THE FEASIBILITY STUDY
FOR
THE POWER AND DESALINATION
COMPLEX PLANT PROJECT
IN
THE SULTANATE OF OMAN

AUGUST 1985

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

It is with great pleasure that I present this Feasibility Study Report on the Barka Power and Desalination Complex Plant Project to the Government of the Sultanate of Oman.

This report embodies the result of a field survey which was carried out in Barka, Batinah coast, from January 24 to February 17, 1985 by the Japanese survey team commissioned by the Japan International Cooperation Agency following the request of the Government of the Sultanate of Oman to the Government of Japan.

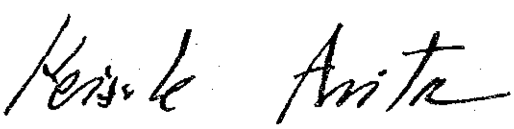
The survey team, headed by Dr. Shigeo UEKI, held a series of close discussions on the Project with the officials concerned of the Government of the Sultanate of Oman, and conducted a wide scope of field survey and data analyses.

After the survey team returned to Japan, further studies were made and the present Report has been prepared.

I hope that this report will be useful as a basic reference for development of the Project, and contribute to the promotion of friendly relationship between our two countries.

I wish to express my deep appreciation to the officials concerned of the Government of the Sultanate of Oman for their close cooperation extended to the team.

August, 1985



KEISUKE ARITA
President
Japan International Cooperation Agency

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ELECTRICAL TERMINOLOGY

Load factor		Ratio of average power demand to maximum power demand
Plant factor	:	Ratio of average output of power plant to its installed capacity
Diversity factor	:	Ratio of the aggregated toral of maximum power demands of individual consumers to the integrated maximum power demand (peak load) of the power system

DESALINATION TERMINOLOGY

Performance ratio:		Ratio of distillate production to steam flow to brine heater

ABBREVIATIONS

MEW	:	Ministry of electricity and Water
PDO	:	Petroleum Development Oman
JICA	:	Japan International Cooperation Agency
MSF	:	Multi-stage flush evaporation (process)
RO	:	Reverse Osmosis (process)

EQUIVALENTS

Cubic measures:

1 gallon = 4.54609 $m^3 \times 10^{-3}$
1 m^3 = 219.975 gallons

Stresses and pressures:

1 lb/sq.in. = 0.070307 kg/cm^2
1 kg/cm^2 = 14.2233 lb/sq.in.

Heat:

1 B.T.U. = 0.252 cal
1 kcal = 3,968.32 B.T.U.

CURRENCY EQUIVALENTS (Approximate)

US$ 1.00 = 0.342 R.O. (Rial Oman) = 250 Yen
2.00 R.O. = 1,000 Baizas = US$ 2.942 = 731 Yen

CHAPTER 1

INTRODUCTION

CHAPTER 1 INTRODUCTION

1.1 BACKGROUND AND OBJECTIVES OF THE STUDY

1.1.1 Background of the study

Oman achieved rapid economic growth after 1970 due to increase of oil revenues, with the result that the demand for electricity and water in Muscat and its surrounding regions soared from year to year. Such being the case, shortage in electricity and water supplies appears inevitable by the late 1980s.

To avoid this situation and in order to smoothly advance its Third 5-Year Economic Development Program that starts from 1986, the government of Oman made a plan of constructing a large-scale power generation and seawater desalination complex plant near Barka in the outskirts of Muscat, and requested the Japanese government to conduct a feasibility study in connection with this project.

In response to the request, the Japan International Cooperation Agency (JICA) being entrusted by the Japanese government, dispatched a preliminary survey mission headed by Mr. Kiso Tsuruoka to Oman in order to deliberate with the Ministry of Electricity and Water (MEW) of Oman on the scope of the feasibility study, and both parties (MEW and JICA) signed the agreement of scope of work in carrying out feasibility study on 11th, Nov. 1984.

1.1.2 Objectives of the study

The objective of this feasibility study is to carry out the conceptual design of the power and desalination complex plant and its associated auxiliary facilities, and at the same time, to check and examine the technical and financial feasibility of this new project.

1.2 SCOPE AND CONTENTS OF THE STUDY

The study relating electricity will cover the Capital Area and the Batinah coast area, while the study relating water will cover the capital area only.

The following describes the scope of the Study, which comprises two phases:

(1) Phase I

Phase I comprises 1) reveiw and analysis of existing data and information, and 2) inspection of proposed sites of the plant and other constructions (transmission lines, substations, and water conduit lines).

1) Review and analysis of information, data and reports relevant to the study.

   a. The social, economic, and industrial development programs in connection with power and water consumption.

   b. Characteristics of power and water consumption patterns.

   c. Existing and planned power plants and water production facilities.

   d. Existing and planned substation, transmission lines, and water pipelines.

   e. Existing and planned power transmission, and water supply system.

2) Inspection of proposed plant site will be made to check;

   a. topographical and geological conditions
   b. soil conditions
   c. tidal and current condition
   d. marine topology and sedimentology
   e. sea water characteristics
   f. environmental effects

3) Field survey and data review of proposed power transmission routes, and water conduit pipe routes including plant sites.

a. topographical survey
b. map review
c. seismic data review
d. meteorological data review

(2) Phase II

Phase II comprises 1) preliminary design of the plant and other constructions (transmission lines, substations, and water conduit lines), and 2) economic analysis of the project.

1) Preliminary design of the power plant

a. Selection of number, size, type (gas turbine, steam turbine, and/or combined turbine), and characteristics of power units, taking into consideration the optimum economic load flow.

b. Preliminary design of turbines, generators, boilers, control system, communication equipments, and auxiliary equipments.

2) Preliminary design of the desalination plant

a. Optimization study of Multiple Stage Flash (MSF) method versus Reverse Osmosis (RO) method.

b. Preliminary design of pretreatment, desalination, and post-treatment units.

c. Preliminary design of water intake facilities, and brine and waste discharge facilities.

3) Preliminary design of main buildings of the plant

a. General layout of the plant and facilities
b. Preliminary design of civil and plant structure

4) Preliminary design of transmission line and substations.

5) Preliminary design of water conduit pipelines design criteria and determination of route(s).

6) Training program

7) Timing, staging and phasing of the construction of the plant and auxiliary works.

8) Economic analysis

   a. The demand forecasts of power and water up to 1995

   b. The estimation of the construction cost of the plant and other facilities

   c. Estimation of annual operation and maintenance costs

   d. Calculation of the cost-benefit ratio and economic internal rate of return

9) Financial analysis

   a. Projection of income statement, cash flow and internal rate of return

   b. Calculation of adequate price of electricity and water

1.3 EXECUTION OF THE STUDY

In order to carry out this study in the scopes described previously, JICA dispatched a feasibility study team headed by Dr. Shigeo Ueki to Oman during the period of from January 25 to February 16, 1985. The team conducted field surveys having the contents described below, followed with surveys in Japan, based on which the Feasibility Study Report was compiled.

1.3.1 Field surveys

Field surveys were conducted by four specialized groups.

(1) Deliberation and acquisition of information and data

Deliberations were held with MEW and information and data were acquired through the cooperation of MEW and related organizations.

(2) Visits to various kinds of plants

Various kinds of plants related to the feasibility study were visited, such as power plants, substations, sea water desalination plants, oil refinery and industrial estates.

(3) Surveying and other activities

1) Surveying of plant compounds

The topography and compounds were surveyed at the plant site.

2) Sounding of sea depth

In order to obtain data necessary for designing the water intake and water discharge structures for acquiring cooling water for the power plant's condenser and feed water for the sea water desalination plant, the sounding of sea depth in the region surrounding the plant site was made.

3) Measurement of sea water temperature and analysis of sea water quality

The temperature and quality of the sea water in the plant site region were measured and analyzed in order to acquire data necessary for designing the power plant's condenser and sea water desalination plant.

4) Survey of water supply conduit route

Survey was conducted to determine the route for the water supply conduit by using aerial photographs and through field inspection.

5) Survey of power transmission line and substation construction sites

Survey was conducted by using maps and through field inspection.

1.3.2 Studies conducted in Japan

Various kinds of studies were made in Japan on the basis of information and data acquired through field surveys in Oman and those acquired in Japan. The principal items were as follows:

1) Projection of power and water demands.

2) Selection of the unit capacities for the power plant and sea water desalination plant.

3) Selection of the types of power plant and sea water desalination plant.

4) Drafting the preliminary designs of the power generation plant, sea water desalination plant and their ancillary facilities.

5) Drafting the plant construction schedule.

6) Estimate of required capital.

7) Economic evaluation

8) Financial analysis

1.4 ACKNOWLEDGEMENT

Sincere gratitude is expressed herewith for the unreserved cooperation and convenience extended to the Study Team in carrying out its feasibility study and related activities by following persons.

Mr. Abdulla Ali Dawood, Director General of Projects, MEW
Mr. Taher Mohamed Ali Sajwani, Director of Planning, MEW
The persons concerned in MEW and other organizations in Oman.

CHAPTER 2

SUMMARY AND RECOMMENDATION

A. SUMMARY

2.1 BACKGROUND AND NECESSITY OF THE PROJECT

In the Sultanate of Oman the demands for electric power and water have grown rapidly and are still growing at very high pace with the social and economic development of the country and the rise of standard of living of the people. This will lead to the shortage in supply capabilities of the existing power plants and water supply facilities to meet the growing demands. To cope with this situation the Ministry of Electricity and Water (MEW) plans to construct a large scale power and desalination complex plant near Barka town.

Japan International Cooperation Agency (JICA), in response to the request of the Government of Oman, has conducted feasibility study on the above project and compiled the results of studies in this report.

This project is very important for the country, and also it should be completed early as possible when considering demand and supply condition. Therefore, it is suggested that the construction work be started in the immediate future.

2.2 PRESENT CONDITIONS OF ELECTRIC POWER SUPPLY AND DESALINATION

2.2.1 Existing power facilities

(1) Power facilities in the Capital area

a) Power stations

There are three power stations in the Capital area, and their total installed capacity as of the end of January 1985 is 566.1 MW as shown below:

Power station	Type of plant	Installed capacity (MW)
Ghubrah	Steam	72.5
Ghubrah	Gas turbine	212.5
Sub-total		285.0
Rusail	Gas turbine	249.0
Riyam	Diesel	32.1
Total		566.1

MEW has a plan to shift diesel units of Riyam power station to rural areas in the coming one or two years, and to install at Rusail gas turbine power station No. 4 and No. 5 units of each 83.0 MW in 1986 and No. 6 unit of 83.0 MW in 1987.

Power consumption for station service is estimated at 10.4 MW for Ghubrah power and desalination complex plant and 0.65% of installed capacity for Rusail gas turbine power station. Therefore, the total installed capacity and sending-end capacity in the Capital area excluding Riyam power station for 1986 and 1987 will be as follows:

(MW)

Power station	1986			1987		
	Installed capacity	Station service	Sending-end cap.	Installed capacity	Station service	Sending-end cap.
Ghubrah	285.0	10.4	274.6	285.0	10.4	274.6
Rusail	415.0	2.6	412.4	498.0	3.2	494.8
Total	700.0	13.0	687.0	783.0	13.6	769.4

b) Transmission lines

Two double circuit 132 kV transmission lines run from Ghubrah power station, the one to Wadi Adai substation and the other to Al Falaj substation. Another two double circuit 132 kV lines run from Rusail power station. They are to Seeb and Ghubrah substations.

The construction of three double circuit 132 kV transmission lines are scheduled to be started in June 1985. They are:

- From Rusail power station to Wadi Adai substation
- From Rusail power station to Barka substation
- From Wadi Adai substation to Wadi Kabir substation

In addition, tender call for the construciton of double circuit 132 kV line between Barka substation and Musanna substation is scheduled to be made by the end of 1985.

33 kV and 11 kV lines are used for power distribution. The public supply is carried out at 200/240 V, 50 Hz.

c) Substations

There are five 132/33 kV substations of Al Falaj (250 MVA), Wadi Adai (250 MVA), Rusail (150 MVA), Ghubrah (84 MVA) and Seeb (126 MVA).

Barka, Wadi Kabir and Musanna substations of each 250 MVA are under planning.

d) Interconnection of Musanna, Suwaiq, Rustaq and Mabellah

Plan is on-going to supply electricity by 33 kV lines from planned Musanna substation to three towns of Musanna, Suwaiq and Rustaq. These towns are now fed by diesel power stations. The interconnection of these towns and Mabellah with power system of the Capital area is scheduled to be commissioned in 1986.

(2) Power facilities in the Batinah coast

a) Power stations

In Musanna, Suwaiq and Rustaq there are diesel power stations of 7.4 MW, 6.9 MW and 7.2 MW, respectively. However, MEW plans to supply electricity to these towns from the Capital area by inter-connected transmission line from 1986 as described before.

In the Batinah coast excluding the above towns, there are three power stations of the total installed capacity of 65.8 MW as shown below:

Location	Type of plant	Installed capacity (MW)
Copper mine	Gas turbine	51.0
Shinas	Diesel	3.9
Khabourah	Diesel	10.9
Total		65.8

Power station at copper mine is equipped with three gas turbine-generators of each 17.0 MW. Of these three units, one unit is of MEW, one unit of Oman Mining Company and the remaining one unit is operated for common use by MEW and Oman Mining Company. It is planned that two units of each 27.0 MW gas turbine-generator (MEW) be added to this power station in 1985 and two units of each 30.0 MW gas turbine-generator (Rural Development Committee) be added in 1986. Therefore, the total installed capacity at copper mine will increase to 105.0 MW in 1985 and 165.0 MW in 1986.

b) Transmission lines and substations

Energy generated by gas turbine power station at copper mine is transmitted from Magan substation (66/33 kV) to three substations of Sohar, Saham and Majis (each 33/11 kV).

Power transmission to the Inland area such as Buraimi, Ibri and surrounding villages is planned to be started in 1986.

2.2.2 Existing water supply system

The planned water supply district covered by this Project is the Batinah coastal area of 70 km from Muscat to Barka.

Up to the year 1976, the water supply to the Capital Area had been dependent on pumping up of underground water only. To meet the rapid growth of water demand, the first desalination plant was constructed in Ghubrah and entered service in 1977. In 1983, the No.2 plant was put into parallel operation with the above No.1 plant. The present water production capacity of the desalination plants is 47,730 m^3/day.

Name of Plant	Water Production Capacity	Commis-sioning year
Existing	MIGPD m^3/d	
No.1 MSF Plant	5 (22,730)	1977
No.2 MSF Plant	5.5 (25,000)	1983
Sub-total	10.5 (47,730)	
Under construction		
No.3 MSF Plant	5.5 (25,000)	1986
No.4 MSF Plant	5.5 (25,000)	1986
Sub-Total	11 (50,000)	
Total	21.5 (97,730)	

Note: Water production capacity in the table is the average of capacity at high temperature operation and capacity at low temperature operation.

MIGPD = Million Imperial Gallon/day
1 Imperial gallon = 0.004546 m^3

At present, two more plants of No.3 and No.4, each with the same capacity (25,000 m^3/day), are being constructed in Ghubrah and scheduled to be put into commercial operation in March 1986. Consequently, by March 1986, the total production capacity of all desalination plants will reach 97,730 m^3/day.

Most of wells in the Capital Area are located at five ground water regions of Wadi Adai, Wadi Hatat, Seeb, Mawallaa, and Al Khawd. The ground water pumping quantity increased to 23,000 m^3/day in 1982. But in order to prevent the ground water from contamination by sea water penetrating into the ground due to excessive pumping, MEW has a policy to maintain the average ground water pumping quantity of 22,000 m^3/day as shown in the following table.

Ground Water Pumping Plan after 1985

District	Max. pumping rate (m^3/d)	Average pumping rate (m^3/d)	No. of wells
Wadi Adai	50,000	10,000	approx. 30
Mawallaa	2,000	1,000	3
Seeb	18,000		12
Al-Khawd Dam Well Field	22,000	10,000	14
Old Government Well Field	10,000		20
Rusail	1,000	1,000	2
Total	103,000	22,000	approx. 80

2.3 DEMAND FORECAST FOR ELECTRIC POWER AND WATER

For both electric power and water, demand forecasts for the period from 1985 through 1990 have been established by the MEW. Demand forecast for electricity covers the Capital area and the Batinah coast including Inland area, while demand forecast for water is for the Capital area only. These forecasts have been reviewed and extended up to 1995 by JICA study team. Results of study are summarized as follows:

2.3.1 Demand forecast for electricity and scale of development of the proposed Barka power plant

In the Capital area, peak load grew from 46.6 MW in 1976 to 135.5 MW in 1980 and 340.3 MW in 1984, representing an average growth rate of 30.6% per annum for the period from 1976 to 1980 and 25.9% per annum for the last 4 years from 1980 to 1984. This high-paced growth in power demand is due partly to the construction of various kinds of infrastructure and partly to the rapid growth in population.

For the coming several years, the following new loads are anticipated in addition to the natural growth of the existing lighting load:

- Growth in industrial load at cement factory, oil refinery and Rusail industrial estate, etc.

- New bulk load which will be produced with the completion of Qaboos university and its hospital, Ghubrah hospital, etc.

- New residential load which will be produced with the completion of community projects.

- Loads in Musanna, Suwaiq, Rustaq and Mabellah in the Batinah coast which are scheduled to be connected to the Capital area through expansion of transmission line.

In the northern half of the Batinah coast there are load centers of Khabourah, Saham, Sohar, Liwa, Shinas, etc.

