimes referred to as tertiary recovery, generally is understood to include stimulative methods applied to a reservoir after waterflooding has reached an economic limit. EOR techniques, however, can also be applied following primary production or pressure maintenance. The principal EOR methods are chemical flooding (micellar-polymer, polymer, caustic, or others); thermal (steam cycling, steam drive, forward and reverse in situ combustion, or others); and miscible-phase injection (carbon dioxide, high-pressure hydrocarbons, or others).

4.2.1.1 Primary production: It is important, during primary production from a reservoir, to produce at a rate not exceeding the maximum efficient rate (MER) for that reservoir. Detailed production data for individual Egyptian reservoirs are not available, but the assumption is that the engineering expertise available within EGPC and its partner oil companies is such that the fields are being and will continue to be produced at a rate below the MER, which should result in no reservoir damage. This is not a distinct option. Nevertheless, it should be practiced regardless of other options.

4.2.1.2 Reservoir pressure maintenance: Pressure maintenance has apparently not been practiced by the companies operating Egyptian fields. It is highly unlikely that pressure maintenance by gas injection is an attractive option because of the high and increasing value of natural gas and the appreciable costs of compression and injection. Pressure maintenance by water injection, however, should be attractive and must be considered as one option. In the exercise of this option, consideration should be given to maintaining the pressure before it drops below the bubble point.

4.2.1.3 Waterflooding: Waterflooding was begun in the El Morgan field in the Gulf of Suez in February 1974. The Kareem Sandstone is flooded at an average depth of 6,100 feet. The formation has an average thickness of 400 feet, an average permeability of 600 millidarcys, and an average porosity of 21 percent. Sea water, treated to reduce oxygen content, adjust pH, and guard against corrosion and bacterial action, is injected at an average wellhead pressure of 1,200 psi and an average injection rate of 200,000 barrels daily. Cumulative water injected equals 252 million barrels. No injection problems were reported. Reservoir pressure, initially 3,000 psi, had dropped to about 1,000 psi, or about 1,000 psi below the bubble point when injection was started. Water is injected peripherally from the south and west edges of the field. Oil production as a result of water injection averages 25,000 barrels daily; cumulative waterflood oil production is 20 million barrels. Water production is about 18,000 barrels daily, with 18.8 million barrels cumulative. The success of waterflooding in the El Morgan field is encouraging. It is not practicable to calculate the additional oil that might have been recovered had water injection been started at a higher reservoir pressure.

The El Morgan waterflood is the only current oil-production-stimulation project in Egypt. Current plans are to begin a waterflood in the July field, in the Gulf of Suez, later in 1978. It is not known whether the pressure in this reservoir has fallen below the bubble point. The possibility of waterflooding other fields is an option that should receive careful consideration.

4.2.1.4 Enhanced oil recovery: Enhanced oil recovery (EOR) in the United States is receiving increased emphasis from both industry and government. Of the various EOR technologies, cyclic steam injection and, to a lesser extent, conventional steam-drive technology may be considered to be commercial processes. Carbon dioxide flooding may be considered near commercial. At present, EOR technology contributes about 373,000 barrels daily of the United States 8 million barrels of production. The EOR total includes some oil produced by cyclic steam and non-CO₂ gas injection.

At present the U.S. Department of Energy (DOE) has 21 contracts with industry for field demonstrations, on a significant scale, of EOR processes. Total estimated cost of the program is about \$155 million

over a four- to six-year period, toward which the industry is funding about 64 percent. Goals are an incremental daily increase in production of 800,000 barrels and additions to proven reserves of 3 billion barrels by 1985.

DOE has been cooperating with the Egyptian Government in a study of the feasibility of applying EOR technology to the Ras Charib field. A preliminary reservoir evaluation was made by DOE engineers, and the scope of a recommended reservoir engineering study was prepared for use by EGPC in requesting proposals for conducting the study. It is understood (April 1978) that requests will be delivered to potential contractors soon. DOE has offered to evaluate the reservoir engineering study when it is completed and to receive two or more Egyptian petroleum engineers at one or more of its Energy Research Centers after the evaluation is complete, to familiarize them with EOR technology.

If the reservoir study indicates that the Ras Charib field may be amenable to an EOR technology, application to other Egyptian fields should be considered.

Qualitatively, the following observations may be made with respect to petroleum production:

Performance Capabilities. Oil is produced in Egypt largely by Egyptian-international or wholly international companies. The expertise possessed by those companies and by the Egyptian engineers is such that there should be no particular performance problems. Egypt has an adequate labor force. For example, the number of petroleum engineers graduated appear to be about three times the immediate domestic need. Technicians may not be as plentiful, and there may be some need for additional training of skilled and semi-skilled oilfield workers.

Availability and Timing. The availability of EOR technologies is immediate, and the timing of increased oil production from their application may depend mostly upon continued high world oil price (a realistic expectation) and the production potential of new fields discovered as a result of current high level of exploration activities.

Construction, Operation, Maintenance Characteristics. As already noted, construction, operation, and maintenance capabilities should be adequate.

Supporting Industry Requirements. Oil production will require steel and other metal products, such as drilling rigs and platforms, tubular goods, pumps, compressors, tanks, instruments, and chemicals, (e.g., drilling additives and surfactants). Egypt should be in a competitive position with the rest of the oil-producing world in acquiring such products.

Environmental Impact. The environmental factors associated with oil production in Egypt are much like those incidental to production in

other countries. There is always a possibility of greater adverse environmental impacts in offshore production than in onshore operations, such as through oil spills. Increased production should not disproportionately increase current adverse environmental effects. Reservoir repressuring, such as by pressure maintenance, waterflooding, or by an EOR technology, might increase the possibility of contamination of aquifers. In chemical flooding, the produced waste may contain some harmful chemicals.

Since produced waters usually are saline to some degree, their disposal, whether by injection into the oil reservoir or into some other subsurface formation, or by discharge into the Gulf or sea, always poses some problem. It is not likely that the problem would be greatly magnified if the water contained some small concentration of chemicals.

On the whole, increased oil and gas production in Egypt should not cause unmanageable environmental problems.

Social/Economic/Institutional. The socioeconomic and institutional effects of enhanced oil recovery are obscure and hence difficult to evaluate. Economically, increased oil and gas production should result in a higher GNP, an increasingly favorable balance of trade with exports appreciably exceeding imports, and a resulting general increase in the standard of living.

Manpower. More skilled and semi-skilled workers should become employable in the oil industry. The number of available Egyptian petroleum engineers should be adequate.

