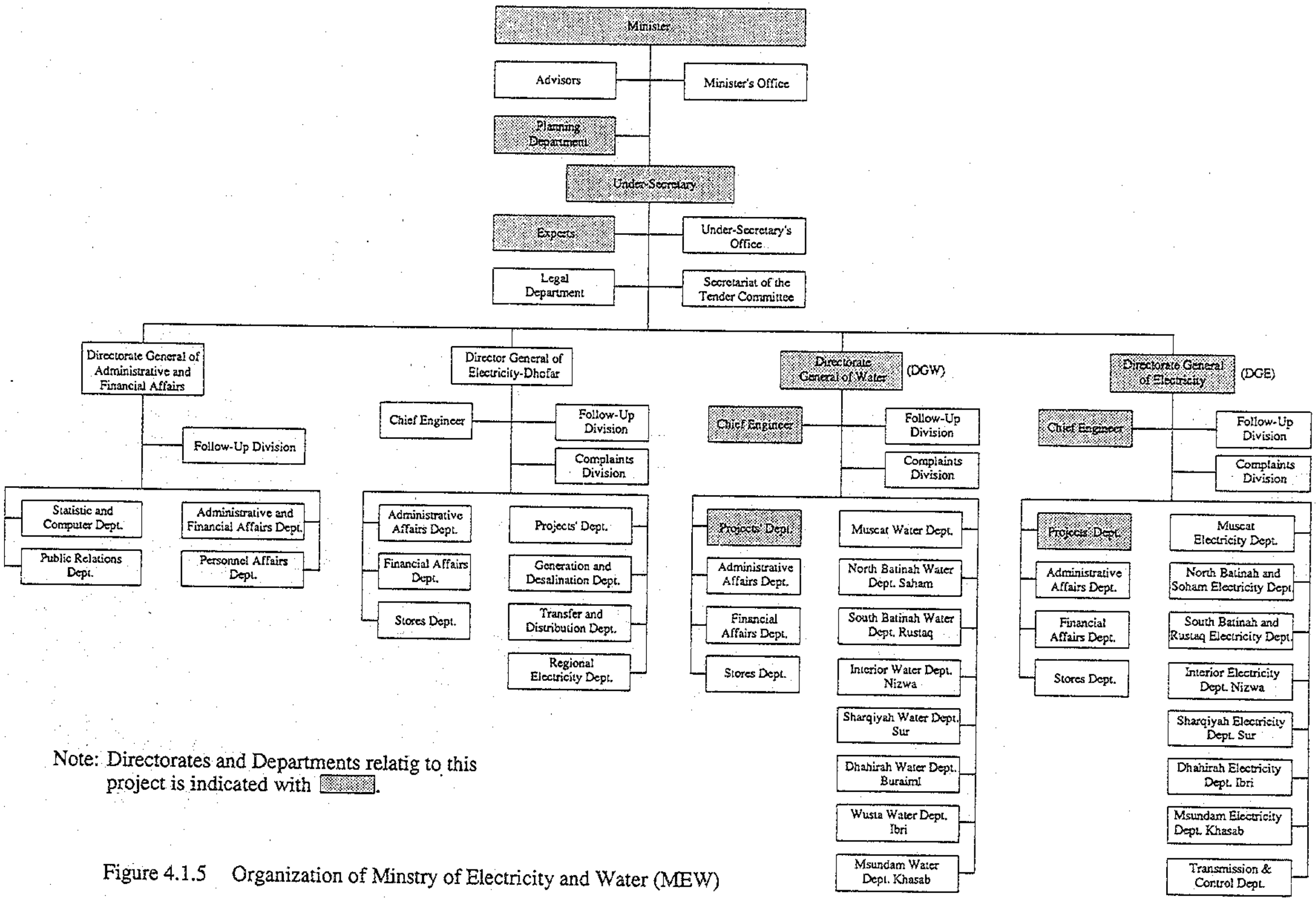
Table 4.1.6 Electricity Rates by Category

Category	Range(Slab) (KWH)	Rates (Baiza/KWH)
Domestic	0 - 3,000	10
	3,001 - 5,000	15
	5,001 - 7,000	20
	7,001 - 10,000	25
	10,001 -	30
Government	same as for Domestic	
Industrial	Specified areas - summer	24
	- winter	12
	Other areas - summer	24
	- winter	16
Commercial	0 -	20
Agricultural and fisheries	0 - 7,000	10
	7,001 -	20
Hotel/Tourism	0 - 3,000	10
	3,001 - 5,000	15
	5,001 -	20

Source: MEW Annual Report 1993

4.1.5 Organization of Power Utilities

The government of Oman executes its program to develop, generate, transmit and distribute power through the Ministry of Electricity and Water (MEW). Figure 4.1.5 shows the organization of MEW. As can be seen in the figure, MEW comprises four directorates: the Directorate General of Administrative and Financial Affairs, the Directorate General of Electricity - Dhofar, the Directorate General of Water (DGW), and the Directorate General of Electricity (DGE). The Directorate General of Administrative and Financial Affairs manages the administrative, personnel and finances of MEW; the Directorate General of Electricity - Dhofar is in charge of construction of power generation facilities and supply of power to the Dhofah region including Salalah and Raysut. The Directorate General of Water is directly responsible for managing construction of water supply facilities and supplying water to the capital. The Directorate General of Electricity is responsible for all matters relating to electricity in the capital, except for those areas that fall under the



Note: Directorates and Departments relatig to this project is indicated with ▒.

Figure 4.1.5 Organization of Minstry of Electricity and Water (MEW) responsibility of the Directorate General of Electricity - Dhofar. The Muscat and Wadi Jizzi power systems are at the center of its area of responsibilities.

This project falls under the jurisdiction of the Muscat system. Consequently, the DGE will be responsible for the implementation of the project. The DGE contains sections that take the project from initiation to the signing of the project contract. The DGE also includes a project planning department, and outerlying area distribution departments (seven in all), as well as 3 sections for general administration and finances, giving a total of 10 departments.

4.1.6 Operation and Maintenance of Facilities

The operation and maintenance of the power supply facilities in the Muscat system is being carried out by SOGEX Co., a private Omani commercial firm, under contract with MEW. The contract is renewed every five years.

The overhaul of power generating facilities and equipment are based on the manufacturer's recommendations. All parts are replaced and overhauled at the manufacturer's factory. Power generation capacity is maintained at the rated output level.

4.1.7 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 (OIFC) based on the contract between MEW and OIFC. Payment of charges is made in bank remittances every month by general consumers and every three months by ministries.

4.2 Existing Power Supply Facilities

Section 4.1 provided a general overview of the power utilities. This section will describe existing power supply facilities relating to power development plan and power transmission plan of the project. A general description is as follows:

4.2.1 Existing Power Generation Facilities

The power system under this project consists of power supply to the capital area and the region that immediately adjoins the capital. The pertinent systems are the Muscat system and the Wadi Jizzi system in the Batinah area, which will be joined by the Manah System in the near future. These systems operate independent of each other, but plans are in place to interconnect them to reduce reserve capacity requirements and improve reliability.

(1) The Muscat System

As shown in Table 4.2.1 two power plants located at Ghubrah and Rusail supply power to the Muscat System. These plants have a total capacity of 815 MW. The Ghubrah Power Plant operates with a desalination plant, and steam is supplied from the steam turbine to the MSF process desalination plant. The Rusail Power Plant has 61 % the capacity of the Muscat System, and is connected to the Ghubrah Power Plant via a 132 KV transmission line, meeting electricity demand in the capital.

Table 4.2.1 Existing Power Stations of Muscat System

Power Stations	Unit No.	Machine Type/Model	Maker	Installed Capacity (MW)	Year of Commissioning
Ghubrah	ST - 1	KAE/20/71/118/100	BBC	8.5	1976
	ST - 2	KAE/20/71/118/100	BBC	8.5	1976
	ST - 3	KAE/20/71/118/100	BBC	8.5	1976
	ST - 4	KAE/20/106/180/200	BBC	50.0	1977
	ST - 5	1-K-2301	ABB	30.0	1993
	GT - 1	GE Frame 5	Alsthom	17.5	1978
	GT - 2	GE Frame 5	Alsthom	17.5	1978
	GT - 3	GE Frame 5	Alsthom	17.5	1978
	GT - 4	GE Frame 5	Alsthom	17.5	1979
	GT - 5	GE Frame 5	Alsthom	17.5	1979
	GT - 6	GE Frame 5	Alsthom	17.5	1979
	GT - 7	GE Frame 5	Alsthom	17.5	1979
	GT - 8	GE Frame 5	Alsthom	17.5	1979
	GT - 9	GE Frame 5	Alsthom	17.5	1979
	GT-10	GE Frame 6	GE	27.0	1983
	GT-11	GE Frame 6	GE	27.0	1983
	Total			317.0 MW	
	(ST Total 105.5 MW, GT Total 211.5 MW)				
Rusail	GT - 1	GE Frame 9	JBE	83.0	1984
	GT - 2	GE Frame 9	JBE	83.0	1984
	GT - 3	GE Frame 9	JBE	83.0	1984
	GT - 4	GE Frame 9	GE	83.0	1987
	GT - 5	GE Frame 9	GE	83.0	1987
	GT - 6	GE Frame 9	GE	83.0	1987
	Total			498.0 MW	
Total Installed Capacity				815.0 MW	

Source : MEW Statistical Year Book 1992
MEW Annual Report 1993

(Note) ST : Steam Turbine, GT : Gas Turbine

(2) The Wadi Jizzi System

As shown in Table 4.2.2, the Wadi Jizzi Power Plant is the only power generation plant in the Wadi Jizzi system. The plant is equipped with nine small capacity gas turbine generators, and has a total capacity of 222 MW.

Table 4.2.2 Existing Power Stations of Wadi Jizzi System

Power Station	Unit No.	Machine Type/Model	Maker	Installed Capacity (MW)	Year of Commissioning
Wadi Jizzi	GT - 1	GE Frame 5	GE	18.0	1982
	GT - 2	GE Frame 5	GE	18.0	1982
	GT - 3	GE Frame 5	GE	18.0	1982
	GT - 4	GE Frame 6	Thomassen	28.0	1985
	GT - 5	GE Frame 6	Thomassen	28.0	1985
	GT - 6	GE Frame 6	Alsthom	28.0	1986
	GT - 7	GE Frame 6	Alsthom	28.0	1986
	GT - 8	GE Frame 6	Thomassen	28.0	1990
	GT - 9	GE Frame 6	Thomassen	28.0	1993
	Total Installed Capacity			222.0 MW	

Source : MEW Statistical Year Book 1992
MEW Annual Report 1993

(Note) GT : Gas Turbine

4.2.2 Existing Power Transmission Lines and Substations

(1) General description

The power transmission lines and substations in Oman are connected via 132 KV, 33 KV and 11 KV systems. The outerlying area at the Wadi Jizzi Power Plant has a 66 KV transmission line that supplies power to the Magan area. Major power supply source is the Muscat and Wadi Jizzi systems, which have the highest voltage of 132 KV.

(2) The Muscat System

Figure 4.2.1 shows the principal network of the Muscat System. The Ghubrah and Rusail Power Plants are connected by double circuit 132 KV transmission lines. There are seven 132 KV/33 KV primary substations, located at Wadi

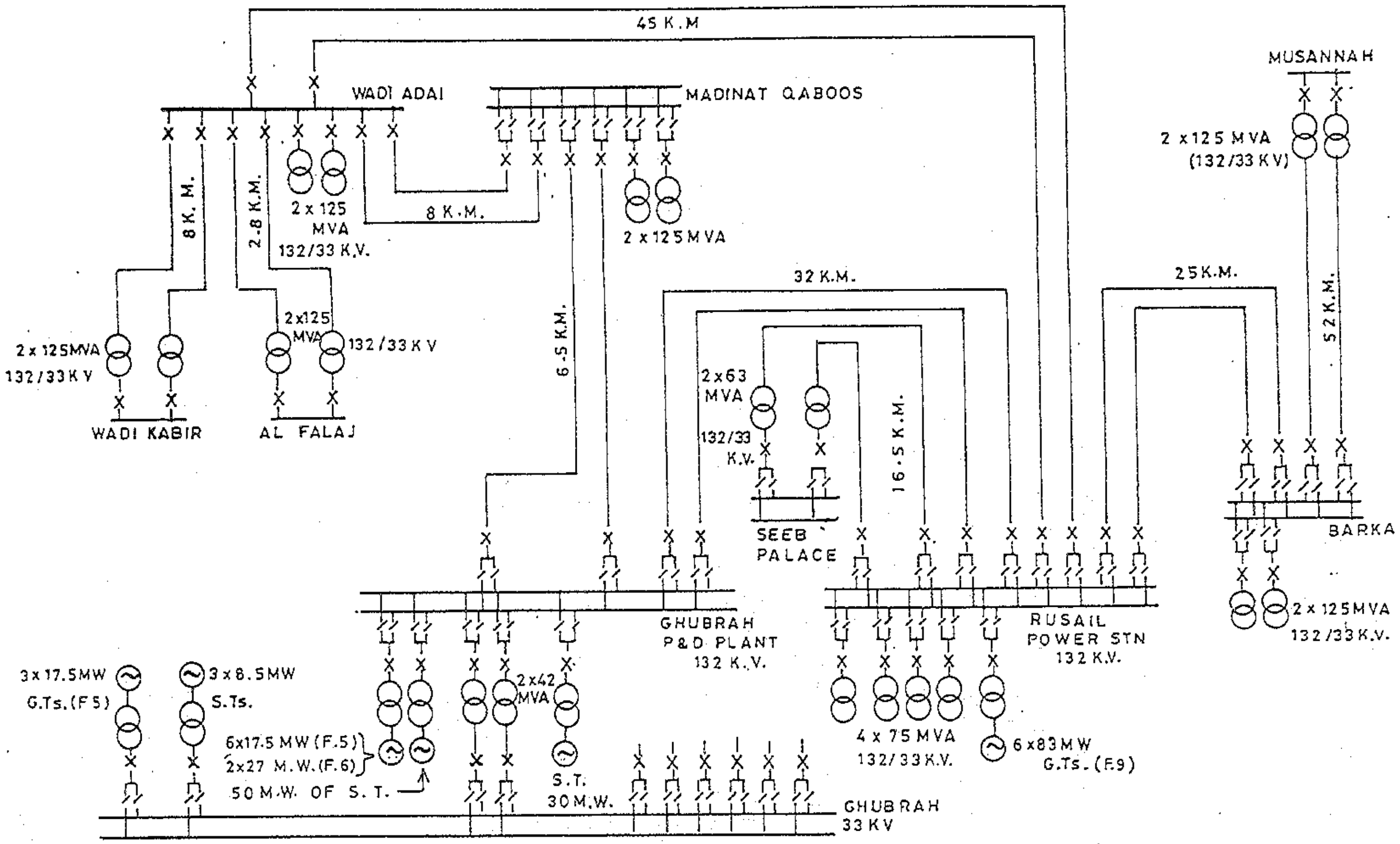
Kabir, Al Falaj, Wadi Adai, Madinat Qaboos, Seeb Palace, Bait Barka and Musanah. The largest transformer is 135 MVA for the power plant, and 125 MVA for the substation. The 132 KV transmission line uses the overhead line a distance of 200 km, and the conductor is an all aluminum alloy conductor (AAAC) of 400 mm^2 and ACSR (aluminum clad steel reinforced cable) of 240 mm^2, and a double circuit transmission line is used in the trunk line.

(3) The Wadi Jizzi System

Figure 4.2.2 shows the principal components of the Wadi Jizzi System. The Wadi Jizzi Power Plant has a total capacity of 222 MW, and incorporates a 132 KV transmission system, with power transmitted to Buraimi, Al Wasit, Dank, Al Hayl, Sohar, and Ibri, where 132 KV/33 KV primary substations are located. There is also a 66 KV transmission line to Magan. The largest transformer is 63 MVA. The total length of the 132 KV overhead transmission line is 300 km, and is either AAC or AAAC (aluminum stranded wires).

(4) Location of Power Supply Facilities

Figure 4.2.3 shows the location of power plants, primary substations, and the 132 KV transmission lines. The Muscat and Wadi Jizzi systems are not inter-connected, and power supply and demand are regulated within the system. The Manah System is a proposed line, with construction expected to begin in the near future aiming at commercial operation to commence in 1996.



LEGEND

G.T. – GAS TURBINE
S.T. – STEAM TURBINE
F. 5 – FRAME 5
F. 6 – FRAME 6
F. 9 – FRAME 9

Figure 4.2.1 Muscat System 132 KV Network (1993)

Source: MEW Statistical Year Book 1992

MUSCAT SYSTEM 132 K.V. NETWORK (1993)

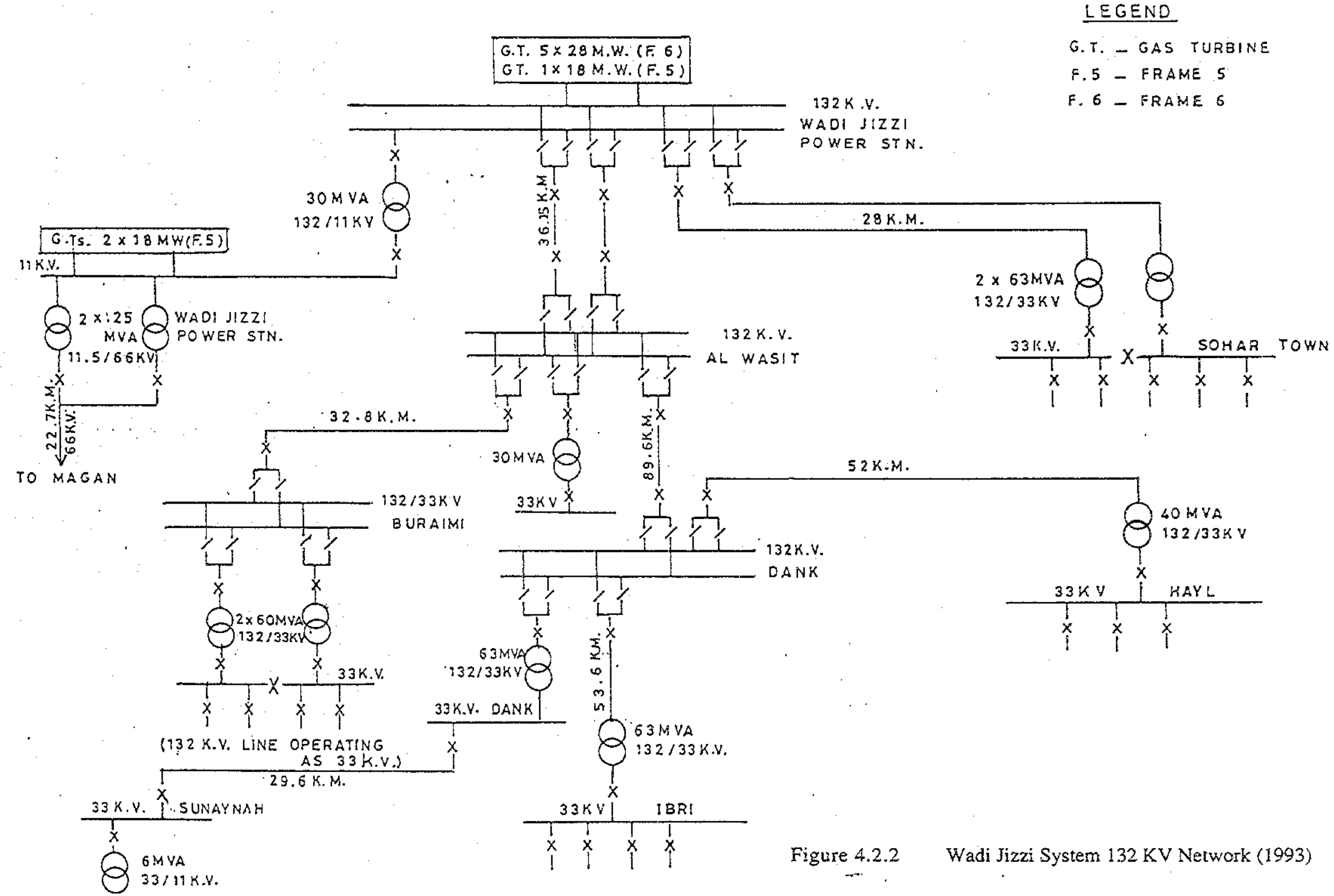


Figure 4.2.2 Wadi Jizzi System 132 KV Network (1993)

Source: MEW Statistical Year Book 1992

WADI JIZZI SYSTEM 132 KV NETWORK (1993)

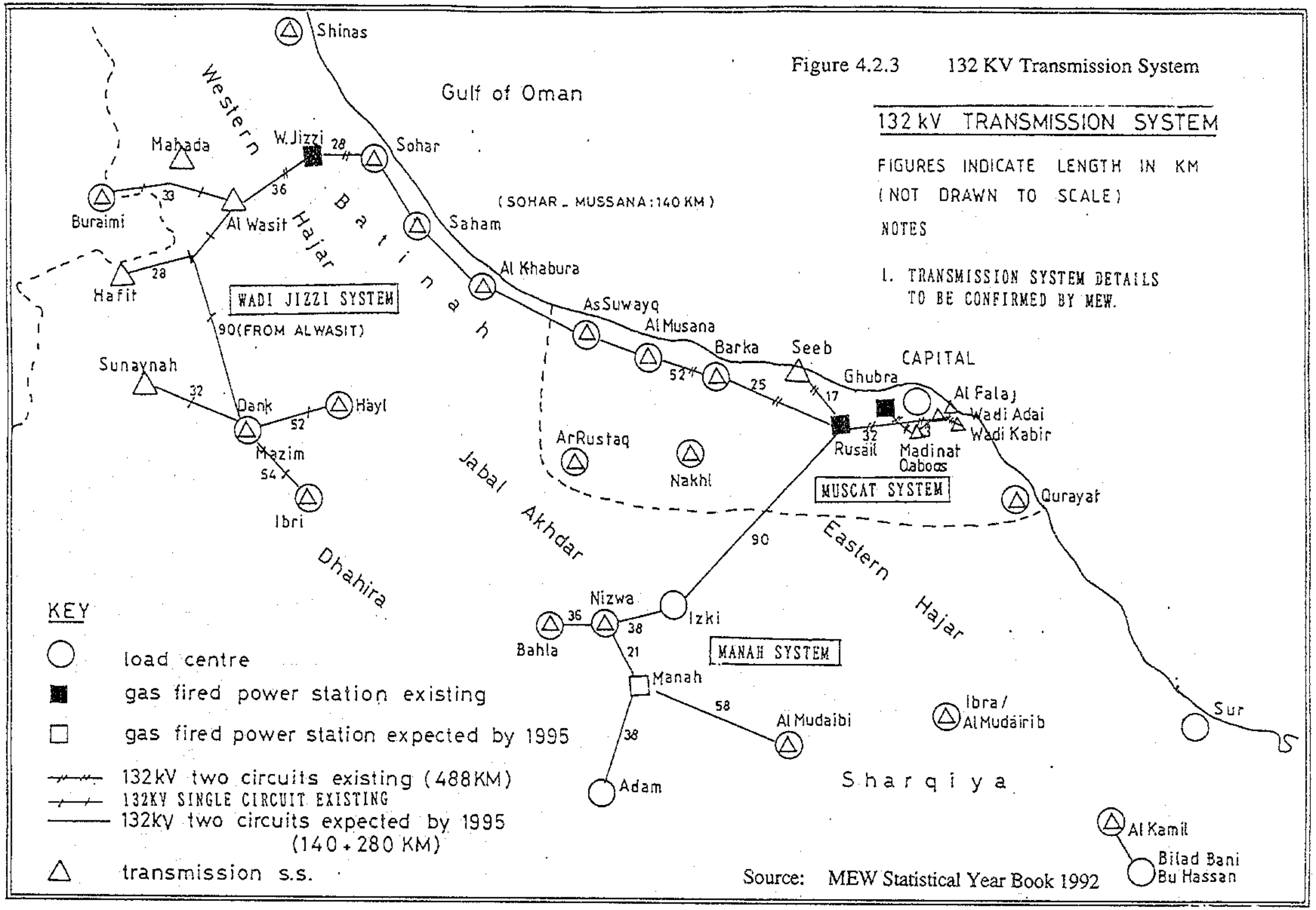


Figure 4.2.3 132 KV Transmission System

4.3 Characteristics of Load Variations

4.3.1 Change in Power Demand

The change in the generated power, maximum electricity (peak load), and installed generating capacity in each in the Muscat and Wadi Jizzi Systems has been examined as follows:

(1) Table 4.3.1 shows the situation for the Muscat System. The average increase in generated power and peak load was 8.5 % for the five years from 1988 to 1993, showing outstanding growth. Installed capacity has increased in line with demand with the decreasing reserve margin by the year. Generated power increased 31.6 % from 1976 to 1980, 23.9 % from 1980 to 1984. Peak load rose 30.6 % from 1976 to 1980 and 25.9 % from 1980 to 1984, recording still substantial increases. According to the MEW Annual Report 1993, a load shedding of 20 MW was necessary to meet the demand for power on the maximum load day in the summer of 1993. It was also pointed out in the Report that the peak load in 1994 would reach 900 MW, necessitating a load shedding of 90 MW.