Power demand and supply balance for the period up to 1995 in the integrated power system including the Capital area and the Batinah coast is forecasted as follows:

(MW)

Item	1987	1988	1990	1991	1992	1995
<u>Peak load</u>						
Capital area	703	840	1,068	1,180	1,270	1,527
Batinah coast	-	191	258	288	329	468
Total (A)	703	1,031	1,326	1,468	1,599	1,995
<u>Reserve capacity</u>						
Capital area	82	82	82	82	82	82
Batinah (copper mine's power plant)	-	30	30	30	30	30
Total (B)	82	112	112	112	112	112
<u>Required capacity</u>						
(A) + (B) = (C)	785	1,143	1,438	1,580	1,711	2,107
<u>Supply capacity</u> (Existing and under planning)						
Capital area	769	769	769	769	769	769
Batinah (copper mine's power plant)	-	225	225	225	225	225
Total (D)	769	994	994	994	994	994
Demand & supply balance (D) - (C)	-16	-149	-444	-586	-717	-1,113

Note: 1. Supply capacity in the Capital area does not include capacity of the proposed Barka power station.

2. Peak load of the Capital area includes loads of Musanna, Suwaiq, Rustaq and Mabellah.

3. Load of Khabourah is included in the load of Batinah coast.

4. Expansion of copper mine's power plant for the period up to 1986 is already authorized. However, it is suggested that additional two units of each 30 MW gas turbine-generator be installed in 1986/87 near Sohar town to secure demand and supply balance in the Batinah coast before commissioning of the proposed Barka power station.

From the above table, it is suggested that the proposed Barka power station be developed with a capacity of more than 150 MW by 1988 and more than 700 MW by 1991.

2.3.2 Demand forecast for water and scale of development of the proposed Barka desalination plant

The demand for water in the Capital area has also grown rapidly in the recent years with the economic development and the growth in population. The water production increased from 4,555,000 m^3 (12,400 m^3/day) in 1977 when the first desalination plant was commissioned at Ghubrah to 11,177,000 m^3 (30,600 m^3/day) in 1980 and 23,488,000 m^3 (64,400 m^3/day) in 1984. This represents an average growth rate of 34.8% per annum for the period from 1977 to 1980 and 20.4% for the period from 1980 to 1984. Of the total water production in 1984, 82% was produced by desalination plant and the remaining 18% by wells.

In addition to the natural growth of the existing demands, the following new demands are anticipated:

- Bulk demands of the Rusail industrial estate, cement factory, sports-stadium, Qaboos university and its hospital, etc.

- New residential water demand which will be produced with the completion of community projects at Azaiba, Ghala, Bosher, Lansab, etc.

- Growth in demand by use of landscaping and by extension of service area.

Based on the existing and under construction facilities, the water demand and supply balance for the period up to 1995 in the Capital area is forecasted as follows:

(m^3/day)

Item	1985	1987	1988	1990	1991	1995
Required water production (Average)	99,274	136,958	155,088	193,596	206,877	260,000
Peak demand in the summer season (A)	114,165	157,500	178,350	222,635	237,908	299,000
Reserve capacity (B)	30,000	30,000	30,000	30,000	30,000	30,000
Required supply capacity (A) + (B) = (C)	144,165	187,500	208,350	252,635	267,908	329,000
Water Supply Capacity						
Wells	22,000	22,000	22,000	22,000	22,000	22,000
Ghubrah desalination plant	47,730	97,750	97,750	97,750	97,750	97,750
Total (D)	69,730	119,750	119,750	119,750	119,750	119,750
Demand & supply balance (D) - (C)	-74,435	-67,750	-88,600	-132,885	-148,158	-209,250

In the Capital area there is no large dam and reservoir, and the supply of water depends mainly on the desalination plant. Therefore, in order to secure stable supply of water it is necessary for desalination plant to have additional one unit at least (30,000 m^3/day) as the reserve capacity, taking into account the lowering of supply capability due to accidents or scheduled maintenance.

To meet the growing demand for water, Barka desalination plant should be commissioned with the shortest construction period technically possible. If construction works are started in May 1986, Barka desalination plant will be able to enter service around the end of 1988 with a capacity of 90,000 m^3/day including reserve capacity of 30,000 m^3/day. This capacity should be increased to 150,000 m^3/day including reserve capacity in 1991 to cover shortage in supply capability of 148,000 m^3/day in the same year. However, when considering the shortage in supply capability of 209,000 m^3/day in 1995, it will be appropriate for Barka desalination plant to be developed up to the ultimate capacity of 180,000 m^3/day by the end of 1990 in accordance with commissioning date of the power plant from viewpoint of economy and stability of supply.

2.4 SELECTION OF UNIT SIZE

2.4.1 Power plant

In general, the larger the unit size of the power plant the less the construction cost per kW installed. Therefore, it is appropriate to select unit size as large as possible in the standardized size. However, the selection of unit size of power plant has a close relation with operation of power system. Taking these into account, the optimization study on the unit size of power plant was carried from two positions.

Position 1: Selection of unit size made by attaching the most importance to the economy of Barka power plant which works as the main power source in the power system.

Position 2: Selection of unit size made by attaching the most importance to the reliability of power system including Barka and other power plants.

The results of study show that when economy must be respected the most the selection of a unit capacity of 120 MW is suitable, but if reliability of power system must be respected by all means it is appropriate to select a unit capacity of 60 MW.

As described later, the total costs (present worth) of the plant adopting a unit capacity of 120 MW will be about 5% less than those of the plant adopting a unit capacity of 60 MW.

However, influence exerted on the power system by adopting a unit capacity of 120 MW is larger than that exerted by adopting a unit capacity of 60 MW, i.e. the frequency drop of the power system caused by fault of a turbine-generator in the low load period of January and February in 1991 will be 48.75 to 47.50 Hz for the 120 MW unit and 49.17 to 48.33 Hz for the 60 MW unit.

The frequency drop risks to give a grave effect to turbine-generator. In general, the allowable limit of operation frequency in the 50 Hz power system is 48.5 Hz, and frequency drop to 47.5 Hz will require immediate shutdown of operation. Therefore, when fault occurs on the 120 MW unit it will be necessary to execute load shedding in order to prevent overall failure of the power system. This means that when reliability and stability of power system should be secured by all means it is suitable to adopt a unit capacity of 60 MW.

2.4.2 Desalination plant

For desalination plant also, it is more economic to select unit size as large as possible. At present, the largest unit size having performance record of long-run commercial operation is around 36,000 m^3/day.

Desalination plant must be operated to cope with seasonal variation of water demand and scheduled maintenance. In the Capital area, seasonal variation of demand for water is about ±15% of the average demand. The demand variation in 1995 is forecasted to be 260,000 m^3/day x 0.3 = 78,000 m^3/day. Therefore, if unit size of 30,000 m^3 is adopted, it will be possible to shut down two units for maintenance in the winter season every year. Taking these into account, it will be appropriate to select a unit size of 30,000 m^3/day.

2.5 SELECTION OF TYPE OF PLANT

2.5.1 Desalination plant

For desalination plant, comparative study was carried out on the multi-stage flush evaporation (MSF) process and reverse osmosis (RO) process, mainly from the following viewpoints:

a) Actual results of commercial operation
b) Adaptability to large scale plant
c) Adaptability to dual purpose plant
d) Operation and maintenance
e) Length of construction period
f) Economy

The results of study show that the both processes have merits and demerits, i.e. MSF process is superior to RO process in actual results of commercial operation, adaptability to large scale plant and also adaptability to dual purpose plant, while RO process is superior to MSF process in operation and maintenance, construction period and economy. However, MSF process is predominant for desalination plants in commercial operation and especially for large scale plant such as the proposed plant. Therefore, it is considered suitable to adopt MSF process from viewpoint of reliability.

For MSF process, the performance ratio 8 was judged the most economical both in the extraction turbine alternative and in the back pressure turbine alternative. Consequently, it is suggested that MSF process of a performance ratio 8 be adopted for the desalination plant to be jointly operated with the proposed power plant.

2.5.2 Power plant

The proposed power plant should be capable to correspond to daily and seasonal large variation of load on one hand and supply continuously steam in a given quantity to the desalination plant on the other hand. Taking these into account, comparative study was carried out on the 6 combinations of power plant and desalination plant, i.e. Type-A, Type-B, Type-C, Type-D, Type-E and Type-F. Turbine-generators of the power plant in each type of combination are as follows:

Type-A

- Gas/steam combined cycle power plant: 360 MW (Power generation)

  3 units of each 80 MW gas turbine-generator
  1 unit of 120 MW steam turbine-generator

- Steam power plant: 360 MW (Power generation and desalination)

  3 units of each 120 MW steam turbine-generator

Type-B

- Gas/steam combined cycle power plant: 720 MW (Power generation and desalination)

  7 units of each 80 MW gas turbine-generator
  2 units of each 80 MW steam turbine-generator

Type-C

- Gas/steam combined cycle power plant: 360 MW (Power generation
- Steam power plant: 360 MW and desalination)

  Same constitution as Type-A power plant.
  Steam feed pipes of both plants are connected
  to supply steam to desalination plant

Type-D

- Gas/steam combined cycle power plant: 360 MW (Power generation)

  3 units of each 80 MW gas turbine-generator
  1 unit of 120 MW steam turbine-generator

- Gas turbine power plant: 400 MW (Power generation and desalination)

  5 units of each 80 MW gas turbine-generator
  with heat recovery steam generator for
  desalination plant

Type-E

- Steam power plant: 160 MW (Power generation and desalination)

  2 units of each 80 MW back pressure steam turbine

- Gas/steam combined cycle power plant: 560 MW (Power generation)

  5 units of each 80 MW gas turbine-generator
  2 units of each 80 MW steam turbine-generator

Type-F

- Steam power plant: 180 MW (Power generation and desalination)

  3 units of each 60 MW back pressure steam turbine

- Gas/steam combined cycle power plant: 560 MW (Power generation)

  5 units of each 80 MW gas turbine-generator
  2 units of each 80 MW steam turbine-generator

2.5.3 Economic evaluation

For each type of combination of power plant and desalination plant (types A, B, C, D, E and F), the total costs (construction cost, operation and maintenance costs, administration expenses, fuel cost, etc.) incurred from the beginning of the construction works to the end of service life of the plant were converted to the present worth as of the beginning of 1986 to calculate the following ratio and rate:

Benefit/cost ratio (B/C ratio)
Economic internal rate of return (EIRR)

In principle, the purpose of feasibility study is to formulate the most economical project. Therefore, the project which meets the least cost solution is recommended as the optimum project.

However, when equipment considered has not enough operation record or there is a special condition in demand pattern, these conditions should be taken into account.

In spite of the fact that in the desalination sector RO process is more economical than MSF process, MSF process was recommended in this study, considering that MSF process is predominant for large scale desalination plant in commercial operation while RO process has almost no performance record for power and desalination dual purpose plant. Also in the desalination sector it was planned to adopt the performance ratio 8 because this ratio is the most economical both in the extraction turbine alternative and in the back pressure turbine alternative.

The special condition in the demand pattern is for power generation sector, and this problem has a close relation with stability of electricity supply and reliability of plant operation.

The overall evaluation of the project including considerations on the economy and on the reliability of supply is described below.

(1) Benefit/cost ratio and economic internal rate of return

The present worth of the total costs of each type of combination (combination of power plant and desalination plant), as well as, the benefit/cost ratio (B/C ratio) of Type-F combination are as follows:

Present Worth of the Total Costs and Costs Economized against Type-F Combination

	Discount rate 8%		Discount rate 10%	
	Present worth of the total costs	Costs economized against Type-F combination	Present worth of the total costs	Costs economized against Type-F combination
Type-A	756.0	40.6	634.9	34.7
Type-B	758.9	37.7	636.6	33.0
Type-C	756.6	40.0	635.7	33.9
Type-D	758.1	38.5	633.1	36.5
Type-E	789.3	7.3	662.3	7.3
Type-F	796.6		669.6	

B/C ratio of Type-F combination

	Discount rate 8%	Discount rate 10%
Against Type-A	0.949	0.948
Against Type-B	0.953	0.951
Against Type-C	0.950	0.949
Against Type-D	0.952	0.945
Against Type-E	0.991	0.989

Note: C: Cost of Type-F combination

B: Cost of other type of combination. This cost is regarded as the benefit of Type-F combination because it is the expenditure to be saved by the execution of Type-F combination.

As shown in the above table, the most economical solution is Type-A combination when using a discount rate of 8%. The economic ranking of projects can be clarified by the economic internal rate of return (EIRR) which is the discount rate equalizing present worths of the total costs of two projects. When taking Type-A combination as the basis, the EIRR of this alternative is calculated as follows:

Against Type-B combination: 11.5%
Against Type-D combination: 8.9%

Against Type-E combination: Meaningless to calculate because
Against Type-F combination: EIRR will be more than 30%

Seen from economic viewpoint, the least advantageous solution is Type-F combination. This alternative costs higher than Type-A combination by more than 5% (41 million R.O. in the present worth calculated at the discount rate of 8%).

(2) Consideration on the stability of supply

Type-A combination is the most economical. However, in Type-A combination, when fault occurs on the 120 MW turbine-generator supplying base load at the minimum load time in January and February it is necessary to execute partial load shedding in order to prevent overall failure of the power system. Such a counter-measure is needed for only several years after commissioning of the power plant, and probability of occurrence of fault at the minimum load time in the winter season is extremely low. Therefore, when the most importance is attached to the long-term economy, it is suggested that Type-A combination be adopted as the optimum solution.

However, stability of electricity supply is the most important for electric utility. Since Barka power plant is planned to play as the main power source in the integrated grid system covering the Capital area and the Batinah coast, the safety and reliability of operation are especially required for this power station. When standing on this viewpoint, any type of power plant giving fears of load shedding is not desirable, and it is rather suitable to adopt a power plant which is more reliable in operation and supply, though it may be less economic. Type-F power plant is the most suitable to meet requirements of stability of supply and reliability of operation.

2.5.4 Conclusion

As stated before, detailed comparative study was carried out on the six types of combination of power plant and desalination plant.

Of these six types of combination, Type-A has a defect that the influence exerted on the power system is large when fault occurs on its steam turbine-generator in the minimum load time in the winter season, but has a merit in its high economic performance. Therefore, seen from long-term economic viewpoint, Type-A combination is considered recommendable.

On the other hand, the cost of Type-F combination is higher than Type-A combination by around 5%, but the influence on the power system caused by fault of its steam turbine-generator is the least. This means that this type has a high reliability in operation.

The merit of high reliability of Type-F combination, though impossible to express in a quantitative manner, would be by no means so small. On the other hand, when considering economic conditions of Oman at present and for the future up to the end of service life of the plant, the above excess cost of 5% would be by no means decisively large amount.

Taking account of the above conditions and the present situation of Oman, Type-F combination, though less economic, is judged more recommendable than Type-A combination.

2.6 CONSTRUCTION SITE OF POWER AND DESALINATION COMPLEX PLANT

2.6.1 Topography, geology and foundation treatment

The site for power and desalination complex plant, designated by MEW, is located about 9 km east of Barka town. The land is large enough to obtain required area (1,000 m x 1,000 m) for the complex plant.

The elevation of the ground is approximately 1 meter above H.H.W.L. (highest predicted tide at port Qaboos), so that an area of approximately 660,000 sq meters for plant related facilities is to be raised at least 1 meter from the original height, taking into consideration the discharge plans for waste water from the plant and high waves due to monsoons.

Seen from results of borings at Ghubrah desalination plant and borings executed near Barka town for the prospection of subterranean water, the value N of the standard penetration test is estimated to be more than 20 at 5 to 6 meters depth from the ground surface. Therefore, reinforced concrete double slab and mat, and reinforced concrete mat are considered suitable for foundation of civil structures, heavy equipment, buildings, etc.

However, at the stage of definite study, it is necessary for detailed geological investigations to be executed to determine finally the structure of foundation.

2.6.2 Sea water depth and temperature of sea water

The sea is shallow. The results of sounding of the sea water depth show that gradient of the sea bottom is from 1/110 to 1/280.

The sea water temperature was around 24°C disregarding depth and distance from sea-shore. This is because measurement of the sea water temperature was carried out in the winter season of this country (average ambient temperature: 24°C). According to data, temperature of the sea water at the surface in the summer season reaches above 30°C. Therefore, at the stage of definite study, it is necessary to carry out measurement of sea water temperature in the summer season in order to determine finally sea water intake system, taking into account gentle slope of the sea bottom and temperature distribution of the sea water.

2.7 TRANSMISSION LINES AND SUBSTATIONS

2.7.1 275 kV transmission line from Barka power station to Khuwair interconnection substation (60 km)

According to power demand forecast, the peak load in the Capital area in 1988-1991, when Barka power station is planned to enter service by stage, is considered to be about 90% of the integrated system peak load including the Capital area and the Batinah coast. The site for substation where transmission line from Barka power station is connected to the existing system of the Capital area should be near load centers and favorable for interconnection. Taking into account these conditions and also results obtained from power system analysis, it is suggested that an interconnection substation (Khuwair interconnection substation) be constructed on a flat area at the foot of mountain about 3 km south of Ghubrah power station.

To transmit a bulk power of 740 MW of Barka power station for a distance of 60 km at 132 kV several circuits are required. Therefore, from economic and technical viewpoint, this transmission voltage is not suitable, and higher voltage should be selected.

Comparative study was carried out on the three transmission voltages of 220 kV, 275 kV and 330 kV. As the result of study, 275 kV line was selected taking into consideration the adaptability to the future extension of the power system.