Other Resources. Potential increases in oil and gas production would require increased services of drilling companies, oilfield service companies, and other ancillary industries.

4.2.2 New refinery construction: Egypt's current planning for petroleum refining capacity involves the construction of a 100,000 barrel per day (5 million metric tons per year) low-gasoline type refining unit at the Suez refining complex, which will be completed by 1982. Thus, in 1982, Egypt's domestic refining capacity will be 16.55 million metric tons per year, distributed as shown in table 8.

A low-gasoline type refinery means that no processing (e.g., catalytic cracking) is incorporated. This increases the yield of gasoline per barrel of crude oil beyond the straight-run yield. Only catalytic refining is incorporated to improve gasoline quality (octane rating). This pattern of processing produces the mix of petroleum products which fits Egypt's historic pattern of demand. It appears that this process mix will fit the demand pattern through 2000.

Two minor exceptions exist. The Suez refinery of the Suez Oil Processing Company includes a coking unit which was installed in the 1960's - probably in anticipation of a demand for petroleum coke for

TABLE 8
 PETROLEUM REFINERIES IN EGYPT - 1982

Location	Capacity	Responsible Company
	10 ⁶ MTY	
Suez ¹	5.0	New Refinery Unit
Suez ¹	1.5	Nasr Petroleum Company
Suez ¹	0.8	Suez Oil Processing Co.
Cairo (Mostorod)	3.5	Suez Oil Processing Co.
Tanta	0.75	Suez Oil Processing Co.
El Almeriya (Alexandria)	2.0	Nasr Petroleum Company
El Mex (Alexandria)	3.0	Alexandria Petroleum Co.
	16.55	

¹ The new refining unit may be incorporated with the two existing refineries into one refinery with a single administration.

Source: Egyptian General Petroleum Corporation

electrode manufacture specifically for Egypt's aluminum smelter at Nag Hammadi. The coking unit is now damaged, but is being rebuilt for a capacity suited to the planned smelter capacity. Coking units are normally incorporated into the refinery processing when there is a market for the coke produced. Although light distillate products are simultaneously produced, these alone do not warrant the coking unit installation. The reason is the highly unsaturated state of the distillates, which require stabilization and hydrotreating to saturate the molecules and remove sulfur to be marketable. The preferred route when the refinery product mix emphasizes lighter distillates over residual fuel oils is hydrocracking.

The other exception is the inclusion of lubricating oil processing facilities for the El Almeriya refinery, which processes western Egyptian paraffinic type crude oil. The effect is to reduce residual fuel oil production at the refinery to the extent that this fraction contains the needed lube oil fractions. The capacity of the lube oil processing facilities at El Almeriya is less than the expected future domestic demand. Some asphalt for road pavement is also produced, which has been off specification because of inadequate removal of wax.

Current and projected production of refinery products is shown in table 9. The proportions of the different products in the mix are remarkably consistent through the completion of the planned new refining unit at Suez.

Egypt currently produces a surplus of light naphtha and fuel oil which is exported. However, some distillate products are imported, particularly where product mix imbalances with domestic demand are better redressed at a lower cost by import of selected products with a corresponding export of crude oil. In 1977, the monetary value of product exports was L.E. 141.6 million while the value of product imports was L.E. 31.1 million. The forecast for 1982, when the 100,000 barrel per day refinery at Suez is completed, is for the expected exports to be valued at L.E. 105 million, and the product imports at L.E. 37 million as shown in table 7.

By 1982, crude oil originating in the Gulf of Suez will be supplied to the refineries (table 8) by pipeline, except for the supply to the two refineries in Alexandria. It appears that both refineries at Alexandria receive all their crude oil by tanker, both from western desert production and from Gulf of Suez production. An oil pipeline, 26" in diameter, is now in the early stages of construction. It will extend from El Shukheir to Suez. Oil is to be received at El Shukheir by a submarine line from the offshore El Morgan field. Completion is expected by 1981. It is not clear from the information gathered in Egypt whether the oil pipeline from Suez to Cairo to Tanta to Damanshour also extends to Alexandria.

In the period 1982 through 2000, Egypt will require additional refining capacity. It seems reasonable to project that the product mix

TABLE 9

CURRENT AND PROJECTED PRODUCT MIX FROM EGYPTIAN REFINERIES (1978-1982)

PRODUCT	1977 Actual		1978 Estimated		1982 Projected	
	10 ³ MTY	wt%	10 ³ MTY	wt%	10 ³ MTY	wt%
Butane/Propane	63	0.6	54	0.5	93	0.6
Gasoline/Naphtha	1,556	14.7	1,533	14.0	2,151	14.2
Kerosene	1,381	13.1	1,400	12.8	1,747	11.5
Turbine Fuel	123	1.2	220	2.0	166	1.1
Gas Oil/Diesel Fuel	1,957	18.5	1,788	16.3	2,525	16.7
Fuel Oil	5,272	49.8	5,582	51.0	7,899	52.1
Asphalt	145	1.4	235	2.1	330	2.2
Lube Oils	48	0.5	80	0.7	150	1.0
Others	20	0.2	69	0.6	96	0.6
TOTAL	10,565	100.0	10,961	100.0	15,157	100.0

SOURCE: Egyptian General Petroleum Corporation.

will not change, that EGPC intends the construction of a new 100,000 B/D unit through procurement by tender from recognized international engineering construction firms. Further, refinery projects will probably be launched between 1982 and 2000 to the extent demand growth justifies. This option will extend the present base of refining capacity and the experience this represents in construction, operation, and the utilization of supporting industry. Thus, no unique or new problems should arise.

Likely locations appear to be El Shukheir (a new refinery at the location of the on-shore terminal of the gathering system for the off-shore production in the Gulf of Suez) and additions to the refineries at Cairo (Mostorod) and Alexandria (El Almeriya).

The following qualitative observations may be made concerning the refinery construction program.

Environment. The principal atmospheric emissions from oil refineries include particulates, SO_x, NO_x, hydrocarbons (HC) and CO. Emissions of sulfur oxides and particulates that characterize refinery operations are discussed in the Environmental Annex of the Report.

In any event, air pollution from El Shukheir should be of little consequence due to the small human population in the area. This will not be the case in Alexandria, however. Egypt's second largest population concentration is in Alexandria, and air pollution is already severe. Additional pollution loading would be likely to increase adverse health effects. For this reason, any new refineries planned for Alexandria should be equipped with anti-pollution hardware. Recommendations for pollutant-removal efficiencies are discussed in the Environmental Annex noted above. The net effect of the inclusion of such efficiencies would be a mitigation of public health impacts that could occur if new refinery capacities were added to population centers such as Alexandria.