(2) Table 4.3.2 shows the growth in generated power and peak load of the Wadi Jizzi system for the five years from 1988 to 1993. Average growth has outstripped that of the Muscat System, reaching 12.9 % for generated power and 13.3 % peak load.

Table 4.3.1 Power Generation Statistics - Muscat System

Year	Electricity Generated (Million KWH)				Peak Load (MW)	Installed Capacity (MW)			
	Ryam	Ghubrah	Rusail	Total		Ryam	Ghubrah	Rusail	Total
1976	130.3	83.9		214.2	45	36	26		62
1977	80.4	248.8		329.2	65	36	76		112
1978	37.9	338.8		376.7	77	36	128		164
1979		473.0		473.0	107	36	233		269
1980		611.0		611.0	136	36	233		269
1981		773.4		773.4	175	36	233		269
1982		940.1		940.1	214	36	233		269
1983		1,133.9		1,133.9	281	36	287		323
1984	15.7	1,031.2	469.6	1,516.5	340	36	287	166	489
1985	0.6	1,069.5	781.9	1,852.0	397		287	250	537
1986		1,206.3	974.3	2,180.6	492		287	250	537
1987		1,096.5	1,187.2	2,283.7	494		287	500	787
1988		822.9	1,759.5	2,582.4	551		287	500	787
1989		779.9	1,905.2	2,685.1	593		287	500	787
1990		780.6	2,257.6	3,038.2	658		287	500	787
1991		781.0	2,302.4	3,083.4	679		287	500	787
1992		978.1	2,419.2	3,397.3	725		287	500	787
1993	MOD (4.6)	1,298.2	2,559.7	3,862.5	826		317	500	817
Average Growth Rate for the past 5 years				8.5%	8.5%				0.8%

Source : MEW Statistical Year Book 1992
MEW Annual Report 1993

Table 4.3.2 Power Generation Statistics - Wadi Jizzi System

Year	Electricity Generated (Million KWH)	Peak Load (MW)	Installed Capacity (MW)
1982	9.7	3	54
1983	123.0	29	54
1984	178.1	34	54
1985	240.6	52	110
1986	266.4	58	166
1987	391.2	100	166
1988	475.5	118	166
1989	541.7	143	166
1990	635.6	172	194
1991	668.3	177	194
1992	755.8	192	194
1993	870.8	2 1.8	222
Average Growth Rate for the past 5 years	12.9%	13.3%	6.3%

Source : MEW Statistical Year Book 1992
MEW Annual Report 1993

4.3.2 Load Variation Characteristics

The daily load curve should be produced to determine the load for the Barka Power Plant, and the characteristics of the load variation must be understood in order to analyze the annual power balance. The 1985 feasibility study examined load variations in the capital for 1984. The new feasibility study made a similar analysis based on 1993 load variation records for the Muscat System. The results are as follows:

(1) General Description

The temperature in the capital and Batinah regions varies greatly between seasons, reaching a maximum of 45° to 47° during summer, and occasionally falling below 10° during the winter months. Construction of the Rusail Industrial Estate in 1983 was expected to accelerate Oman's industrialization, however industrial power demand remains low. Demand for air conditioning, fluctuating rapidly in response to changing temperatures, accounts for a large proportion of power consumption.

(2) Monthly Load Variations

The load variations of the Muscat and Wadi Jizzi systems for the maximum and minimum electricity are given for 1993 in Appendix (Table 4.3.1). Tables 4.3.3 and 4.3.4 show the monthly maximum and minimum electricity and the ratio against maximum annual electricity for 1993 on the Muscat System, and those for the capital in 1984 respectively. Figure 4.3.1 compares monthly variations for 1993 and 1984. The characteristics of the monthly variations can be obtained from these tables and figures and are as follows:

1) Compared to maximum annual electricity for 1993, demand in the winter months of January and February when load is at a minimum, was about 36 % during the day and about 17 % at night. The same pattern was seen in 1984, with 33 % and 17 % respectively.

2) The minimum electricity in the winter of 1993 was approximately 17 % to 25 % of the annual peak load. Thus annual peak load has a base load of less than 25 %.

3) The load factor (= average load/max. load) was 54.0 % in 1993, 54.7 % from 1976 to 1980 and 50.9 % from 1980 to 1984. This indicates that air conditioning loads in the capital have stabilized for the time being.

(3) Daily load variations

Table 4.3.5 shows the load variations of the maximum load day (June 22) and minimum load day (January 16), on the Muscat System in 1993. Figure 4.3.2 shows the daily load curve. Figures 4.3.3 and 4.3.4 compare the load variations of the maximum load day (June 19 in 1984) and minimum load day (February 3 in 1984). The figures reveal the following characteristics:

1) Peak load during summer occurs during the day, between 14:00 and 15:00 hours. The highest temperatures are recorded during this time, and air conditioners run at maximum capacity. During winter, peak load occurs between the hours of 18:00 and 19:00 hours, when the lighting load is the largest. The maximum and minimum daily loads are reached gradually.

2) Demand for power in the summer and winter months falls off from late night to early morning. Minimum power demand is 70 % of maximum

power demand in the summer, and is less than 70 % for about three hours during the day.

3) The daily load curves for maximum and minimum load days in 1993 and 1984 are very similar. It can be assumed that the structure of power demand has changed little over the past ten years.

In summary, monthly and daily load variations for 1984 and 1993 show similar characteristics. Unless industrial demand increases markedly and the nature of power consumption changes much, it can be assumed that load variations will generally remain the same. Section 7.5 will describe the assumed load variation curve for the proposed project and the load to be borne by the Barka Power Plant in the year 2010.

Table 4.3.3 Monthly Load Variation for Muscat System in 1993

Month	Maximum Load Day: Maximum Load (MW)	Maximum Load Day: Minimum Load (MW)	Minimum Load Day: Maximum Load (MW)	Minimum Load Day: Minimum Load (MW)	Ratio to Annual Maximum Load: Maximum Load Day (%)	Ratio to Annual Maximum Load: Minimum Load Day: Maximum (%)	Ratio to Annual Maximum Load: Minimum Load Day: Minimum (%)
January	325	185	279	137	39.3	33.8	16.6
February	355	228	296	157	43.0	35.8	19.0
March	399	266	267	186	48.3	32.3	22.5
April	639	386	358	251	77.4	43.3	30.4
May	791	534	580	350	95.8	70.2	42.4
June	826	537	673	456	100.0	81.5	55.2
July	820	565	763	465	99.3	92.4	56.3
August	820	594	676	438	99.3	81.8	53.0
September	736	470	638	383	89.1	77.2	46.4
October	653	414	386	283	79.1	46.7	34.3
November	449	304	325	205	54.4	39.3	24.8
December	375	216	336	187	45.4	40.7	22.6

Table 4.3.4 Monthly Load Variation for Muscat System in 1984

Month	Maximum Load Day: Maximum Load (MW)	Maximum Load Day: Minimum Load (MW)	Minimum Load Day: Maximum Load (MW)	Minimum Load Day: Minimum Load (MW)	Ratio to Annual Peak Load: Peak Load Day (%)	Ratio to Annual Peak Load: Minimum Load Day: Maximum (%)	Ratio to Annual Peak Load: Minimum Load Day: Minimum (%)
January	112	61	111	58	32.9	32.5	16.9
February	112	60	102	56	32.8	30.0	16.5
March	191	117	121	68	56.0	35.5	20.0
April	249	146	175	112	73.2	51.5	32.8
May	296	211	206	137	87.0	60.5	40.2
June	340	226	306	182	100.0	90.0	53.5
July	329	238	261	168	96.6	76.8	49.4
August	302	194	250	171	88.7	73.5	50.3
September	295	201	258	165	86.6	75.8	48.5
October	254	157	176	116	74.6	51.7	34.1
November	184	110	153	91	54.1	45.0	26.7
December	161	101	133	78	47.3	39.1	22.9

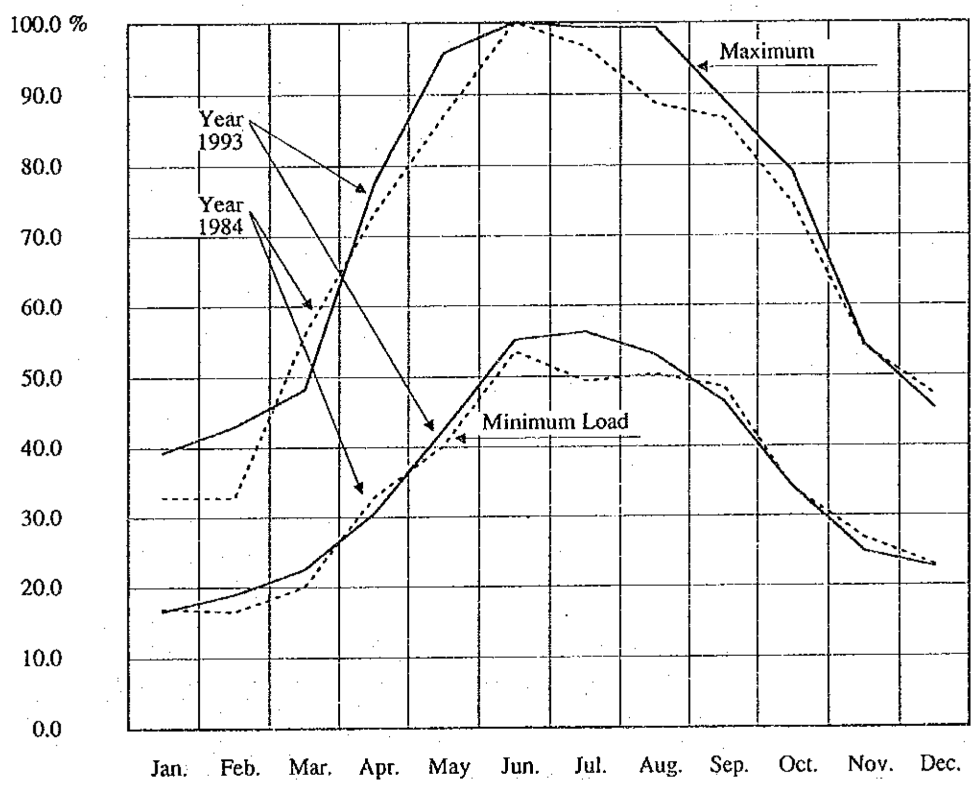


Figure 4.3.1 Monthly Load Variation Curve in 1993 and 1984

Table 4.3.5 Daily Load Variation for Muscat System in 1993

Time (Hrs)	Maximum Load Day (June 22 : 826 MW) System Load (MW)	(%)	Amb. Temp. (°C)	Minimum Load Day (January 16 : 137 MW) System Load (MW)	(%)	Amb. Temp. (°C)
0100	741	89.7	38.0	147	52.7	16.5
0200	726	87.9	37.0	142	50.9	16.0
0300	710	86.0	38.0	137	49.1	17.0
0400	696	84.3	37.0	139	49.8	16.5
0500	638	77.2	37.0	147	52.7	16.0
0600	567	68.6	37.0	187	67.0	16.0
0700	537	65.0	39.0	225	80.6	16.0
0800	591	71.5	41.0	231	82.8	16.0
0900	610	73.8	41.5	239	85.7	17.0
1000	626	75.8	43.5	237	84.9	17.0
1100	647	78.3	44.0	231	82.8	18.0
1200	677	82.0	44.0	225	80.6	19.0
1300	730	88.4	44.5	218	78.1	19.0
1400	785	95.0	43.5	202	72.4	19.0
1500	773	93.6	44.0	197	70.6	19.0
1600	778	94.2	44.5	207	74.2	18.5
1700	700	84.7	43.0	215	77.1	18.0
1800	614	74.3	41.0	278	99.6	17.5
1900	605	73.2	40.0	279	100.0	17.5
2000	670	81.1	39.0	266	95.3	16.0
2100	721	87.3	39.0	248	88.9	16.0
2200	768	93.0	40.0	229	82.1	16.0
2300	794	96.1	40.0	191	68.5	16.5
2400	785	95.0	37.0	169	60.6	16.0

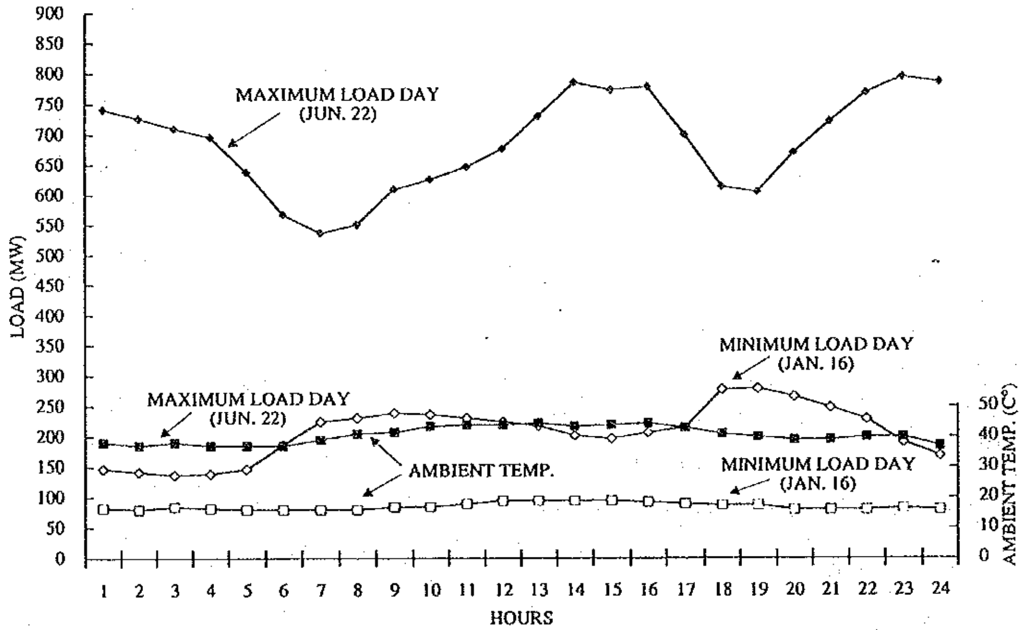
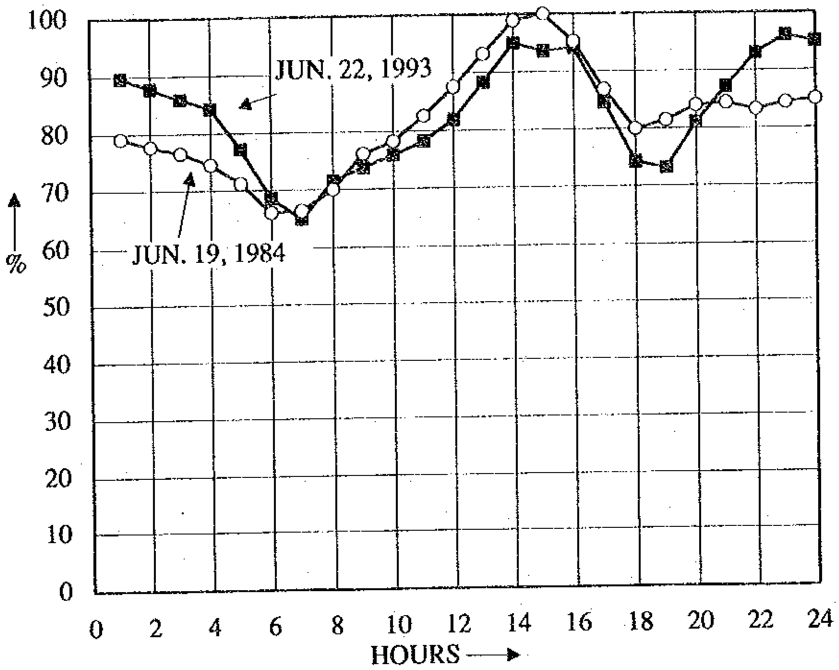
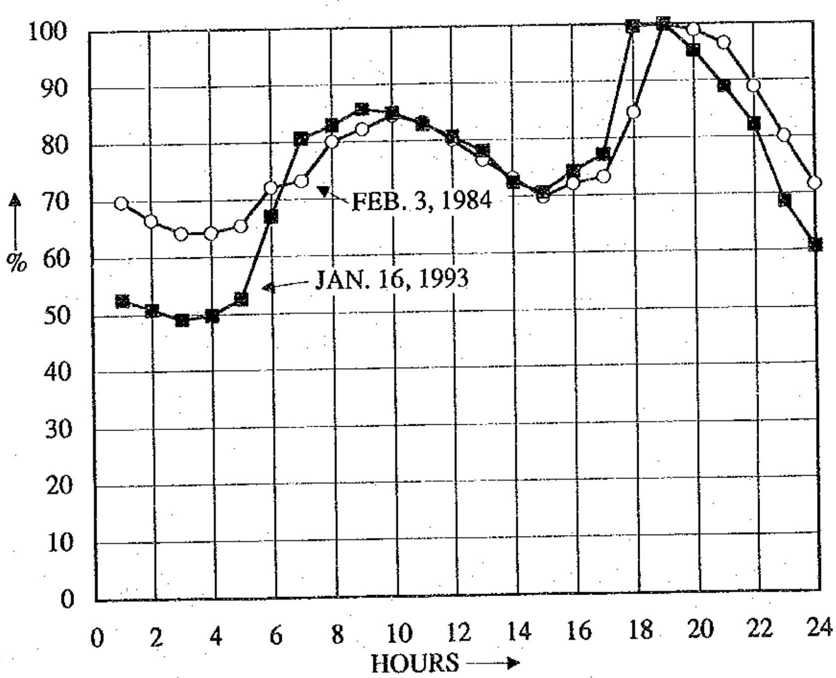


Figure 4.3.2 Daily Load Variation Curve for Muscat System in 1993



HOURS	YEAR 1993	YEAR 1984
1	89.7 %	79.2 %
2	87.9	77.7
3	86.0	76.5
4	84.3	74.5
5	77.2	71.2
6	68.6	66.2
7	65.0	66.5
8	71.5	70.0
9	73.8	76.2
10	75.8	78.3
11	78.3	82.7
12	82.0	87.6
13	88.4	93.2
14	95.0	98.9
15	93.6	100.0
16	94.2	95.2
17	84.7	86.9
18	74.3	80.0
19	73.2	81.5
20	81.1	84.1
21	87.3	84.5
22	93.0	83.3
23	96.1	84.5
24	95.0	85.0

Figure 4.3.3 Maximum Load Day Load Variation Curve



HOURS	YEAR 1993	YEAR 1984
1	52.7 %	69.8 %
2	50.9	66.5
3	49.1	64.2
4	49.8	64.2
5	52.7	65.4
6	67.0	72.1
7	80.6	73.2
8	82.8	80.0
9	85.7	82.1
10	84.9	84.4
11	82.8	83.2
12	80.6	80.0
13	78.1	76.5
14	72.4	73.2
15	70.6	69.8
16	74.2	72.1
17	77.1	73.2
18	99.6	84.4
19	100.0	100.0
20	95.3	98.9
21	88.9	96.6
22	82.1	88.8
23	68.5	80.0
24	60.6	71.5

Figure 4.3.4 Minimum Load Day Load Variation Curve

4.4 Planning the Power System

4.4.1 Basic Concept for Power System Planning

To supply quality power to consumers, a wide range of power supply facilities shall have to be brought together into one coordinated system. The prime mission is to supply consumers with electricity of the regulated voltage and frequency, with minimal power failures. If maintaining technical requirements is too demanding, this will necessitate greater investment requirements and a higher cost of power. It will therefore be necessary to find common ground between the level of reliability and investment needs.

Power supply facilities take a long time to construct, and have a long useful life, which is necessary because such facilities also require a large initial investment, and demand fuel, maintenance and repairs. Energy and labor savings and protecting the environment are mandatory, and have prompted recent technical advances to be brought into the planning of the power supply facilities.

4.4.2 Period for Power System Planning

Planning for power system will require information on future trends for power demand and development plans for a long-range capital investment while recognizing technological advances. In general, a period for power system planning is targeted at about ten years. In discussions with MEW, it was decided to adopt a time frame from 1994 to 2010, a period of 17 years. JICA prepared the feasibility study for this project in 1985, and to date there have been no major social changes that would justify major revisions to the framework of the study. As MEW requested that the project be compatible with the National Development Program and 2010 be adopted, the time period was extended beyond the ten year project planning period. However, the demand and supply of power varies from year to year greatly depending on the change in economic activities, thus necessitating short- and mid-term revisions to the system planning and operation.

4.4.3 Order of System Planning

Power system planning will start with forecasting of power demand for the planned project period (1994 - 2010), as well as the power generation plan and the power transmission plan.

The basis of the power facilities plan rests with estimated demand, which covers annual maximum electricity (peak load) and generated power. Power development planning requires construction of the necessary power supply capacity in phases, including reserve margin and power source mix, to comply with the load variations. Power transmission planning will provide for power transmission, substations, and distribution facilities. For this project, only transmissions from the Barka Power Station to certain substations will be studied.

Figure 4.4.1 shows the order of system planning.

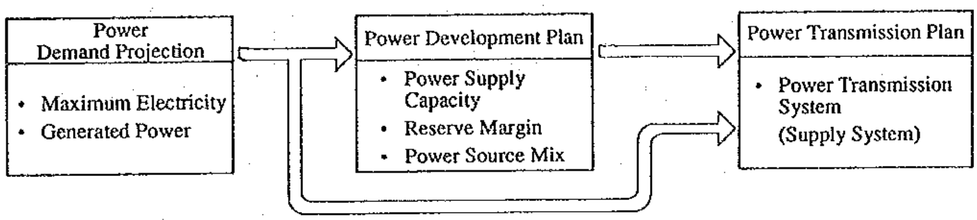


Figure 4.4.1 Order of System Planning

4.4.4 Balance of Power Supply and Demand

Planning of power source development will follow the order established for power system planning. Balanced power will be supplied to meet estimated demand, and to ensure economical power supply and operation. To determine the maximum electricity balance and the generated power balance, the supply capacity and supplied power will be calculated. The calculations will be made as follows:

(1) Calculation of supply capacity:

In making short-term forecasts, the average of three days of monthly largest loads is taken (the average of the highest three days). However, since this project has a long planning period, up to 2010, the annual maximum loads will be used for supply capacity. The monthly load variation curve in Figure 4.3.1 shows that maximum load days appear in the summer, and maximum load periods can continue for several months. From these records, maximum loads can be obtained for the year.

Power supply must be able to meet annual maximum loads. Power not exported due to stoppage in supply (owing to repairs) and power for plant service should be deducted from plant installed capacity to give net supply capability. Demand for power is low in winter, so repairs are planned for this period. Plant supply capacity can be calculated using the following formula:

Supply Capacity = Generator output - Plant service power

= Power at sending end (in MW)

Reserve margin is calculated by supply capacity minus demand, and the result is compared to the standard reserve margin calculated separately to judge the balance between supply and demand. The reserve margin ratio is obtained using the following formula and maximum electricity balance is evaluated:

$$\text{Reserve margin ratio} = \frac{\text{Supply reserve margin (MW)}}{\text{Maximum Electricity (MW)}} \times 100\ (\%)$$

(2) Calculation of Supplied Power

Supplied power (in MWH) is calculated by assuming the operation of the power supply system, and is used to determine annual generated power based on actual operations. Supplied power is determined by multiplying the hours of operation, excluding average hours of stoppage, by the unit supply capacity.

Power demand is represented by the monthly maximum three day average load, the normal day average load, holiday average load, and monthly power demand. However, as with supply capacity calculations, this is a long-range plan. The quarterly load curve of the project will be assumed, and the representative load will be multiplied by the number of hours to obtain load demand. To reflect Omani situations, the time frames will be from 1:00 to 6:00 hours, 7:00 to 14:00 hours, and 15:00 to 24:00 hours.

Figure 4.4.2 shows the above order of power supply planning diagrammatically.

	Calculation of Supply Capacity (expressed in MW)	Calculation of Supplied Power (expressed in MWH)
Project Objective	Annual Maximum Electricity Balance	Annual Generated Power Balance
Supply Capacity	A. Power generating capacity (generator output) B. Power Stoppage by Planned Repairs C. Station Service Power D. Supply Capacity (power at sending end) (D = A - B - C)	A. Supply Capacity B. Hours of Operation C. Supplied Power (C = A x B)
Demand	E. Annual Maximum Electricity	D. Annual Demand Power (Average Daily Load Curve)
Reserve margin	F. Reserve margin (F = D - E)	E. Reserve Power (E = C - D)

Figure 4.4.2 Order of Power Supply Planning

4.4.5 Design Factors for Equipment Capacity Planning

Design factors to consider in planning new power plants are reserve margin, ratio of station service, and the transmission loss ratio. This Section considers the following design factors for the Barka Power Plant (Reserve margin will be discussed in Section 4.6.3).