The proposed line route is as follows:

Starting from Barka switchyard, the line takes a course southward, across the highway and then turns to the east to reach Barka substation which is under planning. Power for Batinah coast is stepped down to 132 kV here and transmitted by 132 kV line. After branching at Barka substation, the 275 kV line crosses over 132 kV Barka-Musanna line, then takes a course for Rusail and bypasses Rusail power station on the south. Then it takes course to the east and reaches Khuwair interconnection substation. At this substation 275 kV line from Barka is interconnected with two 132 kV lines from Ghubrah to Wadi Adai, and from Rusail to Wadi Adai.

2.7.2 132 kV transmission line from Musanna substation to Sohar substation (125 km)

To meet the growing demand for electric power in the northern half of the Batinah coast (Khabourah, Saham, Sohar, Liwa, Shinas, etc.) and in the Inland area (Buraimi, Ibri and other small towns and villages), MEW plans to increase generating capacity of copper mine power station located about 20 km south of Sohar from the present 51 MW to 165 MW by the end of 1986. However, as described in paragraph 2.3.1, additional two units of each 30 MW gas turbine-generator are necessary to be installed in 1987/1988. By this expansion program, power demand and supply balance in these areas can be secured up to 1988, but in 1989 shortage in supply capacity will be produced.

In the Capital area, on the other hand, construction program of 132 kV line from Rusail power station to Musanna is now on-going. This line, together with Musanna substation, is scheduled to enter service in 1986. In consideration of this situation, it is suggested to extend the 132 kV transmission line from Musanna substation to Sohar substation. For this purpose, construction of Khabourah substation and expansion of Sohar substation are suggested.

In this connection, it is to be noted that, apart from the proposed project, another 132 kV line must be constructed between copper mine power station and Sohar substation by the end of 1986, because the existing lines (single circuit 66 kV line between copper mine power station and Magan substation and double circuit 33 kV line between Magan substation and Sohar substation) are already over-loaded.

2.7.3 Substations

General characteristics of substations to be constructed together with transmission lines are as follows:

. Khuwair interconnection substation	275/132 kV, 3 units of transformers, each 250 MVA 132/ 33 kV, 2 units of transformers, each 125 MVA
. Khabourah substation	132/ 33 kV, 2 units of transformers, each 45 MVA
. Barka substation	275/132 kV, 2 units of transformers, each 250 MVA (Extension)

2.8 PRODUCT WATER DISTRIBUTION FACILITIES

2.8.1 Product water reservoir

It is planned to construct a product water reservoir in the plant site. Taking into account the capacity of desalination plant (180,000 m^3/day) and the maximum quantity of well water for blending (36,000 m^3/day), the reservoir is designed to have a total capacity of 216,000 m^3. With this capacity, the reservoir can regulate supply quantity of product water.

The product water reservoir is divided into four tanks of each 54,000 m^3.

2.8.2 Product water pumps

In consideration of variation of supply quantity of product water and stoppage of pumps for periodic inspection and maintenance, seven units of product water pump including one unit for reserve are planned to be installed. General characteristics of each pumps are as follows:

- Capacity	27.5 m^3/min
- Head	100.0 m
- Revolution	980 rpm
- Motive power	750 kW electric motor

2.8.3 Water conduit pipes

The following two water conduit pipes are planned to be installed along the highway between Muscat and Sohar.

Section	Capacity (m^3/day)	Pipe diameter (mm)
(1) Line-A conduit pipe		
Barka plant - Ghubrah reservoir	108,000	1,200 (35 km) 1,000 (25 km)
(2) Line-B conduit pipe		
Barka plant - Seeb town branch valve	108,000	1,200
Seeb town branch valve - Airport branch valve	70,000	900
Airport branch valve - Azaiba branch valve	38,000	700

2.9 OPERATION AND MAINTENANCE STAFF

The estimated required total number of operation and maintenance staff is about 350 persons. Classification of the staff is as follows:

	Number
Common department	6
Plant Manager	1
Deputy Plant Manager	2
Others	3
Administrative department	36
Operation department	175
Chief	1
Operator (Power plant)	106
Operator (Desalination plant)	68
Maintenance department	131
Total	348

Practical training of staff should be executed under the direction of guarantee enginer from 6 months prior to the test operation of the plant to the end of guarantee period, and using operation and maintenance manuals.

2.10 CONSTRUCTION SCHEDULE

To meet the growing demand for electricity, it is necessary for generating capacity of at least 160 MW to enter service by the middle of 1988. In the desalination sector, even when No. 3 and No. 4 units are installed at Ghubrah desalination plant, the shortage in water supply capability will still continue. Therefore, it is necessary for Barka desalination plant to be commissioned as early as possible. Taking these conditions into account, the works should be started in the following conditions:

- Definite study and preparation of tender documents: Completion by the beginning of 1986

- Award of contract and start of works: May 1986

If works are started in the above conditions, the increase in capacities of power plant and desalination plant will be as follows:

Item	1988	1989	1990	1991
Power plant (MW)				
Commissioning	160	160	280	140
Accumulated total	160	320	600	740
Desalination plant (1,000 m^3/d)				
Commissioning	60	30	90	-
Accumulated total	60	90	180	180

2.11 CONSTRUCTION COST ESTIMATE

The construction costs were estimated at 1985 prices, and both the foreign currency portion and local currency portion were escalated at the rate of 3% per annum. These construction costs include physical contingencies (10%), MEW's administration expenses (3%) and engineering fee (2.5%). According to construction price indices for the period from 1980 to 1985 in Japan and those for the period from 1978 to 1983 in Oman, the compounded price rise was calculated at about 2.5% per annum, but in this project 3% per annum was adopted including margin.

Thus, the total construction costs of the project at 1985 prices were estimated at 343.28 million R.O. of which 241.60 million R.O. is for electric power sector and 101.68 million R.O. for desalination sector. When applying the price escalation rate of 3% per annum, the construction costs for electric power sector will increse to 264.12 million R.O. and those for desalination sector to 109.85 million R.O., totalling 373.97 million R.O. of which 320.24 R.O. (US$936.37 million) is foreign currency portion and 53.73 million R.O. local currency portion as shown below (Cost of power and desalination complex plant is of Type-F):

Construction Cost of Type-F

(Million R.O.)

Sector	Item	Foreign Currency		Local currency	Total
			(Million US$)		
Electric power	Generating facilities	160.33	(468.79)	10.79	171.12
	Transmission facilities	10.86	(31.75)	4.35	15.21
	Substation facilities	19.22	(56.20)	3.64	22.86
	Sub-total (Base direct cost)	190.41	556.74	18.78	209.19
	Physical contingencies, administration expenses, engineering fee	24.27	70.96	8.14	32.41
	Total (1985 prices)	214.68	627.70	26.92	241.60
	Escalated prices	235.41	688.33	28.71	264.12
Desalination	Processing facilities	51.52	(150.64)	9.16	60.68
	Product water distribution facilities	17.88	(52.28)	9.48	27.36
	Sub-total (Base direct cost)	69.40	(202.92)	18.64	88.04
	Physical contingencies administration expenses, engineering fee	9.14	(26.72)	4.50	13.64
	Table (1985 prices)	78.54	(229.64)	23.14	101.68
	Escalated prices	84.83	248.04	25.02	109.85
Grand total	1985 prices	293.22	(857.34)	50.06	343.28
	Escalated prices	320.24	(936.37)	53.73	373.97

2.12 FINANCIAL ANALYSIS

2.12.1 Conditions for analysis

In this analysis Type-F combination was adopted for power and desalination complex plant. The conditions for analysis are as follows:

a) Conditions for funds procurement

Taking into account the terms of loans generally adopted by the export and import banks of industrial countries and some examples of government loan given to Oman, the following conditions were assumed for the procurement of construction costs in foreign currency:

Interest rate:	7.3% (compounded rate)
Repayment period:	15 years after commissioning

It is assumed that the local currency portion of the construction costs will be financed by the budget of the government, so there will be no interest charged on the project. But, in order to calculate adequate prices on the cost basis for electricity and water, the following loan conditions of Oman Development Bank was used in the project:

Interest rate:	8.0%
Repayment period:	10 years after commissioning

b) Loss factors in supply of electricity and water

The power transmission and distribution loss factor was estimated at 15% based on data in 1983.

For product water, the loss factor due to leakage and other reasons was estimated at 20% including un-metered consumption.

c) Prices of electricity and water

The prices of electricity and water used for estimating operating revenues were calculated on the cost basis.

2.12.2 Results of analysis

Calculations for financial analysis were made over the period up to 2010 as in the case of economic evaluation. Results of analysis made on the above-mentioned loan conditions and assumed tariffs for electricity and water are as follows:

a) Profit and loss calculation and cash-flow

The annual balance will show a slight deficit up to 1994 and keep black every year after 1995, and accumulated net income will amount to 279.57 million R.O. by 2010.

Due to interest during construction, deficit in the accumulated cash balance will continue up to 1999 and turn to black in 2000.

b) Rate of return

The rate of return, that is the ratio of operating income to the fixed assets in operation is as follows:

- For the first 10 years after completion of the project: 6.1%
- Over the whole service life: 11.7%

c) Rate of net income

The rate of net income, that is the ratio of net income to the fixed assets in operation is as follows:

- For the first 10 years after completion of the project: 0.75%
- Over the whole service life: 6.2%

B. RECOMMENDATION

(1) In view of the timing of initial operation in 1988 of both power plant and desalination plant, it is necessary for tender documents of the project to be prepared by the beginning of 1986 and for construction works to be started at the latest in May, 1986. Therefore, it is suggested that experienced engineering companies be selected as soon as possible to carry out definite study including:

- Measurement of sea water temperature in the summer season,
- Detailed geological investigation (boring and others)

(2) For the procurement of funds, it is suggested to contact financial institutions abroad.

(3) In order to secure power demand and supply balance in the Batinah coast and in the Inland area, it is suggested that two units of each 30 MW gas turbine-generator be installed near Sohar town in 1987/1988, and 132 kV transmission line be constructed in 1986 between copper mine power station and Sohar substation to cover shortage in transmission capactity of the existing facilities.

(4) The following facilities are excluded from scope of study of this project, but their construction should be carried out in parallel with the construction of the proposed power and desalination complex plant.

- Facilities to supply natural gas to the plant at Barka.
- Well water supply facilities for the desalination plant.
- Accommodation facilities for plant personnel.

C. GENERAL CHARACTERISTICS OF FACILITIES

Facilities	General characteristics
(A) *Power and Desalination Complex Plant*	
1. Civil works	
(1) Water intake channel:	
Intake quantity:	40 m^3/sec
Structure:	Open channel with dredged waterway and dykes
Waterway:	Length: 850 m, Width: 65 m
Dyke:	Length: 2 x 850 m + 210 m = 1,910 m (Max. height: 11.5 m)
(2) Seawater Intake Facility:	Intake and Pump Pit
Structure:	Reinforced concrete open channel, curtain-wall type
Length:	60.00 m
Width:	73.00 m
Height:	13.20 m
(3) Water Discharge Facilities:	Discharge Pit and Discharge Channel
Structure:	Reinforced concrete open channel
Length:	130.00 m
Width:	8.00 - 21.00 m
Height:	2.80 - 8.50 m
(4) Product Water Reservoir:	
Capacity:	54,000 m^3 x 4 Units
Structure:	Reinforced concrete mat, including soil stabilization

Facilities	General characteristics
2. Buildings	
(1) Power Plant Main Building (for Steam Turbine Generator)	
Foundation:	Reinforced concrete double slab and mat
Structure:	Steel construction, 3 stories
Scale:	Building area 17,341 m^2 Building volume 138,000 m^3
(2) Administration Building (Common Use Building)	
Foundation:	Reinforced concrete mat, including soil stabilization
Structure:	Reinforced concrete construction, 2 stories
Floor area:	2,940 m^2
(3) Power Plant Control Building	
Foundation:	Reinforced concrete mat, including soil stabilization
Structure:	Reinforced concrete construction, 2 stories, partially with mezzanine floor
Floor area:	8,183 m^2
(4) Desalination Plant Control Building	
Foundation:	Reinforced concrete mat, including soil stabilization
Structure:	Reinforced concrete construction, one story
Floor area:	540 m^2
(5) Other Buildings (Chemical injection building, product water treatment building, common use building)	

Facilities	General characteristics
(6) Self-standing stack (3 units)	
Foundation:	Reinforced concrete mat, including soil stabilization
Structure:	Steel construction
Height:	80 m
Top diameter:	2.4 m

3. Power Plant (Type F)

3.1 Steam turbine-generators

(1) Steam generator (3 units)	
Type:	Natural circulation module type finned water tube
Evaporation:	ca.400 t/h
Steam pressure:	ca.80 kg/cm^2
Main fuel:	Natural gas
(2) Steam turbine (3 units)	
Type:	Impulse type
Rated capacity:	60 MW
Inlet steam pressure:	ca.80 kg/cm^2
Speed:	3,000 rpm
(3) Generator (3 units)	
Rated capacity:	75 MVA
Power factor:	0.8
Short circuit ratio:	About 0.5

Facilities	General characteristics
3.2 Gas turbine-generator	
(1) Turbine (5 units)	
Type:	Heavy duty industrial type
Rated capacity:	84 MW (50°C), 109 MW (15°C)
Speed:	3,000 rpm
(2) Generator (5 units)	
Rated capacity:	140 MVA
Power factor:	0.8
Short circuit ratio:	About 0.5
3.3 Steam turbine-generator for gas/steam combined cycle	
(1) Heat recovery steam generator (4 units)	
Type:	Natural circulation module type finned water tube
Evaporation:	ca.160 t/h
Outlet steam pressure:	ca.60 kg/cm^2
(2) Steam turbine (2 units)	
Type:	Impulse type
Rated capacity:	80 MW (50°C), 85 MW (15°C)
Inlet:	ca.60 kg/cm^2
Speed:	3,000 rpm
(3) Generator (2 units)	
Rated capacity:	110 MVA
Power factor:	0.8
Short circuit ratio:	About 0.5

Facilities	General characteristics
4. Desalination plant (6 units)	
(1) Evaporator	
Type:	Cross tube rectangular type
Stage No.	Heat recovery 20 stages Heat rejection 3 stages Total 23 stages
(2) Brine heater	
Type:	Horizontal shell and tube type
(3) Deaerator	
Type:	Vacuum packed tower type
Performance:	Dissolved oxygen, Max. 20 ppb
(4) Venting equipment (per 1 unit)	
Steam ejector:	Twin 3 stages type
Vent condenser (1 unit):	Horizontal shell and tube type
Ejector condenser (1 unit):	Horizontal shell and tube type
(5) Main process pump (per 1 unit)	
Brine recycle pump (1 unit)	Cap. 13,150 m^3/h, Total head 50 m
Brine blow down pump (1 unit)	Cap. 1,812 m^3/h, Total head 20 m
Distillate pump (2 units)	Cap. 1,500 m^3/h, Total head 20 m
Condensate pump (2 units)	Cap. 198 m^3/h, Total head 35 m

Facilities	General characteristics
(6) Product water treatment equipment (Total 1 unit)	
Type:	Lime stone filter type using the exhaust gas from the evaporator
Treatment capacity:	Total 180,000 m^3/day
Total hardness of treated water:	60 ± 10 mg/l (as $CaCO_3$)
(7) Auxiliary steam generator (Total 2 units)	
Type:	Water tube outdoor service
Evaporation:	300 Tons/h (per 1 unit)
Steam pressure:	10 kg/cm^2G
Steam temperature:	183°C
Fuel:	Natural gas (Heavy oil for stand-by)

Facilities	General characteristics
(B) <u>Transmission Facilities</u>	
1. <u>Barka - Khuwair line</u>	
(1) Section and length	
Barka PS - Barka SS	13 km
Barka SS - Khuwair SS	47 km
(2) Voltage:	275 kV
(3) Number of circuit:	2
(4) Conductor	AAAC 400 mm^2 x 4
(5) Supporting facility:	Double circuit angle steel tower
2. <u>Musanna - Khabourah - Sohar line</u>	
(1) Section and length	
Musanna SS - Khabourah SS	60 km
Khabourah SS - Sohar SS	65 km
(2) Voltage:	132 kV
(3) Number of circuit:	2
(4) Conductor:	AAAC 400 mm^2 x 2
(5) Supporting facility:	Double circuit angle steel tower
(C) <u>Substation Facilities</u>	
1. <u>Kuwair interconnection substation</u>	
(1) Transformer capacity	250 MVA / 125 MVA
(2) Voltage	275/132 kV / 132/33 kV
(3) Number of unit	3 / 2

Facilities	General characteristics
2. Khabourah substation	
(1) Transformer capacity	45 MVA
(2) Voltage	132/33 kV
(3) Number of unit	2
3. Barka substation (Extension)	
(1) Transformer capacity	250 MVA
(2) Voltage	275/132 kV
(3) Number of unit	2

(D) Product Water Distribution Facilities

1. Product water reservoir (Refer to (A) 1.(4))

2. Product water transfer pump

(1) Number of unit	7 (6 Units: Working, 1 Unit: Stand-by)
(2) Capacity	27.5 m^3/min
(3) Head	100 m
(4) Revolution	980 rpm
(5) Driver	750 kW electric motor

3. Water conduit pipe

	Capacity (m^3/day)	Pipe diameter (mm)
(1) Line-A conduit pipe		
Barka plant - Ghubrah reservoir	108,000	1,200 (35 km) and 1,000 (25 km)

Facilities	General characteristics	
(2) Line-B conduit pipe		
Barka plant - Seeb town branch valve	108,000	1,200
Seeb town branch value - Airport branch valve	70,000	900
Airport branch valve - Azaiba branch valve	38,000	700

CHAPTER 3

NATURAL AND ECONOMIC CONDITIONS

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3.1 LAND

3.1.1 Location

The Sultanate of Oman is located at the south-eastern corner of the Arabian Peninsular between latitudes 16°40'N and 26°20'N and longitudes 51°50'E and 59°40'E, having a coast line stretching about 1,700 km from the Straits of Hormuz in the north to the frontier with the People's Democratic Republic of Yemen in the south-west. It is bounded in the north-east by the United Arab Emirates and in the south-west by the Kingdom of Saudi Arabia.