Discharges from petroleum refineries contain pollutants that can degrade water quality. Land disposal or discharge into the Gulf of Suez are the options for the disposal of liquid wastes. Land disposal in evaporation ponds might be preferable to discharge into the Gulf; the environmental consequences of both methods should be considered by the Egyptian authorities.

Untreated effluents from new refinery capacity at Alexandria (and in a similar vein at Mostorod) should not be discharged into the Bay of Alexandria nor into Lake Maryut. The bay is already polluted from industrial wastes, untreated sewage, and discharges from ships awaiting loading or unloading. Most pollutants that characterize petroleum refinery liquid effluents can be removed.

Treatment of refinery liquid effluent streams results in the generation of solid wastes. Refinery operation also results in the

generation of other wastes. In areas where water pollution is of environmental concern, the option of land disposal of refinery waste solids, and solids extracted from liquid effluent streams should be preferred to the option of discharge into waters.

4.2.3 Alternative utilization of petroleum coke: The aluminum smelter at Nag Hammadi is set up as primarily an export-oriented smelter. By January 1981, the expectation is that its production capacity will be approximately 200,000 metric tons per year of primary aluminum, of which about 70 percent will be exported. The electricity consumption for this production will be about 400 MWe. Export specifications require close control of the iron, silicon, vanadium, and nickel content of the metal.

The production will consume about 116,000 metric tons per year of petroleum coke and 19,000 metric tons per year of coal tar pitch, both for electrode manufacture. The smelter's coke specification limits its vanadium content to 150 ppm maximum, and its nickel content to 150 ppm maximum. With these specifications the smelter management expects a satisfactory vanadium content in the finished metal. They have contracted to obtain their petroleum coke supplies from the Suez refinery of the Suez Oil Processing Company.

The coking unit at the refinery has been damaged and is being rebuilt by the oil company to a capacity of 190,000 tons per year. It appears that an investment of about L.E. 13-20 million is being made for this habilitation. Its original capacity was 310,000 tons per year. The unit design is based on upgrading residues to middle distillates, using a heavy Belayim crude. The coke produced is expected to have a vanadium content of about 300 ppm, twice the specification stated by the aluminum smelter. The prospects are, then, that the coke produced by the refinery will not be usable in the aluminum smelter, even though a contract exists covering this use.

The refinery management states that they have no intention of changing the coker feed, although later they plan to use other heavy (20-25° API) crudes of unknown metal content. They believe that the smelter management is committed by contract to purchase the coke for the refinery and that they are aware of its high vanadium content. Should they not purchase, a penalty clause becomes effective.

Thus, it is possible for an impasse to occur after the coking unit goes into production and the smelter finds themselves committed to the purchase of an unsatisfactory coke. Two options are available, in the event such an impasse materializes. One is to burn the coke as a fuel, in which case it would take a somewhat less than fuel oil value. The increased cost handling, crushing, and burning the coke compared with fuel oil required this devaluation. Also, an investment in a specially designed coke-fired power station would be required. The net effect of this option is that fuel oil will have been unnecessarily processed in order to burn it as a more cumbersome petroleum coke.

The other, more attractive, option is to use the petroleum coke as a blending agent in the production of metallurgical coke, similarly to the blending of the Maghara coal, or char, discussed above. The entire output of 190,000 tons per year could be absorbed at a corresponding reduction of input of metallurgical coal. The coke could be valued at L.E. 51 per ton, and the amount of new investment to exercise this option would be insignificant.

Some qualitative observations may be made:

Performance Capabilities. The testing procedure available at the Helwan coke works, and in the iron and steel works already noted, can serve to determine the acceptability of a petroleum coke substitution for some of the metallurgical coal. The percentage content of petroleum coke in the blend would be about 15 percent, which agrees with industrial experience.

Availability and Timing. About a year of testing would be needed, once it becomes clear that the option should be implemented, in order to establish the acceptability of the substitution.

Construction and Operation. The option requires no new capital facility. Operational practices are essentially unchanged, since the coke works can blend coals from different sources.

Supporting Industry. It appears that petroleum coke can be transported from the Suez refinery to the Helwan coke works by railroad. No other supporting industry is required.

Environmental Impact. The substitution of petroleum coke for part of the imported metallurgical coal would have insignificant environmental consequences. The basic environmental impact of coke making remains unchanged.

Social and Institutional Impact. No significant impact is apparent.

Economic Impact. The option provides a way to use an otherwise unneeded product. However, it appears likely that the savings in foreign exchange incurred by replacement of part of the metallurgical coal would balance the increased foreign exchange requirement for the importation of suitable petroleum coke for the aluminum smelter.

Manpower. Manpower requirements and skill levels remain unchanged.

4.2.4 Power generation from residual fuels: Egypt already generates part of its need for electricity thermally via the combustion of residual fuel oil to raise steam in the conventional steam-turbine cycle. This option concerns continuing this type of electricity supply through continued installation of fuel-oil fired thermal electric stations. The present installed generation capacity of this type is shown in table 10.

TABLE 10

CURRENT INSTALLED THERMAL ELECTRICITY GENERATING CAPACITY (1978)

<u>Plant/Location</u>	<u>Units and Size MW</u>	<u>Total Name Plate Capacity</u>
Assiut	3 x 30	90
Cairo North	2 x 10 1 x 20 2 x 30	100
Cairo West	3 x 87	261
Cairo South	4 x 60 3 x 15	285
Talhka	3 x 12.5 3 x 30	127.5
Damanhour	2 x 15 3 x 65	225
Sieuf	2 x 26.5 2 x 30	113
Karmous	4 x 16	64
Suez ¹	4 x 25	100
Total	41	1,365.5

¹ Under reconstruction because of damage.

SOURCE: Ministry of Electricity and Energy.

Total current installed thermal capacity is 1,365 MWe distributed among 41 units in 9 different stations. Current construction of new oil-fired thermal stations is shown in table 11. Thus, by 1982, an additional 1,807 MWe of oil-fired thermal power should be completed, making a total of 3,172 MWe.

New units tend to be provided with dual-fuel burners so that natural gas as well as residual fuel oil can be fired. Fuel oil specifications call for 2 to 3 percent maximum sulfur. No regulation of sulfur oxide emissions exists. Older stations (according to information gathered at the Cairo West Station) consume fuel oil at a rate 600 grams per kWh. This consumption corresponds to a heat rate of about 6,000 kcal per kWh (23,800 Btu per kWh). The newer, and presumably larger, plants consume only 280 grams, which is a heat rate of about 2,800 kcal per kWh (11,111 Btu per kWh). A controlled test at the El Seouf station (relatively small units) in January 1977 showed a fuel consumption of 81.3 percent load of 33.5 grams per kWh, or a heat rate of 3,326 kcal per kWh (13,200 Btu per kWh). At 70 percent load, the heat rate was the lowest, 3 percent lower than the rate of 81.3 percent load.