(1) Ratio of station service power

The ratio of station service power represents the ratio of station service power against (generated power) at the generator. To ensure an efficient supply of power to the consumer, this ratio must remain low. According to the MEW Annual Report 1993 this ratio was 3.3 % for the Ghubrah Power Plant. Adding the load ratio 11.8 % for the desalination plant brings the figure to 15.1 %. For the Rusail Power Plant, the ratio was 1.0 %. The higher ratio for the Ghubrah Plant reflects the service loads of the boilers and steam turbines. The Rusail Power Plant uses gas turbines and service loads are low, as is evident in the service load ratio. After deducting desalination plant loads, the ratio for the power plants in the Muscat System is 1.8 %. Existing power plants are all maintained at a reasonable level, and the ratio of station service power should remain unchanged in the future as the load factor would level off at a certain figure.

(2) Transmission loss ratio

Of power transmitted from power plants (generated power minus station service power) to consumers, a transmission loss ratio of 12.2 % was calculated for the Muscat System in 1993 (according to the MEW Annual Report 1993). This loss was incurred in the transmission lines, substations, and distribution lines. This ratio is inordinately large when compared with the 5.7 % figure in Japan, although a simple comparison does not appear to be appropriate.

Transmission losses can be attributed to the magnitude of the load and line resistance, and have an inverse relationship to the square of the voltage and the power factor. Reducing transmission line losses requires to install static capacitors in the places of increasing demand density to improve the power factor. Raising line voltage and expanding the line size may also be necessary. These improvements would demand a large investment, so MEW must consider improvements over the long term.

This project will assume a transmission loss of 12 % for existing facilities and facilities under the project.

The KWh loss ratio was used to represent average loss ratio during the relevant period. However, the KW loss ratio may be used to represent the loss ratio at the time of maximum power demand. The ratio of KWh loss and KW loss will be used as the loss factor, and will be obtained from the Buller-Woodrow empirical formula as follows:

$$Ls = 0.3Ld + 0.7\,Ld^2$$

where:

Ls : Loss factor (= KWh loss/KW loss)

Ld : Load factor

Using this formula, the loss ratio, loss factor, load factor can be calculated as follows:

$$\frac{\text{KWh Loss Ratio}}{\text{KW Loss Ratio}} = \frac{\text{Loss Factor}}{\text{Load Factor}} = \frac{0.3Ld + 0.7Ld^2}{Ld}$$

$$= 0.3 + 0.7\,Ld$$

With a transmission loss ratio of 12 %, and assuming a load factor of 70 %, the KW loss ratio can be calculated as 15 %.

(3) Annual load factor

The annual load factor is the ratio of annual average power to maximum load. It is used to represent load characteristics. When the period is one year the annual load factor can be determined using the following formula:

$$\text{Annual Load Factor} = \frac{\text{Annual Average Electricity}}{\text{Annual Max. Electricity}} \times 100\ \%$$

The annual load factor is influenced by the climate, seasons, social changes, etc. In particular, the factor falls with greater use of air conditioners in homes and offices.

(4) Unscheduled stoppage ratio

Power supply services are affected by sudden accidents and unscheduled repairs. Planning for power supply must consider unscheduled stoppages, which can be reached using the following formula:

Unscheduled Stoppage Ratio

$$= \frac{\text{No. of days unscheduled Stoppage}}{\text{No. of days of operation + No. of days of unscheduled stoppage}} \times 100\ (\%)$$

In Japan, this ratio is a very low 2.0 % for the combined cycle plants. As stated in Section 4.6.3, this project proposes to maintain a reserve margin of 5 %. As the reserve margin is to have the capacity to absorb unscheduled stoppages, this ratio will not be incorporated.

4.5 Power Demand Forecasting

The objective of this section is to project future demand of electricity. It is assumed that the Project's service area (or market area) will cover all the areas involved in the existing Muscat and Wadi Jizzi Power Systems, and that the two systems will be interconnected by the time the first phase of the Project is completed. The forecasting targets the year 2000 as the year for immediate action programs and 2010 as the year for long-term master plans.

Our forecasting will employ two methods: (1) a macro trend extrapolation method based on changes in peak load in recent years, and (2) a typical micro approach in which demand is assessed for different consumer groups including households, commercial and industrial establishments, and government agencies and entities. It is hoped, by comparing forecasting results by the two methods, that the use of multiple methods will increase the reliability and accuracy of the forecasting results, and so compensating the insufficiency of the data available for the forecasting. Main reference data include consumer-category-wise power consumption data, which however is limited only to the last four years, and the statistical data of peak load and power generation which covers more than 10 years.

We first discuss the correlations between major economic indicators and power demand which we have found with the limited data available. The findings are expected to help us understand the link between power demand and the nation's macro economic environment.

4.5.1 Associations with Economic Indicators

The data for power consumption by consumer group, as it covers only the last four years, is not sufficient to be used for the correlation study between the power demand and economic indicators. Even if strong relationships were found between them, the findings would not be used for long-term forecasting. Therefore, for this correlation analysis, the annual peak load and the electricity generated are used as alternative variables for the electricity demand (dependent variables), the data for which covers a comparatively long period of more than 10 years.[1]

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1 However, as demonstrated in the Progress Report, even the sample sizes of those two variables are too small to conduct multiple regression analysis, in which multiple independent variables are involved. (Usually, for each independent variable, more than 10 observations are required.)

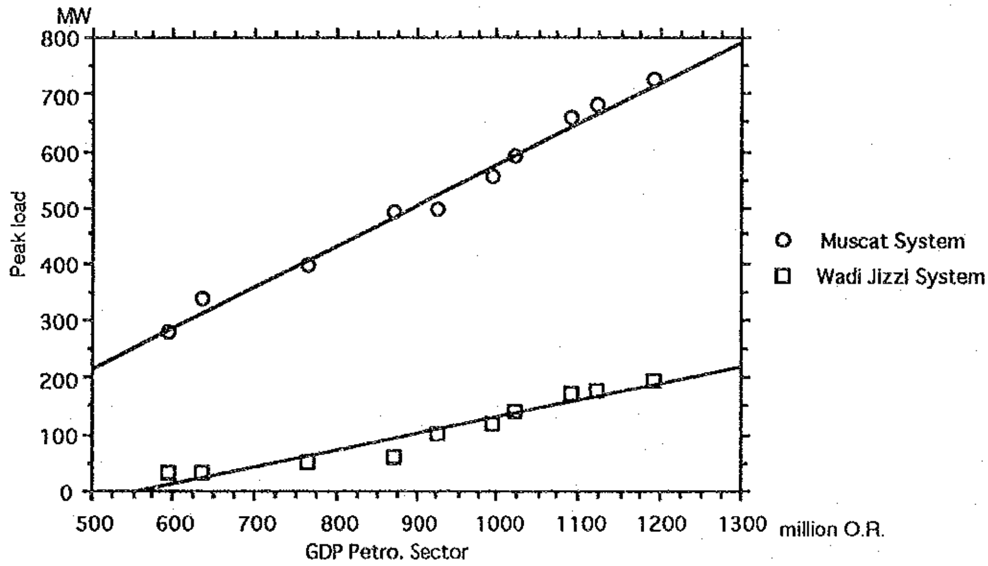
Economic indicators that are deemed to affect the level of power demand and for which data are available are the following: (Data are exhibited in Appendix 4.5.1 of this chapter.)

- Petrole fineum Sector of GDP
- Non-petroleum Sector of GDP
- GDP
- Government capital formation
- Private capital formation
- Privatal consumption

The findings of the correlation analysis between those indicators and the demand variables are as follows. First, no strong relationships were observed between the demand variable and any variable concerning capital formation or final consumption (see Appendix 4.5.2 of this chapter). The result might be different, if power consumption data categorized by consumer group were used instead of annual peak load or power generated.

The petroleum sector of GDP refers to the production of crude oil and natural gas, which is the largest revenue source of the Government. It is safe to say that the level of investment in infrastructures including power transmission/distribution facilities, is determined by the level of income from the sale of crude oil and natural gas. The country's power demand increased as the result of not only the increase in unit consumption but also the expansion of the supply area. As reasonably anticipated, there is a strong relationship between the petroleum sector of GDP and the power demand, as exhibited in Figure 4.5.1.

(1) Peak load



(2) Electricity generated

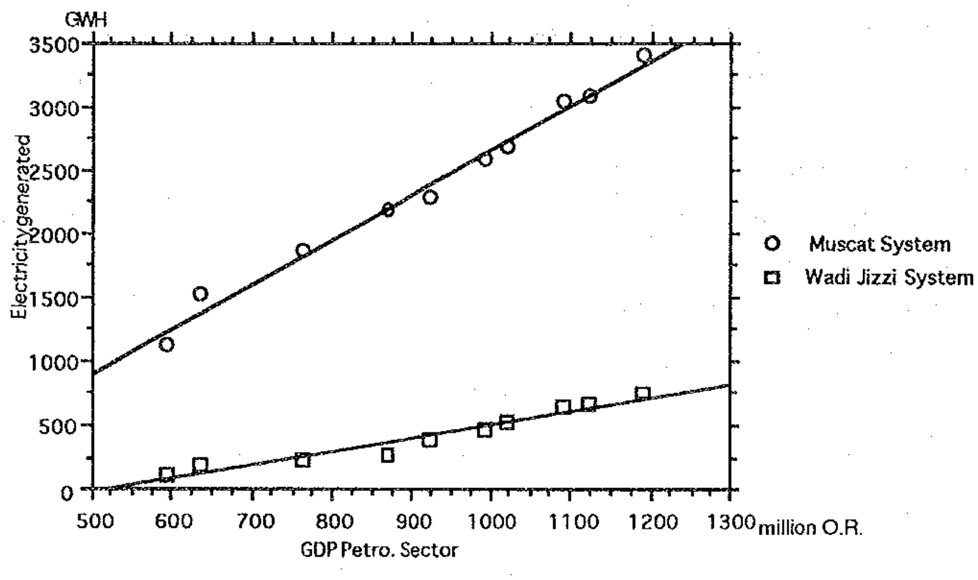


Figure 4.5.1 GDP Petroleum Sector and Annual Peak Load and Electricity Generated (Muscat and Wadi Jizzi Systems) 1983-1993

Linear relations are observed between the GDP petroleum sector and the power demand of the Muscat System. The same relationship can be seen with the other system, although in 1986, when the GDP petroleum sector reached approximately 87 million O.R., the peak load and the power generated for the system did not increase proportionally, or as much as expected. The Muscat System area receives a large portion of public investment, and hence it can be assumed that the power demand in the area is sensitive to the changes in the GDP petroleum sector. It seems that the sensitivity level of the Wadi Jizzi System's peak load and power generated to GDP petroleum sector has risen in recent years. This reflects the fact that the public investment in the Wadi Jizzi System area has become more active.

From the correlation analysis, the following functions are derived:

(1) Muscat System

a. Peak load (MW)

$$Y = -143{,}721 + 0.721 \times X \text{ (GDP Petro. Sector in mil. O.R.)}, \; r^2 = 0.987$$

b. Power generated (GWH)

$$Y = -867{,}284 + 3.518 \times X \text{ (GDP Petro. Sector in mil. O.R.)}, \; r^2 = 0.989$$

(2) Wadi Jizzi System

a. Peak load (MW)

$$Y = -162{,}837 + 0.293 \times X \text{ (GDP Petro. Sector in mil. O.R.)}, \; r^2 = 0.936$$

b. Energy generated (GWH)

$$Y = -867{,}284 + 3.518 \times X \text{ (GDP Petro. Sector in mil. O.R.)}, \; r^2 = 0.951$$

The notation r^2 denotes the coefficient of determination, a measure of the degree of linear association between X and Y.[2] (If r^2 equals 1, the association is perfect.) The comparison of the above r^2 suggests that, with the GDP petroleum sector, the association of the peak load and the energy generated for the Muscat System is stronger than the counterparts for the Wadi Jizzi System.[3]

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2 It denotes the proportional reduction in error achieved by using the linear prediction equation instead of $\bar{Y}$ (mean of Y values) to make the predictions.

3 In Figure 4.4.1, the association between the GDP petroleum sector and the electricity generated of the Wadi Jizzi System, for instance, may appear non-linear rather than linear. From the non-linear regression analysis for this association, we can obtain $Y = 337{,}732 - 1.045X + 0.0001187X^2$ ($r^2 = 0.985$) or $Y = 0.00001197473X^{2.534732}$ ($r^2 = 0.974$). The coefficient of determination of each of these functions is satisfactory high. Because of the insufficiently large sample size (10 observations), however, these results should be treated as references only.

GDP (or the GDP non-petroleum sector) is a good indicator measuring the changes in overall economic activity level, and therefore is expected to have strong association with the power demand. (Strictly speaking, GDP, as it includes the production of power and other utilities, cannot be used as an independent variable predicting power demand.) However, no significant relationships, whether linear or non-linear, were observed, when values of GDP (and GDP non-petroleum sector), and those of peak load and electricity generated for both systems were plotted. With an assumption that there exists linear associations between GDP and the peak load and electricity generated of the Muscat System, computation was made for r^2 of those associations. The r^2 values obtained were 0.92 for the peak load and 0.93 for the electricity generated. As the GDP petroleum sector accounts for approximately 40 % of GDP, it is apparent that these associations reflect the strong correlation with the GDP petroleum sector. Thus, GDP (or the GDP non-petroleum), unlike the GDP petroleum sector, is not an appropriate economic indicator to make projections with for the power demand.

As discussed above, the GDP petroleum sector is the only variable, among the variables of which data are available, that has a clear correlation with the peak load and the electricity generated as variables indicating electricity demand. It became evident that the level of power demand is dependent upon the governmental revenue from crude oil production. The increase in power demand is a result of (1) the expansion of the power supply area by building power transmission and distribution facilities, (2) the increasing public investment in industrial real-estates, hospitals, schools, streets, and so on, and (3) private investments in housing and private consumption of electrical appliances, as diffusion of public spendings.

The linear regression functions exhibited earlier could be used as so-called econometric models for the projection of future power demand. However, for the following two reasons, we do not take this approach.

One reason is that international oil prices will, as always occurred in the past, fluctuate in the future, thus making it difficult to project the future level of the GDP petroleum sector.[4] It has been reported that unless new oil fields are discovered, the country's oil resources will be exhausted in two decades, which makes it difficult to estimate the future level of oil production. The GDP petroleum sector has been

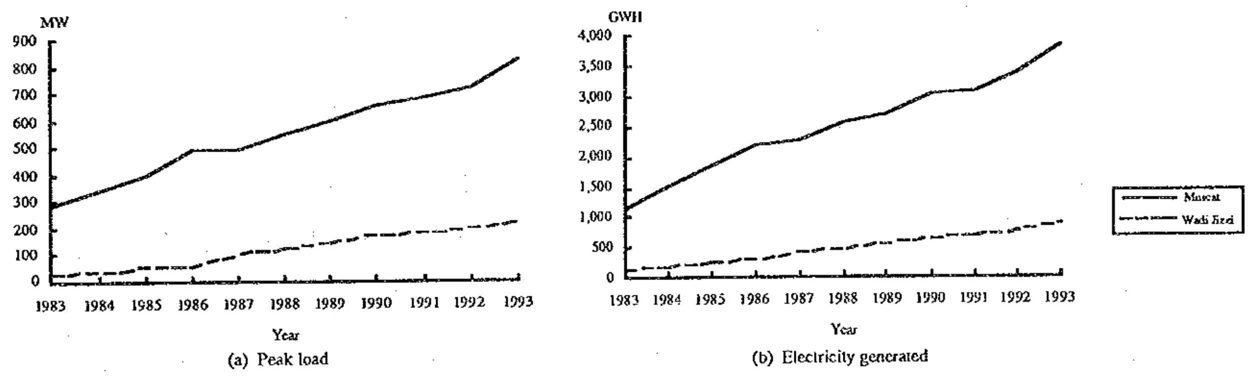
4 According to the World Energy Outlook for 1994 published by International Energy Agency, the average IEA imported crude oil price will rise steadily to $28 per barrel by 2005, after which it will remain flat. This projection is based on the assumption that the corresponding price is $17 per barrel in 1994 and 1995.

growing steadily, 2.4 times for the last 15 years. The oil production reportedly has been increased to compensate the recent years' decreases in oil prices. The question arises as to whether this production adjustment will continue to be possible in the future.

The other reason is that the elasticity of the economic variable(s) in the econometric model tends to be overestimated, if no variables measuring the number of connections are included in the model. Considering the fact that the increase in the number of connections has been the primary determinant of the rises in the country's power demand, it is surely not appropriate to rely upon such forecasting models that include only economic variables.

4.5.2 Macro trend extrapolation

As evidently suggested in Figure 4.5.2, the peak load and the energy generated for both Muscat and Wadi Jizzi Systems increased steadily and almost at constant rates in the past. It can be assumed that these linear increases will continue in the foreseeable future.



Source: Ministry of Electricity and Water, "Electricity Generation & Distribution and Water Production from Desalination Plants: Annual Report 1992 and 1993".

Figure 4.5.2 Changes in Peak Load and Electricity Generated

Assuming that the peak load and the energy generated for the subject two systems will continue to increase at constant rates, we extrapolate the future values of those variables on the basis of linear regression (see Figures 4.5.3 - 4.5.4). The functions of the extrapolating trend lines are expressed as shown below.

Description	Equation	r^2	Year 2000 (Projected)	Year 2010 (Projected)
Peak load (MW)				
Muscat	Y = -99610.327 + 50.382 x X	.986	1,154	1,657
Wadi Jizzi	Y = -40058.127 + 20.209 x X	.982	360	562
Electricity generated (GWH)				
Muscat	Y = -484513.764 + 244.982 x X	.983	5,450	7,900
Wadi Jizzi	Y = -148162.109 + 74.764 x X	.991	1,366	2,114

Note: X = Year

All the coefficients of determination (r^2) are acceptably high. The aggregate of the peak loads of the two systems is projected to reach 1,514 MW in the year 2000 and 2,219 MW in 2010.

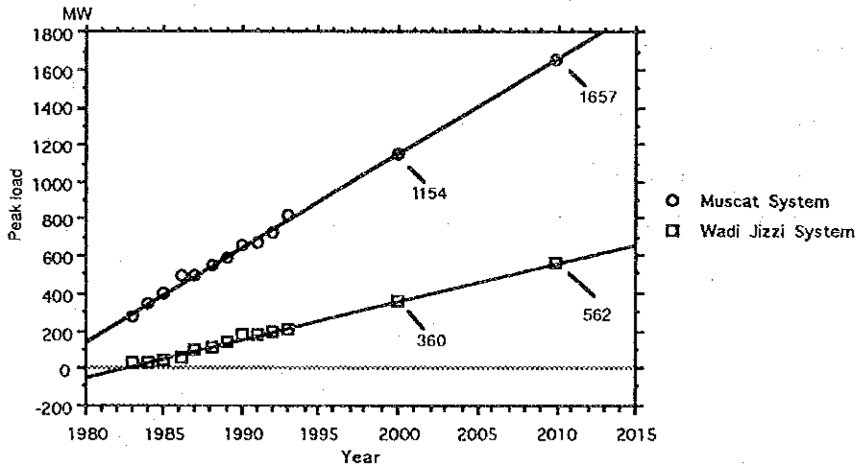


Figure 4.5.3 Extrapolated Peak Load
(Muscat & Wadi Jizzi Systems) 2000 & 2010

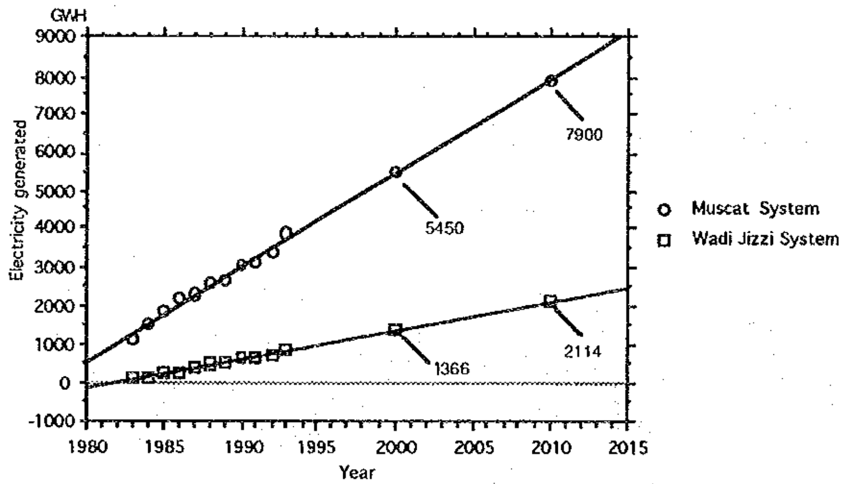


Figure 4.5.4 Extrapolated electricity generated
(Muscat & Wadi Jizzi Systems) 2000 & 2010

4.5.3 Micro approach

In the micro forecasting approach, the consumption of power by type of customers will be projected with estimated growth rates for the number of connections and estimated changes in the unit consumption (i.e., consumption per connection). Power service areas were expanded into towns and villages rapidly in recent years. It is expected that the increase in the number of consumers will not be as rapid as that in the past, since all the major towns covered by the subject systems have already been connected to the systems, and future expansion of the systems is limited only to small rural settlements. This point has to be fully considered in estimating the future increase in the number of consumers.

For commercial and industrial consumptions, comparatively high growth rates are expected, because of the government policies and measures for industrialization. It can also be anticipated that the unit consumption for domestic use will continue to grow vigorously for some time, as the sale of airconditioners is reported to be steady these days.

We first examine briefly the power demand by major consumers, and then make demand projections for other consumers, estimating the future increases in the number of connections and changes in the unit consumption for different uses. Figure 4.5.5 shows the consumers' classification used for our micro forecasting. Among major consumers, only those in the government sector are treated separately from other non-major consumers.

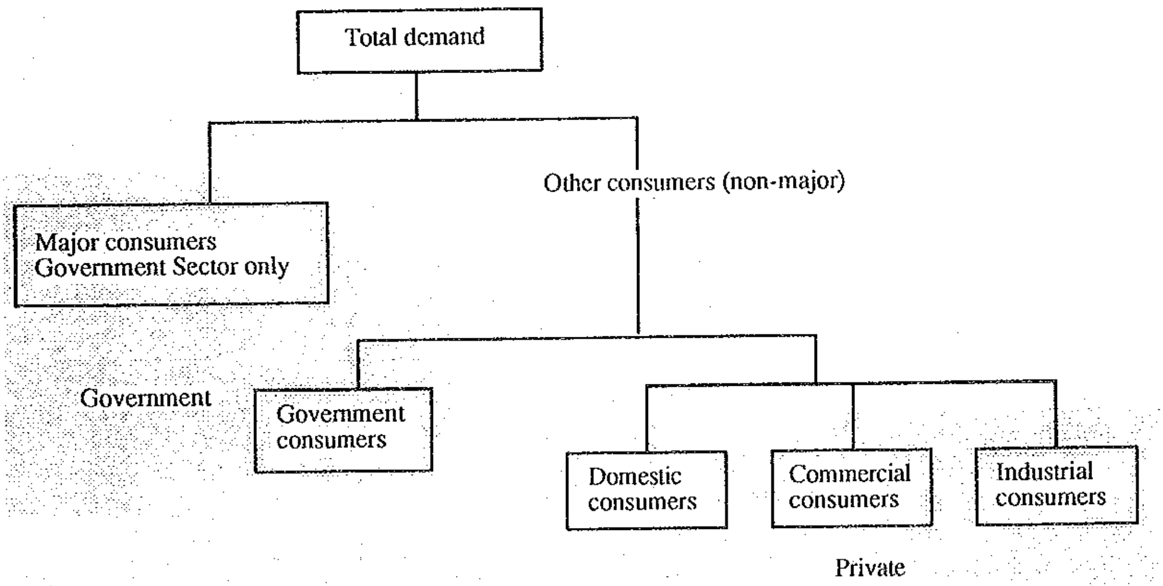


Figure 4.5.5 Power Consumers' Classification for Micro Approach

(1) Major consumers

Tables 4.5.1 and 4.5.2 exhibit recent changes in the total power consumption by all the consumers and that by major consumers, respectively. All the major customers in the government sector except Oman Mining Company are provided power from the Muscat System. The industrial tariff is applied to Oman Cement, and the commercial tariff to Oman Refinery. Oman Mining Company, which maintains its own generators at the Wadi Jizzi Power Station, is served with power from the Wadi Jizzi System. The future power needs by the Ghubrah desalination plant have to be projected in line with the future expansion plans of its capacities.