3.1.2 Geographical features

The country has a total area of approximately 300,000 sq km, and geographically falls into the following areas:

(1) Capital area

The capital area is commercial, industrial and administrative center of the country. Having a coast line of about 90 km from Barka in the north to Yiti in the south of Muscat, the area is composed of the following regions:

Muscat : includes Muscat, Riyam, Sidab, Al Bustan, Yiti
Mutrah : includes Greater Mutrah, Ruwi, Wataya, Hamriya
Bawshar: includes Qurum, Medina Qaboos, Khuwair, Ghubrah, Azaiba
Seeb :

This area is the most densely populated in the country. Near Muscat there are two ports (Port Qaboos and Port Al Fahal). Seeb international airport is situated about 30 km north-west of Muscat.

(2) Batinah coastal area

The Batinah coastal plain runs from Shinas to Barka for a stretch of about 240 km. It is situated between the coast and the Western Hajar, varying from 10 to 30 km in width. Cultivation is limited to a narrow strip of less than 3 km in width, adjacent to the sea. The Batinah is one of the most populous areas of Oman. The main towns are Barka, Musanna, Suwaiq, Khabourah, Saham, Sohar, Liwa and Shinas.

(3) Western Hajar area

In parallel with the Batinah area, the Hajar mountain range runs from Musandam in the north to Sumail Gap in the south. The highest points are in the south-east, the Jebel al Akhdar with peaks rising up to 3,000 meters in height. The main towns on the seaward side of the mountains are Rustaq, Awabi and Nakhl.

(4) Eastern Hajar area

The Eastern Hajar is the continuation of mountains from the Sumail Gap to Jebel Jaalan in the south-east, covering a distance of more than 200 km. The highest elevation is 2,100 meters. The principal towns on the seaward edge of the mountains are Sur, Tiwi and Quriyat.

(5) Oman Interior area

The Oman Interior area is a central plateau sloping from the Jebel al Akhdar in the north towards the desert in the south. There are four main valleys: Wadi Sumail, Wadi Halfeen, Wadi Batha and Wadi Bahla. The Wadi Sumail and the Wadi Halfeen together form a natural gap in the main mountain range. This gap is a traditional route between Muscat and the Oman Interior, as well as being one of the most populous areas of the country. The main towns are Nizwa, Bahla, Izki, Manah, Adam and Sumail.

(6) Dhahirah area

This is a semi-desert plain, sloping from southern flanks of the Western Hajar into the Rub al Khali Desert in Saudi Arabia. The main towns in the area are Ibri and Dank.

(7) Buraimi area

This is the northern extension of the Dhahirah area. In this small area, population is concentrated around the irrigated date cultivation area of the Buraimi oasis.

(8) Shargiya and Jaalan areas

The Shargiya is an area of sandy plains and valleys, laying on the inland side of the Eastern Hajar. The main towns are Ibra, Mudaibi and Samad.

The Jaalan is also sandy plain forming the southern extension of the Shargiya and extending to the Arabian Sea. It is bordered on the northern side by the Eastern Hajar and on the southern side by the Wahiba sands. The principal towns are *Bilad Bani Bu Ali*, *Bilad Bani Bu Hasan* and *Kamil*.

(9) Southern area - Dhofar

The southern area occupies almost one-third of the area of the country. Dhofar is composed of two different climate zones. The narrow coastal plan, extending from Raysut to Taqa is nowhere wider than 8 km, but the fertile soil is well watered between June and September by the south-west monsoon. The monsoon also reaches the wooded Kara Mountains rising up to 1,500 meters in height behind the coastal plain. In the north of the mountains there is very little rainfall and the area has desert vegetation. The principal towns are Salalah, Raysut, Taqa, Marbat, Thamarit, etc.

(10) Musandam

This is the northern-most of the country having an area of about 2,000 sq km, separated from the main body of the country by the United Arab Emirates. The land consists of rugged mountains rising up to 1,800 meters in height. The main villages are Khasab and Bukha.

(11) Masirah Island

The Masirah Island is situated about 60 km offshore in the Arabian Sea. The other important islands, also in the Arabian Sea, are the Kuria Muria group, the largest of which is Hallaniya.

3.1.3 Climate

(1) Capital area

In the capital area the wet season continues 6 months from November to April but annual rainfall is only about 100 mm.

The maximum temperature in the summer season which continues from May to October sometimes exceeds 45°C, and in the winter season the minimum temperature sometimes falls down to below 10°C.

Humidity is very high, sometimes exceeding 95% in the summer season.

Monthly rainfall, temperature and humidity measured at Seeb International Airport and Sohar are shown in Table 3.1.

(2) Southern area

In the Dhofar area where rainfall is concentrated in the summer season, annual precipitation is about 110 mm in the coastal plain and 550 to 600 mm in the mountainous area.

In this area, temperature does not rise so high even in the summer season due to cloudy weather. The climate is more moderate throughout the year.

In the coastal plain, humidity is very high, sometimes exceeding 95% like in the capital area.

Table 3.1 Monthly temperature, rainfall and humidity

(Capital area and Batinah coast)

Month	Capital area (at Seeb International Airport)						Sohar (1983)		
	Maximum temperature		Rainfall		Maximum humidity		Maximum temperature	Rainfall	Maximum humidity
	1982	1983	1982	1983	1982	1983			
	(°C)	(°C)	(mm)	(mm)	(%)	(%)	(°C)	(mm)	(%)
January	31.0	25.0	2.9	-	98	90	25	0.4	100
February	30.0	25.0	59.6	25.6	100	100	24	59.9	100
March	38.0	26.0	35.1	4.5	99	94	26	37.7	100
April	40.0	32.0	0.9	46.7	92	97	31	24.4	100
May	43.0	40.0	-	-	92	94	40	-	100
June	45.0	41.0	-	-	96	96	34	-	100
July	43.0	38.0	-	-	97	92	38	-	100
August	43.0	36.0	-	0.9	92	98	36	-	99
September	42.0	36.0	-	-	94	93	36	-	100
October	41.0	35.0	-	-	88	87	35	-	98
November	35.0	30.0	4.5	-	89	90	30	-	99
December	33.0	27.0	29.5	2.6	95	97	27	-	100

Source: Statistical Year Book 1983 - Development Council

3.2 ECONOMIC BACKGROUND

3.2.1 Population and manpower

No nationwide census has so far been conducted in Oman. The Government estimates the total population at about 1,500,000, but in a report of the United Nations its population is estimated to have grown from 674,000 in 1971 to 920,000 in 1981 and 950,000 in 1982 at an average rate of 3.15% per annum. The population growth in the urban areas is said to be about 5% per annum.

About one-third of the total population inhabits the Capital and Batinah coastal areas, and a half small villages and towns scattered in the inland areas. In the Dhofar area there are about 100,000 habitants and in the Musandam area about 5,000 habitants. No city has a population of more than 100,000.

As described later, one of the economic characteristics of Oman is a heavy dependence on expatriate manpower. A report of the Development Council shows that as at the end of 1982, of the total government employees of 51,402 (excluding Defense and Police) the expatriate employees were 20,639 (40%) and the labour cards issued by the Directorate General of labour Affairs to expatriates working in the private sector were 186,821. Therefore, the total number of expatriate workers in 1982 was 207,460 (22%) of the total population of 950,000.

3.2.2 Economic development

The era of economic development in Oman began in 1970 when the Sultan Qaboos took over in order to initiate the transformation of Oman from internationally isolated and medieval society into a prosperous modern state. The achievements realized since then are very remarkable: Oman's economy today stands on a firm ground and the standard of living of the people continues to rise. The sequence of economic development after 1970 can be divided into the following periods:

(1) Preparation for economic growth (1970-1975)

The first half of the 1970's was the preparation period for economic growth. Although no concrete economic development plan was formulated, emphasis were placed on the construction of infrastructure, such as power stations, water supply facilities, Qaboos port, Seeb international airport, roads, schools, etc. During this period, GDP grew from 125.1 million R.O. in 1971 to 724.2 million R.O. in 1975 at an average rate of 55% per annum (at 1972 prices the growth rate was 44% per annum). This rapid growth is mainly due to rapid increase in oil export revenue caused by price hike of crude-oil in 1973.

(2) Switching over to diversification of Plan (1976-1980)

Experiences during the period from 1970 to 1975 led the government to establish the Development Council in 1975 and launch the First 5-Year Plan for the period from 1976 to 1980 under the guidance of the IBRD.

Emphasis of the Plan were placed on the a) keep of crude-oil production at the previous level and encouragement of natural gas production, b) economic development of the Dhofar and other rural areas, c) development of small and medium scale industries, d) encouragement of investment in the private economic sector, etc.

During this period, GDP grew at high rate of 23.6% per annum (at 1972 constant prices the growth rate was 13.6% per annum) due mainly to rapid increase in oil export revenue caused by price hike of crude-oil in 1979.

(3) Diversification of industries (1981-1985)

The current Second 5-Year Plan for the period from 1981 to 1985 has a characteristic of supplementing the First 5-Year Plan. Aiming at growing GDP from 2,066.6 million R.O. in 1980 to 3,824.4 million R.O. in 1985 at an average rate of 13.1% per annum, emphasis of the Plan are placed on the a) diversification of industries, b) encouragement of investment in the private economic sector, c) acceleration of rural development in the Musandam, Dhofar and other inland areas.

It is worth mentioning that the amount of public investment realized so far during the years 1981, 1982 and 1983 exceeded fairly the projected disbursement during the same period, and that crude-oil production in 1983 was maintained at the rate of 389,000 barrels a day as opposed to the previous (1982) target of 330,000 barrels a day.

The main projects already completed in the framework of the Second 5-Year Plan are the following:

Project	Production	Location	Commis-sioning
Oil refinery	50,000 b/d	Al Fahal port	1982
Cement factory	620,000 b/y	Rusail	1983
Copper mining and smelting	20,000 b/y	Sohar	1983
Industrial estate	172 ha (109 plots)	Rusail	1984

The above projects were all undertaken in the Capital and Batinah areas.

At the population growth rate of 3.15%, the total population is forecasted to grow from 890,000 in 1980 to 1,041,000 in 1985. Since GDP is anticipated to grow from 2,066.6 million R.O. in 1980 to 3,824.4 million R.O. in 1985, the per capita GDP is estimated to grow from 2,322 R.O. (US$6,790) in 1980 to 3,667 R.O. (US$10,720) in 1985 which is almost equal to GDP per capita in Japan at present.

The growth of GDP registered during the First 5-Year Plan period from 1976 to 1980 and the first 3 years (1981-1983) of the Second 5-Year Plan is shown in Table 3.2.

3.2.3 Prices

Oman was hanted by high inflation during 1973 and 1974 due partly to the world price hike of commodities caused by the oil crisis in 1973, and partly to the planless investments executed from 1970. However, emergent measures taken by the government in 1973 and 1974 and its prudent development policies taken thereafter had an effect of controlling inflation.

The consumer price index rose from 100 in 1972 to 176.3 in 1973 and 226.7 in 1974 but fell down to 172.2 in 1975 and 159.3 in 1976.

When adopting 1978 prices as the basis (=100), the consumer price index rose from 85.0 in 1976 to 124.0 in 1982 and fell down to 118.6 in 1983. Thus, the annual average price increase rate over the period from 1976 to 1983 was 4.9%.

Year	Consumer price index	
1972	100.0	-
1973	176.3	-
1974	226.7	-
1975	172.2	-
1976	159.3	85.0
1977	164.4	87.7
1978	187.4	100.0
1979	198.6	108.5
1980	223.6	119.3
1981	229.9	122.7
1982	234.2	124.0
1983	-	118.6

Source: Statiscal Year Book 1983

3.2.4 Characteristics of economic structure

The economic structure of Oman has the following characteristics:

a) Heavy dependence on oil production

b) Heavy dependence on expatriate manpower

c) Sluggish development of private economic sectors

Of the above characteristics, the most important is the heavy dependence on oil. The share of oil revenue in the total internal revenue shows clearly the fact. *It was 89% in 1981, 90% in 1982 and 88% in 1983 as shown below:*

(Million R.O.)

Internal revenue	1981	1982	1983
Oil revenue	1,125.4 (89%)	1,117.3 (90%)	1,187.6 (89%)
Other revenue	136.8 (11%)	118.1 (10%)	146.3 (12%)
Total	1,262.2 (100%)	1,235.4 (100%)	1,339.9 (100%)

Source: Directorate General of National Statistics

The shares of categorical economic sectors in the GDP are shown in Table 3.2. According to this table, of the GDP in 1983 share of petroleum production was 49.5% against shares of construction and trade of 6.8% and 11.5% respectively. Contribution of manufacturing to GDP was only 2.3%. Share of government administration and national defense is relatively high, namely 13.1% of GDP.

3.2.5 Activities of main economic sectors

(1) Petroleum production

Oil reserves in Oman is not so large. In 1980 they were estimated at about 2,440 million barrels of which 70% is of the northern oil fields, 21% of the southern oil fields and 9% of the central oil fields as shown below:

Oil fields	Reserves (Million barrels)
Northern fields	1,718 (70%)
Central fields	216 (9%)
Southern fields	506 (21%)
Total	2,440 (100%)

However, with discovery of new oil fields in the recent years the reserves are now estimated to be more than 2,600 million barrels.

Oil production began in 1967 and has shown a rising trend since the beginning of 1970, and the levels of production reached their peaks in 1976 and 1983 when daily production reached 365 thousand barrels and 389 thousand barrels, respectively. Oil production for the period from 1975 to 1983 is reported as follows:

Year	Annual production (Million barrels)	Daily production (Thousand barrels)
1975	124.6	341
1976	134.7	365
1977	124.1	340
1978	114.7	314
1979	107.7	295
1980	103.3	282
1981	119.7	328
1982	122.7	336
1983	141.9	389

At the rate of production of 350 thousand barrels a day, Oman will still be able to enjoy benefits from its oil reserves for more than 20 years.

36-inch main pipeline (capacity: 385,000 b/d) runs from Fahud in the northern oil fields to Al Fahal port for a stretch of about 250 km, and another pipeline of 565 km (capacity: 70,000 b/d) branches from halfway of this main pipeline to the central and southern oil fields.

Petroleum Development Oman (PDO) was the sole oil producing company in Oman until ELF-Sumitomo-Wintershall group commissioned a field in Butabul in 1980. The crude of this group is exported by piping it to Al Fahal port to be blended with PDO crude according to an agreement between the two companies.

(2) Natural gas production

Natural gas is the fuel of the future as far as Oman is concerned. Gas reserves are located in the north, Central and southern oil fields in association with crude oil and also in dry gas reservoirs. There are also small reservoirs in widespread localities. The gas reserves of the PDO concession area are estimated at 183.3 billion cu meters.

(Billion m^3)

Reserve	Associated	Non-associated	Total
North Oman	24.6	109.2	133.8
Central Oman	5.3	23.8	29.1
South Oman	14.2	6.2	20.4
Total	44.1	139.2	183.3

Out of the PDO concession area, there are additional reserves of some 133 billion cu meters as described later.

The major users of natural gas are:

- Ministry of Electricity and Water
- Oman Mining company (Sohar)
- Oman Cement Company (Rusail)
- Ministry of Defense

The Yibal gas reservoir is the sole non-associated gas reservoir supplying these electrical and industrial needs of the Capital area and the Batinah coastal area. Its reserve is estimated at about 77.3 billion cu meters.

A 20-inch gas pipeline from Yibal to Ghubrah for a stretch of 325 km was commissioned in 1978 to allow substitution of natural gas for imported diesel oil for electricity and water production in the Capital area. The designed capacity of this pipeline is 4.73 million cu meters a day without compression.

In 1982 a 16-inch pipeline of 227 km branching from the Yibal-Ghubrah pipeline to the north-west was commissioned to feed copper mining and smelting plant of Oman Mining Company located in the inland of Sohar.

According to a demand forecast of natural gas, the reserve of Yibal can supply the needs of the above-mentioned users for 20 to 30 years but it is insufficient to supply large volume industries in the long term, such as fertilizer, methanol or aluminium smelting plants.

However, it is worth mentioning that out of the PDO concession area there are gas reservoirs discovered by ELF Group, Gulf Oil Co. Group and other concessionnaires. These reservoirs are in the Straits of Hormuz (Oman/Iran offshore) and in the north-west of the country. A study also indicates that geological and seismic surveys show that additional reserves of some 133 billion cu meters are probably available at relatively small depths.

All oil concessions granted by the Government of Oman to international oil companies stipulate that any natural gas discovered remains a government property and is not subject to the concession agreements.

(3) Mining

Geological surveys aiming at prospecting for mineral resources have been carried out since 1966 and especially from the start of the First 5-Year Plan. Although the whole aspect of mineral deposits is not yet brought to light, the available geological surveys indicate the existence of copper, iron ore, manganese, nickel, coal and large deposits of limestone, gypsum, asbestos, marble, etc. It is said that there is also possibilities of existence of uranium in the Dhofar area and in the Ras al Hadd area.