The exposure received to power plant operations during the visit to Egypt was limited to two power plants. The indications from this limited exposure are that operating policies place secondary consideration on the instrumentation and maintenance needed to insure peak efficiency and minimal fuel consumption at the load. Hence, it is likely that a deliberate program of refurbishing combustion controls, or installing new equipment, particularly at the larger plants, can help to reduce fuel oil consumption, without detriment to the load. Quantities of fuel saved in this manner can thereby be released for export.

The total generating capacity in 1982 will be approximately 5,600 MWe, which includes the installed hydrogeneration capacity of about 2,500 MWe. A reasonable increment for expansion is one that is larger than the largest unit in any station, 150 MWe (table 11), but not larger than about 10 percent of system capacity, i.e., 560 MWe. Thus, the option to increase Egypt's thermal electricity generation capacity after 1982, as demand increases, is to construct new thermal capacity in increments of 450 MWe.

Such a unit would be designed to operate baseloaded for 330 days per year for 30 years. Its heat rate would be about 2,390 kilocalories per kWh (9,500 Btu per kWh). It would use residual fuel oil as the basic fuel, with natural gas as an alternative, and light fuel oil as an emergency alternative.

The first choice of location for new units should be additions to existing power stations (tables 10 and 11). These stations are already connected to the transmission lines of Egypt's unified power system, and are provided with the basic infrastructure of administration, water

TABLE 11

CURRENT CONSTRUCTION OF NEW THERMAL ELECTRICITY GENERATING CAPACITY

Station	Units and Size MW	Total Name Plate Capacity	Operation Date
Kafr-el-Dowar	2 x 110	220	1978
Cairo West, No. 4	1 x 87	87	1979
Abu Qir	4 x 150	600	1980/81
Ismailia	2 x 150	300	1982
Suez	4 x 150	600	1982
Total	13	1,807	

SOURCE: 1976 Annual Report of Electric Statistics, Ministry of Electricity and Energy.

upply, labor force, and maintenance facilities. The new units would be built in anticipation of load growth, perhaps far enough in advance so that the older, less efficient, units can be retired to peaking service (see discussion below).

The next choice for new power generation would be in new central stations. New stations would depend on the locations of new load centers and hence on the growth of new population centers. The national policy in Egypt to encourage population dispersal to new undeveloped areas could require design of new central stations to provide minimum water consumption. Emphasis should be placed on a high cycle efficiency, maximum water reuse, and maximum utilization of air cooling.

If the demand for electricity in the year 2000 reaches a total 20,000 Mwe as projected, an additional 14,400 MWe of generating capacity above the installed capacity in 1982 would have to be built. Assuming an average heat rate of 2,390 kcal per kWh (9,500 Btu/kWh) and a load factor of 60 percent, the consumption of fuel oil for this incremental capacity would reach about 340,000 B/D.

The following qualitative observations may be made concerning a construction program for the fuel-oil fired power stations:

Environment. The major emissions would be sulfur oxides, nitrogen oxides, and particulates. Some minor emissions, namely carbon monoxide, hydrocarbons, and aldehydes may also occur.

Given a 2 to 3 percent sulfur content in the fuel, sulfur oxide emissions will range from 6.8 to 9.1 kilograms per barrel of fuel oil fired (15 to 20 lbs.). Incremental fuel oil consumption between 1982 and 2000, accordingly, would represent sulfur oxide emissions to the atmosphere, dispersed throughout the populated areas of Egypt, of 900 to 1,250 metric tons per day.

Nitrogen oxide emissions would be about 2 kilograms (4.4 pounds) per barrel of fuel oil fired. Incremental fuel oil consumption between 1982 and 2000, accordingly, would represent nitrogen oxide emissions to the atmosphere, dispersed throughout the populated areas of Egypt, of about 600 metric tons per day.

Particulate emissions would be 0.15 kilograms per barrel of fuel oil (0.34 pounds); incremental particulate emissions in the year 2000 would be about 45 metric tons per day.

At the heat rate envisaged, the cooling load (if only water evaporation were used) represents the evaporation of 208 million metric tons of water per year dispersed throughout the populated areas of Egypt. This consumption of water could be reduced if coastal locations were used, where sea water is the cooling medium, and if direct air cooling were used inland.

Economic. The fuel oil that would be consumed in the generation of the incremental electricity between 1982 and 2000 could be exported if alternative sources for the electricity were available. At current prices, the value of such an export would be about L.E. 2.3 million per day. It is unlikely that the export market would disappear.

Manpower. The operation would require limited manpower. Each unit, regardless of size, could be staffed (personnel directly involved in the operation) by 20 to 30 persons. The skills should be available in Egypt because of the presently installed capacity. Little or no unique training of personnel should be necessary.

4.2.5 Power generation from distillate fuels: Because of costs, distillate fuels are used in power generation only for supplying peak loads. New equipment installed for the purpose (gas turbines) is a lower efficiency, lower capital-cost unit in comparison with baseloaded, high-efficiency central station equipment. At the current stage of development, because of its design, gas turbine equipment is capable of burning only clean distillate fuel oils or natural gas. Because excess distillate can be exported, while export prospects of Egyptian natural gas are poor, the option here is to limit distillate fuel consumption in peak power stations to locations where natural gas is not available and to use as an emergency fuel source in case of natural gas interruption.

An alternative source of equipment for peak power generation is the retirement of the older and smaller baseloaded units, especially those of low efficiency. To enable quick startup and trouble-free operation, they may be operated on natural gas or distillate fuels. The equipment may be simplified to facilitate easy operation by removal of such items as air heaters.

In all likelihood, new peaking stations will be built only where natural gas supplies exist. Thus, the role for distillate fuel in this application is that of an emergency fuel. The discussion of this option accordingly is incorporated with the option discussed below, peak load electricity generation utilizing natural gas.

4.3 Natural Gas

The Egyptian General Petroleum Corporation cites proved reserves of natural gas at the end of 1977 as 1.27×10^{11} m³ (4.5×10^{12} SCF). This figure is inconsistent with the reserve and production picture presented in table 12 (footnote 2). Also noteworthy is the indication in the table that no new finds of natural gas will be made before 1982, despite the likelihood that new finds of petroleum (table 2) can be accompanied by associated gas.