Table 4.5.1 Power consumption - Muscat & Wadi Jizzi Systems 1990 -1993

(MWH)

Year	1990		1991		1992		1993	
1. Muscat System								
Domestic	1,367,831	(57.1%)	1,423,984	(58.7%)	1,621,077	(60.8%)	1,856,789	(61.1%)
% change	-		4.1%		13.8%		14.5%	
Government	777,339	(32.4%)	769,168	(31.7%)	799,188	(30.0%)	884,520	(29.1%)
% change	-		-1.1%		3.9%		10.7%	
Industrial	45,693	(1.9%)	57,379	(2.4%)	68,791	(2.6%)	88,212	(2.9%)
% change	-		25.6%		19.9%		28.2%	
Commercial*	206,505	(8.6%)	175,854	(7.2%)	177,554	(6.7%)	208,955	(6.9%)
% change	-		-14.8%		1.0%		17.7%	
Total	2,397,368	(100.0%)	2,426,385	(100.0%)	2,666,610	(100.0%)	3,038,476	(100.0%)
% change	-		1.2%		9.9%		13.9%	
2. Wadi Jizzi System								
Domestic	316,899	(76.4%)	335,889	(76.9%)	398,270	(77.2%)	452,956	(75.6%)
% change	-		6.0%		18.6%		13.7%	
Government	64,723	(15.6%)	68,020	(15.6%)	77,524	(15.0%)	90,514	(15.1%)
% change	-		5.1%		14.0%		16.8%	
Industrial	356	(0.1%)	2,481	(0.6%)	4,321	(0.8%)	5,076	(0.8%)
% change	-		596.9%	(0.0%)	74.2%		17.5%	
Commercial*	32,706	(7.9%)	30,540	(7.0%)	35,943	(7.0%)	50,827	(8.5%)
% change	-		-6.6%		17.7%		41.4%	
Total	414,684	(100.0%)	436,930	(100.0%)	516,058	(100.0%)	599,373	(100.0%)
% change	-		5.4%		18.1%		16.1%	
3. Oman Mining Company (no billing)	119,275		121,230		122,738		129,458	
% change	-		1.6%		1.2%		5.48%	
4. Ghubrah desalination plant (no billing)	121,929		130,726		135,951		156,852	
% change	-		7.2%		4.0%		15.37%	
5. Total consumption	3,053,256		3,115,271		3,441,357		3,924,159	
% change	-		2.0%		10.5%		14.03%	

Source: Ministry of Electricity and Water, "Electricity Generation & Distribution and Water Production from Desalination Plants: Annual Reports 1992 and 1993".

*Including Agriculture, Fisheries, Hotels and Tourism.

Table 4.5.2 Major Power Consumers 1991 - 1993

Government sector	1991	1992	1993	Private sector	1991		1992		1993	
	Consumption (MWH)	Consumption (MWH)	Consumption (MWH)		No. of Accounts	Consumption (MWH)	No. of Accounts	Consumption (MWH)	No. of Accounts	Consumption (MWH)
Ghubrah Desalination Plant	130,726	135,812	156,852	Industrial tariff	52	59,723	72	73,314	79	93,516
Oman Cement Co.	96,494	99,701	98,582	Commercial tariff	99	27,924	92	33,637	115*	35,677*
Oman Refinery	8,469	12,496	16,267	Stepped tariff	-	-	8	25,523	-	-
Oman Mining Co.	121,230	122,738	129,458							
Total	356,919	370,747	401,159	Total	151	87,647	172	132,474	194	129,193

* Including stepped tariff.

Source: Ministry of Electricity and Water, "Electricity Generation & Distribution and Water Production from Desalination Plants: Annual Reports 1992 and 1993".

The consumption of Oman Cement, Oman Refinery, and Oman Mining Companies represented respectively 2.5 %, 0.4 % and 3.3 % of the total consumption in 1993. Historical changes in the consumption of these three entities are not known, while it is known that the combined consumption of the three increased by at an annual rate of 3.9 % between 1991 and 1993. We simply apply an estimated future annual economic growth rate of the Middle East of 3.5 % for the future yearly increase in the consumption of the three entities. The combined consumption is computed at 310,827 MWH in 2000 and 438,452 MWH in 2010.

Compared to the major consumers in the public sector, those in the private sector are large in number and small in unit consumption. Their total consumption accounted only for 3.3 % of the aggregate consumption of the two systems. Besides the fact that details of those customers (e.g., the types of industries and future expansion plans) are not known, it seems to be not necessary to make projections for their future consumption separately from that of the other users in the private sector.

(2) Number of Connections

1) Muscat Power System

The Muscat Power System covers a wide area extending from Muscat Governorate, and Al Batinah and A'Dakhiliya Regions, including the Walayats of Muscat, A'Seeb, Muttrah, Bausher, Quriyat, A'Rustaq, Al Khabourah, A'Suwaiq, Nakhal, Al Awabi, Al Masnaah, Barka, Samail, and Bid Bid (see Table 4.5.3). Table 4.5.5 exhibits changes in the number of connections of the Muscat and Wadi Jizzi Systems between 1990 and 1993.

Table 4.5.3 Total Population by Walayat (selected regions), December 1993

Region		Walayat	Total population	No. of families	Average family size	% of Omanis	No. of establishments
Muscat	*	Muscat	51,969	7,046		78 %	
	*	A'Seeb	133,417	15,966		70 %	
	*	Muttrah	261,323	46,888		36 %	
	*	Bausher	108,259	14,052		42 %	
		Al Amirat	36,178	4,371		83 %	
	*	Quriyat	31,360	3,975		89 %	
		Total	622,506	92,298	6.7	53 %	24,211
Al Batinah	#	Sohar	85857	11,284		81 %	
		A'Rustaq	59,379	7,004		90 %	
	#	Shinas	42,533	5,287		85 %	
	#	Liwa	21,463	2,672		88 %	
	#	Saham	71,671	8,586		87 %	
	*	Al Khabourah	38,429	5,108		87 %	
		A'Suwaiq	81,165	10,204		86 %	
	*	Nakhal	12,570	1,576		91 %	
		Wadi Al Maawil	10,630	1,340		91 %	
		Al Awabi	8,488	1,052		92 %	
	*	Al Masnaah	45,414	5,762		87 %	
	*	Barka	61,164	8,498		77 %	
		Total	538,763	68,373	7.9	85 %	22,927
A'Dhahira		Al Buraimi	46,157	6,150		62 %	
	#	Ibri	88,314	9,996		82 %	
		Mahdha	7,721	1,321		61 %	
	#	Yanqul	14,158	1,955		87 %	
	#	Dhank	13,360	1,748		87 %	
		Total	169,710	21,170	7.8	77 %	9,116
A'Dakhliya		Nizwa	56,227	6,990		85 %	
		Samail	36,469	4,488		91 %	
		Bahla	44,804	5,601		90 %	
		Adam	13,238	1,881		82 %	
		Al Hamra	13,698	1,566		94 %	
		Manah	10,088	1,295		90 %	
		Izki	28,631	3,445		88 %	
		Bid Bid	17,248	2,045		87 %	
		Total	220,403	27,311	8.1	88 %	9,442

* Covered by the Muscat Electrical System.
# Covered by the Wadi Jizzi Electrical System.

Source: Development Council, "Preliminary Results of the General Census of Population, Housing, and Establishments", December 1993.

Table 4.5.4 Number of Consumers 1990-1993

Year	1990		1991		1992		1993	
A. Muscat system								
Domestic	108,541	(88.7%)	113,970	(88.6%)	119,371	(88.3%)	127,005	(88.4%)
% change	-		5.0%		4.7%		6.4%	
Government	6,990	(5.7%)	7,731	(6.0%)	8,136	(6.0%)	8,405	(5.9%)
% change	-		10.6%		5.2%		3.3%	
Industrial	42	(0.0%)	49	(0.0%)	58	(0.0%)	62	(0.0%)
% change	-		16.7%		18.4%		6.9%	
Commercial*	6,829	(5.6%)	6,952	(5.4%)	7,675	(5.7%)	8,185	(5.7%)
% change	-		1.8%		10.4%		6.6%	
Total	122,402	(100%)	128,702	(100%)	135,240	(100%)	143,657	(100%)
% change	-		5.1%		5.1%		6.2%	
B. Wadi Jizzi system								
Domestic	38,428	(87.0%)	41,489	(87.5%)	45,297	(86.1%)	48,935	(85.9%)
% change	-		8.0%		9.2%		8.0%	
Government	2,012	(4.6%)	2,122	(4.5%)	2,824	(5.4%)	3,284	(5.8%)
% change	-		5.5%		33.1%		16.3%	
Industrial	4	(0.0%)	6	(0.0%)	8	(0.0%)	8	(0.0%)
% change	-		50.0%		33.3%		0%	
Commercial*	3,720	(8.4%)	3,783	(8.0%)	4,477	(8.5%)	4,754	(8.3%)
% change	-		1.7%		18.3%		6.2%	
Total	44,164	(100%)	47,400	(100%)	52,606	(100%)	56,981	(100%)
% change	-		7.3%		11.0%		8.3%	

* Including Agriculture, Fisheries, Hotels and Tourism.

Source: Ministry of Electricity and Water, "Electricity Generation & Distribution and Water Production from Desalination Plants: Annual Reports 1992 and 1993".

a. Domestic Connections

The Muscat System has expanded its distribution network, sometimes by removing diesel engine generators of rural electrification systems. It is reported that all the load and subload centers of the system, including As Suwaiq, Al Rustaq, Nakhl, and Al Awabi, now receive power generated at the Ghubra and Rusail Power Stations.

The walayats the Muscat System covered had approximately 760,000 residents and 110,000 families, in total, as of 1993 (see Table 4.5.3). For comparison, the total domestic accounts of the system was 127,000 in the same year (see Table 4.5.4). It is reported that the domestic accounts include connections of small commercial establishments. In fact, while there probably were more than 40,000 commercial establishments in the area concerned, the commercial connections totaled only approximately 8,200 in 1993. It is safe to assume that most residents in the system area are already served with power, and the future expansion of the service area is limited only to small settlements in rural areas.[5] We assume that the domestic connections will continue to increase in number, only at the level of population growth, which is estimated at an annual 3.5 percent.[6] Based on this assumption, the domestic connections are estimated to increase to the following numbers:

	1993 (actual)	2000	2010
Number of connections	127,005	161,586	227,933

b. Non-domestic connections

The number of non-domestic connections does not show stable rates of changes. Relevant data exhibited in Table 4.5.4 denotes the average annual growth rates of 6.2 % for commercial connections, 13.9 % for industrial ones, and 6.3 % for government ones between 1990 and 1993. As the service area is rarely extended into new towns any longer, and as the increase of customers becomes attributable mostly to new connections generated in the areas already covered by distribution grids, the percentage growth rates of non-domestic connections are very likely to decrease in the future. Economic expansion and governmental incentives alone cannot sustain the current levels of percentage growth rates.

The average annual increases in the number of non-domestic connections for the last three years were approximately 450 for commercial connections, 7 for industrial, and 470 for government. We

5 The household electrification rate of the entire nation was 76.3 percent in 1993. (Approximately 256,000 households out of the total 335,700 were connected.)

6 The average household size is expected to change little by the year 2010, as the Omanization will increase the ratio of Omani population to the nation's total population. It is apparent that the average family size of the nationals is higher than the counterfigure of the non-Omani residents, most of whom are in Oman for purpose of work, leaving their families in their countries.

estimate that these numbers represent the future increases in the number of connections more appropriately than the growth rates expressed in percentage, although economic advancement might bring rapid increases in the number of commercial and industrial establishments and thus connections[7]. Our estimates for the changes in the number of non-domestic connections are as shown below.

	1994 - 2000	2001 - 2005	2006 - 2010
1. Commercial			
Annual connection increase	400	450	450
Average annual rate of increase	4.3 %	3.8 %	3.2 %
2. Industrial			
Annual connection increase	7	7	7
Average annual rate of increase	8.7 %	7.0 %	4.1 %
3. Government			
Annual connection increase	300	200	150
Average annual rate of increase	3.2 %	1.8 %	1.3 %

2) Wadi Jizzi System

The Wadi Jizzi System includes the Walayats of Sohar, Shinas, Liwa, Saham in the Al Batinah Region, and Walayats of Al Buraimi, Ibris, Yanqul, and Dhank in the A'Dhahira Region. The total population of those wilayats were approximately 384,000 in 1993 (Table 4.5.3).

a. Domestic connections

The system has expanded rapidly. For example, in Sohar alone, where 11,300 families were residing in 1993, 3,646 domestic and non-domestic connections were added in 1992. The average annual increase in the number of domestic connections during the last three years was 3,500. The system in 1993 had nearly 49,000 domestic connections, compared to the estimated number of households of 47,700.

We assume that most of the households are already connected to the system, and thus that the future increase is limited to the level of the

7 We speculate that the high economic growth experienced in recent years (i.e., annual GDP growth rate of 8% between 1990 and 1992) may not be feasible in the future provided that the current macro economic environment changes significantly, for example, with substantial improvement of international oil prices.

estimated annual population growth rate of 3.5 percent. This rate of increase corresponds with the following numbers of domestic connections:

	1993 (actual)	2000	2010
Number of connections	48,935	62,259	87,822

b. Non-domestic connections

Between 1990 and 1993, the government and commercial connections increased in number by 1,272 and 1,034, or annually by approximately 420 and 340, respectively, whereas the industrial connections doubled, from 4 to 8. In line with the government's stated policy of reducing regional development disparities between the Muscat area and other regions, it is assumed that the area the system covers will continuously receive economic stimulus from the government. As the region's economy is expected to grow steadily and fast, the annual increase in the number of commercial connections could be as large as that in Muscat, whose economy is far larger than that in the Wadi Jizzi System area. We estimate that, whereas connections for industrial use will increase by 2 annually until the year 2000, and by 3 thereafter, and thus from 8 in 1993 to 22 in 2000 and 52 in 2010, those for commercial and government uses will increase by the following numbers at the following rates:

	1994 - 2000	2001 - 2005	2006 - 2010
1. Commercial			
Annual connection increase	300	350	300
Average rate of increase	5.4 %	4.7 %	3.3 %
2. Government			
Annual connection increase	350	250	200
Average rate of increase	8.3 %	4.0 %	2.7 %

(3) Unit Consumption

a. Domestic Consumption

Table 4.5.5 exhibits the average consumption per connection or unit consumption of each type of users during the last three years. It is important to note that for all the uses except the government use of the Wadi Jizzi System, the unit consumption grew significantly in 1993. Levels of unit consumption tend to fluctuate conspicuously.

Table 4.5.5 Average consumption per connection (MWH) 1990-1993

Year	1990	1991	1992	1993
A. Muscat System				
Domestic	12.6	12.5	13.6	14.6
Government*	N/A	85.9	84.4	91.6
Industrial	1,087.9	1,171.0	1,186.1	1,422.8
Commercial#	30.2	25.3	23.1	25.5
B. Wadi Jizzi System				
Domestic	8.2	8.1	8.8	9.3
Government	32.2	32.1	27.5	27.6
Industrial	89.0	413.5	540.1	634.5
Commercial#	8.8	8.1	8.0	10.7

* Consumption by major customers is excluded.
\# Excluding Agriculture, Fisheries, Hotels and Tourism.

The domestic unit consumption increased at yearly rates of 5.0 % for the Muscat System and 4.3 % for the Wadi Jizzi System. These increases are attributable largely to vigorous purchase of airconditioner units by households. The future growth rates are expected to be lower than these levels, as the average household total load should not rise substantially for years. As for the Muscat System, we assume that after reaching the level of approximately 19 MWH at an annual growth rate of 3.5 % in 2000, the growth rate will decrease to 2.5 % by 2010. On the other hand, the corresponding rates for the Wadi Jizzi are expected to be slightly higher. Estimated growth rates for the two systems and corresponding levels of unit consumption are as follows:

	Average annual growth rate		
	1994 - 2000	2001 - 2005	2006 - 2010
Muscat System	3.5 %	3.0 %	2.5 %
Wadi Jizzi System	4.0 %	4.0 %	3.5 %

	Projected unit consumption	
	2000	2010
Muscat System	18.6 MWH	24.4 MWH
Wadi Jizzi System	12.2 MWH	17.7 MWH

b. Non-Domestic Consumption

The levels of unit consumption of non-domestic consumer groups fluctuated notably between 1990 and 1993, with those of some groups having decreased. The decline was attributed presumably to the tendency that as the service area is extended into rural areas, the unit consumption will decrease. We expect that the changes in unit consumption will become smaller and more persistent in the future. General tendencies of the changes among government and commercial consumers of both Muscat and Wadi Jizzi Systems will be slight, but clearly upward, due to the office automation progress in urban areas. As for the industrial use, the unit consumption will continue to rise. Industrialization will be continuously supported by the government. There will be more industrial establishments requiring large quantities of power in both Muscat and Batinah, while in the latter region, where opportunities for large scale industrial operations are limited, the unit consumption will remain smaller than that in the Muscat Area. Our estimates for the levels of unit consumption among non-domestic users are exhibited in Table 4.5.6.

Table 4.5.6 Projected Unit Consumption of Non-Domestic Consumers

Year	1993 (actual)	2000	2010
Unit consumption (MWH)			
Muscat System:			
Government	91.6	105.2	134.7
Industrial	1,422.8	2,022.0	3,108.7
Commercial	25.5	29.3	37.5
Wadi Jizzi System:			
Government	27.6	31.7	38.6
Industrial	634.5	1,087.4	2,138.2
Commercial	10.7	13.2	18.6

Year	1994 - 2000	2001 - 2005	2006 - 2010
Growth rate			
Muscat System:			
Government	2 %	3 %	2 %
Industrial	5 %	5 %	4 %
Commercial	2 %	3 %	2 %
Wadi Jizzi System:			
Government	2 %	2 %	2 %
Industrial	8 %	8 %	6 %
Commercial	3 %	4 %	3 %

(4) Projected Total Consumption

Based on the above-mentioned, estimated growth rates and numbers of increase for connections and unit consumption, the future consumption of electricity is projected as shown in Table 4.5.7 (see also Figures 4.5.6 and 4.5.7).

The total power consumption of the two systems is projected to increase by about three times, from 3,767 GWH in 1993 to 10,874 GWH by 2010. The structure or the composition of the consumption is not expected to change significantly (see Figure 4.5.7). The Muscat System will experience a proportional decrease in the government use, offset by an increase in commercial and industrial shares, reflecting a progressive shift in the government's development role from direct involvement to indirect assistance to the private sector.

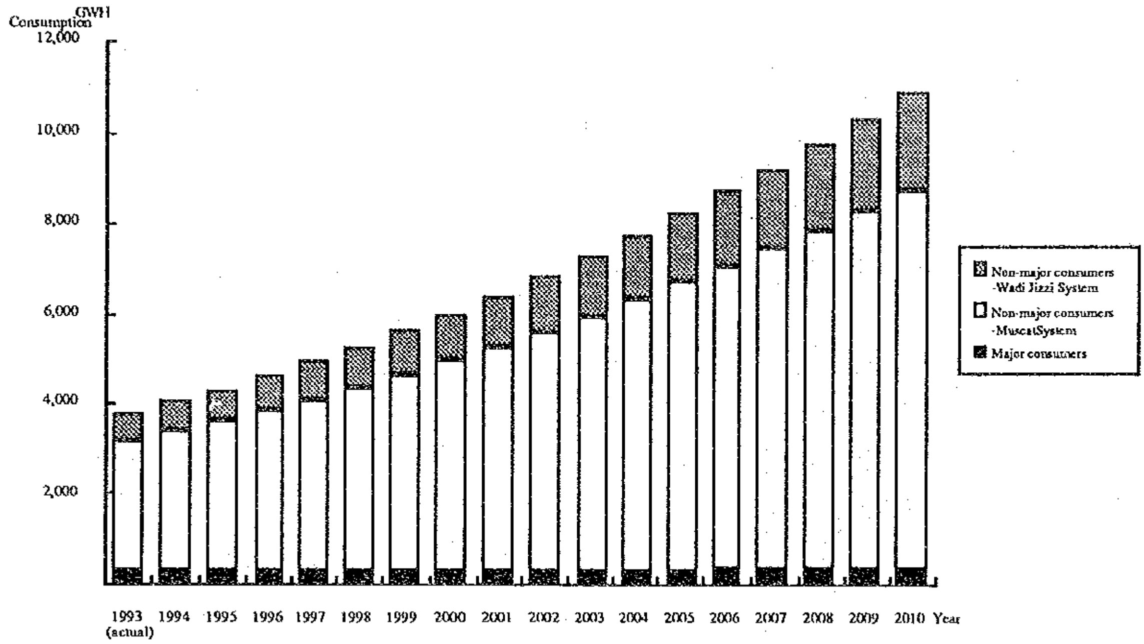


Figure 4.5.6 Changes in Power Consumption (projected) 1993-2010

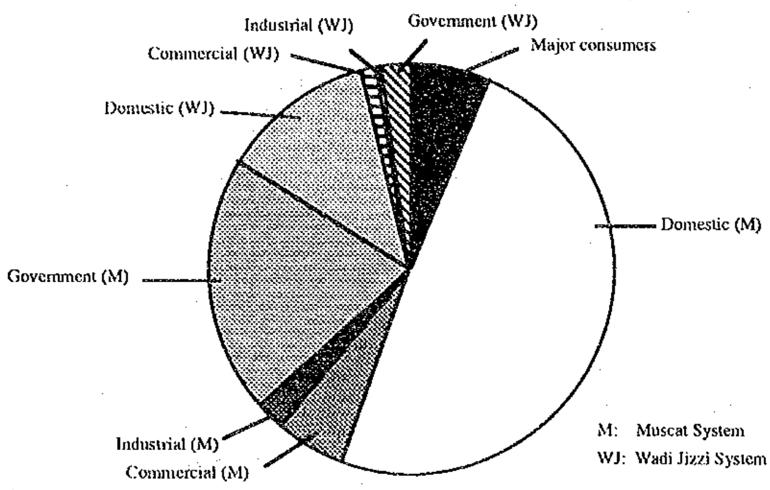
Table 4.5.7 Projected power consumption

(MWH)