In Oman which depends on oil production only, the mining sector is expected to substitute oil sector in the future. Therefore, the second priority is attached to the development of mineral resources.

In 1978 Oman Mining Company was created by the Government to concentrate efforts to prospecting for copper in the inland of Sohar.

As the drill-proven deposits of copper in Al-Baida, Al-Asail and Al-Arja reached 13 million tons, it was decided to start a copper mining and smelting project, while continuing the drilling to ascertain further quantities of raw materials. The indications of the existence of further quantities of copper deposits are abundant. The discovered raw materials contain 2.1% copper. This project was completed in 1983, and at present about one million tons of raw materials are extracted annually to concentrate and smelt it in order to produce and export about 20,000 tons of copper per annum.

(4) Industry

Up to 1978 when a flour mill factory of a capacity of 45,000 tons a year was constructed at Mutrah, industrial activity in Oman was very limited. There were only small-sized handicraft industries engaged in producing food, soft drinks, gold and silver articles, tailoring and textiles, furniture and wooden products, cement blocks and floors for construction purposes, or in processing iron parts and products. However, during the First 5-Year Plan period the private investments in the industrial sector increased gradually. The main feature of these investments was that the majority of the projects were oriented to producing intermediate goods required for construction and related activities.

In the Second 5-Year Plan the Government takes the following policies in order to develop and diversify the industrial activities:

- To give financial support to the private sector

- To exempt companies engaged in industry from the corporate income tax

- To give higher priority to industrial projects which use local materials and high percentage of local manpower

- To encourage foreign investors to join in the industrial projects which produce the benefit of a relative advantage in export markets

Supported by these policies, Rusail Cement Factory (Oman Mining Company) of a capacity of 620,000 tons a year was completed in 1983. This will undoubtedly facilitate and promote construction activities in the country. Another impressive achievement is the completion of Rusail Industrial Estate in 1983. Its total area is 172 hectares, consisting of 109 industrial plots which will be offered to the private sector industrial enterprises.

Share of industrial sector in GDP is small at present, but good economic performance of this sector is expected to be realized in the future. However, there are some difficulties in the industrial development of Oman. Firstly, difficulty of implementing large scale industries due to small local market may lead to relatively high commodity prices as compared with those of imported goods and materials. Secondly, shortage in local manpower and insufficience of technical discipline may bring about difficulties in the operation of undertakings.

(5) Agriculture and fisheries

Before oil was discovered, the Omani economy was supported by agriculture and fisheries. Some studies estimate that about half the population lives in agricultural communities and finds means of living in agriculture. The population engaged in fisheries is estimated at seven to eight thousand.

However, due to rapid and continuous improvement in the standard of living of the people and to the natural increase in the population, the country has to import large quantities of food stuffs. The total imports of food stuffs in 1983 amounted to 108.9 million R.O., i.e. 12.6% of the total import amount (860.9 million R.O.), while the exports of food stuffs (dates, lime, fish, fruits and vegetables) in the same year amounted to 7.14 million R.O.

Because agriculture in Oman relies on underground water, cultivated land is scattered in small and numerous plots, depending on the availability of water. However, some studies indicate that productivity of agricultural land in Oman can be doubled. Hence, efforts are made towards reaching this objective by establishing extension service centers and research stations. These centers and stations provide various services to the farmers including the provision of improved seeds, tractor service, insecticides, fertilizers, water-pumps and other equipments.

The ultimate target of the Government in the agricultural sector is to secure the self-sufficiency of foodstuffs. For this purpose, a) further increase in productivity of the existing farms, b) reclamation of additional agricultural land by development of new water resources and c) improvement of the traditional "falaj system" are undertaken as the main tasks for the future.

Fisheries are still an important source of employment and also important source of protein. They have a large potential for substantial growth because Oman enjoys some 1,700 km of coast line on the ocean; rich with all varieties of fish such as sardine, snapper, cuttlefish, anchovy, lobster and abalone. Accordingly, the Government assigns top priority to their development.

In accordance with the above policy, the modernization of this sector is being accelerated by establishment of fishing centers which include cold storage, ice-plants, refrigerated trucks, boats and motor repair workshop and by establishment of fish-marketing center. One center was established in Mutrah which was also provided with four trawlers for deep-water fishing. The other centers were established in Salalah, Musandam and Masirah, as well as, a repair workshop in Mirbat and a fish-marketing center in Buraimi.

For the development of agriculture and fisheries, the Government established an agriculture and fisheries credit bank in 1981.

3.2.6 Balance of payments

The balance of trade keeps black every year due to large export amount of crude-oil. Revenue from oil export holds about 95% of the total export amount. Services and private transfers show deficit every year, but the overall balance of payments including official loans and transfers and oil sector investment keeps substantial black every year. Detail of balance of payments is shown in Table 3.3. Both in export and import, Japan occupies the first place almost every year. Of the total oil production about 40 to 50% is exported to Japan.

Table 3.2 GDP achieved by economic sector (Current price)

(Million R.O.)

	Sector	1976	1977	1978	1979	1980	1981	1982	1983	Share (1983)
1)	Agriculture and fisheries	18.3	24.1	30.7	40.3	52.6	62.1	66.1	80.5	2.9%
2)	Petroleum	517.5	532.8	491.1	712.7	1,272.6	1,475.2	1,402.0	1,353.3	49.5%
3)	Natural gas and mining	-	-	2.7	7.0	13.3	20.3	22.7	31.3	1.1%
4)	Manufacturing	4.3	6.7	8.5	9.6	13.4	24.0	35.9	63.2	2.3%
5)	Construction	88.5	78.0	71.4	86.1	117.8	144.9	169.8	187.4	6.8%
6)	Transport and communication	13.5	17.6	20.7	25.5	38.3	53.8	64.9	72.9	2.7%
7)	Electricity and water	6.4	9.2	11.1	12.7	16.0	18.7	21.3	24.0	0.9%
8)	Trade, restaurants, hotels	76.5	94.2	104.0	137.1	188.3	251.3	299.5	315.7	11.5%
9)	Financing, insurance and business services	92.0	96.2	100.1	123.0	162.7	206.4	231.0	255.5	9.3%
10)	Community and personal services	4.4	5.8	7.6	9.6	13.0	16.9	20.7	25.4	0.9%
11)	Government services	69.3	90.5	109.2	137.9	194.6	260.5	305.0	360.0	13.1%
12)	Import duties	4.5	4.6	4.6	7.0	8.6	11.3	14.7	21.7	0.8%
13)	Less: Bank service charges	-10.9	-12.9	-14.2	-19.0	-24.6	-39.0	-43.9	-49.6	-1.8%
	Total GDP	884.3	946.8	947.5	1,289.5	2,066.6	2,506.4	2,609.7	2,741.3	100.0%

Source: Statistical Year Book 1984 - Development Council

Table 3.3 Balance of payments

(Million R.O.)

Item	1978	1979	1980	1981	1982
Trade balance	113.7	294.2	581.3	681.6	440.6
Export and re-export f.o.b.	552.0	787.4	1,294.6	1,621.9	1,527.7
(Oil exports)	(521.8)	(745.7)	(1,244.6)	(1,526.4)	(1,409.6)
(Other exports and re-exports)	(30.2)	(41.7)	(50.0)	(95.5)	(118.1)
Imports c.i.f.	-438.3	-493.2	-713.3	-940.3	-1,087.1
Services and private transfers	-134.3	-169.1	-196.6	-275.3	-331.8
Profit remittances	-39.7	-43.8	-59.5	-104.4	-114.5
Official interest (net)	1.6	-7.6	21.8	79.4	133.2
Other services (net)	-22.9	-31.8	-46.5	-95.5	-114.4
Worker's remittances	-73.3	-85.9	-112.4	-154.8	-236.1
Official loans and transfers	-2.5	48.4	36.2	105.6	37.3
Oil sector capital	15.6	9.0	26.9	9.6	45.9
SDR allocation	-	1.4	1.0	-	1.0
Errors and omissions	-27.3	-81.2	-125.4	-40.5	100.3
Overall balance	-34.8	102.7	323.4	481.0	293.3

Source: Statistical Year Book - 1982

CHAPTER 4

PRESENT CONDITIONS OF ELECTRIC SUPPLY INDUSTRY, LOAD FORECAST AND POWER DEVELOPMENT PROGRAM

CHAPTER 4 PRESENT CONDITIONS OF ELECTRIC SUPPLY INDUSTRY, LOAD FORECAST AND POWER DEVELOPMENT PROGRAM

4.1 ORGANIZATION

4.1.1 General situation

When the Sultan Qaboos came to power in 1970, the power generating capacity for public supply in Oman was only 4.98 MW of Riyam diesel power station in the Capital area, while annual water production was only 386,000 cu meters in 1971. At this time, urban water was produced by wells only. In a report of the United Nations the total population in 1971 was estimated at about 674,000. This means that in 1971 power generating capacity and annual water production per capita in Oman were only 7.4 Watt and 0.57 cu meters, respectively.

Therefore, immediately after political change in 1970, the government had to begin tackling the problem of providing people with enough power and water. Efforts made by the government up to present have brought about brilliant results. As far as the Capital area is concerned, the total installed capacity of the government power stations grew from 4.98 MW in 1970 to 566.1 NW in 1984 and the total water production from 386,000 cu meters in 1971 to 19,698,000 cu meters in 1984.

Establishment of power development programme, generation, transmission and distribution of electricity are directly undertaken by the government through the Ministry of Electricity and Water (MEW) which was formed in 1978 from the former Ministry of Communication. Construction of water supply facilities and supply of urban water are also undertaken by MEW, while the Ministry of Agriculture and Fisheries implements water projects for irrigation purpose.

Supply of electric power and water in the Musandam area and in the Buraimi area falls under the jurisdiction of the Musandam Development Committee and the Rural Development Committee, respectively. In the Southern area MEW is responsible for supplying electricity but not for water.

Petroleum Development Oman (PDO) and Oman Mining Company (OMC) possess and operate their own power stations, and the Ministry of Defense has also its own power stations for stand-by use.

Up to April 1976 when the first desalination plant was commissioned at Ghubrah, urban water had been produced by wells only.

4.1.2 Organization and function

(1) Organization of MEW

Electric power and water supply systems of the country consist of a) Capital area system, b) Batinah coast system, c) Southern area system (not including water supply) and d) all rural systems. Organization and function of MEW are set up to conform to the respective characteristics of power and water supply undertakings and to the above geographical divisions of supply systems.

Under general management and control by the Minister of Electricity and Water, five directors general of the following directorates general are responsible for daily business operation of MEW:

- Directorate General DIWAN
- Directorate General of Projects
- Directorate General of Electricity
- Directorate General of Water
- Directorate General of Electricity - Southern area

Directorate General DIWAN manages administrative, personnel and financial affairs of the whole MEW. Directorate General of Projects manages power and water projects from the stage of planning to the end of execution of contracts.

Directorate General of Electricity is directly responsible for managing all technical matters including construction of power facilities, generation, transmission and distribution of electricity in the Capital area and in the rural areas, and also manages relating administrative and financial affairs.

Directorate General of Water is directly responsible for managing construction of water supply facilities and supplying urban water to the people in the Capital area and in the rural areas, and also manages administrative and financial affairs.

Directorate General of Electricity - Southern area is responsible for managing construction of power generating facilities and supply of power to the southern area including Salalah, Raysut, Marbat, Sadah and Taqa, and also manages relating administrative and financial affairs.

Organization chart of MEW as of the end of January 1985 is shown in Talbe 4.1.

(2) Operation and maintenance system

The operation and maintenance of power stations and desalination plant are carried out by foreign companies based on contracts between MEW and these companies. For example, Rusail power station and Ghubrah power and desalination plant are operated and maintained by John Brown Engineering Company and SOGEX, respectively. The operation and maintenance staff are directly employed by these companies.

(3) Meter reading, billing and collection of charges

The meter reading, billing and collection of charges for electricity and water are carried out by Oman Investment and Finance Company based on contract between MEW and this company. Payment of charges is made in bank remittance every month by general consumers and every three months by ministries.

Table 4.1 Organization chart of MEW

- Minister of Electricity and Water
  - Advisers
  - Minister's Office
  - Under Secretary
    - Under-Secretary's Office
    - Directorate General Diwan
      - Department of Administrative Affairs
        - ∘ Public relation and services section
        - ∘ Archives and typing section
        - ∘ Carpentry workshop section
      - Department of Personnel Affairs
        - ∘ Personnel affairs section
        - ∘ Organizing and training section
        - ∘ Files and registers section
      - Department of Financial Affairs
        - ∘ General accounts section
        - ∘ Subscriber accounts section
        - ∘ Contracts and purchasing section
    - Directorate General of Electricity - Southern Area
      - Department of Technical Affairs
        - ∘ Planning section
        - ∘ Construction section
        - ∘ Operation and maintenance section
        - ∘ Equipment test section
        - ∘ Salalah power generating section
        - ∘ Raysut power generating section
        - ∘ Marbat power generating section
        - ∘ Sadah power generating section
        - ∘ Thaqa power generating section
        - ∘ Salalah distribution section
        - ∘ Raysut distribution section
        - ∘ Marbat distribution section
        - ∘ Sadah distribution section
        - ∘ Thaqa distribution section
      - Department of Administrative Affairs
        - ∘ Public relations and services section
        - ∘ Personnel affairs section
        - ∘ Transport section
        - ∘ Archives section
        - ∘ Maintenance section
      - Department of Financial Affairs
        - ∘ General accounts section
        - ∘ Stores accounts section
        - ∘ Salaries and treasury section
        - ∘ Stores section
        - ∘ Purchasing section
        - ∘ Accounts section
    - Directorate General of Projects
      - Chief Engineer - Energy
      - Chief Engineer - Water
      - Department of Administrative Affairs
      - Department of Financial Affairs
      - Planning Department
      - Contract Department-Tender Office
    - Directorate General of Water
      - Department of Administrative Affairs
        - ∘ Personnel affairs section
        - ∘ Public relations section
        - ∘ Transport section
        - ∘ Archives section
      - Department of Financial Affairs
        - ∘ General accounts section
        - ∘ Stores accounts section
        - ∘ Salaries and treasury section
        - ∘ Purchasing section
        - ∘ Stores section
      - Department of Technical Affairs
        - ∘ Muscat section
        - ∘ Mutrah section
        - ∘ Qurum section
        - ∘ Seeb section
        - ∘ Al Ghubrah section
        - ∘ Pumping station section
        - ∘ Excavation section
        - ∘ Maintenance section
        - ∘ Outside area section
      - Directorate of Rural Water
    - Directorate General of Electricity
      - Department of Administrative Affairs
        - ∘ Personnel affairs section
        - ∘ Public relations section
        - ∘ Transport section
        - ∘ Archives section
        - ∘ Riyam vehicle section
      - Department of Financial Affairs
        - ∘ General accounts section
        - ∘ Stores accounts section
        - ∘ Salaries and treasury section
        - ∘ Stores section
        - ∘ Purchasing section
      - Department of Technical Affairs
        - ∘ Planning section
        - ∘ Construction section
        - ∘ Operation and maintenance section
        - ∘ Equipment test section
        - ∘ Generating equipment section
        - ∘ Riyam power generating section
        - ∘ Ghubrah power generating section
        - ∘ Rusail power generating section
        - ∘ Distribution section
        - ∘ Distributing section emergency
        - ∘ Distributing Ruwi emergency
        - ∘ Distributing Qurum emergency
        - ∘ Distributing Seeb emergency
        - ∘ Distributing Barka emergency
        - ∘ Street lighting section
      - Directorate of Rural Electricity

4.2 EXISTING POWER FACILITIES

4.2.1 Power facilities in the Capital area

(1) Power stations

There are three power stations in the Capital area, and their total installed capacity as of the end of January 1985 is 566.1 MW as shown below:

Power station	Type of plant	Installed capacity (MW)
Ghubrah	Steam	72.5
Ghubrah	Gas turbine	212.5
Sub-total		285.0
Rusail	Gas turbine	249.0
Riyam	Diesel	32.1
Total		566.1

MEW has a plan to shift diesel units of Riyam power station to rural areas in the coming one or two years, and to install at Rusail gas turbine power station No. 4 and No. 5 units of each 83.0 MW in 1986 and No. 6 unit of 83.0 MW in 1987.

Power consumption for station service is estimated at 10.4 MW for Ghubrah power and desalination complex plant and 0.65% of installed capacity for Rusail gas turbine power station. Therefore, the total installed capacity and sending-end capacity in the Capital area excluding Riyam power station for 1986 and 1987 will be as follows:

(MW)

Power station	1986			1987		
	Installed capacity	Station service	Sending-end cap.	Installed capacity	Station service	Sending-end cap.
Ghubrah	285.0	10.4	274.6	285.0	10.4	274.6
Rusail	415.0	2.6	412.4	498.0	3.2	494.8
Total	700.0	13.0	687.0	783.0	13.6	769.4

(2) Transmission lines

Two double circuit 132 kV transmission lines run from Ghubrah power station, the one to Seeb substation and the other to Al Falaj substation. Another two double circuit 132 kV lines run from Rusail power station. They are to Seeb and Ghubrah substations.

The construction of three double circuit 132 kV transmission lines are scheduled to be started in June 1985. They are:

- From Rusail power station to Wadi Adai substation
- From Rusail power station to Barka substation
- From Wadi Adai substation to Wadi Kabir substation

In addition, tender call for the construction of double circuit 132 kV line between Barka substation and Musanna substation is scheduled to be made by the end of 1985.

33 kV and 11 kV lines are used for power distribution. The public supply is carried out at 200/240 V, 50 Hz.