More recent data (table 13) offered by EGPC (June 1978) covers projected production of associated gas from existing fields in the Gulf of Suez, and potential production from the new Amal field. Thus it appears that production of associated gas can be maintained at an 80 or

TABLE 12

PROJECTED EGYPTIAN NATURAL GAS RESERVES AND
PRODUCTION (1978-1982)

	EXISTING FIELDS		NEW DISCOVERIES		TOTAL	
	10 ⁶ tons	10 ⁹ SCF ¹	10 ⁶ tons	10 ⁹ SCF	10 ⁶ tons	10 ⁹ SCF
<u>1978</u>						
Reserves, first of year	74.0	3,241 ²	-	-	74.0	3,241
Production	0.6	26	-	-	0.6	26
Reserves, end of year	73.4	3,215	-	-	73.4	3,215
<u>1979</u>						
Reserves, first of year	73.4	3,215	-	-	73.4	3,215
Production	2.0	88	-	-	2.0	88
Reserves, end of year	71.4	3,127	-	-	71.4	3,127
<u>1980</u>						
Reserves, first of year	71.4	3,127	-	-	71.4	3,127
Production	2.7	118	-	-	2.7	118
Reserves, end of year	68.7	3,009	-	-	68.7	3,009
<u>1981</u>						
Reserves, first of year	68.7	3,009	-	-	68.7	3,009
Production	2.7	118	-	-	2.7	118
Reserves, end of year	66.0	2,891	-	-	66.0	2,891
<u>1982</u>						
Reserves, first of year	66.0	2,891	-	-	66.0	2,891
Production	2.7	118	-	-	2.7	118
Reserves, end of year	63.3	2,773	-	-	63.3	2,773
<u>5-Year Plan</u>						
Reserves, beginning	74.0	3,241	-	-	74.0	3,241
Production	10.7	468	-	-	10.7	468
Reserves, end	63.3	2,773	-	-	63.3	2,773

¹ Conversion factor used: 43,800 SCF = 1 ton.

² Does not agree with other figure cited by EGPC₃ for reserves at end of 1977, i.e., $4,500 \times 10^9$ SCF (1.27×10^{11} nm³).

So : Egyptian General Petroleum Corporation, April 1978.

TABLE 13

POTENTIAL GULF OF SUEZ PRODUCTION OF
ASSOCIATED NATURAL GAS

PROJECTED PRODUCTION FROM EXISTING FIELDS (10 ⁶ SCF/DAY)						PROJECTED PRODUCTION FROM AMAL FIELD TO PROVIDE TOTAL DAILY	
<u>Year</u>	<u>Morgan</u>	<u>July & Ramadan</u>	<u>Location 382</u>	<u>Location 391</u>	<u>Total</u>	<u>80 MM SCF</u>	<u>90 MM SCF</u>
1978	15	114	15	-	144		
1979	10	144	41	7	202		
1980	5	106	66	14	201		
1981	-	89	62	18	169	(Start of Development)	
1982	-	42	49	14	105	-	-
1983	-	27	40	10	77	30	103
1984	-	20	30	7	57	23	33
1985	-	20	25	5	50	30	40
1986	-	20	20	-	40	40	50
1987	-	20	18	-	38	42	52
1988	-	20	16	-	36	44	54
1989	-	20	14	-	34	46	56
1990	-	20	13	-	33	47	57
1991	-	20	10	-	30	50	60
1992	-	20	8	-	28	52	62
1993	-	15	6	-	21	59	69
1994	-	15	-	-	15	65	75
1995	-	15	-	-	15	65	75
1996	-	15	-	-	15	65	75
1997	-	15	-	-	15	65	75
1998	-	12	-	-	12	68	78
1999	-	12	-	-	12	68	-
2000	-	12	-	-	12	68	-

Source: Egyptian General Petroleum Corporation, November 1977.

90 million SCFD level through the year 2000. The EGPC also offers data (shown in table 14) illustrating the estimated associated natural gas reserves by producing field in the Gulf of Suez. Table 15 gives actual, estimated, and projected production data for non-associated natural gas.

Gas production during 1977 was: (1) non-associated, 5.0×10^8 nm^3 (17.7×10^9 SCF), and (2) associated, 2.0×10^8 nm^3 (53.0×10^9 SCF) was flared. Natural gasoline produced equalled 600,000 barrels. Most of the liquified petroleum gas is marketed as bottled butagas and used primarily for industrial and residential cooking and water heating. Some gas is injected into wells in the Suez fields to produce oil through gas lift. There is no oil-reservoir pressure maintenance by gas injection and none is planned. Water and natural-gas liquids are separated at central locations in the various fields.

No stimulation of non-associated gas-producing formations have been attempted, as the gas is not critically needed at present and the permeabilities of the formations are such that stimulation by fracturing or other means has not been considered necessary.

4.3.1 Production: Unlike the stimulation of oil production, the stimulation of natural gas production normally does not involve the addition of energy to the reservoir through fluid injection. Stimulation is effected by various means of fracturing the reservoir rock when the permeability is inadequate to permit free gas flow through the reservoir rock into production wells. Fluid injection is not needed because the reservoir already contains a fluid (gas) under pressure. The various methods of fracturing that have been or are being attempted in the United States include the use of nuclear explosives (no longer active), hydraulic fracturing, chemical-explosive fracturing (and combinations thereof), and fracturing wells deviated from vertical to intersect natural fractures.

4.3.2. Formation of a national pipeline grid: Two approaches to conserving the associated gas production in Egypt are (a) capture and storage and (b) capture and utilization. Natural gas is frequently stored underground in the United States (386 projects) in depleted gas reservoirs, aquifers, and, to a lesser extent, in depleted oil reservoirs. There are five underground storage projects in salt and one in an abandoned coal mine². With respect to utilization, the unique uses for natural gas in Egypt are household cooking and water heating (now provided mostly by butagas, with some by electricity), and in industry for nitrogen fertilizer manufacture and (as the iron and steel industry expands) for the direct reduction of iron ore. Other industrial uses that may be included are as fuel in cement manufacture or in baseload power generation. But these uses are not unique since they can just as well be satisfied by a residual fuel oil.

² American Gas Association. The Underground Storage of Natural Gas in The United States and Canada, December 31, 1976.

TABLE 14
ASSOCIATED NATURAL GAS RESERVES IN SELECTED
GULF OF SUEZ PRODUCING FIELDS

FIELD	OIL RESERVES	GAS TO OIL RATIO	GAS RESERVES
	Million Barrels	SCF/Barrel	SCF x 10 ⁹
July	350	550	192.5
Ramadan	500	400	200.0
Location 392	150	1000	150.0
Location 391	40	800	32.0
TOTAL	1,040		574.5

Source: Egyptian General Petroleum Corporation, November 1977.