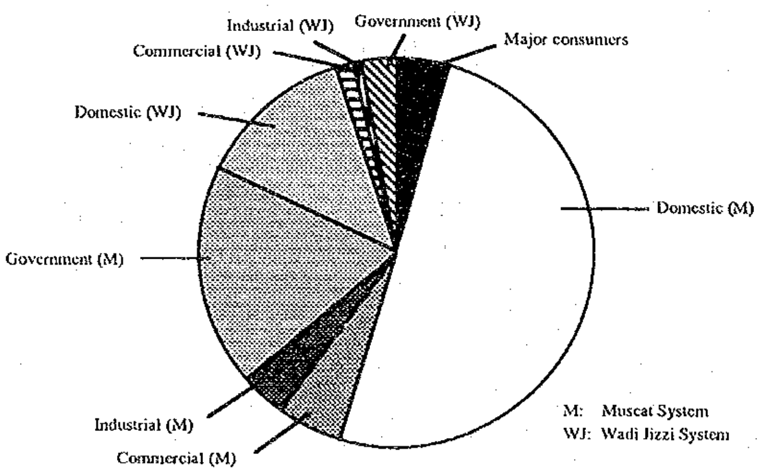
Description / Year	1993	1994	1995	1996	1997	1998	1999	2000	2001
Major consumers									
1 Oman Cement, Refinery, and Mining Cos.	244,307	252,858	261,708	270,868	280,348	290,160	300,316	310,827	321,706
% change		3.5%	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%
Non-major customers									
Muscat System									
2 Domestic	1,856,692	2,054,369	2,200,691	2,357,436	2,525,344	2,705,212	2,897,890	3,104,293	3,309,331
Number of connections	127,005	131,450	136,051	140,813	145,741	150,842	156,122	161,586	167,241
% change of connections		3.5%	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%
Unit consumption	15.1	15.6	16.2	16.7	17.3	17.9	18.6	19.2	19.8
% change of unit consumption		3.5%	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%	3.0%
combined % change		7.1%	7.1%	7.1%	7.1%	7.1%	7.1%	7.1%	6.6%
3 Commercial	208,955	223,296	238,374	253,966	270,086	286,749	303,971	321,767	344,997
Number of connections	8,185	8,585	8,985	9,385	9,785	10,185	10,585	10,985	11,435
% change of connections		4.9%	4.7%	4.5%	4.3%	4.1%	3.9%	3.8%	4.1%
Unit consumption	25.5	26.0	26.5	27.1	27.6	28.2	28.7	29.3	30.2
% change of unit consumption		2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	3.0%
combined % change		7.0%	6.8%	6.5%	6.3%	6.2%	6.0%	5.9%	7.2%
4 Industrial	88,212	103,082	119,216	136,707	155,648	176,142	198,296	222,224	252,255
Number of connections	62	69	76	83	90	97	104	111	120
% change of connections		11.3%	10.1%	9.2%	8.4%	7.8%	7.2%	6.7%	8.1%
Unit consumption	1422.8	1493.9	1568.6	1647.1	1729.4	1815.9	1906.7	2002.0	2102.1
% change of unit consumption		5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
combined % change		16.9%	15.7%	14.7%	13.9%	13.2%	12.6%	12.1%	13.5%
5 Government	640,213	813,326	858,182	904,508	952,343	1,001,730	1,052,712	1,105,332	1,160,167
Number of connections	8,405	8,705	9,005	9,305	9,605	9,905	10,205	10,505	10,705
% change of connections		3.6%	3.4%	3.3%	3.2%	3.1%	3.0%	2.9%	1.9%
Unit consumption	91.6	93.4	95.3	97.2	99.2	101.1	103.2	105.2	108.4
% change of unit consumption		2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	3.0%
combined % change		5.6%	5.5%	5.4%	5.3%	5.2%	5.1%	5.0%	5.0%
6 Total (Items 2 to 5)	2,794,072	3,194,072	3,416,464	3,652,616	3,903,421	4,169,833	4,452,869	4,753,616	5,066,750
Wadi Jizzi System									
7 Domestic	452,956	489,865	527,290	567,575	610,938	657,614	707,856	761,936	820,148
Number of connections	48,935	50,648	52,420	54,255	56,154	58,119	60,154	62,259	64,438
% change of connections		3.5%	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%
Unit consumption	9.3	9.7	10.1	10.5	10.9	11.3	11.8	12.2	12.7
% change of unit consumption		4.0%	4.0%	4.0%	4.0%	4.0%	4.0%	4.0%	4.0%
combined % change		7.6%	7.6%	7.6%	7.6%	7.6%	7.6%	7.6%	7.6%
8 Commercial	50,827	55,700	60,777	66,108	71,704	77,576	83,736	90,196	98,594
Number of connections	4,754	5,054	5,354	5,654	5,954	6,254	6,554	6,854	7,204
% change of connections		6.3%	5.9%	5.6%	5.3%	5.0%	4.8%	4.6%	5.1%
Unit consumption	10.7	11.0	11.4	11.7	12.0	12.4	12.8	13.2	13.7
% change of unit consumption		3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	4.0%
combined % change		9.5%	9.1%	8.8%	8.5%	8.2%	7.9%	7.7%	9.3%
9 Industrial	5,076	6,853	8,881	11,190	13,812	16,781	20,137	23,923	29,360
Number of connections	8	10	12	14	16	18	20	22	25
% change of connections		25.0%	20.0%	16.7%	14.3%	12.5%	11.1%	10.0%	13.6%
Unit consumption	634.5	685.3	740.1	799.3	863.2	932.3	1006.9	1087.4	1174.4
% change of unit consumption		8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%
combined % change		35.0%	29.6%	26.0%	23.4%	21.5%	20.0%	18.8%	22.7%
10 Government	90,514	102,304	114,401	126,940	139,935	153,399	167,346	181,789	193,509
Number of connections	3,284	3,634	3,984	4,334	4,684	5,034	5,384	5,734	5,984
% change of connections		10.7%	9.6%	8.8%	8.1%	7.5%	7.0%	6.5%	4.4%
Unit consumption	27.6	28.2	28.7	29.3	29.9	30.5	31.1	31.7	32.3
% change of unit consumption		2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%
combined % change		12.9%	11.8%	11.0%	10.2%	9.6%	9.1%	8.6%	6.4%
11 Total (Items 7 to 10)	599,373	654,722	711,349	771,813	836,389	905,370	979,075	1,057,844	1,141,612
12 Grand Total (Items 1, 6 and 11)	3,637,752	4,101,652	4,389,521	4,695,297	5,020,158	5,365,363	5,732,260	6,122,287	6,530,067

Description / Year	2002	2003	2004	2005	2006	2007	2008	2009	2010
Major consumers									
1 Oman Cement, Refinery, and Mining Cos.	332,965	344,619	356,681	369,165	382,085	395,458	409,299	423,625	438,452
% change	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%
Non-major customers									
Muscat System									
2 Domestic	3,527,913	3,760,931	4,009,341	4,274,158	4,534,347	4,810,375	5,103,207	5,413,865	5,743,434
Number of connections	173,095	179,153	185,423	191,913	198,630	205,582	212,778	220,225	227,933
% change of connections	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%
Unit consumption	20.4	21.0	21.6	22.3	22.8	23.4	24.0	24.6	25.2
% change of unit consumption	3.0%	3.0%	3.0%	3.0%	2.5%	2.5%	2.5%	2.5%	2.5%
combined % change	6.6%	6.6%	6.6%	6.6%	6.1%	6.1%	6.1%	6.1%	6.1%
3 Commercial	369,330	394,814	421,494	449,419	473,994	499,371	525,575	552,626	580,550
Number of connections	11,885	12,335	12,785	13,235	13,685	14,135	14,585	15,035	15,485
% change of connections	3.9%	3.8%	3.6%	3.5%	3.4%	3.3%	3.2%	3.1%	3.0%
Unit consumption	31.1	32.0	33.0	34.0	34.6	35.3	36.0	36.8	37.5
% change of unit consumption	3.0%	3.0%	3.0%	3.0%	2.0%	2.0%	2.0%	2.0%	2.0%
combined % change	7.1%	6.9%	6.8%	6.6%	5.5%	5.4%	5.2%	5.1%	5.1%
4 Industrial	284,733	319,828	357,720	398,603	433,148	469,820	508,732	550,005	593,766
Number of connections	129	138	147	156	163	170	177	184	191
% change of connections	7.5%	7.0%	6.5%	6.1%	4.5%	4.3%	4.1%	4.0%	3.8%
Unit consumption	2207.2	2317.6	2433.5	2555.1	2657.4	2763.6	2874.2	2989.2	3108.7
% change of unit consumption	5.0%	5.0%	5.0%	5.0%	4.0%	4.0%	4.0%	4.0%	4.0%
combined % change	12.9%	12.3%	11.8%	11.4%	8.7%	8.5%	8.3%	8.1%	8.0%
5 Government	1,217,298	1,276,812	1,338,801	1,403,361	1,450,091	1,498,129	1,547,508	1,598,263	1,650,429
Number of connections	10,905	11,105	11,305	11,505	11,655	11,805	11,955	12,105	12,255
% change of connections	1.9%	1.8%	1.8%	1.8%	1.3%	1.3%	1.3%	1.3%	1.2%
Unit consumption	111.6	115.0	118.4	122.0	124.4	126.9	129.4	132.0	134.7
% change of unit consumption	3.0%	3.0%	3.0%	3.0%	2.0%	2.0%	2.0%	2.0%	2.0%
combined % change	4.9%	4.9%	4.9%	4.8%	3.3%	3.3%	3.3%	3.3%	3.3%
6 Total (Items 2 to 5)	5,399,273	5,752,384	6,127,356	6,525,540	6,891,580	7,277,695	7,685,021	8,114,759	8,568,179
Wadi Jizzi System									
7 Domestic	882,807	950,253	1,022,853	1,100,999	1,179,417	1,263,421	1,353,409	1,449,805	1,553,067
Number of connections	66,693	69,028	71,444	73,944	76,532	79,211	81,983	84,853	87,822
% change of connections	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%
Unit consumption	13.2	13.8	14.3	14.9	15.4	16.0	16.5	17.1	17.7
% change of unit consumption	4.0%	4.0%	4.0%	4.0%	3.5%	3.5%	3.5%	3.5%	3.5%
combined % change	7.6%	7.6%	7.6%	7.6%	7.1%	7.1%	7.1%	7.1%	7.1%
8 Commercial	107,520	117,001	127,070	137,756	146,836	156,337	166,276	176,670	187,539
Number of connections	7,554	7,904	8,254	8,604	8,904	9,204	9,504	9,804	10,104
% change of connections	4.9%	4.6%	4.4%	4.2%	3.5%	3.4%	3.3%	3.2%	3.1%
Unit consumption	14.2	14.8	15.4	16.0	16.5	17.0	17.5	18.0	18.6
% change of unit consumption	4.0%	4.0%	4.0%	4.0%	3.0%	3.0%	3.0%	3.0%	3.0%
combined % change	9.1%	8.8%	8.6%	8.4%	6.6%	6.5%	6.4%	6.3%	6.2%
9 Industrial	35,514	42,465	50,300	59,118	67,746	77,196	87,537	98,841	111,186
Number of connections	28	31	34	37	40	43	46	49	52
% change of connections	12.0%	10.7%	9.7%	8.8%	8.1%	7.5%	7.0%	6.5%	6.1%
Unit consumption	1268.4	1369.8	1479.4	1597.8	1693.6	1795.3	1903.0	2017.2	2138.2
% change of unit consumption	8.0%	8.0%	8.0%	8.0%	6.0%	6.0%	6.0%	6.0%	6.0%
combined % change	21.0%	19.6%	18.5%	17.5%	14.6%	14.0%	13.4%	12.9%	12.5%
10 Government	205,626	218,149	231,092	244,464	256,494	268,908	281,715	294,927	308,555
Number of connections	6,234	6,484	6,734	6,984	7,184	7,384	7,584	7,784	7,984
% change of connections	4.2%	4.0%	3.9%	3.7%	2.9%	2.8%	2.7%	2.6%	2.6%
Unit consumption	33.0	33.6	34.3	35.0	35.7	36.4	37.1	37.9	38.6
% change of unit consumption	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%
combined % change	6.3%	6.1%	5.9%	5.8%	4.9%	4.8%	4.8%	4.7%	4.6%
11 Total (Items 7 to 10)	1,231,467	1,327,869	1,431,315	1,542,337	1,650,494	1,765,862	1,888,936	2,020,243	2,160,347
12 Grand Total (Items 1, 6 and 11)	6,963,705	7,424,873	7,915,351	8,437,042	8,924,159	9,439,016	9,983,257	10,558,627	11,166,978

(1) Year 1993 (actual)



(2) Year 2000 (projected)



(3) Year 2010 (projected)

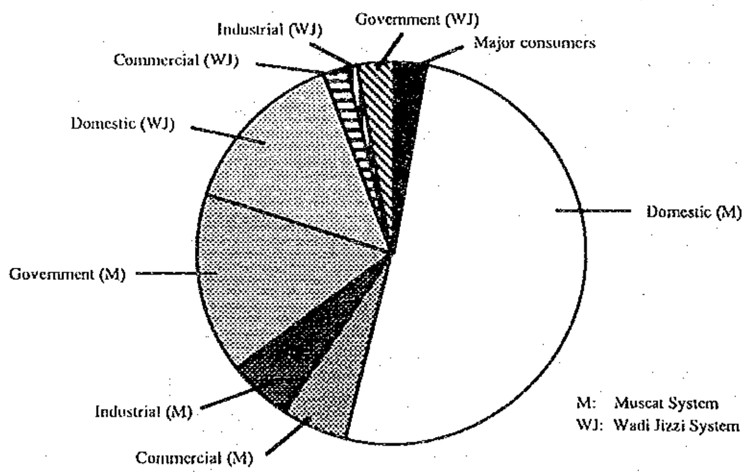


Figure 4.5.7 Changes in the Composition of the Power Consumption

(5) Projected Peak Load

Accordingly to the MEW's annual reports, the system loss factors for the last three years, which include station uses, are as follows:

Muscat System:	1991 - 15.5 %
	1992 - 16.0 %
	1993 - 15.6 %
Wadi Jizzi System:	1991 - 15.0 %
	1992 - 14.9 %
	1993 - 15.3 %

The future loss factor (excluding station use) for both systems, which are to be interconnected in the near future, is assumed to be 12 %, with 88 % of the transmitted power being consumed. The total power transmitted to be required is the aggregate of the power consumed and the transmission loss.

In order to compute estimated levels of peak load upon the basis of the estimated power consumption, we also make the following assumptions.

1. The total power transmitted from the existing stations--Ghubrah, Rusail, and Wadi Jizzi Stations--will increase from approximately 4,383 GWH in 1993 to 5,501 GWH in 1997 and thereafter remain constant.[8] The balance between the total power transmitted to be required and the power transmitted from the existing stations will be met by the Barka Power Station.

2. Regarding the type of the desalination plant to be built by the Project, either MSF or RO system is sought. In the case of MSF, approximately 5.4 KWH of energy will be required for the desalination of every cubic meter of water, and, in addition 3 % of the power generated will be required for the station use. In the case of RO, about 6.8 KWH of electricity will be needed for the desalination of each cubic meter of water, and for the station use, 2 % of the power generated will be required. These requirements have to be included in calculating the total power generated at the Barka Station.

8 An additional capacity of 220 MW is scheduled to be installed at Ghubrah Station in 1996, whereas two 28 MW gas turbine units are expected to be added at Wadi Jizzi Station in the same year.

3. The following equation will be used to project the load factor with which the electricity generated can be converted into the peak load or the total power requirement:

Y (peak load in MW) = 11.45 + 0.22 x X (electricity generated in GWH)

This function was obtained by linear regression analysis, based on the historical relationship between the power generated and the peak load of the Muscat and Wadi Jizzi Systems combined. The equation's coefficient of determination is satisfactorily high at 0.996, and no factors can be expected in the foreseeable future that may significantly distort the trend of the changes in the load factor. (See Figure 4.5.8 and Appendix 4.5.3.) The function suggests that the load factor will become closer to (and remain at) approximately 52 %, as the electricity generated increases.

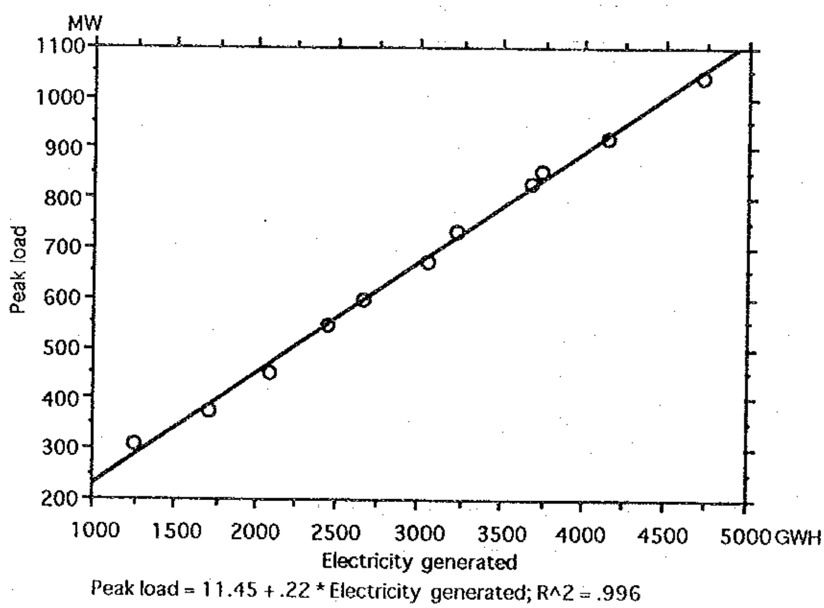


Figure 4.5.8 Relationship between Peak Load and Electricity Generated (Muscat and Wadi Jizzi Systems combined)

Based on the above-mentioned assumptions, the power requirement for the Barka Power Station is calculated as shown in Table 4.5.8. A comparison is made in Table 4.5.9 with the power requirement projected by the trend extrapolation (also see Figure 4.5.9). The difference is significant, particularly in later years.

Table 4.5.8 Projected peak load for the Barka Station

Description / Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1 Projected power consumption (MW)	3,637,752	4,101,652	4,389,521	4,695,297	5,020,158	5,365,363	5,732,260	6,122,287	6,530,067	6,963,705	7,424,873	7,915,351	8,437,042	8,924,159	9,439,016	9,983,257	10,558,627	11,166,978
2 Transmission loss (12%)	496,057	559,316	598,571	640,268	684,567	731,640	781,672	834,857	890,464	949,596	1,012,483	1,079,366	1,150,506	1,216,931	1,287,139	1,361,353	1,439,813	1,522,770
3 Total power transmited (requirement)	4,133,809	4,660,968	4,988,092	5,335,564	5,704,725	6,097,004	6,513,932	6,957,145	7,420,531	7,913,301	8,437,355	8,994,717	9,587,548	10,141,090	10,726,154	11,344,610	11,998,440	12,689,748
4 Power transmitted from Ghubrah, Rusail and Wadi Jizzi Stations (Less)	4,133,809	4,660,968	4,988,092	5,335,564	5,704,725	5,867,000	5,867,000	5,867,000	5,867,000	5,867,000	5,867,000	5,867,000	5,867,000	5,867,000	5,867,000	5,867,000	5,867,000	5,867,000
5 Power transmitted from Barka Station (requirement)	0	0	0	0	0	230,004	646,932	1,090,145	1,553,531	2,046,301	2,570,355	3,127,717	3,720,548	4,274,090	4,859,154	5,477,610	6,131,440	6,822,748
Option 1 (MSF desalination system)																		
6 Power consumption at Barka desalination plant						0	19,967	39,862	68,983	99,536	131,592	165,227	198,135	226,841	256,817	288,127	320,838	355,021
7 Power used at Barka Station (3%)						7,114	20,626	34,949	50,181	66,366	83,565	101,844	121,196	139,204	158,226	178,322	199,555	221,993
8 Power generated at Barka (requirement)						237,117	687,525	1,164,956	1,672,695	2,212,204	2,785,513	3,394,788	4,039,879	4,640,134	5,274,197	5,944,059	6,651,833	7,399,762
9 Projected peak load for Barka (MW)						52	151	256	368	487	613	747	889	1,021	1,160	1,308	1,463	1,628
Option 2 (RO desalination system)																		
9 Power consumption at Barka desalination plant						0	25,144	50,197	86,868	125,342	165,709	208,064	249,503	285,651	323,399	362,827	404,019	447,064
10 Power used at Barka Station (2.0%)						4,694	13,716	23,272	33,478	44,319	55,838	68,077	81,021	93,056	105,766	119,193	133,377	148,364
11 Power generated at Barka (requirement)						234,698	685,791	1,163,614	1,673,876	2,215,963	2,791,902	3,403,858	4,051,072	4,652,796	5,288,320	5,959,630	6,668,835	7,418,175
12 Projected peak load for Barka (MW)						52	151	256	368	488	614	749	891	1,024	1,163	1,311	1,467	1,632
Water production at Barka (m3/d)							10,131	20,224	34,999	50,500	66,764	83,829	100,525	115,089	130,298	146,183	162,779	180,122

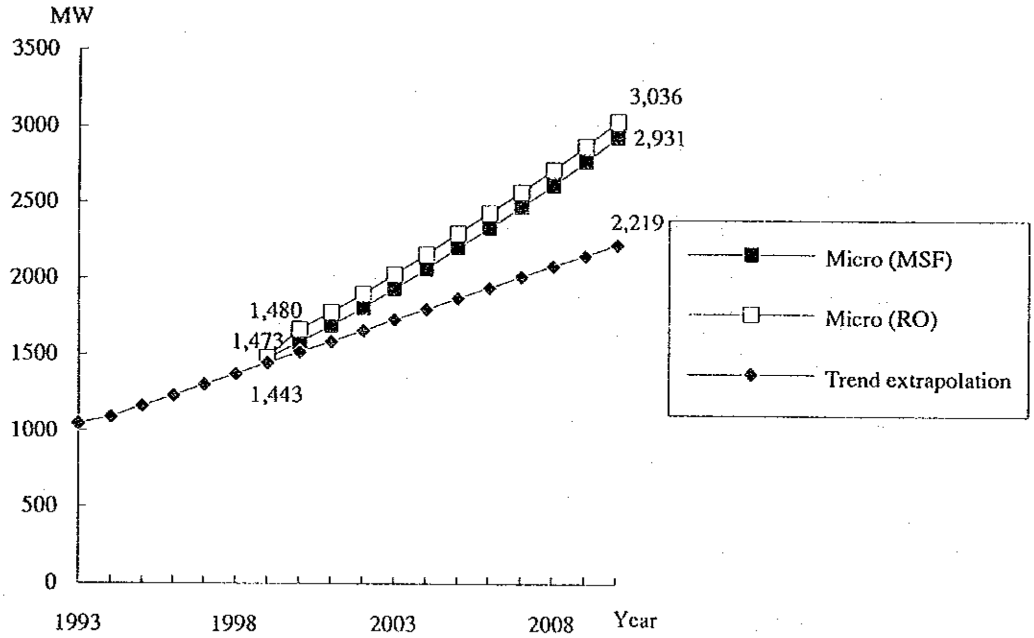
Power consumption for desalination (kwh/m3)		
MSF System	5.4	
RO System	6.8	
Well water (m3/d)	20,000	
Water production at Ghubrah (m3/d)	136,196	
Billed consumption (Water)	83%	1993
	85%	1994-2010
Station use at Barka (Water)	2%	

Note: For water production requirements, see relevant chapters of this report.

Table 4.5.9 Comparison of Projected Power Requirement for the Barka Station

Year	2000	2010	(MW)
Micro forecasting			
MSF desalination system	302	1,620	
RO desalination system	304	1,640	
Trend extrapolation*	226	931	

Note: In 1996, the total installed capacity of the existing plants will reach 1,288 MW. This figure was subtracted from the total power requirement.



Note: Micro (MSF): Forecast by the micro forecasting method. The desalination process assumed is MSF system.
Micro (RO): Forecast by the micro forecasting method. The desalination process assumed is RO system.
Trend extrapolation: Forecast by the trend extrapolation.

Figure 4.5.9 Comparison of projected peak load for Muscat and Wadi Jizzi Systems combined 1993-2010

We will adopt the micro forecasting results for this study, with a condition that the results be reviewed and modified in five years. It must be noted that it is not reasonable to make a long-term forecast extending 16 years (from 1994 to 2010) based on the (power consumption) data covering only 4 years (from 1990 to 1993). On the other hand, there are some reasons to support the micro forecasting results rather than the ones by the trend extrapolation.

First, according to MEW, the peak load this year has already reached 877.8 MW for the Muscat System and 233.5 MW for the Wadi Jizzi System, with additional shedded load being 51.5 MW for the former system and 11.5 MW for the latter. These actual figures for the peak load clearly exceed the corresponding figures projected by the trend extrapolation, although these discrepancies can be regarded simply as statistical errors. Importantly, when these data for 1994 are included in the regression analysis, the estimated total peak load for Muscat and Wadi Jizzi Systems for 2010 will rise from 2,219 MW to 2,298 MW, which is a significant change. The forecasts could be higher, if data for shedded loads for other years were also included, which however, is not available.

Secondly, the projected power consumption does not show substantial changes in the composition in the structure of the consumption from what it is today. It is safe to say that no unreasonable assumptions were made in forecasting increases in the number of connections and unit consumption of respective consumer groups.

Thirdly, we might argue that the entire projection is of overestimation. However, the share of the domestic consumption of the Muscat System to the total consumption is projected to be consistent at approximately 50 %. As we can justify the projected increase in the consumption by the households of that system, we can deny the allegation. The projected increase can be explained by the combination of the increase in the number of connections and that in the unit consumption. The former, which is 3.5 % annually, is based on the population growth. The annual population growth rate of 3.5 % is a rate used among government agencies and offices for coordinated development efforts. This rate is not unreasonably high among Middle East Countries. However, it is not known whether the rate reflects the fact that non-Omani people, most of whom stay in Oman for work reasons, have substantially lower birth rates, and whether the number of expatriates may decrease in the long run due to the Omanization policies. Even if the overall growth rate is 3 %, the difference in the annual increase in the number of connections and therefore in the power consumption is not significant--the consumption increases in 16 years by 73 % at the annual rate of 3.5 %, and by 60 % at 3.0 %. The annual unit-consumption growth is estimated at 2 - 3.5 %, and the cumulative growth rate for the next 16 years is 62 %. The electrical appliance with the largest load among domestic consumers is an air conditioner. Some households have more than one unit of airconditioner, whereas others have only one for the average family size of 7-8. It is quite reasonable to assume that the average household will have two units of air conditioner--for example, each unit for a room of 4 persons--by the year 2010, increasing the domestic unit consumption by more than 50 percent from the present level.[9] Thus, the projected increase in the power consumption among households of the Muscat System is not unreasonable.

For the reasons discussed above, we take the micro precasting results, suggesting that the future increase in the peak load will be faster than that in the past.

4.6 Power Development Plan

4.6.1 Kinds of Power Supply Capacity

The power supply capacity can be classified by the source of energy -- hydroelectric, thermal or nuclear. Supply capacity can be further classified into base load supply, mid-range load supply, and peak load supply by the load allocation in the daily load curve.

In the Sultanate of Oman, the main source of energy is thermal power using natural gas. Oman uses gas turbines, steam turbines and diesel engines. Thermal power generation plants generally require periodic repairs and maintenance, including inspections of boilers every year and of turbines, gas turbines and steam turbines every two years. Combined cycle power plants boast high efficiency and start up and shut down is comparatively simple and quick.