(3) Substations

There are five 132/33 kV substations of Al Falaj (250 MVA), Wadi Adai (250 MVA), Rusail (150 MVA), Ghubrah (84 MVA) and Seeb (126 MVA).

Barka, Wadi Kabir and Musanna substations of each 250 MVA are under planning.

(4) Interconnection of Musanna, Suwaiq, Rustaq and Mabellah

Plan is on-going to supply electricity by 33 kV lines from Musanna substation under planning to three towns of Musanna, Suwaiq and Rustaq. These towns are now fed by diesel power stations. The interconnection of these towns and Mabellah with power system of the Capital area is scheduled to be commissioned in 1986.

4.2.2 Power facilities in the Batinah coast

(1) Power stations

In Musanna, Suwaiq and Rustaq there are diesel power stations of 7.4 MW, 6.9 MW and 7.2 MW, respectively. However, MEW plans to supply electricity to these towns from the Capital area by interconnected transmission line from 1986 as described before.

In the Batinah coast excluding the above towns, there are three power stations of the total installed capacity of 65.8 MW as shown below:

Location	Type of plant	Installed capacity (MW)
Copper mine	Gas turbine	51.0
Shinas	Diesel	3.9
Khabourah	Diesel	10.9
Total		65.8

Power station at copper mine is equipped with three gas turbine-generators of each 17.0 MW. Of these three units, one unit is of MEW, one unit of Oman Mining Company and the remaining one unit is operated for common use by MEW and Oman Mining Company. It is planned that two units of each 27.0 MW gas turbine-generator (MEW) be added to this power station in 1985 and two units of each 30.0 MW gas turbine-generator (Rural Development Committee) be added in 1986. Therefore, the total installed capacity at copper mine will increase to 105.0 MW in 1985 and 165.0 MW in 1986.

(2) Transmission lines and substations

Energy generated by gas turbine power station at copper mine is transmitted from Magan substation (66/33 kV) to three substations of Sohar, Saham and Majis (each 33/11 kV).

Power transmission to the Inland area such as Buraimi, Ibri and surrounding villages is planned to be started in 1986.

General characteristics of power facilities in the Capital area and in the Batinah coast are shown in Tables 4.2 and 4.3, respectively.

Transmission line map of the Capital area is shown in Fig. 4.1.

Table 4.2 Power facilities in the Capital area (January 1985)

1. Power stations

(MW)

Power station	Type of power plant	Unit capacity x No. of unit	Installed capacity	Commissioning year
Existing				
Ghubrah	Steam	3 x 7.5	22.5	1976
	Steam	1 x 50.0	50.0	1977
	Gas turbine	9 x 17.5	157.5	1978-79
	Gas turbine	2 x 27.5	55.0	1982
Total			285.0	
Rusail	Gas turbine	3 x 83.0	249.0	1984
Riyam	Diesel	1 x 4.98	4.98	1968
	Diesel	1 x 1.40	1.40	1972
	Diesel	1 x 2.40	2.40	1972
	Diesel	1 x 2.98	2.98	1972
	Diesel	3 x 6.78	20.34	1974-75
Total			32.1	
Grand total			566.1	
Under planning				
Rusail	Gas turbine	2 x 83.0	166.0	1986
	Gas turbine	1 x 83.0	83.0	1987

2. Transmission lines (132 kV)

Section	Line length(km)	Conductor
Existing		
Ghubrah P.S. - Wadi Adai S.S.	14	AAAC 400 sq mm x 2, 2 cct
Wadi Adai S.S. - Al Falaj S.S.	4	AAAC 400 sq mm x 2, 2 cct
Ghubrah P.S. - Rusail P.S.	22	ACSR 240 Sq mm x 1, 2 cct
Rusail P.S. - Seeb S.S.	14	ACSR 240 sq mm x 1, 2 cct
Bidded or uner planning		
Rusail P.S. - Wadi Adai S.S.	34	AAAC 400 sq mm x 2, 2 cct
Rusail P.S. - Barka S.S.	22	AAAC 400 sq mm x 2, 2 cct
Barka S.S. - Musanna S.S.	48	AAAC 400 sq mm x 2, 2 cct
Wadi Adai S.S. - Wadi Kabir S.S.	4	AAAC 400 sq mm x 1, 2 cct

3. Substations

Substation	Voltage (kV)	No. of unit x capacity (MVA)
Existing		
Al Falaj	132/33	2 x 125
Wadi Adai	132/33	2 x 125
Ghubrah	132/33	2 x 42
Rusail	132/33	2 x 75
Seeb	132/33	2 x 63
Bidded or under planning		
Barka	132/33	2 x 125
Musanna	132/33	2 x 125
Wadi Kabir	132/33	2 x 125

Table 4.3 Power facilities in the Batinah coast (January 1985)

1. Power stations

(MW)

Power station	Type of power plant	No. of unit x unit capacity	Installed capacity	Commissi-oning year
Existing				
Copper mine	Gas turbine	3 x 17.0	51.0	1981
Shinas	Diesel	2 x .465	50.0	1979
	Diesel	1 x 3.0	3.9	1984
Khabourah	Diesel	4 x .465	55.0	1979
	Diesel	1 x 3.0		1982
	Diesel	2 x 3.0	10.9	1984
Total			65.8	
Bidded or under planning				
Copper mine	Gas turbine	2 x 27.0	54.0	1985 (MEW)
	Gas turbine	2 x 30.0	60.0	1986 (RDC)

Note: In addition there are three power stations at Musanna (7.4 MW), Suwaiq (6.9 MW) and Rustaq (7.2 MW). These towns are planned to be fed by interconnected transmission line of the Capital area from 1986.

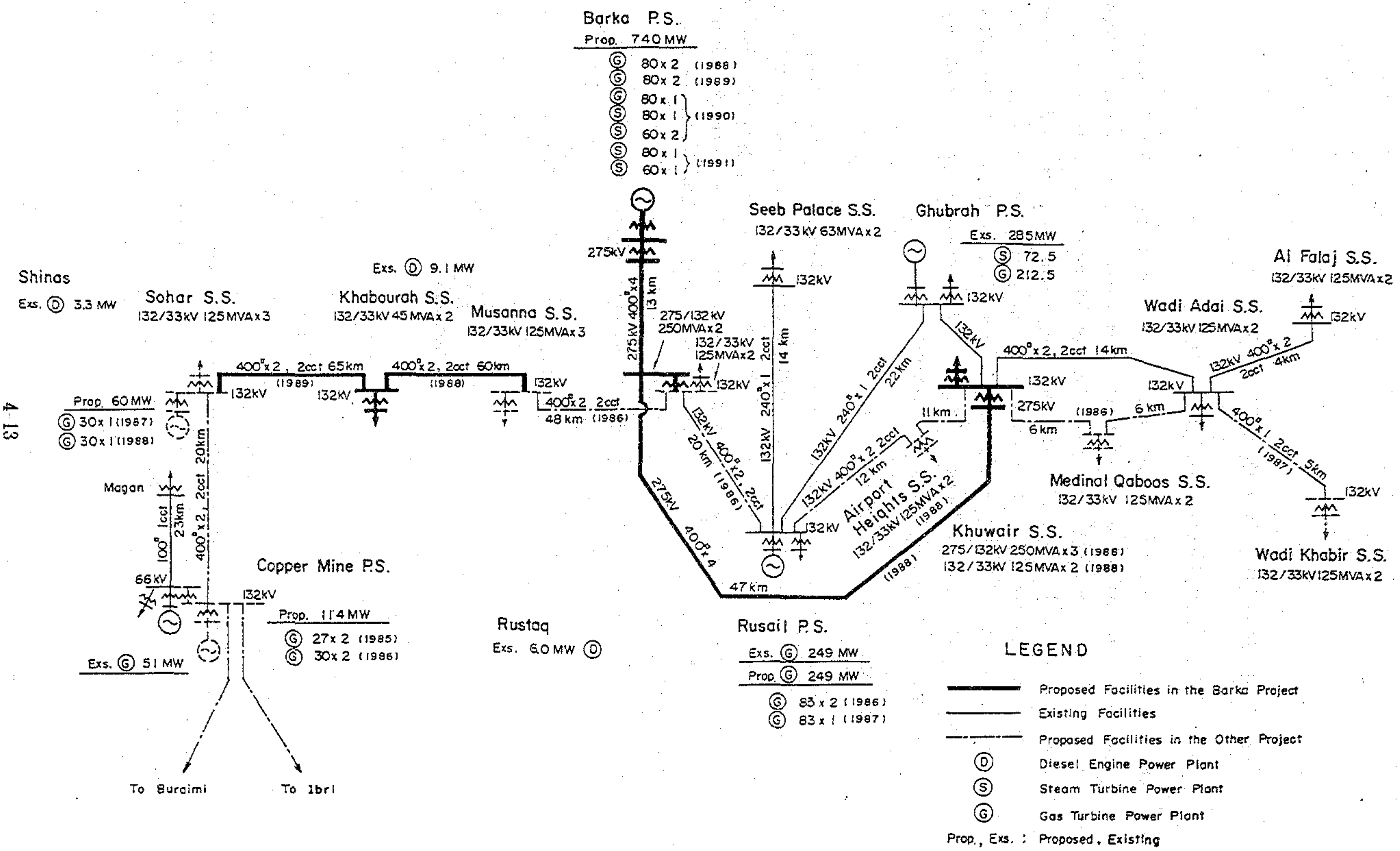
2. Transmission lines

Section	Line length (km)	Voltage (kV)
Existing		
Copper mine - Magan S.S.	22.7	66
Magan S.S. - Liwa S.S.		33
Magan S.S. - Majis S.S.	5.5	33
Majis S.S. - Sohar S.S.	21.0	33
Sohar S.S. - Saham S.S.	30.0	33
Under planning		
Copper mine - Ibri		

3. Substations

Substation	Voltage (kV)	Capacity (MVA)
Magan	66/33	
Liwa	33/11	3
Majis	33/11	3
Sohar	33/11	10
Saham	33/11	10

Fig. 4 · 1 ELECTRIC POWER SYSTEM
(Capital and Batinah Areas)



4.3 POWER GENERATION AND ELECTRICITY TARIFF

4.3.1 Power generation in the Capital area

Even the Capital area had remained under-developed until 1970. However, since then onwards and especially after discovering new oil fields around the middle of the 1970's, considerable sums of public and private funds have been spent on infrastructure including roads, schools, offices, residential accommodations, Qaboos port, Seeb international airport, etc., and the population of the Capital area has grown from 53,000 in 1970 to 241,000 in 1983, raising the standard of living. These developments have led to a very rapid growth in demand for electricity.

(1) Energy generation and peak load

Main load centers of the Capital area are Muscat, Mutrah, Ruwi, Qurum, Seeb, etc. Energy generation of the MEW's power stations grew rapidly from 214.2 GWh in 1976 to 1,512.6 GWh in 1984, while peak load grew from 46.6 MW in 1976 to 340.3 MW in 1984. Annual average growth rate of energy generation was 31.6% for the period from 1976 to 1980 and 23.9% for the period from 1980 to 1984. Annual average growth rate of peak load for the corresponding periods was 30.6% and 25.9%, respectively, as shown below:

Year	Energy generation (GWh)	Peak load (MW)
1976	214.2	46.6
1980	642.1	135.5
1984	1,512.6	340.3
Average growth rate		
1976-1980	31.6%	30.6%
1980-1984	23.9%	25.9%

(2) Load factor

Load factor was 54.7% in average for the period from 1976 to 1980, but fell down to 50.9% for the period from 1980 to 1984. This decline is explicated by the spreaded use of air cooler. In the summer months load increases sharply in accordance with rise in temperature.

(3) System loss factor

Energy loss factor for station service has decreased gradually to attain 5.7% in 1984. Historical data on energy sold could not be obtained, but in 1983 energy sold was 918.4 GWh against energy sent-out of 1,087.8 GWh. Therefore, it is estimated that transmission and distribution loss factor be around 15%.

4.3.2 Power generation in the Batinah coast

Main load centers of the Batinah coast are Sohar, Shinas, Saham, Khabourah, Musanna, Suwaiq and Rustaq. In these towns there are only residential and commercial consumers except for copper mining and smelting factory at inland of Sohar which produces about 20,000 tons of copper per annum.

Since it is only 4 to 6 years ago that electricity was introduced in the Batinah coast, the growth in power demand up to present was very rapid as shown below:

Towns	1980	1984
Sohar, Shinas, Saham, Khabourah	4.9 MW	29.0 MW
Musanna, Suwaiq, Rustaq	1.6 MW	19.2 MW (plus load shedding 1.0 MW)

Load factor fluctuates between 29% and 35% with an average of 32%.

Tables 4.4, 4.5 and 4.6 show power generation from 1976 to 1984 in the Capital area and in the Batinah coast.

4.3.3 Electricity tariff

MEW does not distinguish between different classes of consumers in the tariff charged. All electricity generated by MEW's power stations is sold to consumers at 20 Baizas per kWh plus monthly meter rent of 150 Baizas.

4.4 CHARACTERISTICS OF LOAD VARIATION

As seen in Table 3.1 of Chapter 3, the maximum temperature in the Capital area and in the Batinah coast reaches 45°C to 47°C in the summer season, while in the winter season the minimum temperature sometimes falls down to below 10°C.

The share of industrial load in the total power demand is small, therefore residential load (mainly of air cooler) which is sensitive to change in temperature plays a predominant role in the load variation. Characteristics of monthly and daily load variations are described as follows:

4.4.1 Monthly load variation

When analyzing monthly peak load, minimum load and average load calculated from monthly energy generation, the following characteristics of monthly load variation can be pointed out:

a) In the minimum load days in January and February, the daily maximum and minimum loads are about 30 to 33% and 17% of the annual peak load respectively.

b) However, monthly average load in January and February is about 24% of the annual peak load, and during these two months the difference of demand size is almost negligible between minimum load day and maximum load day. Therefore, it can be considered that the base load is below around 25% of the annual peak load in the load curve.

4.4.2 Daily load variation

From daily load curves of the annual peak load day (June 19, 1984) and the annual minimum load day (February 3, 1984), the following characteristics are pointed out for daily load variation in the Capital area:

a) Daily peak load in the summer season occurs at around 14:00 to 15:00 hours due to air-conditionning, while in the winter season it occurs between 17:00 and 21:00 hours reflecting lighting load.

b) Both in the summer season and in the winter season, load fairly falls down from mid-night to early morning but the minimum load is fairly high, namely about 65% of the daily peak load. It is only 3 to 4 hours per day that the load falls down below 70% of the daily peak load.

Fig. 4.2 shows daily load curves of the peak load day and the minimum load day in 1984. Monthly load variation and monthly load curve are shown in Table 4.7 and Fig. 4.3, respectively.

Table 4.4 Energy generated and energy sent-out in the Capital area

(GWh)

Month	1976	1977	1978	1979	1980	1981	1982	1983	1984
Energy generation									
January	-	-	-	-	23.9	31.0	36.9	47.2	59.5
February	-	-	-	-	24.5	29.1	32.4	42.7	54.6
March	-	-	-	-	31.6	39.1	42.4	50.3	78.4
April	-	-	-	-	55.3	61.5	69.3	68.3	130.0
May	-	-	-	-	70.8	77.3	104.7	134.6	165.5
June	-	-	-	-	74.4	93.3	119.3	155.9	184.7
July	-	-	-	-	81.6	106.0	121.3	148.1	186.2
August	-	-	-	-	69.7	97.6	117.1	136.1	175.8
September	-	-	-	-	67.0	87.5	103.5	131.9	167.5
October	-	-	-	-	64.5	73.8	102.9	112.6	132.3
November	-	-	-	-	45.0	47.6	65.2	76.0	95.0
December	-	-	-		33.7	40.1	48.0	63.9	83.2
Total	214.2	329.2	376.7	497.7	642.1	783.9	963.0	1,167.6	1,512.6
Energy sent-out									
January	-	-	-	-	20.0	26.8	32.3	40.9	52.5
February	-	-	-	-	21.1	25.2	28.9	36.8	48.8
March	-	-	-	-	30.0	35.6	40.9	46.1	72.6
April	-	-	-	-	52.4	58.8	64.6	62.7	122.5
May	-	-	-	-	64.9	72.3	98.8	128.2	158.7
June	-	-	-	-	68.2	87.6	113.2	148.2	176.7
July	-	-	-	-	75.6	99.9	115.1	140.1	177.9
August	-	-	-	-	63.9	91.7	111.3	128.6	167.8
September	-	-	-	-	62.6	81.8	97.8	124.0	159.7
October	-	-	-	-	59.1	68.1	95.8	105.1	124.6
November	-	-	-	-	40.4	42.7	60.4	69.8	88.1
December	-	-	-	-	29.1	35.2	43.1	57.3	75.6
Total	188.1	294.8	327.0	434.0	586.8	725.9	902.2	1,087.8	1,425.6
Loss factor (%)	12.2	10.4	13.2	12.8	8.6	7.4	6.3	6.8	5.7

Table 4.5 Peak load in the Capital area

Month	1976	1977	1978	1979	1980	1981	1982	1983	1984
January	-	-	-	-	46.6	61.7	74.5	87.0	113.0
February	-	-	-	-	56.3	66.7	78.0	98.9	113.5
March	-	-	-	-	72.5	80.2	102.0	105.5	190.5
April	-	-	-	-	111.2	125.0	147.5	171.5	258.0
May	-	-	-	-	119.5	153.0	190.0	252.0	309.0
June	-	-	-	-	127.5	160.8	211.5	281.0	340.3
July	-	-	-	-	135.5	175.4	214.0	276.5	332.5
August	-	-	-	-	124.9	169.5	196.7	247.4	301.2
September	-	-	-	-	116.8	152.2	189.8	227.7	295.2
October	-	-	-	-	112.6	138.3	183.9	214.0	254.0
November	-	-	-	-	91.0	95.0	144.6	148.0	191.0
December	-	-	-	-	71.0	76.7	101.8	123.2	161.0
Annual peak load	46.6	65.3	76.8	106.5	135.5	175.4	214.0	281.0	340.3
Load factor (%)	52.5	57.5	55.8	53.6	54.1	51.1	51.4	47.4	50.7