TABLE 15
ACTUAL, ESTIMATED, AND PROJECTED EGYPTIAN NON-ASSOCIATED
NATURAL-GAS PRODUCTION (1977-1982)

FIELD	ACTUAL 1977		ESTIMATED 1978		PROJECTED							
					1979		1980		1981		1982	
	10 ³ Tons	10 ⁹ SCF	10 ³ Tons	10 ⁹ SCF	10 ³ Tons	10 ⁹ SCF	10 ³ Tons	10 ⁹ SCF	10 ³ Tons	10 ⁹ SCF	10 ³ Tons	10 ⁹ SCF
Abu Madhi	132	5.9	168	7.4	500	21.9	900	39.4	900	39.4	900	39.4
Abu Gharadiq	264	11.6	515	22.6	700	30.7	800	35.0	800	35.0	800	35.0
Abu Qir	-	-	85	3.6	800	35.0	1,000	43.8	1,000	43.8	1,000	43.8
TOTAL	396	17.6 ¹	768	33.6	2,000	87.6	2,700	118.2	2,700	118.2	2,700	118.2

¹ Agrees with other EGPC estimate of 0.5×10^9 M³
(17.7×10^9 ft.³). Conversion factor used: 43,800 SCF = 1 ton.

Source: Egyptian General Petroleum Corporation, April 1978.

This option is based on the formation of a National Pipeline Grid fed with natural gas from all sources, associated and non-associated, with the demand encouraged to the extent that all associated gas production can be consumed. In 1977, associated gas production was 80 percent of the total natural gas produced.

A 610 mm (24") diameter gas pipeline has been in operation since late 1977 from Abu Gharadiq in the western desert to Helwan, transporting the non-associated gas production from that field. Currently being studied is a new line, about 250 kilometers long, 406 mm (16") in diameter, to bring the Gulf of Suez associated-gas production on shore at El Shukheir and transport it to Suez. A branch is planned to the Mostorod refinery at Cairo, not far from Helwan.

In addition, a 200-250 mm (8 to 10") line is under construction from Abu Qir to Kafr el Dauwar power station, which will be dedicated to the power station. Abu Qir production is non-associated gas. A 305 mm (12") line is under construction from Abu Madi (also a non-associated gas field) to Talkha, which will be dedicated to a urea plant now under construction there.

This option calls for integrating these gas projects into one national pipeline system extending from El Shukheir to Suez to Cairo to the Alexandria area and to Abu Gharadiq. It would operate so that the priority source of natural gas would be any associated gas production. The pricing formula adopted for the gas in order to encourage its use in the national interest should assure that all associated production would be consumed. The four categories of use might be:

1. Domestic cooking and water heating;
2. Use as a chemical feedstock;
3. Peak load electricity generation; and
4. Baseloaded electricity generation.

The first is the superior use of the gas while the last is the inferior use. The reasons for the priorities involve the value of the superior use in eliminating import of butagas and direct consumption of electricity as a heating agent. Baseload electricity generation is last because of a possible scarcity of gas, and because alternative energy sources could satisfy this demand. In the intermediate use category, utilization of natural gas as a chemical feedstock can spur desirable growth of industry, such as expansions of fertilizer production and steel making; at the same time, through the alternative processing this offers, this use can release blocks of electricity to superior uses. Although there is no formal policy, current thinking by the Egyptians gives top priority to industrial use, second priority to domestic use, and last priority to electricity generation.

Ultimately, as new marketing centers develop the grid could be expanded, by constructing a line to Aswan from El Shukheir, for example.

The major impact of a national natural gas pipeline grid on the Egyptian economy would be to avoid wasting a high quality energy resource, by putting it to work in a manner that reduces imports (butagas), that avoids an indirect and inferior use of a derived energy resource (electricity) as a heat producing agent, and that permits the growth of two basic industries which otherwise could consume an exportable commodity (light naphtha with respect to nitrogen fertilizer production) or cause the importation of a commodity (metallurgical coke for steel making). Moreover, if unrestrainable associated gas production causes a surplus of natural gas, this surplus can be consumed in peak and baseload electricity generation.

4.3.3 Urban distribution system: Implementing the option above to establish a National Pipeline Grid would involve assuring a demand in the superior use of natural gas, which is presumed to be the household cooking and water heating load. Such an assurance requires the construction of urban gas distribution systems in major population centers, fed from the grid.

Construction and planning of the first of such systems has already begun, based on a supply of non-associated gas from the Abu Gharadiq line. The urban distribution system would begin at Helwan and reach Helwan, Maadi, Nasr City, and Heliopolis. Completion of this distribution system is planned for 1983, when 160,000 individual consumers are expected. By the year 2000, 360,000 consumers are expected. Marketing will be done by the recently formed Natural Gas Company. Burner orifices will be altered without charge. An advertising campaign is to be launched to make natural gas acceptable to the public. The need for such a campaign apparently has arisen from inadequate treatment of natural gas supplies to remove the condensables. Slugs of liquid in the lines could have caused failures and reduced the confidence of the public in this supply.

The first system could be extended into Cairo itself, where a town gas system, based on the reforming of light naphtha and the use of some coal gas may be currently operating. A second such system may be warranted in the Alexandria area.

4.3.4 Use as a chemical feedstock: An apparently attractive part of the equation to justify the National Pipeline Grid option is the generation of industrial demand sufficient to assure the consumption of all associated gas production. The type of industrial demand needed is that where the natural gas is a unique fuel and the industrial product satisfies an internal demand, which in turn suppresses an import. In the Egyptian economy, the two demands that should be encouraged are natural gas in the manufacture of nitrogen fertilizer and natural gas in the production of iron and steel.

Egypt currently produces calcium ammonium nitrate (CAN) as a basic fertilizer product, but is also building a urea plant. Both of these products require the intermediate production of ammonia, which requires

hydrogen to react with nitrogen extracted from the atmosphere. The hydrogen can be made by reforming natural gas to mixtures of carbon monoxide (CO) and hydrogen, and subsequently shifting the CO with steam to hydrogen and carbon dioxide.

For CAN production, half of the ammonia produced is oxidized to nitric acid. The acid and the remaining half of the ammonia react to form ammonium nitrate, which in turn is reacted with limestone as a neutralizer and stabilizer to form a complex solid mixture of free or combined calcium nitrate with ammonium nitrate. About 340 normal cubic meters (12,000 SCF) of natural gas would be consumed per metric ton of CAN produced. CAN contains about 31 percent nitrogen.