The base load in the daily load curve is allocated to large-capacity power plant with high thermal efficiency. The mid-range load usually rely on more flexible medium capacity power plant. The peak load is handled, depending on the load, by small-capacity power plant that can be easily controlled against load variations. Combined cycle power plant has a large load variation range and can handle a wide operational range, from the base load to the peak load.

9 It is reported that the average household has one air conditioner unit, a color TV set, and a refrigerator, as major electric appliances.

Given consideration of the load characteristics of the Sultanate of Oman, this project will use thermal energy as the power supply capacity. The part allocated in the daily load curve covers the base load to the peak load as stated in Section 7.5. The combined-cycle power plant will be the recommended means of power generation.

4.6.2 Forecast of Power Supply

(1) Plants Under Construction and Firm Planning

Current power supply is provided by the Muscat system, with 815 MW capacity, and the Wadi Jizzi system, with 222 MW capacity. Total capacity is therefore 1,037 MW (see Tables 4.2.1 and 4.2.2). By 1996, with the planned addition of new power plants shown in Table 4.6.1, the Muscat system will add 220 MW, and Wadi Jizzi System 56 MW, totaling 276 MW, and both systems will have a combined total supply capacity of 1,313 MW by 1996. The Manah system will be interconnected to the Muscat system in the future, with a capacity of 90 MW by 1996. The Manah system will not be considered for this project.

Table 4.6.1 Power Plants Under Planning Construction

System	Power Station	Type	Installed Capacity	Expected Year of Commissioning
Muscat	Ghubrah	GT	95	1995
	Ghubrah	GT	95	1995
	Ghubrah	ST	30	1996
	Total		220	
Wadi Jizzi	Wadi Jizzi	GT	28	1994
	Wadi Jizzi	GT	28	1995
	Total		56	
Manah	Manah	GT	30	1996
	Manah	GT	30	1996
	Manah	GT	30	1996
	Total		90	

(Note) GT : Gas Turbine, ST : Steam Turbine

(2) Assumed Life of Existing Power Stations

The Ghubrah Power Plant uses steam turbine generators (3 x 8.5 MW). Since it was commissioned in 1976, steam turbine and gas turbine generators have been added at both the Ghubrah and Rusail Power Plants to respond to increasing power demand. MEW has contracted with a private firm to maintain and operate the plants, and the plants have been maintained at a high availability rate. However, the equipment that make up the power plant such as boilers, steam turbines, and gas turbines have an economical life, and there is no guarantee that they will remain at a high availability rate. Equipment life varies with the performance of the equipment, their operation and maintenance, and cannot therefore be determined with certainty. However, based on MEW's depreciation calculations, steam turbines and gas turbines are assumed to have a useful life of 20 years (as is recorded on the books at MEW). Table 4.6.2 shows assumed life of existing individual power plant units of the Muscat and Wadi Jizzi systems. As can be seen from this table supply capacity will peak in 1996 at 1,288 MW, before falling to 304 MW in 2010. MEW's plans to augment existing facilities are unknown at this stage.

(3) Comparison of economic life

The operational life of the equipment (assumed to be 20 years for all units) in the previous clause primarily refers to the life for accounting purposes. It is necessary to determine the economic life. With a longer service life, the return on investment will decline, while the costs of operation and maintenance will increase at higher rates as the equipment nears the end of its useful life. Therefore the annual cost comprising the return on investment plus the operating cost reaches minimum after a certain number of years of operation. This is the economic life, which is the most appropriate period from an economic viewpoint. Figure 4.6.1 shows the relationship between period of use and average annual cost. When the cost is lowest, this shows the economic life.

Operating costs consist of the increased operating cost due to aging and the lower operating costs achieved through technological improvements. The increased operating cost that results with aging is manifest as shown in Figure 4.6.2. An economic comparison of existing equipment against new equipment is required, and shall be used to determine the loss in operating efficiency.

Table 4.6.2 Assumed Operational Life of Existing Power Plant Unit

ST: STEAM TURBINE (20 YEARS)
GT: GAS TURBINE (20 YEARS)

POWER STATION	TYPE	NO. & CAPACITY (MW)	YEAR																																			
				1976		1978		1980		1982		1984		1986		1988		1990		1992		1994		1996		1998		2000		2002		2004		2006		2008		2010	
GHUBRAH	ST	3 x 8.5 (25.5)		25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5																
	ST	1 x 50 (50)			50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50															
	ST	1 x 30 (30)															30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30					
	GT	3 x 17.5 (52.5)				52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5													
	GT	6 x 17.5 (105)					105	105	105	105	105	105	105	105	105	105	105	105	105	105	105	105	105	105	105	105												
	GT	2 x 27 (54)									54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54									
	GT	2 x 95 (190)																					190	190	190	190	190	190	190	190	190	190	190	190	190	190	190	190	→
(537 MW)	ST	1 x 30 (30)																						30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	→
RUSAIL	GT	3 x 83 (249)										249	249	249	249	249	249	249	249	249	249	249	249	249	249	249	249	249	249	249	249								
(498 MW)	GT	3 x 83 (249)													249	249	249	249	249	249	249	249	249	249	249	249	249	249	249	249	249	249	249	249					
WADI JIZZI	GT	3 x 18 (54)								54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54										
	GT	2 x 28 (56)												56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56						
	GT	2 x 28 (56)											56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56							
	GT	1 x 28 (28)																28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28		
	GT	1 x 28 (28)																			28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	→
	GT	1 x 28 (28)																				28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	→
(278 MW)	GT	1 x 28 (28)																					28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	→
TOTAL INSTALLED CAPACITY (MW)				25.5	75.5	128	233	233	233	287	341	590	646	702	951	951	981	1,009	1,009	1,009	1,037	1,065	1,283	1,288	1,238	1,185	1,080	1,080	1,080	1,026	972	723	667	611	332	332	332	304	

With the recent advances in technology, and the energy and time saving devices introduced for power generation equipment, the loss in operating efficiency is becoming more pronounced. In other words, the older stands to lose economically. Combined cycle power plant has thermal efficiency that is superior to that of gas turbines. On the basis of an economic life of 20 years, it is clear that operating and maintaining existing generation equipment over the years will not be advantageous. As data at hand is insufficient, the service life of 20 years established by MEW will be adopted in forecasting power supply capacity.

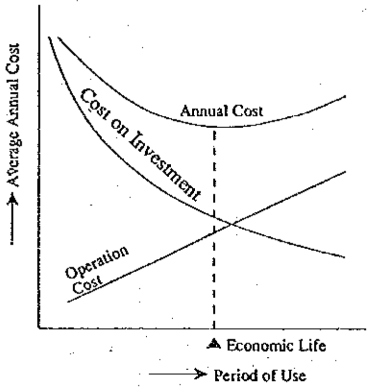


Figure 4.6.1 Economic Life

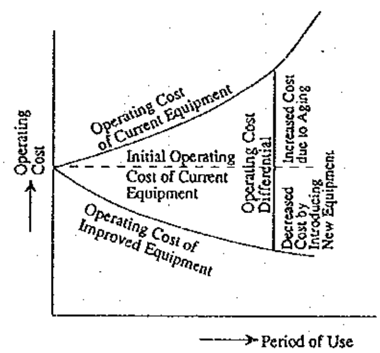


Figure 4.6.2 Operating Cost Differential

4.6.3 Reserve Margin

(1) Basic policy for reserve margin

To provide a stable supply of electricity, a reserve margin is necessary to counter accidents in power generation and/or transmission lines. The difference between total installed capacity and actual power demand is reserve margin. When the reserve margin is insufficient and an accident occurs, the frequency of the system begins to fall, causing the turbine blades to vibrate and resulting in operational problems. With an adequate reserve margin available, supply reliability is high, and operational problems are averted. However, this requires additional investment in equipment. To avoid this and monitor power supply reliability, it is necessary to adopt a method of understanding the probability of accidents and demand variations, and of comparing this with the maximum power continuity curve, thereby responding to the forecast number of days of which there will be a shortfall of power. The desired number of such days is less than 0.3 days/month, and the level of reserve margin to maintain is 8 to 10 % of maximum electricity.

(2) Desired reserve margin levels

Reserve margin is classified into three kinds: spinning reserve, hot reserve and cold reserve. Table 4.6.3 shows how these reserve margin classifications function and what levels must be maintained for each.

Table 4.6.3 Reserve Margin Levels

Type	Function	Start up Time	Period of Continuous Operation	Target Reserve Margin
Spinning reserve	Quick recovery of frequency	Less than 10 s	About 10 min.	5 %
Hot reserve	Maintain reference frequency	Less than 10 min.	Several hours	5 %
Cold reserve	Respond to change in demand	Less than several hours	More than several hours	3-5 %

Peak load on the Muscat System reached 826 MW on June 22, 1993, and exceeded the installed capacity of 815 MW. For this reason, a load shedding of 20 MW was placed on the system, limiting the maximum load to 806 MW. Excess demand occurred on several days in the months of June to August in 1993, with no reserve margin secured. If future demand continues to grow at 8.5 %, which is an average growth rate for the past five years the number of load sheddings and hours will no doubt increase.

To respond to the demand structure and to maintain supply reliability of the Muscat System, it is proposed to secure the hot reserve and the reserve margin of 5 % to maintain the reference frequency. The maximum electricity of the Muscat and Wadi Jizzi systems combined are estimated at 2,929 MW at the generators (in case of RO process desalination plant), the required reserve margin will be 2,929 x 5 % = 146 MW. A combined cycle plant consisting of two 100 MW class gas turbines, two heat recovery steam generators (HRSGs) and one 100 MW class steam turbine, with a total output of 300 MW, is taken up as an applicable power plant for this project. In the event that one gas turbine drops from the power system, the total output of the power plant will decrease to 150 MW from 300 MW. This means that a 5 % reserve margin corresponding to 146 MW can maintain the reference frequency under a situation where a single unit with a maximum unit capacity drops from the system.

In discussions with MEW, it was confirmed that even if one unit were to drop out, the system would maintain the reference frequency. Assuming a system characteristic constant of 1.0 (%MW/0.1 Hz), if a 100 MW class gas turbine were to drop out, decreasing the power supply capacity by 150 MW, the frequency drop would be 0.5 Hz, and there would be no operational problems. Assuming again a minimum system load of 486 MW in 2010, if a similar unit were to drop out, the frequency drop would be on the order of 1.7 Hz. In this case, because the minimum load would occur during the period of low demand, the operational reserve margin could be ensured without difficulty.

4.6.4 Capacity of the Barka Power Plant

Figure 4.6.3 shows the estimated maximum electricity, supply capacity and demand/supply balance of the Muscat and Wadi Jizzi Systems combined after they are interconnected by 2010. If the existing power plants were required to gradually shut down their operations according to the operational life as shown in the Table 4.6.2, then the Barka Power Plant would have to provide 475 MW in 2000, and 2,625 MW in 2010 to make up for the loss in supply excluding the reserve margin of 150 MW. As the system capacity is estimated at 2,929 MW in 2010, the Barka Power Plant would have to produce electricity equal to 90 % of the system capacity, which is very large. As the unit capacity of the power plant grows larger, construction, operations and maintenance costs will decrease and economies will improve. However, the reliability of supply (resulting from disbursement of power supply sources), system stability to frequency variations, and the transmission loss caused by centralization of the power source, would be more serious drawbacks. Even if the total facility were large, it could be provided by combining small units. Yet, excessive centralization could disrupt the reliability of the power supply system.

The total output of the Muscat and Wadi Jizzi systems is 1,037 MW in 1993, while the capacity of the Rusail Power Plant is 498 MW, about 48 % (= 498/1,037). It is therefore recommended to keep the capacity of the Barka Power Plant at the level not exceeding 50 % to a large extent. It is proposed that the Barka Power Plant will have a total output of approximately 1,600 MW, or 55 % of the 2010 level of 2,929 MW, and by using other stations to supply the remaining capacity of 1,300 MW. The firm capacity of 1,313 MW in 1996 can absorb 1,300 MW, so it will be necessary to gradually replace existing power plants that have reached the end of the their useful life with more reliable and economical power plants under another project, so as to avoid rapid increases in operation and maintenance expenses.

Given the above, the capacity of the Barka Power Plant in 2010 should remain in balance with the 1996 capacity with the addition of the capacity shown in Table 4.6.4. The capacity to be commissioned in stages is given below in coordination with the requirements of RO process desalination plant. The type of power plant to be applied to this project will be the combined cycle plant stated in the previous clause, and the single machine unit capacity shall be 96 MW for the gas turbines and 100 MW for the steam turbines.

Stage	Year of Commissioning	Capacity to be Commissioned
1	1999	388 MW
2	2002	292 MW
3	2007	584 MW
4	2010	584 MW
Total		1,848 MW

MEW has drawn up a power demand and supply plan for the Manah Power System, as shown in Table 4.6.5, and plans a separate project (on a BOT base) for additional power.

PROJECTED PEAK LOAD (Alternative B : RO PROCESS)

YEAR	1996	1997	1998	1999	2000	2001	2002	2003
EXISTING PEAK LOAD	1,288	1,288	1,288	1,288	1,288	1,288	1,288	1,288
BARKA PEAK LOAD	0	0	106	202	304	413	529	652
TOTAL	1,288	1,288	1,394	1,490	1,592	1,701	1,817	1,940

UNIT : MW

2004	2005	2006	2007	2008	2009	2010
1,288	1,288	1,288	1,288	1,288	1,288	1,288
783	921	1,050	1,185	1,329	1,480	1,640
2,071	2,209	2,338	2,473	2,617	2,768	2,928

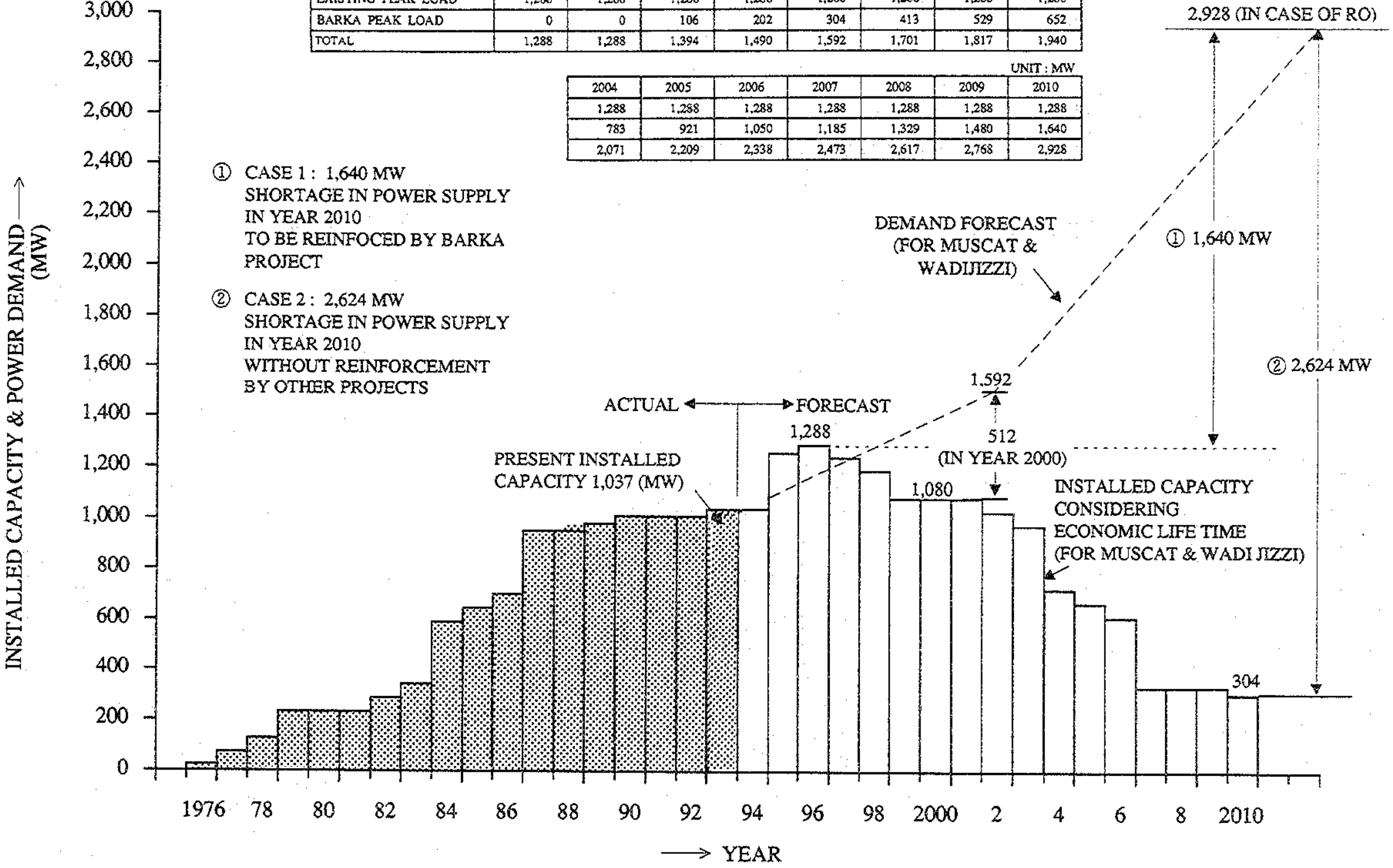


Figure 4.6.3 Expected Maximum Electricity Demand and Supply Balance

Table 4.6.4 Overall Power Demand and Supply Forecast & Power Development Program

OPTION	YEAR	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
A (M S F)	(a1) BARKA PEAK LOAD (MUSCAT & W/JIZZI)	0	0	106	201	302	409	523	644	774	910	1,037	1,171	1,313	1,462	1,620
	(a2) RESERVE MARGIN	0	0	96	150	150	150	150	150	150	150	150	150	150	150	150
	(a3) TOTAL REQUIREMENT = (a1)+(a2)	0	0	202	351	452	559	673	794	924	1,060	1,187	1,321	1,463	1,612	1,770
	(a4) GTG 96MW			96			96			96			96		96	
	(a5) GTG 96MW			96				96			96		96		96	
	(a6) STG 100MW				100				100		100			100		100
	(a7) GTG 96MW (OPEN)					96										
	(a8) BPST 60MW				60			60				60			60	
	(a9) TOTL CAPACITY = (a4)+(a5)+(a6)+(a7)+(a8)	0	0	192	160	96	96	156	100	96	196	60	192	100	252	100
	(a10) ACCUM. CAPACITY	0	0	192	352	448	544	700	800	896	1,092	1,152	1,344	1,444	1,696	1,796
	(a11) FINAL BALANCE = (a10)−(a3)	0	0	-10	1	-4	-15	27	6	-28	32	-35	23	-19	84	26
B (R O)	(b1) BARKA PEAK LOAD (MUSCAT & W/JIZZI)	0	0	106	202	304	413	529	652	783	921	1,050	1,185	1,329	1,480	1,640
	(b2) RESERVE MARGIN	0	0	96	150	150	150	150	150	150	150	150	150	150	150	150
	(b3) TOTAL REQUIREMENT = (b1)+(b2)	0	0	202	352	454	563	679	802	933	1,071	1,200	1,335	1,479	1,630	1,790
	(b4) GTG 96MW			96		96			96		96		96		96	
	(b5) GTG 96MW			96			96			96		96		96		96
	(b6) STG 100MW				100			100		100			100		100	100
	(b7) GTG 96MW (OPEN)				96											
	(b8) TOTL CAPACITY = (b4)+(b5)+(b6)+(b7)	0	0	192	196	96	96	100	96	196	96	96	196	96	196	196
	(b9) ACCUM. CAPACITY	0	0	192	388	484	580	680	776	972	1,068	1,164	1,360	1,456	1,652	1,848
	(b10) FINAL BALANCE = (b9)−(b3)	0	0	-10	36	30	17	1	-26	39	-3	-36	25	-23	22	58

NOTE : GTG - Gas Turbine Generator
STG - Steam Turbine Generator
BPST - Back Pressure Steam Turbine Generator

Table 4.6.5 Power Demand & Supply Forecast for Manah System

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Annual Peak Demand (MW)				78	84	89	93	97	101	105	109	113	117	121	125	129	133	137
Energy (GWh)				507	529	546	559	573	586	600	613	626	648	652	665	677	691	704
Total Installed Capacity (MW)				90	90	90	120	120	120	120	120	120	150	150	150	150	150	150

CHAPTER 5 WATER SUPPLY CIRCUMSTANCES AND WATER RESOURCES DEVELOPMENT PLAN

CHAPTER 5 WATER SUPPLY CIRCUMSTANCES AND WATER RESOURCES DEVELOPMENT PLAN

5.1 General overview of the Water Supply Utilities

5.1.1 History of Development

In Oman, the habitants depend on many wells for water supply from ancient times as well as Faraj Systems (canato, a kind of intake system from ground-water zone) which are in service even now to supply water to rural areas. In the coastal region of South Batinah, it is also widely applied agriculture using ground-water.

Although the drinking water of Muscat area was insured from wells until 1970's, an advanced desalination project was established to construct the first desalination unit at Ghubrah according to increasing demand of water resource, which was completed in 1976. After the first unit completion, additional units have been provided as one in 1983, more two in 1986, and the last one in 1992, and their total capacity is now 132,000 m^3/d (29 MGPD) in desalinated water production.

In 1989, started 1,000 m^3/d of desalinated water production at the Oman Oil Refinery, there is also a total capacity of 153,000 m^3/d supplying in Muscat area together with ground-water of 20,000 m^3/d, in 1992.

Water consumption in Muscat area is increasing year by year, and the demand has reached 130,000 m^3/d in 1992 comparing to 37,000 m^3/d in 1981. The other hand, as a separate project from the desalination project, the Wadi AL-Khoodh Water Recharging Project of underground recharge dam experiment has met with success so that similar water storage dam projects are being promoted to construct in other districts. Furthermore, there is another project to improve the water supply system in Muscat area by fund-aid of the U.S. Government in addition to the Government fund of Oman. This project was started in 1990, in conjunction with the Projects for Desalination plants at Wadi Al-Khoodh and Ghubrah including Pipeline connects to Ruwi, the Capital Area New Town Water Supply network Rehabilitation Project, and the extension of Ghubrah Underground Reservoir Project.

In 1989, the Government of Oman started to take an active interest to control his water resources to restrict both new well drilling and free intake of water from existing wells.

In 1992, the typical means of water supply to domestic (households) are by both, piped water and tankers, and the ratio of water pipeline available in Muscat area is 86 %, and 90 % including the supply by tankers.

The water resources in Muscat area will be developed according with the Master Plan.

5.1.2 Water Supply Facilities

(1) Muscat area

Almost water supply depends on the Ghubrah Desalination Plant, and is shown as the following statistics of 1992:

Well water	36,196.8	(m^3/d)
Desalination plant	95,086.8	(")
Oil refinery	712.4	(")
Total production	131,996.0	(m^3/d)

(2) South Batinah area

Habitants in this area depend on well in principle, and many of them use it together with water tank on the room being made up from tanker. There is no past statistical record of this area.

5.1.3 Water Rate

Water rate is provided two ranks:

- Generals (households, hospital, university, etc.) : 2 baiza/gallon (440 baiza/m^3)
- Industrial use : 3 baiza/gallon (660 baiza/m^3)

5.1.4 Organization of Water Supply System

All the water supply in Muscat area is managed by MEW and the organization is shown at §4.1.5. While the Ghubrah Desalination Plant is handled by DGE through the construction, operation and maintenance together with the Power Plant, and the Ghubrah water reservoir and the downstream water supply system are taken charge by DGW for both, construction of the facilities and water supply in Muscat area.

5.1.5 Operation and Maintenance

The Ghubrah Desalination Plant is trusted in charged of SOGEX Co. to operate and maintain as same as the Ghubrah Power Station.

The desalination plant is conducted annual maintenance in winter unit by unit with about one month shutdown.

The water supply system from the water reservoir is operated and maintained by the Directory of Muscat Water of DGW.

5.2 Existing Water Supply Facilities

5.2.1 Summary of Existing System

(1) The Ghubrah Desalination Plant was constructed in 1976 with 5 MGPD (22,730 m³/d) capacity which was later increased in three stages, and has the capacity as described in Table 5.2.1, there are 5 MSF plants for a total of 29 MGPD (132,000 m³/d) as of the end of 1993. With the fifth phase construction, 6 MGPD is Plant is also planned to come on stream in 1996.

Pumping from wellfield is restricted below 20,000 m³/d, though the areal well water capacity is relatively large.

Table 5.2.1 Existing Water Supply Capacity

Source of Water	Capacity (m³/d)	Type	Remarks
Desalination Plant:			Commissioned
Ghubrah No. 1	22,730	MSF	1976
Ghubrah No. 2	27,730	MSF	1983
Ghubrah No. 3	27,730	MSF	1986
Ghubrah No. 4	27,730	MSF	1986
Ghubrah No. 5	27,730	MSF	1992
Subtotal	131,930		
Well Water:	20,000*		* Restricted below 20,000 m³/d pumping
East Area	(50,000)		
Central Area	(2,000)		
West Area	(50,000)		
Subtotal	102,000		
Oil Refinery:	1,000		1989
TOTAL AVAILABLE	152,930		

5.2.2 Operating Status of Ghubrah Desalination Plant

In the Ghubrah Desalination Plant, each of the five units is operating in good order and is kept with a high productivity.