Table 4.6 Energy generation and peak load in the Batinah coast

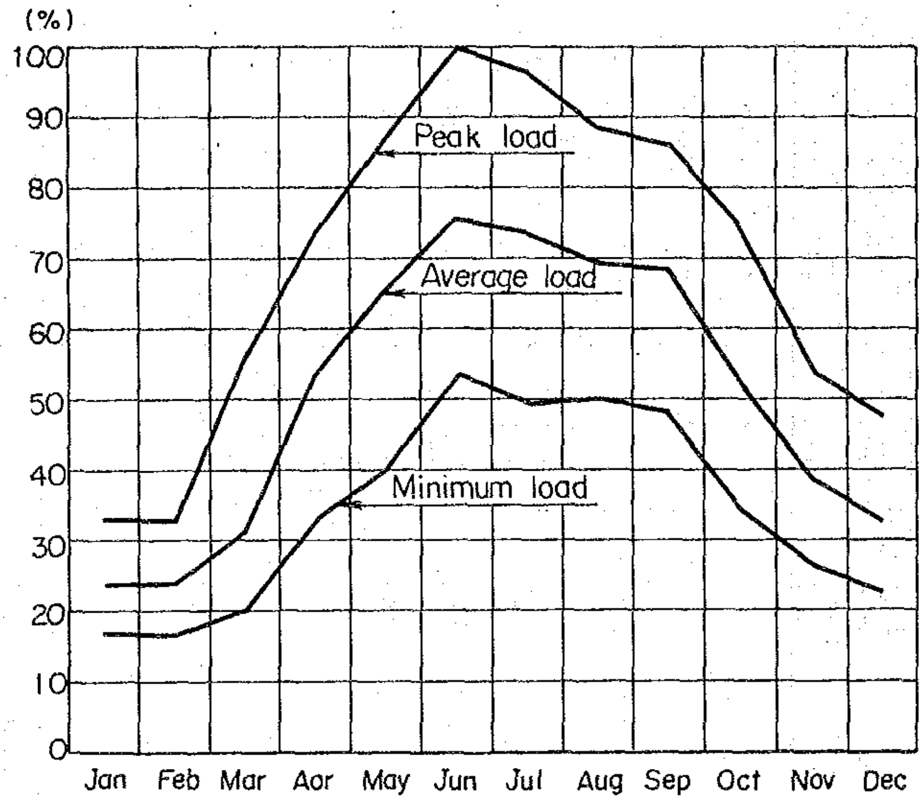
Town	Energy generation (MWh)					Peak load				
	1980	1981	1982	1983	1984	1980	1981	1982	1983	1984
Suwaiq	1,060	3,748	5,466	13,522	21,033	420	985	985	4,080	6,900
Musanna	1,239	3,197	4,918	12,381	15,726	480	1,000	940	4,000 (1,000)	5,450
Rustaq	2,315	3,743	7,179	10,616	17,363	705	1,200	3,000	5,600	6,810 (1,000)
Total	4,614	10,688	17,563	36,519	54,122	1,605	3,185	4,925	13,680 (1,000)	19,160 (1,000)
Shinas	1,980	3,211	4,197	4,451	7,387	720	990	980	980 (600)	2,800
Saham	3,047	5,859	8,341	-	-	990	1,920	1,920	5,250 (2,000)	7,900
Sohar	7,345	13,267	22,241	-	-	2,310	4,500	6,700	7,200	10,600
Khabourah	1,930	3,580	6,343	17,018	21,753	915	1,745	1,820	4,800 (2,800)	7,670
Total	14,302	25,917	41,122	-	-	4,935	9,175	11,420	18,230 (5,460)	28,970

Note: Figures in parentheses mean load shedding.

Table 4.7 Monthly load variation
(1984)

Month	Peak load day		Minimum load day		Average load		Ratio to annual peak load			
	Maximum load (MW)	Minimum load (MW)	Maximum load (MW)	Minimum load (MW)	Energy generat. (GWh)	Average load (MW)	Peak load day (%)	Minimum load day Maximum (%)	Minimum load day Minimum (%)	Average load (%)
January	111.8	61.3	110.5	57.6	59.5	80.0	32.9	32.5	16.9	23.5
February	111.7	60.0	102.0	56.3	54.6	81.3	32.8	30.0	16.5	23.9
March	190.5	117.0	120.7	67.5	78.4	105.4	56.0	35.4	19.8	31.0
April	249.0	146.0	175.4	111.5	130.0	180.6	73.2	51.5	32.8	53.1
May	296.0	211.0	206.0	136.8	165.5	222.4	87.0	60.5	40.2	65.4
June	340.3	225.5	306.2	182.0	184.7	256.5	100.0	90.0	53.5	75.4
July	328.8	237.5	261.2	168.2	186.2	250.3	96.6	76.8	49.4	73.6
August	301.8	194.2	250.2	171.2	175.8	236.3	88.7	73.5	50.3	69.4
September	294.6	201.2	257.8	165.1	167.5	232.6	86.5	75.8	48.5	68.4
October	254.0	157.0	176.0	116.0	132.3	177.8	74.6	57.7	34.1	52.2
November	184.0	110.0	153.0	91.0	95.0	131.9	54.1	45.0	26.7	38.8
December	161.0	101.0	133.0	78.0	83.2	111.8	47.3	39.1	22.9	32.9
Total or average					1,512.6	172.7				50.7

Table 4.2 Monthly load curve and annual duration curve (1984)



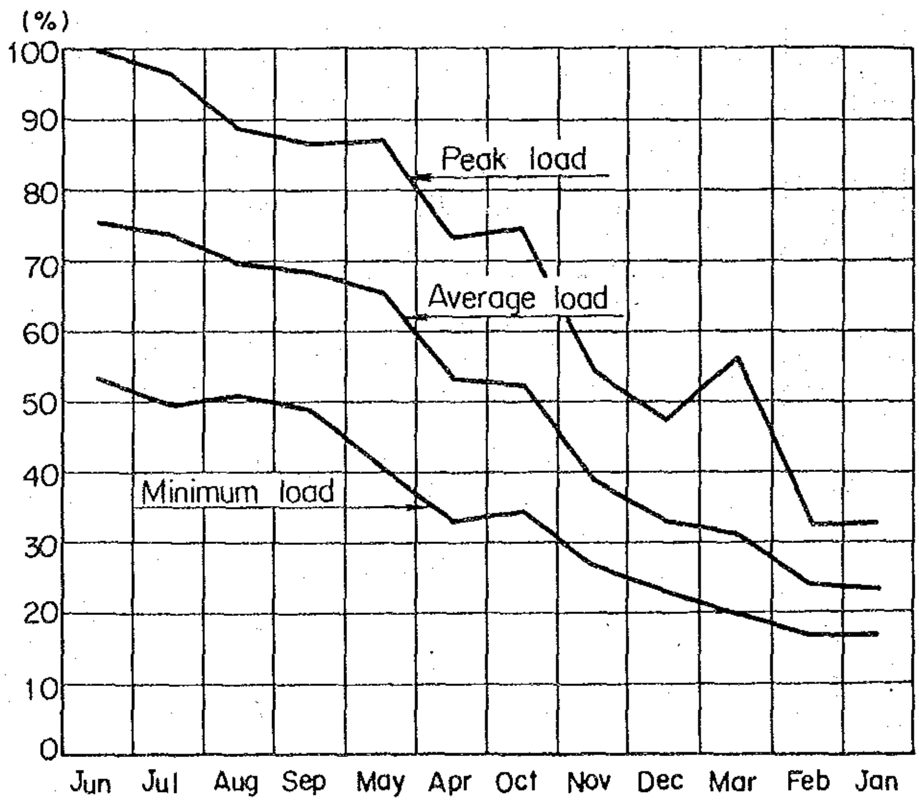
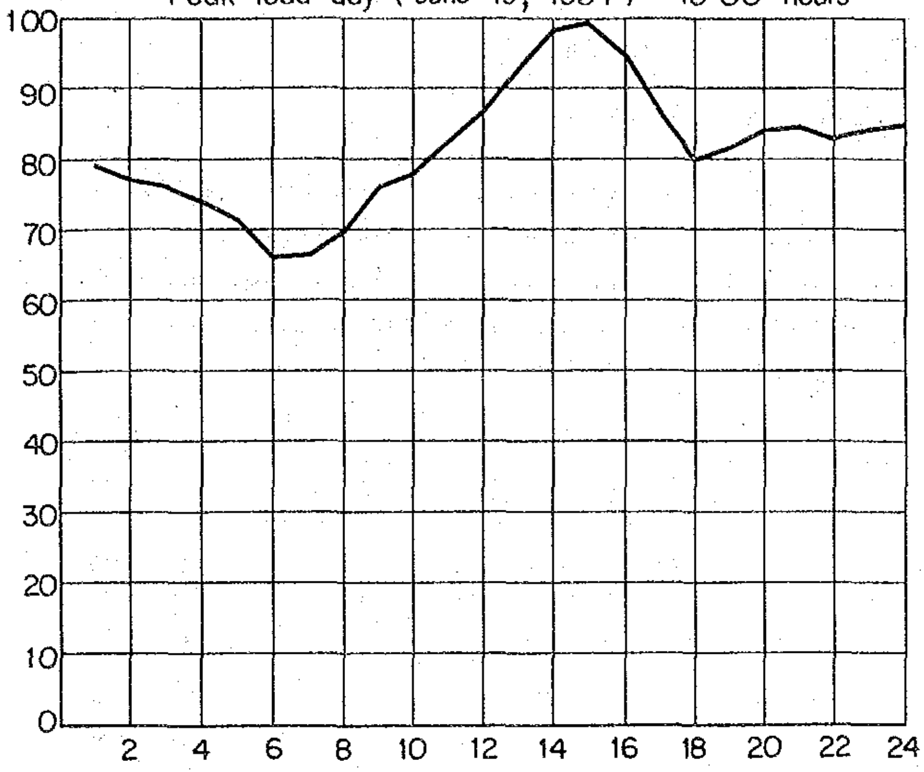


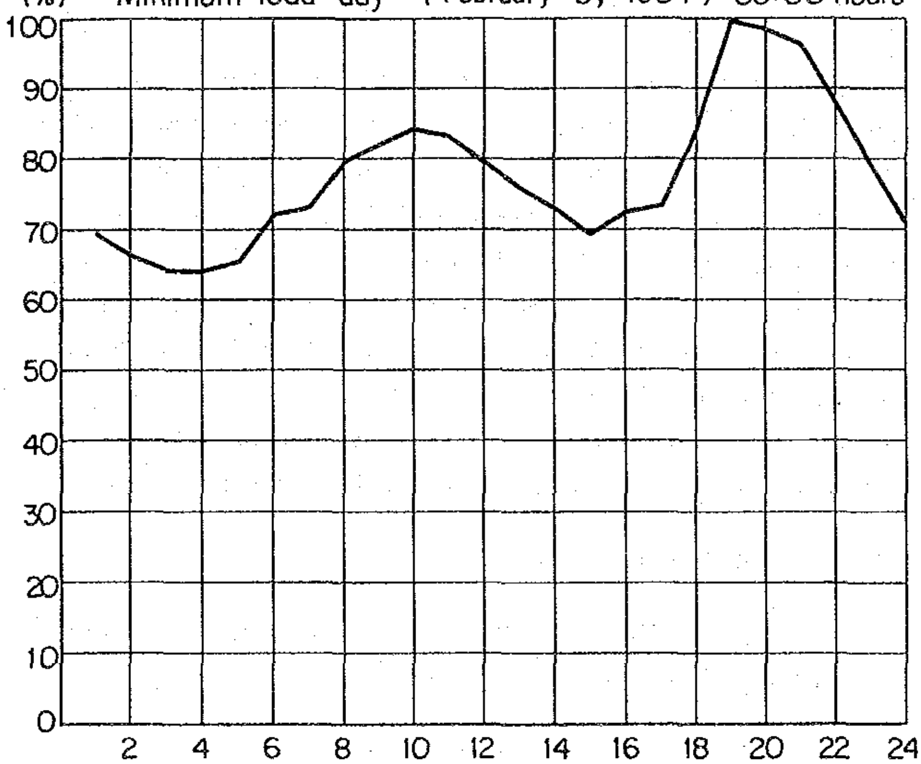
Fig. 4.3 Daily load curve (1984)

Peak load day (June 19, 1984) 15:00 hours



(hr)	(MW)	(%)
1	269.5	79.2
2	264.5	77.7
3	260.5	76.5
4	253.5	74.5
5	242.5	71.2
6	225.5	66.2
7	226.5	66.5
8	238.5	70.0
9	259.5	76.2
10	266.5	78.3
11	281.5	82.7
12	298.2	87.6
13	317.5	93.2
14	336.5	98.9
15	340.3	100.0
16	323.8	95.2
17	295.0	86.9
18	272.5	80.0
19	277.5	81.5
20	286.5	84.1
21	287.5	84.5
22	283.5	83.3
23	287.5	84.5
24	289.5	85.0

Minimum load day (February 3, 1984) 03:00 hours



(hr)	(MW)	(%)
1	62.5	69.8
2	59.5	66.5
3	57.5	64.2
4	57.5	64.2
5	58.5	65.4
6	64.5	72.1
7	65.5	73.2
8	71.5	80.0
9	73.5	82.1
10	75.5	84.4
11	74.5	83.2
12	71.5	80.0
13	68.5	76.5
14	65.5	73.2
15	62.5	69.8
16	64.5	72.1
17	65.5	73.2
18	75.5	84.4
19	89.5	100.0
20	88.5	98.9
21	86.5	96.6
22	79.5	88.8
23	71.5	80.0
24	64.0	71.5

4.5 LOAD FORECAST

4.5.1 Load forecast for the Capital area

(1) MEW's load forecast (1985 - 1990)

For the Capital area, MEW has a load forecast for the period from 1985 to 1990. This forecast is made on a micro-economic framework in which lighting load, industrial load, new bulk load, as well as, loads produced by the execution of community project and power system expansion are taken into account. Detail of this load forecast is shown below:

(MW)

Category	1984 (Actual)	1985	1986	1987	1988	1989	1990
a) Lighting load	305.3	378	413	448	474	500	527
b) Industrial load	35	45	45	60	60	60	60
c) New bulk load	-	6	55	86	87	87	87
Sub-total	340.3	425	513	595	621	647	674
d) Community project	-	-	15	40	140	220	290
e) Power system expansion	-	-	58	68	79	91	104
Total	340.3	425	586	703	840	958	1,068

In the above table, items a), b) and c) show the natural growth of power demand due to growth in population, development of industries and some on-going projects such as Qaboos university, hospitals, etc. The community project of item d) includes Khuwair south town, Ghubrah south town, Qurum beach town, Airport Heights town, Azaiba town, Nahaba town, etc. This is a very big project, and its total load is expected to attain 290 MW in 1990 which exceeds the peak load of the Capital area recorded in 1983 (281 MW). Item e) shows the power demand of the Batinah coast in the eastern part such as Musanna, Suwaiq, Rustaq, Mabellah which will be connected to the power system of the Capital area through expansion of transmission line.

(2) Review of the MEW's load forecast

It is well known that there is a close correlation between growth in power demand and that in the national economy represented by GDP.

There also exists a close correlation between growth in power demand and that in population. Therefore, as a macroscopic method, it is possible to forecast demand for electricity by inputting anticipated growth in population and GDP in a multiple regression model made by using recorded population and GDP in the past as the independent variables and power generation as the dependent variable.

Based on the time-series data on GDP, consumer prices index, population of the whole country and that of the Capital area for the period from 1976 through 1983, the following multiple regression model was obtained. The detail is shown in Table 4.8.

$$y = 0.25733\, x_1 + 5.51291\, x_2 - 857.4$$

Where: y : Energy generation (GWh)

x_1 : GDP/Capita (Rial Oman)

x_2 : Population in the Capital area (1,000 p.)

Note: Multiple correlation coefficient of the above equation:
$R^2 = 0.999$

The result of demand forecast for electricity obtained by using the above regression model is shown in Table 4.9. In this forecast, GDP was assumed to grow at an average annual rate of 13.1% for the period from 1980 to 1985 (target of the Second 5-Year Plan) and 12.0% for the period from 1985 to 1990, while population of the country was assumed to increase at an average annual rate of 3.15% and that of the Capital area at an average annual rate of 8.8% (same as before) for the period from 1980 through 1990.

Comparison of these two load forecasts shows that the load forecasted by using the regression model is almost the same as the total load of items a), b) and c) of the MEW's forecast as shown below:

	Peak load in 1990
Load forecasted by regression model	668 MW
Load forecasted by MEW (Items a), b), c)	674 MW

From the above, MEW's forecast on the natural growth of power demand shown in items a), b) and c) is considered reasonable.

Since the independent variables (GDP and population in the past) used for making the above regression model does not include big events such as large-scale community project and power system expansion, the regression model cannot cover loads of items d) and e). Both the community project and the power system expansion project are now on-going. Therefore, for the period up to 1990 it is considered appropriate to use as the basis of planning the MEW's load forecast covering items a), b), c), d) and e).