Urea is about 47 percent nitrogen. It is synthesized by the isomerization of the ammonium carbamate formed when ammonia, carbon dioxide, and water are reacted under controlled conditions. About 500 normal cubic meters (18,000 SCF) of natural gas is consumed per metric ton of urea.

For direct reduced iron ore, the natural gas is reformed to produce reducing gas mixtures containing carbon monoxide and hydrogen, having a minimized content of carbon dioxide and water vapor. As such, the reducing gas can extract the oxygen in the iron ore, as is done in the blast furnace, except that the extraction occurs without melting either the ore or the product. The melting occurs in the steel making furnace. The consumption of natural gas depends on the amount of metallization of the iron that occurs during reduction and on the method of natural gas reforming. A good range is from 400 to 600 normal cubic meters (15,000 to 20,000 SCF) per metric ton of iron content in the ore reduced to 95 percent metal with the remaining iron as ferrous oxide (FeO).

Egyptian plans for iron and steel production by the year 2000 appear to involve steel production of 3.4 million metric tons per year utilizing direct reduction. For such a production, the natural gas consumption could reach, on the basis of the lower limit of the range of unit gas consumption, 1.44×10^9 normal cubic meters (51×10^9 SCF). In 1977, by way of contrast, total natural gas production in Egypt from all sources was 2.5×10^9 normal cubic meters (88.4×10^9 SCF).

4.3.5 Peak load electricity generation: Egypt already operates natural-gas-fired gas turbine electricity stations for providing peak demands for power. These tend to be small units ranging in capacity from 15 to 25 MWe. They operate only during periods when demand becomes maximum. This generally occurs between 18 and 20 hours. As noted above, low-efficiency, low capital-cost generating equipment is selected, because even with premium fuels (natural gas or petroleum distillates), the limited number of hours of operation per year (about 800 to 1000 hours) does not justify capital investment beyond the bare minimum. For this reason, the more elaborate and more efficient gas turbine installations, such as the combined cycle, are utilized in baseload (see below) rather than in peaking installations.

Future peak-load gas-turbine installations would be larger than those presently installed. These units should be installed near load centers adjacent to natural gas supply. A peaking capacity of 50 MWe seems reasonable for each unit. A tank of distillate fuel would be installed to provide fuel in the event of a natural gas interruption.

A variation of this option is to retire baseloaded but inefficient small generating units to peaking service after replacing them with large, efficient units that foresee demand growth. These older units could be operated, after simple burner changes, with natural gas (or distillate fuels) to reduce operating problems and permit quicker startup. Unnecessary equipment (air heaters, for example) could be removed. Startup times would be longer than for gas turbines, and it might be necessary to fire such plants to a standby condition with a head of steam in the drums.

4.3.6 Baseloaded power generation: Natural gas is an ideal fuel for baseload power generation. Boilers are simplified and the chimney gases are sulfur-free. Combined-cycle gas and steam turbines are practical and perhaps a less costly investment. This option, in view of the foreseeable demand for electricity by 2000, could easily absorb all surplus production for associated gas sources. Modern combined-cycle installations can operate at heat rates as low as 2,040 Kcal/kWh (8,100 Btu/kWh). If the incremental capacity of 14,400 MWe were constructed in this mode, the annual consumption of natural gas in 2000 would be $17.4 \times 10^9 \text{ m}^3$ ($613 \times 10^9 \text{ SCF}$), about eight times the total natural gas production in 1977.

A typical combined-cycle installation may be illustrated by one at the Pacific Gas and Electric Company, Portrero Station, San Francisco, California. The installed generating capacity from both gas turbine and steam turbine is 462 MWe. Of this, 308 MWe is production from the gas turbine section. The plant heat rate is estimated at 2,040 Kcal/kWh (8,100 Btu/kWh). Four gas turbines, rated at 77 MWe each, operate in parallel, each with its own waste-heat steam generator. One steam turbine is installed to serve the steam generated from the four gas turbine units. Gas turbine inlet temperatures may be as high as 2,100°F with exhaust temperatures of 1,050°F. The technology has been maturing over a period of 30 years. The current (1975) installed capacity in the United States is 5,000 MWe in 34 plants with another 5,200 MWe under construction (in eleven plants).

5.0 OBSERVATIONS

This section assigns relative importance to the many fossil energy supply options (table 1) so far presented and discussed. Given these relationships, the Government of Egypt would then have input bearing on the fossil energy resources, which it could use in considering actions with respect to all energy resource development deemed to be in the national interest.

The method of assigning relative importance is to isolate those supply options for fossil energy that appear to have significant effects on (a) meeting the prospective demands for the different energy forms and (b) either reducing the demand for foreign exchange or increasing foreign exchange earnings. Another significant factor would be the individual requirements for capital needed to implement each option. The project schedule and available study resources, however, did not permit these data to be developed.

5.1 Key Supply Options

The supply options that emerge as key are in the areas of petroleum exploration and production and in the utilization of the associated natural gas production. Also of key importance is the potential costly impasse regarding the supply of petroleum coke for electrode manufacture at the Nag Hammadi aluminum smelter and the priority use for the Maghara coal when it becomes available.

5.1.1 Petroleum exploration: The exploration and production records from all operations in Egypt need rationalization. Associated with this need is the lack of coherent, consistent, publicly available summary and regional reports to assist in the private exploration activities. Improvement in these respects appears to be vital if Egypt's stated goal of one million barrels per day production of crude oil (including crude oil equivalent of natural gas) is to be achieved. It appears unlikely that such improvement can occur in time to enable achievement of this goal by 1982. Achievement by the year 2000 appears more realistic, in view of the effort required.

5.1.1.1 Policy modifications: Government policy imposes confidentiality on the release of regional exploration data. This is understandable in an administrative sense, since it is always easier to release nothing than to make judgments on the real need for secrecy in technical data. A reversal of this policy is needed, i.e., a deliberate program should be launched to publish reports of a regional nature relevant to oil exploration. This report will encourage scientific discussion and permit later workers to build on earlier results. In planning such a program, careful attention must be given to protecting the private interests of parties holding exploration concession agreements.

5.1.1.2 Actions required: The key initiating action required is the establishment of an institution that would be given the mission of producing the public regional data base. Because of the sensitive nature of the judgments to be made regarding data release, the institution may have to be a collaboration of company, government, and university geoscientists coordinating their activity in an appropriate sequence. Each year, one or two products should be available for publication. This collaboration might be formalized by the establishment of an Egyptian Petroleum Exploration Society which could be affiliated with the worldwide American Association of Petroleum Geologists, thereby facilitating the interchange of theoretical or regional geological and geophysical information.