(1) Water Production

Fig. 5.2.1 illustrates the transition of water production in total until 1993, and one can see the increase of production duly in proportion to the unit extension in 1986 and 1993.

The each unit production as transition is also shown as Table 5.2.2.

(2) Running Hours

Running hours of each unit is shown as transition in Table 5.2.3, and the availability is given as quotient of running hours divided by one year hours (8,760 hours). It can say the availability is approximately 90 %.

(3) Performance Ratio

Performance ratio of each unit is generally nearby 7, rather than 6 as planned, as seen the transition in Table 5.2.4.

(4) Production Cost

Production cost per the produced water quantities is shown as transition in Table 5.2.5, as well as the cost contents in Fig 5.2.2 as ratio based on 1993 data. It is sure that the cost reduction is required by means of improvement for energy efficiency, because the fuel cost based up to 50 % and more comparing to the other items.

Also, the production cost is about 0.6 R.O./m^3, which equals to about 2.7 baiza/gallon and is rather high priced than the general water rate 2 baiza in the country.

Table 5.2.2 Distillate Production per Year

Mm3

Year/Unit	Unit-1	Unit-2	Unit-3	Unit-4	Unit-5	Total
1990	5.19	8.58	10.10	9.25	-	33.13
1991	7.58	9.38	8.35	9.53	-	34.85
1992	7.50	8.48	8.51	8.50	2.00	34.99
1993	7.50	8.66	8.89	8.95	8.22	42.22

(From MEW)

Table 5.2.3 Running Hours of Each Unit

Year/Unit	Unit-1		Unit-2		Unit-3		Unit-4		Unit-5	
	hr	Availability (hr/8760hr)	hr	Availability (hr/8760hr)	hr	Availability (hr/8760hr)	hr	Availability (hr/8760hr)	hr	Availability (hr/8760hr)
1990	5531	0.63	7611	0.87	8752	1.00	8010	0.91	-	-
1991	7959	0.91	8318	0.95	7257	0.83	8254	0.94	-	-
1992	7961	0.91	7813	0.89	7846	0.90	7737	0.88	1753	0.20
1993	7921	0.90	7852	0.90	7947	0.91	7988	0.91	7315	0.84

(From MEW)

Table 5.2.4 Performance Ratios

Year	Unit-1	Unit-2	Unit-3	Unit-4	Unit-5
1990	6.99	6.55	6.88	6.87	-
1991	7.50	6.36	6.87	6.93	-
1992	7.40	6.43	7.09	6.96	6.74
1993	7.75	6.29	6.99	6.97	6.31

P/R=Distillate Production/Condensate(Brine Heater)

(From MEW)

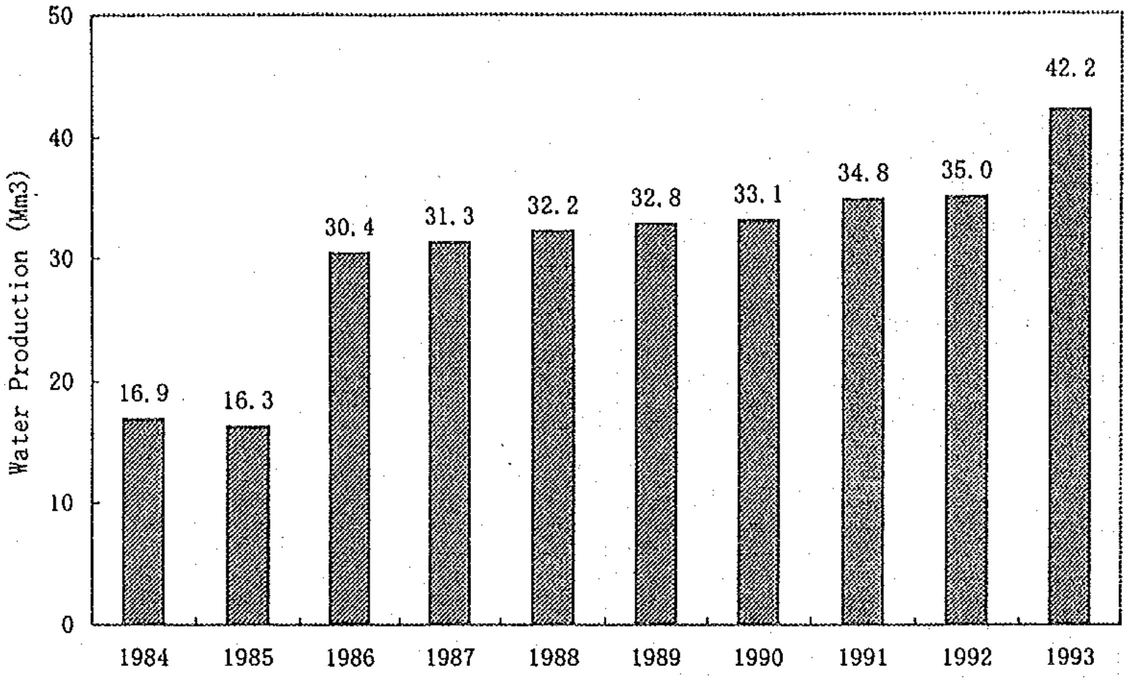
Table 5.2.5 Cost of Production per Cu.M. Export

Unit: RO

Year	Fuel(Gas)	Man-power	Chemical	Depreciation	Spares	Others	Total
1989	0.328	0.034	0.013	0.142	0.012	0.061	0.590
1990	0.314	0.034	0.012	0.148	0.009	0.059	0.570
1991	0.320	0.032	0.011	0.140	0.002	0.059	0.564
1992	0.320	0.037	0.011	0.155	0.011	0.064	0.598
1993	0.320	0.032	0.011	0.167	0.015	0.061	0.606

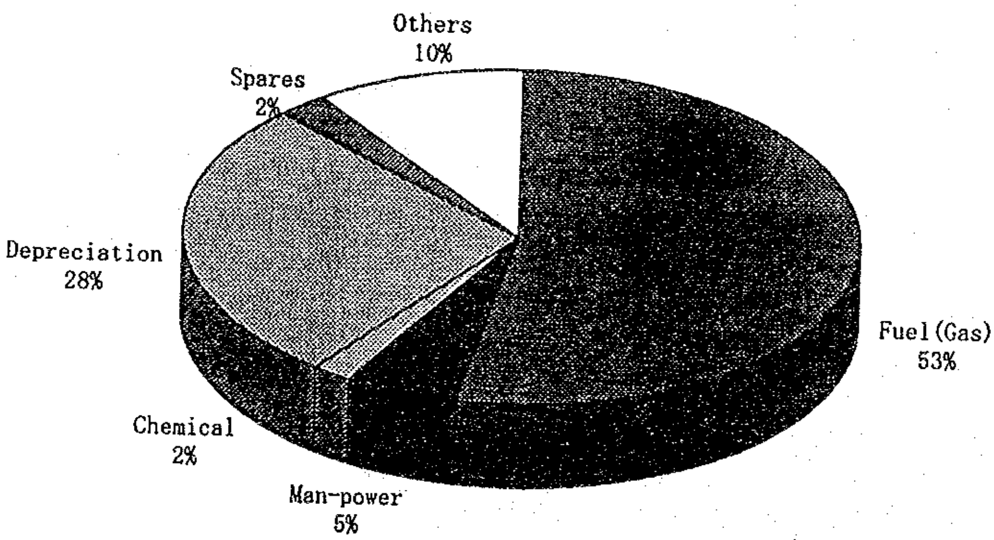
(From MEW)

Figure 5.2.1 Ghubrah Desalination Plant Water Production



(From MEW data)

Figure 5.2.2 Cost Ratio in 1993



(From MEW data)

5.2.3 The Sur Desalination Plant (RO Process)

Sur is a town approximately 350 km south of Muscat along the coast. RO type desalination plant of 1 MGPD (4,550 m³/d) has been smooth in operation since February, 1993. A flow diagram of the Sur Plant is presented in Figure 5.2.3.

A description of the plant is as follows:

(1) Plant Capacity:

0.5 MGPD x 2 Units

(2) History of Construction:

April 1989	:	Conclusion of contract
September 1991	:	Civil work
July 1992	:	Mechanical & electrical work
February 1993	:	Commencement of commercial operation

(3) Basic Specification:

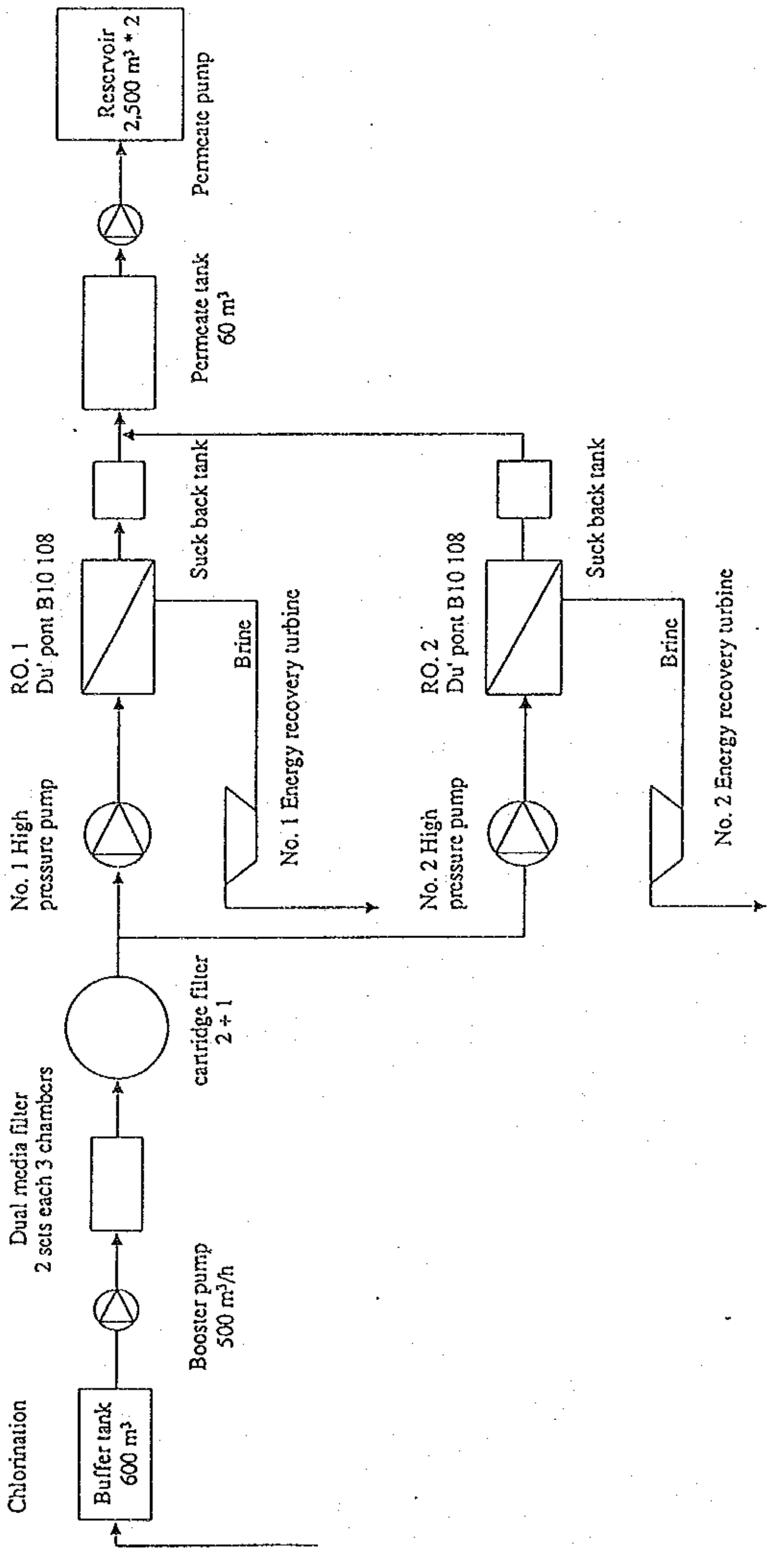
Conductivity of sea water	:	56,000 μs/cm
Temperature of sea water	:	28 ~ 30°C

Operating pressure of high-pressure pump is 61 ~ 64 bar.

Conductivity of the product water	:	400 ~ 580 μs/cm
Electric Power Consumption	:	2.2 MWH

The product water quality is in conformance with the Omanian standard.

Figure 5.2.3 Flow Diagram of Sur Desalination Plant (RO)



5.2.4 Water Transmission Facilities

(1) Water Transmission from Water Sources

Transmission of water to the Muscat area is being made from the following 4 sources:

- Ghubrah Pump Station
- Eastern wellfield
- Central wellfield
- Western wellfield

a. Ghubrah Pump Station:

Product water from the Ghubrah Power/Desalination Plant is being transmitted from Pump Station No. 1 and 2 where there is a reservoir with a capacity of 54,000 m^3 linked together with a total of 108,000 m^3, and another reservoir with 54,000 m^3 capacity is planned. The MEW requirement for storage capacity is to equal the quantities produced daily as stipulated in the MEW Guideline.

Pump Station No. 1 has 6 pumps (1 pump is standby) for a capacity of 6,600 m^3/h, and Pump Station No. 2 has 4 pumps (1 pump standby) which was commissioned in 1993 and has a pumping capacity of 5,000 m^3/h.

The transmission pressure is about 10 bars.

b. Eastern wellfield

Well water is being supplied to Ghubrah from the East Area through a 600 mm. dia. pipeline, and there is a blending facility constructed in 1986, although it is not regularly being used. Instead there is a 600 mm dia. pipeline constructed at Wadi Adai (about 8 km southwest of Muscat) which is connected to the main water pipe near the roundabout and this water is used for blending.

c. Central wellfield

The well water in the Central Area is sent to Ghubrah and used for blending. The underground water from Wadi Baushar and Wadi Lansab are collected and sent to Ghubrah via the 150 mm dia. and 300 mm dia. pipelines and sent to the blending tank at the Ghubrah Desalination Plant, only used if necessary.

d. Western wellfield

The well water quality is better than the Eastern wellfield water, and is mixed at Seeb facility with the product water from the Ghubrah Desalination Plant. There is a plan to supply the well water from the Western well field directly to Ghubrah, and there is pump station at Mowallah.

(2) Water Transmission Pipelines

The transmission pipeline in the Muscat Area is shown in Figure 5.2.4 and 5.2.5, and there are with 1,000 mm dia. pipelines from the Ghubrah Pump Station to the east and west directions for 41 km to the respective service area reservoirs. The main pipeline ends at Mowallah from where it is transmitted in a 600 mm dia. branch line to the Seeb Reservoir. The other transmission lines are 600 mm dia. and 300 mm dia, which transfer the water to service area reservoirs.

(3) Service Area Reservoirs

There are other 12 reservoirs in the Muscat Area as shown in Table 5.2.6. Their sizes are normally standardized.

Their reservoirs are all ground type of reinforced concrete with 5 m height. The water distribution from the reservoirs are all of the gravity type except for the Seeb and Rusail Reservoirs.

In addition to the reservoirs, there are elevated storage tanks at Seeb and Qurm, both with small capacity.

Table 5.2.6 Service Area Reservoirs

Service Area	Location	Capacity (m^3)	High Water Level (m)	Low Water Level (m)	Distribution Method
Eastern District	Qurm	18,000	82	77	Gravity
	Qurm II	5,000	97	92	Gravity
	Wattayah	9,000	75	70	Gravity
	Ruwi	18,000	70	65	Gravity
	Muscat	18,000	70.5	65.5	Gravity
	Al Kabir	3,000	117	112	Gravity
	Bustan	3,000	55	51	Gravity
	Al Amarat (under constr.)	5,000	213	208	Gravity
	Seeb A/P	10,000	52	47	Gravity
Western District	Seeb	18,000	39.5	34.5	Pump
	Rusail	5,000	135	130	Pump
	Cement Factory	5,000	203	198	Gravity

Source: Water Supply Master Plan for Muscat

(4) Water Quality and Blending

As the desalination process at Ghubrah Plant are all MSF process, also the product water contains almost no salinity and is not suitable for drinking without blending and post treatment.

The post treatment process at Ghubrah is performed using the system shown in Figure 5.2.6 and fluoridation are dosed at the pump station.

Table 5.2.7 gives the water quality produced at Ghubrah plant, Table 5.2.8 the range of the well water quality from the Central wellfield, and Table 5.2.9 the water quality supplied to the consumers.