(3) Load forecast for the period 1991 - 1995

JICA study team prepared load forecast for the period from 1991 through 1995 in the following manner:

a) Lighting load of the existing consumers

The growth rate of lighting load over the previous year was forecasted by MEW to decrease from 10.4% in 1986 to 5.5% in 1990. Taking this into consideration, JICA study team adopted an average growth rate of 5.5% per annum for lighting load of the existing consumers for the period from 1991 to 1995.

b) Industrial load

The industrial load was forecasted to remain constant at 60 MW from 1987 to 1990 by MEW. JICA study team forecasted that the load will grow by 5 MW every year from 1991 to 1995 at Rusail industrial estate and elsewhere.

c) Bulk load

The bulk load including Qaboos university and its hospital and Ghubrah hospital was forecasted to remain at 87 MW from 1987 to 1990 by MEW. JICA study team forecasted that this load will remain constant at 87 MW up to 1995.

d) Load of new communities

The load of new communities forecasted by the Ministry of Housings is 290 MW for 1990 which is comparable with the total power demand of the Capital area in 1983 (281 MW).

The lighting load of the existing consumers was forecasted by MEW to grow from 281.0 MW in 1983 to 527 MW in 1990 an average growth rate of 9.5% per annum.

The conditions will be almost the same for the existing lighting consumers and consumers of the new communities. Hence, it will be appropriate to consider that the growth in power demand of the new communities after 1990 will be similar to that of the existing lighting load from 1983 to 1990. Therefore, an average rate of 9.5% per annum was adopted for power demand of these new communities for the period from 1991 to 1995.

e) Load by power system expansion

The load of Musanna, Suwaiq, Rustaq and Mabellah was forecasted to grow at an average rate of 15.7% per annum for the period from 1986 to 1990 by MEW. JICA study team estimated that the growth tempo of power demand for the period from 1991 to 1995 will be slightly lower, namely 15.0% per annum.

Based on the above conditions, the power demand of the Capital area for the period up to 1995 was forecasted as shown in Table 4.10.

4.5.2 Load forecast for the Batinah coast and Inland area

(1) Load forecast for 1985 to 1990

In the western part of the Batinah coast there are six towns of Khabourah, Saham, Sohar, Majis, Liwa and Shinas, of which Khabourah and Shinas are supplied with energy by their diesel power stations and the other towns are fed by gas turbine power station of copper mining and smelting plant constructed in the inland of Sohar. The total installed capacity of this gas turbine power station is 51.0 MW at the end of January 1985, but it is planned that this capacity be increased to 165.0 MW in 1986 to supply power to other nine towns in the Inland area including Buraimi and Ibri.

For these towns except for Khabourah, MEW has a load forecast for the period from 1985 to 1990. Data on population, income and other relevant information necessary for forecasting load of these towns are not available. Therefore, it is appropriate to use MEW's load forecast. The following is the MEW's load forecast for the above towns combined with JICA team's forecast for Khabourah town:

	1985	1986	1987	1988	1989	1990
Khabourah (Note 1)	9	10	12	13	16	18
Other towns (MEW's forecast)						
Magan feeder (Note 2)	27	41	51	61	73.5	87
Copper mining and smelting plant	17	17	17	17	17	17
Other towns (Note 3)	28	68	83	100	118.5	136
Sub-total	72	127	151	178	209	240
Total	81	137	163	191	225	258

Note 1. Annual growth rate of 15% is adopted (Same for Musanna, Suwaiq, Rustaq and Mabellah)

Note 2. Sohar, Saham, Liwa, Majis and Shinas

Note 3. Buraimi, Al Wasit, Hafit, Sunaynah, Dank, Ibri, Mahada, Yanqul and Mazim

(2) *Load forecast for the period 1991 - 1995*

The load for the period from 1991 to 1995 was forecasted by JICA study team as follows:

a) *Saham, Sohar, Liwa, Majis, Shinas and Khabourah*

Since the economic conditions and stage of development of these towns are similar to Musanna, Suwaiq, Rustaq, etc. which are scheduled to be connected to the power system of the Capital area in 1986, the same growth rate of 15% per annum was adopted.

b) Copper mining and smelting plant

The production capacity of the above plant does not change, so the load was forecasted to remain constant at 17 MW up to 1995.

c) Buraimi

The load is forecasted to grow at an average rate of 12.3% for the period from 1985 to 1990 by MEW. JICA study team estimated that the growth tempo of power demand from 1991 to 1995 will be slightly lower, namely 10.0% per annum.

d) Al Wasit, Hafit, Sunaynah, Dank and Mazim

Because of the initial stage of electrification, the power demand of the above towns was forecasted to grow at a high rate of 22% in average up to 1990 by MEW, but after 1990 the growth tempo will be lower. JICA study team adopted an average growth rate of 15% per annum.

e) Ibri, Yanqul and Mahada

Considering that the load of the above towns was forecasted to grow at an average rate of 16.0% per annum up to 1990 by MEW, JICA study team adopted an average growth rate of 12.0% per annum for the period from 1991 to 1995.

The power demand forecast made on the above conditions for the Batinah coast and Inland area is shown in Table 4.11.

(3) Load to be fed by Barka power station

The power demand and supply balance in the Batinah coast and Inland area is shown in Table 4.11. According to this table, the required capacity including reserve capacity of one largest unit is forecasted to grow from 167 MW in 1986 to 193 MW in 1987 and 211 MW in 1988. Therefore, against supply capability of 165 MW in 1986 the shortage in supply capacity of 2 MW in 1986, 28 MW in 1987 and 56 MW in 1988 will be produced as shown below:

(MW)

Year	Peak Load	Reserve capacity	Required capacity	Installed capacity in 1986	Balance
1986	137	30	167	165	-2
1987	163	30	193	165	-28
1988	191	30	221	165	-56

Taking the above conditions into account, it is suggested that two units of each 30 MW gas turbine-generator be installed near Sohar town in 1987/1988. The power demand and supply balance in Table 4.11 gives the conditions after installation of these two units of gas turbine-generator. The load exceeding the required supply capacity must be supplied by Barka power station.

In this context, it is to be noted that the capacity of two diesel power stations at Khabourah and Shinas is not considered in the above supply capability of the Batinah coast.

Table 4.8 Multiple regression model

1. Parameters

Year	GDP at current prices (Milion R.O.)	Consumers prices index (1978=100)	GDP at 1978 price (Million R.O.)	Population of the country (1,000)	GDP/capita (R.O.)	Population of Capital area (1,000)	Energy generation (Capital area) (GWh)
1976	884.3	85.0	1,040.0	790	1,316	133	214.2
1977	946.8	87.7	1,080.0	814	1,327	148	329.2
1978	947.5	100.0	947.5	839	1,129	163	376.7
1979	1,289.5	108.5	1,188.5	864	1,376	178	497.7
1980	2,066.6	119.3	1,732.3	890	1,946	195	642.1
1981	2,506.4	122.7	2,042.7	920	2,220	210	783.9
1982	2,609.7	124.0	2,104.6	950	2,215	226	963.0
1983	2,741.3	118.6	2,311.4	980	2,359	241	1,167.6
Total					13,888	1,494	4,974.4
Median					$\overline{x_1} = 1,736$	$\overline{x_2} = 186.8$	$\overline{y} = 621.8$

2. Multiple regression equation

$$y = 0.25733x_1 + 5.51291x_2 = 857.4$$

Multiple correlation coefficient: $R^2 = 0.999$

Source: GDP and consumers prices index - Statistical Year Book (Development Council)
Population of the country - International Monetary Fund (United Nations)
Population of Capital area - Middle East Electricity (1983)
Energy generation - Ministry of Electricity and Water

Table 4.9 Power demand forecast by multiple regression method

(Reviewal of MEW's load forecast)

Year	GDP at 1978 price	Population of the country	GDP/capita	Population of Capital area	Energy generation	Load factor	Peak load	
							JICA's forecast	MEW's forecast (without community projects)
	(Million R.O.)	(1,000)	(R.O.)	(1,000)	(GWh)	(%)	(MW)	(MW)
1985	3,206	1,043	2,941	286	1,547	49.0	360	425
1986	3,590	1,076	3,195	311	1,784	50.0	407	513
1987	4,021	1,109	3,475	339	2,049	51.0	459	595
1988	4,504	1,144	3,776	369	2,338	51.0	523	621
1989	5,045	1,180	4,104	402	2,660	51.5	590	647
1990	5,650	1,218	4,457	438	3,014	51.5	668	674
1991	6,215	1,256	4,754	460	3,281	52.0	720	-
1992	6,836	1,296	5,068	483	3,567	52.0	783	-
1993	7,520	1,337	5,404	507	3,875	52.5	843	-
1994	8,272	1,379	5,764	532	4,207	52.5	915	-
1995	9,099	1,422	6,148	559	4,569	53.0	984	-
Annual growth rate:								
1980-85	13.1%	3.15%		8.8%			21.6%	25.7%
1985-90	12.0%	3.15%		8.8%			13.2%	9.7%
1990-95	10.0%	3.15%		5.0%			8.0%	-

Table 4.10 Load forecast for the Capital area

(MW)

Category	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
1. Lighting load											
Capital area	253	388	419	440	462	485					
Fanga/Sumail	10	12	14	16	18	20					
Qurait area	11	13	15	18	20	22					
Sub-total	374	413	448	474	500	527	556	587	619	652	690
2. Industrial load											
Cement factor	20	20	25	25	25	25					
Oil refinery factory	15	15	20	20	20	20					
Rusail industrial estate	10	10	15	15	15	15					
Sub-total	45	45	60	60	60	60	65	70	75	80	85
3. New bulk load (A)											
Qaboos university	6	35	65	65	65	65					
Hospital of the above	-	10	10	10	10	10					
Ghubrah hospital	-	10	12	12	12	12					
Sub-total	6	55	87	87	87	87	87	87	87	87	87
Total	425	513	595	621	647	674	708	744	781	819	862
4. New bulk load (B)											
Khuwair south town	-	7	20	30	30	30					
Ghubrah south town	-	8	20	30	30	30					
Qurum beach town	-	-	-	10	20	30					
Airport Heights town	-	-	-	40	80	110					
Azaiba town	-	-	-	10	20	30					
Nahaba town	-	-	-	20	40	60					
Sub-total	-	15	40	140	220	290	352	388	421	439	456
5. New interconnection	-	58	68	79	91	104	120	138	158	182	209
Grand total	425	586	703	840	958	1,068	1,180	1,270	1,360	1,440	1,527

Table 4.11 Load forecast and power demand and supply balance for the Batinah coast and inland areas

(MW)

Load center	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Khabourah	9	10	12	13	16	18	20	24	27	31	36
MAGAN feeder (Sohar, Saham, Majis, Liwa and Shinas)	27	42	51	61	73.5	87	100	115	132	152	175
Copper mine	17	17	17	17	17	17	17	17	17	17	17
Buraimi	28	32	34	39	45	50	55	61	67	73	81
Al Wasit	-	4	5	6	7	8	9	11	12	14	16
Hafit	-	-	1.5	2	2.5	3	3	4	5	5	6
Sunaynah	-	-	1.5	2	2.5	3	3	4	5	5	6
Dank	-	5	6	8	9	11	13	15	17	19	22
Ibri	-	12	15	18	22	26	29	33	37	41	46
Mahada	-	9	11	13	16	18	20	23	25	28	32
Yanqul	-	6	8	10	12	14	16	18	20	22	25
Mazim	-	-	1	2	2.5	3	3	4	5	5	6
Total	81	137	163	191	225	258	288	329	369	412	468
Supply capability (Gas turbine only)	(2x27) 105	(2x30) 165	(1x30) 195	(1x30) 225	225	225	225	225	225	225	225
Balance	24	28	32	34	0	-33	-63	-104	-144	-187	-243
Reserve capacity	-27	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30
Total balance	-3	-2	2	4	-30	-63	-93	-134	-174	-217	-273

4.6 POWER DEVELOPMENT PROGRAM

4.6.1 Development scale of Barka power station

(1) Reserve capacity

In order to secure high reliability of power system operation, a certain amount of generating capacity has to be reserved in the power system. Criteria for reserving capacity differs by power system according to number of generating units, scale of power system, etc. In case of the Capital area and Batinah coast, if there is no large reasonal variation of load it will be appropriate to reserve capacity of the largest and the second largest units. However, in this area the seasonal load variation is very large, i.e. the load in January and February falls down to about one-third of the annual peak load occurring generally in June or July as shown in Table 4.7. Therefore, outage of generating units for maintenance can be executed concentrically in January, February and other low load months without doing it in June and July. Taking these into consideration, capacity of one largest unit was taken as the reserve capacity of power system.

(2) Overall demand and supply balance and power development program

Table 4.12, made by using Tables 4.10 and 4.11, shows the overall power demand and supply balance in the Capital area and Batinah coast. The overall balance shows that it is appropriate for Barka power station to be equipped with more than 700 MW taking into account the following conditions:

a) Against supply capability of 769 MW of the Capital area in 1987, shortage in supply capacity will be 149 MW in 1988, 586 MW in 1991 and 717 MW in 1992 including Capital area and Batinah coast.

b) Barka desalination plant is scheduled to be completed by the end of 1990 with the ultimate capacity of 180,000 m^3/day which can meet the growth in demand for water up to 1995.

One idea for developing Barka power station will be as follows:

Year of commissioning	Capacity commissioned	Accumulated total	Note
1988	160 MW	160 MW	Gas turbine only
1989	160 MW	320 MW	"
1990	280 MW	600 MW	Steam turbine and gas turbine
1991	140 MW	740 MW	"

4.7 OPERATION PROGRAM OF BARKA POWER STATION

4.7.1 Load sharing by type of power plant

Barka power station, as described in Chapter 7, will consist of two types of plant, i.e. one plant is to be operated for dual purpose of power generation and desalination and the other plant for single purpose of power generation, taking into account the forecasted demands for electricity and water.

Using Table 4.7, the peak load, average load and minimum load of every two months for the period from 1985 to 1995 can be forecasted as shown in Table 4.13, and from this table the annual load curve can be traced as shown in Fig. 4.4. In this load curve, it is considered that the base load be supplied by dual purpose plants of Barka and Ghubrah and the middle load be supplied by Barka single purpose plant of high thermal efficiency. The peak load will be fed by gas turbine-generators of Rusail and Ghubrah.

4.7.2 Generation program of Barka power station

Seen from Fig. 4.4, the maintenance of Barka power station (1.5 months for each generating unit) is scheduled to be carried out in January, February and other low load months. Taking into consideration the shape of load curve and outage period of generating units, the generation program of Barka power station can be established as shown in Tables 18.1 (a) and 18.1 (b).

Table 4.12 Overall power demand and supply balance in the interconnected system, and power development program

(MW)

Item	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Power demand											
Capital area	425	586	703	840	958	1,068	1,180	1,270	1,360	1,440	1,527
Shortage in Batinah and inland				4	-30	-63	-93	-134	-174	-217	-273
Total	425	586	703	836	988	1,131	1,273	1,404	1,534	1,657	1,800
Supply capability (Capital area)	522	687	769	769	769	769	769	769	769	769	769
Balance	97	101	66	-67	-219	-362	-504	-635	-765	-888	-1,031
Reserve capacity (Capital area)	-82	-82	-82	-82	-82	-82	-82	-82	-82	-82	-82
Total balance	15	19	-16	-149	-301	-444	-586	-717	-847	-970	-1,113
Power development program											
∘ Barka power station											
Commissioning				2x80	2x80	2x60 2x80	1x80 1x60				
Total capacity				160	320	600	740				
∘ Other new power station											
Commissioning									2x80	2x80	2x80
Total capacity									160	320	480
∘ Station service loss				-1	-2	-30	-30		-31	-33	-34
∘ Capacity at sending-end				159	318	570	710	710	869	1,027	1,186
Final balance	15	19	-16	10	17	126	124	-7	22	57	73

Note: Power loss for station service is estimated.

Table 4.13 Monthly load forecast for the interconnected system

Month	Ratio to peak load	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Peak load												
February	32.8%	139	192	231	276	324	371	418	461	503	543	590
April	73.6%	313	431	517	618	727	832	937	1,033	1,129	1,220	1,325
June	100.0%	425	586	703	840	988	1,131	1,273	1,404	1,534	1,657	1,800
August	88.7%	377	520	624	745	876	1,003	1,129	1,245	1,361	1,470	1,597
October	74.6%	317	437	524	627	737	844	950	1,047	1,147	1,236	1,343
December	47.3%	201	277	333	397	467	535	602	664	725	783	851
Average load												
February	23.9%	102	140	184	200	236	270	304	336	367	396	430
April	53.1%	221	311	373	446	524	600	676	745	815	880	956
June	75.4%	320	442	530	633	745	853	960	1,059	1,157	1,249	1,357
August	69.4%	295	407	488	583	686	785	883	974	1,065	1,150	1,249
October	52.2%	222	306	367	438	516	590	665	733	800	865	940
December	32.9%	140	193	231	276	325	372	419	462	505	545	592
Minimum load												
February	16.5%	70	97	116	139	163	187	210	231	253	273	297
April	32.8%	139	192	231	276	324	371	418	461	503	543	590
June	53.5%	227	314	376	449	529	605	681	751	821	886	963
August	50.3%	214	295	354	422	497	569	640	706	772	833	905
October	34.1%	145	200	240	286	337	386	434	479	523	565	614
December	22.9%	97	134	161	192	226	259	292	322	351	374	412

Fig. 4. 4 Load forecast and power development program