The work program would include the preparation of the uniform set of specialized maps noted above (section 2.2). In addition, the needed physical exploration work referred to above (section 2.2), to establish the third dimension in Egyptian geology, would be undertaken.

5.1.1.3 Effects: Assuming the methodical and prompt accomplishment of the tasks outlined above, it appears likely that the one million B/D production rate can be achieved by the year 2000. The data that were examined during the study do not support the possibility of achieving this goal at an earlier date.

5.1.2 Petroleum production stimulation: Production stimulation is distinct from primary production that occurs by the native energy present in the reservoir. The techniques of production stimulation involve reservoir pressure maintenance through gas or water injection, waterflooding, or enhanced oil recovery methods, usually but not necessarily following waterflooding. The use of these techniques can contribute greatly to achieving the production goal of one million B/D earlier than would be possible by means of the exploration activities noted above.

5.1.2.1 Policy modifications: No policy was noted or identified that is concerned with the optimum recovery to be achieved from a field. Rather, the policy appears to be one of a 70/30 formula split of the oil produced with the concessionaires. It seems obvious that the recovery attractive to the concessionaire because of profit and flexibility to operate worldwide in his own interest is not necessarily the recovery attractive to a government acting in the national interest. National interests would probably dictate a higher recovery than a concessionaire is willing to achieve. At the same time, the first production results available so far from waterflooding in the El Morgan field are encouraging in terms of striking a balance between public and private interests.

The policy modification recommended to encourage petroleum production stimulation is to change the division formula with respect to reservoir pressure maintenance, waterflooding, and enhanced oil recovery. The precise change needed in the formula will differ for reservoir pressure maintenance and waterflooding (the less costly option) and enhanced oil recovery. The extent of change, particularly the reduction in the Government's share of oil produced by stimulative methods, should be the minimum that would still make use of such methods attractive to the concessionaire.

5.1.2.2 Actions required: The key initiating action has already begun, that is, the stimulative production practices reported above (section 4.2.1). The investment and operating costs associated with the incremental production must now be estimated. The practices need to be improved by starting gas or water injection before the reservoir pressure falls below the bubble point. Projects now envisioned using enhanced oil recovery techniques need to be implemented.

When reliable cost data and production increase data are accumulated and evaluated, the results will have to be reevaluated to create incentives for concessionaries to undertake production stimulation. Attractive stimulated-production sharing formulae must be presented in the concession agreements.

5.1.2.3 Effects: Production stimulation would be an operation on known oil fields which, independently of the exploration needs discussed above, could help achieve the desired production goal. The effect would be to move up the date when this goal could be achieved.

5.1.3 Utilization of associated natural gas: Gas produced in association with oil in the Gulf of Suez is now being flared for lack of collection, transmission, and distribution facilities and developed markets for natural gas. The major production of natural gas in Egypt at present is associated. Industrial development plans and growing electricity demand will ultimately generate markets for natural gas which will probably exceed Egypt's production capacity. The collection of the Gulf of Suez associated gas production is now under study.

5.1.3.1 Policy modifications: No overall policy was apparent regarding the position of natural gas in the nation's energy supply picture although the trend of thinking is toward an industrial-domestic-electric priority scheme. Ideally, a policy should be established which gives priority to connecting sources of associated gas (whose production is unrestrained) with consuming centers, rather than providing the same facility for non-associated gas (whose production can be restrained). The 24" line from Abu Gharadiq to Helwan carries non-associated gas. The 16" line under study from El Shukheir to Suez and Cairo would carry associated gas. Based on the reported natural gas production in Egypt in 1977, these line sizes seem reversed.

It would appear that a policy that (a) integrates all natural gas pipelines into a national interconnected system that can be supplied from all production locations and reaches all significant consuming locations and (b) establishes a pricing schedule that at least assures the consumption of all associated gas production, would be in the national interest. Projected demands for natural gas for urban distribution, for fertilizer and steel manufacture, and for power generation would far exceed available supplies from all sources in Egypt.

5.1.3.2 Actions required: The key initiating action is the reconsideration of the objectives and scope of the current study of the El Shukheir to Suez/Cairo associated gas pipeline, and to consider linking it with other existing and projected lines as a national grid. A related action is to categorize all uses of natural gas according to a set of criteria which rank the possible uses, from those most benefitting the national economy to those offering the least benefit. This categorization could involve a broad analysis of the Egyptian economy.

5.1.3.3 Effects: The national grid concept, if implemented, offers the capacity to absorb all foreseeable production of associated

natural gas and thereby avoid waste. This gas can serve distinct markets, and, to the extent it does so, can liberate equivalent liquid oil fuels for export.

5.1.4 Petroleum coke impasse: A situation is developing in which investment in the restoration of petroleum coking capacity at Suez may have little or no return on the capital. The reason is the excessive vanadium content in the coke product, which make it unuseable by the aluminum smelter at Nag Hammadi. The smelter has contracted for the coke output and will be subject to a penalty if they do not accept the product. If the aluminum is to be saleable on the world market (70 percent of the smelter output in 1982 is to be exported), they may have no choice but to reject the coke product.

The situation should be reviewed immediately at the appropriate level in government, to ascertain (a) whether in fact an impasse will exist, and (b) if so, what remedial steps should be taken.

5.1.5 Maghara coal utilization: When the coal deposits at Maghara become available, the best option is to continue with the original intention of using this coal as a component of the coal blend for the metallurgical coke-ovens at Helwan. This use could lead to a mining operation on the scale of 300,000 metric tons per year and to the generation of a cash flow. Then, further exploration to discover additional coal reserves can be undertaken. If reserves increase substantially, consideration could then be given to other options that further reduce the import of metallurgical coal or provide an alternative fuel for the generation of electricity.

5.2 Other Significant Supply Options

The other significant energy supply options are the construction of petroleum refining capacity as the need arises and the construction of thermal electric generating stations to fill the rising demand for electricity. These are straightforward supply options that do not appear to conflict with existing policies or require any unusual initiating actions. One significant supply option is especially noteworthy, and this is the launching of a broad effort to improve the efficiency of combustion of fuel oil in the industrial furnaces, namely central station steam generators and petroleum refinery furnaces. The need is for facilities to maintain measuring instruments in operating conditions and for personnel capable of monitoring furnace efficiency, making suggestions for improvement, and assisting in the implementation of changes to equipment and operating practices.

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