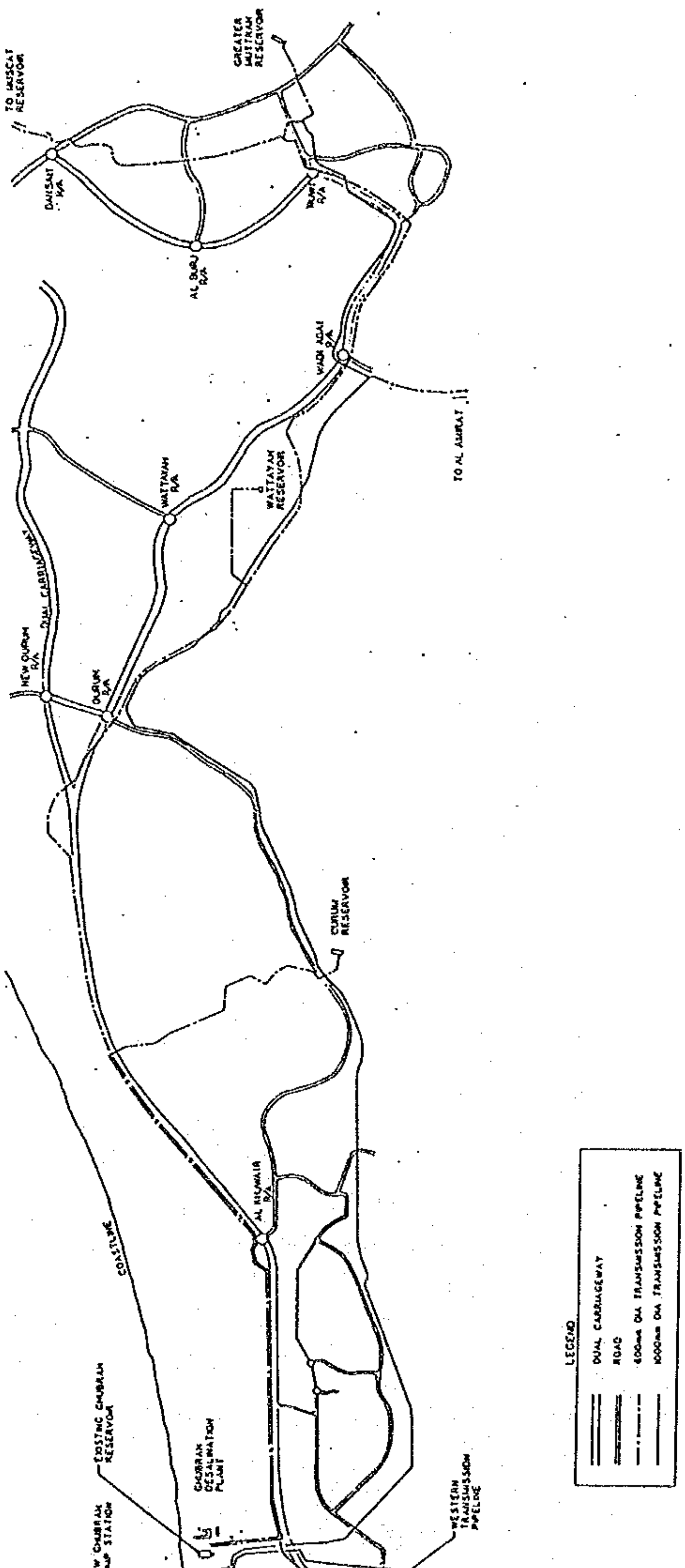


Figure 5.2.4 Eastern Transmission Pipeline Plan

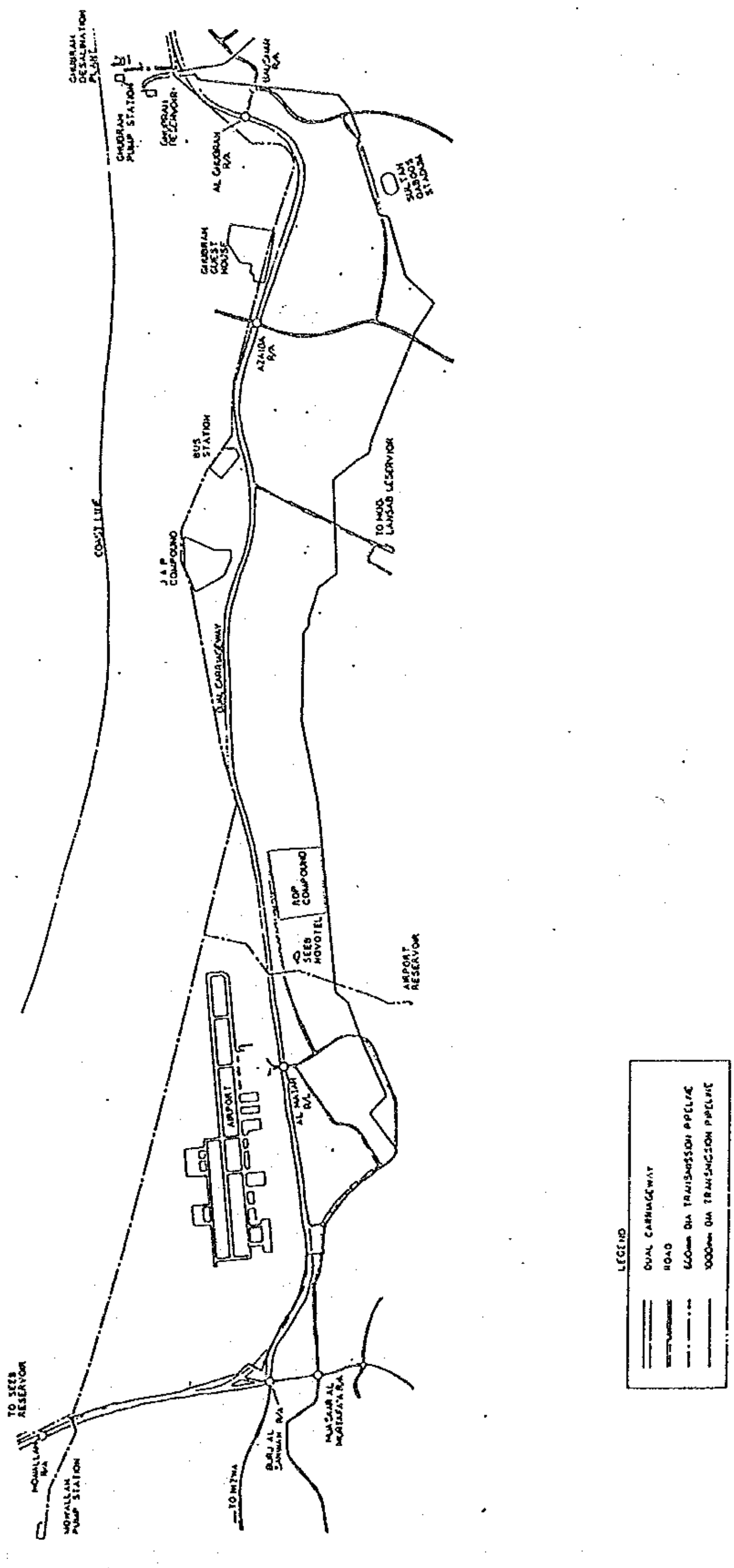


Figure 5.2.5 Western Transmission Pipeline Plan

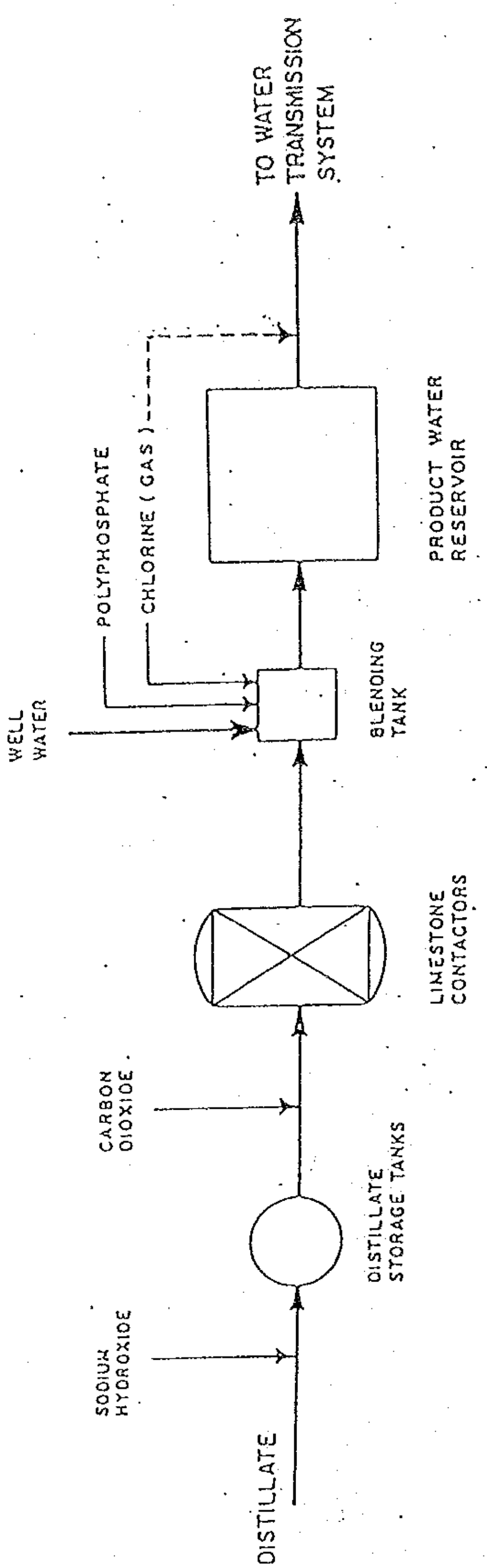


Figure 5.2.6 Flow Diagram of Post-Treatment System

Table 5.2.7 Ghubrah Exported Water Quality

Date	pH	EC µs	Alkalinity as CaCO3 ppm	Chloride ppm	Phosphate ppm	Iron ppm	Chlorine ppm	Calcium Ca ppm	Magnesium ppm	Total Hardness as CaCO3 ppm	[ ]**
09-01-91	8.21	136	44	0	2.5	0.03	0.59	16	1.9	47.9	-0.07
12-01-91	7.64	141	50	0	0	0.02	0.67	20	1.2	55	-0.5
12-03-91	8.02	142	51	14.2	2.5	0.03	0.61	19.3	2.1	56.8	-0.13
20-03-91	8.61	145	39	22.7	0	0.03	0.54	14.8	1.5	41.4	0.23
27-03-91	7.88	133	43	16.31	1.5	0.03	0.51	15.6	1.4	44.6	-0.42
03-04-91	7.86	136	43	17.7	1.4	0.03	0.64	16.8	1.9	50	-0.33
04-04-91	7.88	140	46	0	0	0.02	0.70	16.4	1.7	48.2	-0.71
29-04-91	8.31	101	47	0	0	0.01	0.72	17.2	0.6	45.5	0.16
30-04-91	8.28	100	46	0	0	0.01	0.60	16.2	1.0	44.7	0.08
15-05-91	7.86	128	45	16.3	1.21	0.02	0.61	17.8	1.3	49.3	-0.34
12-06-91	7.83	107	44	10.6	1.27	0.02	0.61	16.6	0.9	45.4	-0.36
19-06-91	7.84	114	45.5	12.8	1.05	0.02	0.55	16	0.6	42.5	-0.37
21-06-91*	7.72	440	52	0	0	0.04	0.44	25.6	9.1	101.8	-0.03
22-06-91*	7.68	560	55	147.2	0	0.08	0.53	28.6	11.4	119.1	-0.57
26-06-91*	7.77	291	46.5	0	1.65	0.02	0.71	21.6	8.4	75	-0.36
27-06-91*	7.75	333	48.5	0	0	0.07	0.61	22.9	6.4	83.9	-0.36
28-06-91*	7.77	354	48	0	0	0.07	0.57	23.4	7.4	89.3	-0.32
29-06-91*	7.68	375	49	0	0	0.06	0.49	18.6	10.3	89.3	-0.5

* Blended with well water
** Langelier Stability Index

(From MEW)

Table 5.2.8 Variation in Quantity of Well Water Delivered to Ghubrah

Parameter	Minimum	Maximum	Average
pH	7.05	7.55	7.24
Conductivity µs	2,160	10,600	4,360
M.O. Alkalinity ppm as Ca CO_3	168	194	177
Total Hardness ppm as $CaCO_3$	535	1,982	1,041
Calcium Hardness ppm as Mg	64	1,380	170
Chloride - ppm	567	4,468	1,479
Total Iron - ppm	0.4	0.82	0.63
Langelier Index	0.45	0.81	0.62

(From MEW)

Table 5.2.9 Distribution System Water Quality

Parameter	Concentration		
Sample ID	[A]	[B]	[C]
Sample Number	2677/115	2659/116	26781116
Date of Analysis	15-09-90	12-09-90	10-09-90
Ammonia - ppm	ND	ND	ND
Nitrite - ppm	ND	ND	ND
Nitrate - ppm	ND	ND	ND
TDS - ppm	90	620	290
Chloride - ppm	30	190	100
Alkalinity - $CaCO_3$ ppm	30	70	40
Hardness - $CaCO_3$ ppm	60	140	80
Calcium - Ca ppm	8	32	24
Magnesium - Mg ppm	10	14	5
Iron - ppm	ND	ND	ND
pH	8.7	8	7.6
Conductance - μs	140	920	440
Langlier Index	-0.35	-0.08	-0.85

*

[A] Influent to Ruwi Storage Tank

[B] Tap in Residence of Tank Watchman

[C] Outlet of Ruwi Reservoir Compartment No. 2

Source: Ministry of Health

5.3 Fluctuation Character on Demand and Supply of Water

5.3.1 Fluctuation of Water Demand

(1) Seasonal fluctuation

Although the water demand varies with a pattern to increase in summer and decrease in winter, similarly to electricity, the difference is not so much. For instance, Table 5.3.1 and Figure 5.3.1 show monthly water demand through 1986 to 1992. There is given a range of the fluctuation of water demands with monthly ratio, each of which consists of a monthly amount to the monthly one averaged from a certain period (plural years). As shown Table 5.3.1, the maximum supply of 111 % in June and the minimum supply of 84.5 % in January to the annually averaged value.

(2) Daily fluctuation

As shown in Table 5.3.2, the maximum daily supply is about 1.3 the annual average value of daily supply from 1986 to 1990 and can be beared enough by the reservoir capacity around the consumption area.

5.3.2 Production Facilities Corresponding to Water Demand

For water measurement, there are some differences between the total reading amount of flowmeters at consumers and total amount produced. In consideration of the differences, it must determine an appropriate capacity for new production facilities.

The following items are evaluated for determination of the capacity.

(1) Revenue ratio

Revenue ratio means ratio of water consumption of consumers, on which water rate should be estiamated, to total water amount produced.

The past ratio of Muscat area until 1990 was about 70 % shown as Table 5.3.3, but recently it is expected that coming up 70 to 75 %. MEW intends to the ratio further up to 85 % within 5 years and is going to take actions along such policy. In this connection, average Japanese revenue ratio was 86.4 % in 1992.

Among the non-revenue value, some inevitable items such as fire-fighting consumption are suggested as well as loss of leakage, flowmeter accuracy, etc., but the details are unknown.

(2) On-site consumption

It is the amount devoted directly to the desalination/power plant and its personnel demands in their living quarters, etc. which are exempted from water rate, and is reported from the Ghubrah Plant record in 1993, as follows:

Water Quantity	Absolute	Ratio
Total water production	42,219,826 m^3/year	100 %
In-plant water consumption	770,652 m^3/year	1.66 %
Drinking water on-site (including camps)	120,383 m^3/year	0.28 %
Total consumption on-site	821,035 m^3/year	1.94 %

(3) Design capacity ratio

Design capacity must be determined in consideration of seasonal fluctuation, etc. to annual average production capacity. By MEW, it is acceptable as 1.2 to annual average capacity.

Design production capacity (m^3/d) =
1.2 x Required daily production capacity (annually averaged)

(4) Availability and load factor

There is a record of Ghubrah Plant given about 90 % as availability averaged until now. And also the load factor is given as 87.6 % induced from the data in 1993 as follows:

Water Quantity	Absolute	Ratio
Total plan capacity	131,930 m^3/d	100 %
Water production (average)	115,671 m^3/d	87.6 %

In the same manner, it is known 91.3 % and 91.6 % as load factor in 1991 and 1992.

These relations are summarized on Fig. 5.3.2.

Table 5.3.1 Monthly Water Demands

Month	Demand (m^3/d)								Ratio (%)
	1986	1987	1988	1989	1990	1991	1992	Average	Monthly /Yearly
January	77,917	87,176	89,456	98,270	102,012	107,298	102,383	94,930	84.50
Feburuary	73,558	88,970	92,562	98,001	99,633	109,677	117,648	97,150	86.48
March	83,144	90,683	104,837	102,355	113,664	113,607	110,488	102,683	91.40
April	90,298	96,683	110,511	112,532	123,293	124,373	116,859	110,650	98.49
May	101,017	113,464	118,958	122,578	130,592	130,235	135,983	121,832	108.45
June	101,370	116,959	123,386	125,050	130,959	131,026	143,605	124,622	110.93
July	104,001	119,055	113,789	124,658	131,711	132,362	135,078	122,950	109.44
Augast	99,850	111,521	115,363	119,108	125,623	125,995	131,011	118,353	105.35
Setember	103,801	111,801	114,911	121,620	123,776	128,710	137,175	120,256	107.04
October	102,584	107,113	114,005	119,560	125,676	127,791	128,294	117,861	104.91
Novemver	98,313	101,145	108,315	112,712	118,236	120,438	129,616	112,682	100.30
December	87,374	92,893	99,567	101,034	112,560	112,859	122,718	104,144	92.70
Average	93,602	103,122	108,805	113,123	119,811	122,031	125,905	112,343	100.00

Table 5.3.2 Daily Fluctuation

	1986 Demand	1987 Demand	1988 Demand	1989 Demand	1990 Demand
	(m3/d)	(m3/d)	(m3/d)	(m3/d)	(m3/d)
Average	93700	103200	109100	113200	119900
Peak Day	122984	129700	135678	143305	145884
Peak Month	104011	119055	123386	125050	131711
Peak Day/Average Day	1.31	1.26	1.24	1.27	1.22
Peak Day/Peak Month	1.18	1.09	1.10	1.15	1.11
Peak Month/Average Day	1.11	1.15	1.13	1.10	1.10

Table 5.3.3 Revenue Ratio

Year	Ave. Demand m^3/D	Increase Rate	Ave. Supply m^3/D	Increase Rate	Unaccountable Rate	Revenue Ratio
1986	63,200		93,700		0.326	0.674
1987	72,200	1.142	103,200	1.101	0.300	0.700
1988	79,300	1.098	109,100	1.057	0.273	0.727
1989	74,400	0.938	113,200	1.038	0.343	0.657
1990	88,500	1.190	119,900	1.059	0.262	0.738
Average	75,520	1.092	107,820	1.064	0.301	0.699

Table 5.3.1 Monthly Fluctuation

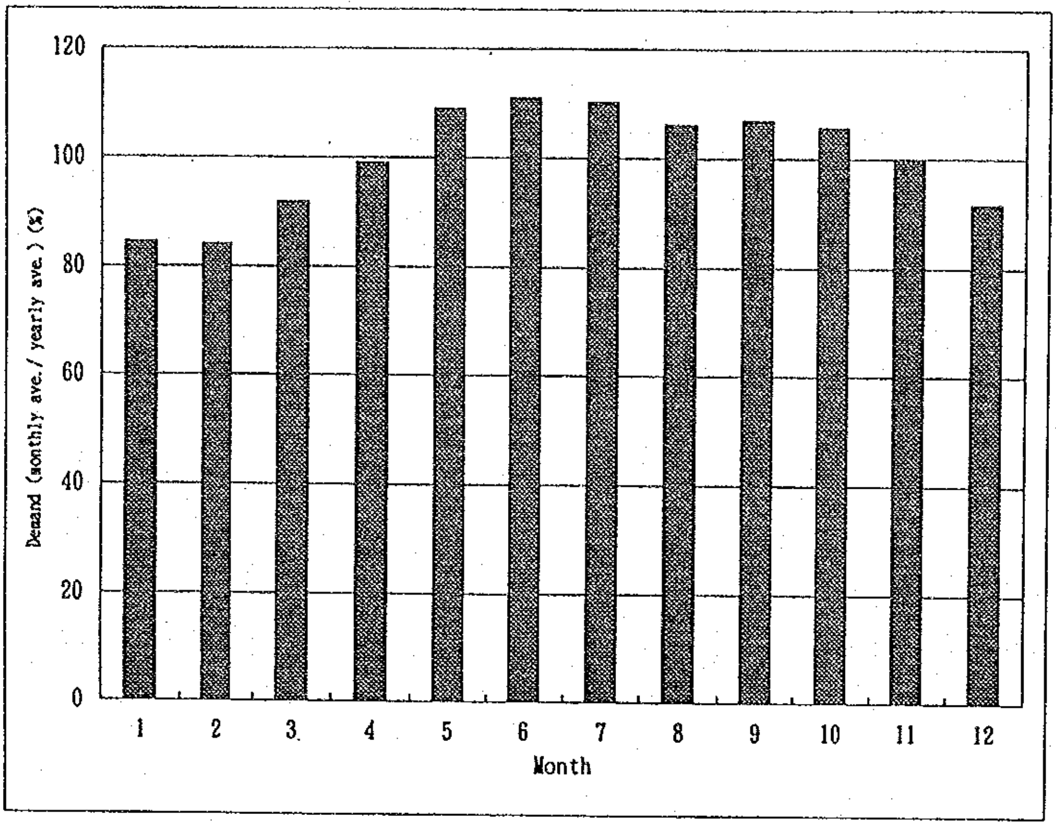
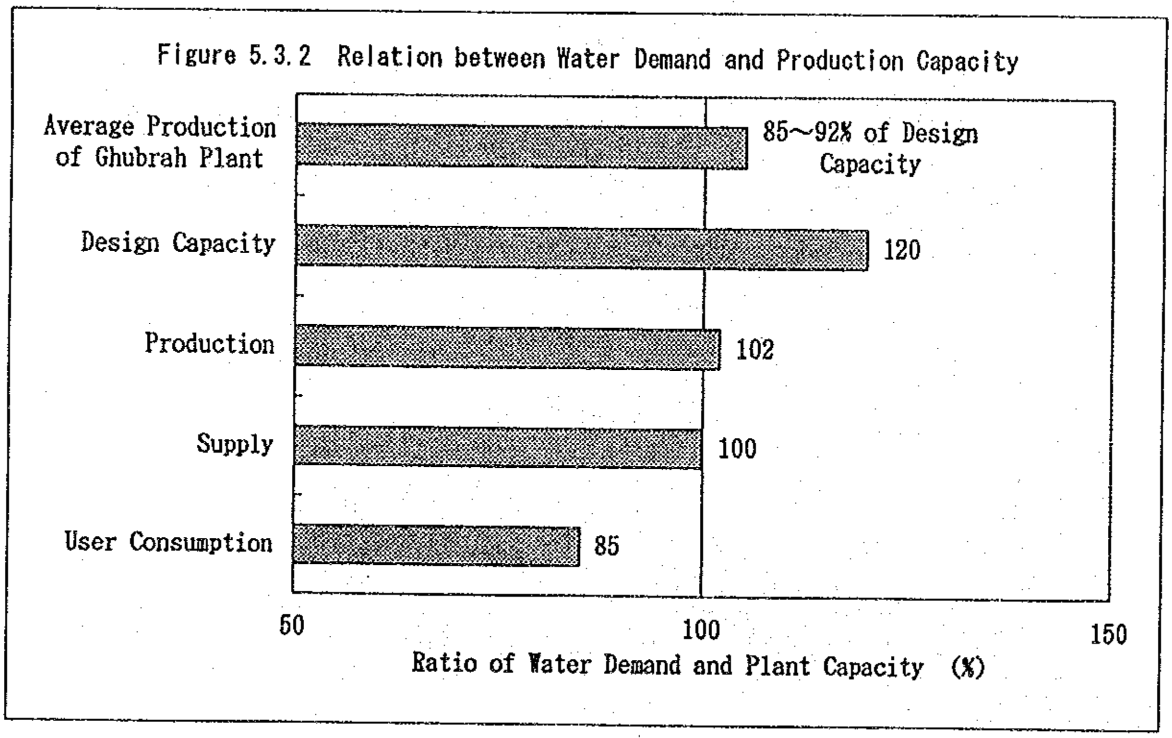


Figure 5.3.2 Relation between Water Demand and Production Capacity



5.4 Water demand forecasting

MEW has an official water master plan called "Water Supply Master Plan for Muscat" (hereinafter referred to as "the Master Plan"), which was prepared by outside consultants in 1993. This document contains water consumption data covering a period between 1981 and 1990. Also, some data obtained at MEW or drawn from governmental publications indicate the total water consumption, the number of connections, and the unit consumption from 1987 to 1993 (excluding 1991 and 1992). With these statistical data, demand projections are made up to the year 2010.

We begin this section with a brief discussion concerning the possible association of the water demand with major economic indicators. Demand forecasting is made by employing two methods, namely, a macro trend extrapolation and a micro forecasting method.

5.4.1 Association with economic indicators

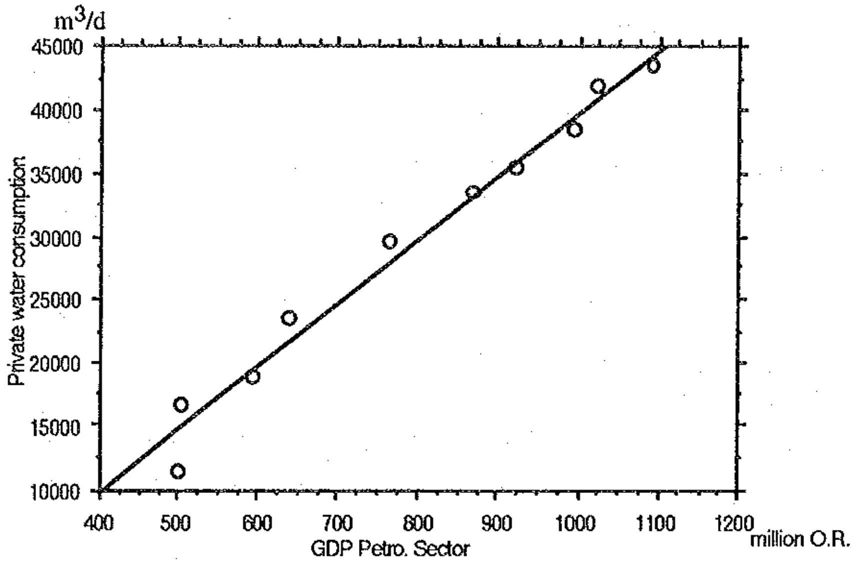
As part of the demand assessment, study was made into the possible link between the water demand and major macroeconomic indicators. Similar to the case of electricity demand, strong association was observed only with the GDP petroleum sector. (See Figure 5.4.1 and also Appendix 2 of this chapter.[1]) It is obvious that the government revenue from crude oil production and its spending push up the water demand through some mechanism. Presumably, the center of the mechanism is the public investment in transmission and distribution facilities for supply water. This presumption would be proved, if sufficient statistical data concerning the capital investment for that purpose, or conversely, the expansion of supply area, were available. Regression lines appearing in Figure 5.4.1 are expressed with the following equations.

Item	Equation
Private water consumption (m^3/d)	Y = -9911.793 + 49.586x X, r^2 = 0.977
Government water consumption (m^3/d)[2]	Y = -16934.127 + 56.503 x X, r^2=0.949

1 No significant association was found with GDP (or the GDP non-petroleum sector), which is deemed to indicate overall economic activities more accurately than the GDP petroleum sector does.

2 The coefficient of determinant of the equation for the government consumption could be higher without a sudden drop of the consumption experienced in 1984 (see Figure 5.4.2). The cause of that drop is not known.

(a) Private water consumption



(b) Government water consumption

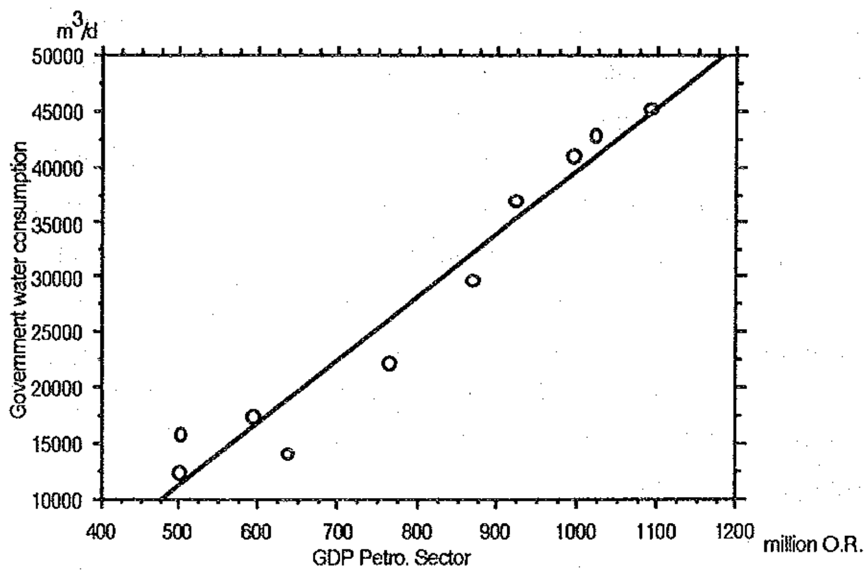


Figure 5.4.1 Water demand and GDP Petroleum Sector

5.4.2 Macro trend extrapolation

Until recently, MEW used four categories to classify its customers: "Private", "Government", "Tanker", and "Coupon". The first two were supplied with water from the connections with the piped system, whereas the others were from water tankers. The Private customers included all the commercial and industrial establishments as well as households. The Government category comprised palaces, government agencies and institutions, and irrigation of public areas. The Tanker and Coupon categories referred respectively to MEW tankers and non-MEW tankers, both of which supplied MEW's water to areas that were not served with piped water. As exhibited in Figure 5.4.2, the average daily total consumption increased from approximately 24,000 m3/d in 1981 to 89,000 m3/d in 1990, or at an average annual rate of 15.7%. Both private and government consumptions increased steadily every year, except in 1984 when an abrupt decrease of the government consumption was recorded.

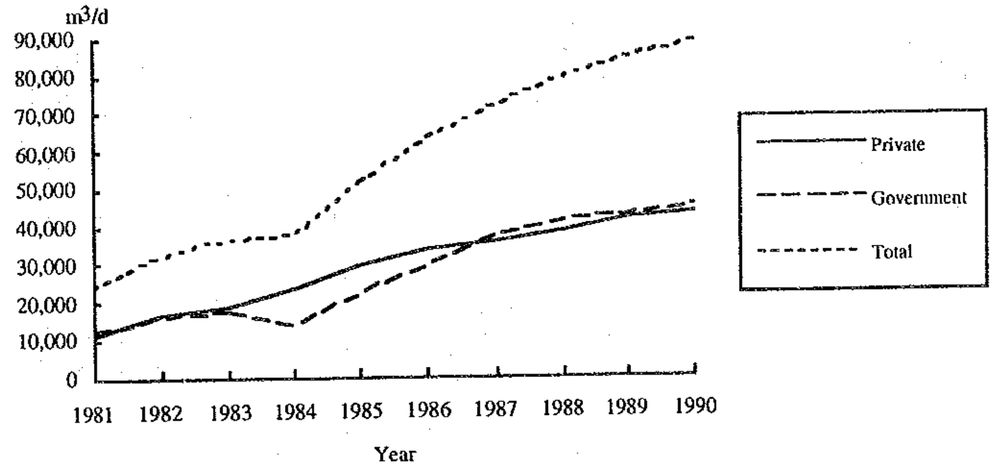


Figure 5.4.2 Changes in average daily water consumption (private and government sectors) 1981-1990

Note: (a) Private consumption includes water supplied by tankers, which in 1990 was 3,909 m^3/day.
(b) The water consumption defined in the source book, is basically the balance between "the total outflow from distribution system" as defined by MEW and the "unaccounted-for-water" as defined by the source book. It is important to note that the water consumption and the "water demand" are different.

Source: Ministry of Electricity and Water, Sultanate of Oman, "Water Supply Master Plan for Muscat", Final Report, Vol. II of Main Report, June 1993.

Based on the actual consumption data contained in the Master Plan and used for Figure 5.4.2, we extrapolate the future water demand. It is known that a large proportion of the tanker water is consumed for domestic use; therefore, for convenience, the tanker water is included in the private use category in our forecasting.

Past changes in the water consumption graphically shown in Figure 5.4.2 suggest that the future changes may take either a linear or a non-linear (polynomial) form. It must