Chapter 5 Results of Current Situation Analysis

5.1 Generation Cost Analysis

5.1.1 Cost Analysis Results of Existing Power Generation Plants

The contracts of OPWP with power stations are considered to be faithful reflections of the payment to their generation cost. In this section, the averaged values of the power generation costs which will be used for the estimation of the energy conservation effects are estimated based on the cost of information about the power generation contracts obtained from OPWP.

(1) Heat Rates of Power Plants

(a) MIS System

The following table lists the power plants that operated in the MIS system in 2011 and their averaged values of the contracted heat rates. The higher power generation thermal efficiency creates a lower heat rate, because the power plants with a high thermal efficiency require a small amount of prime energy. The Ghubrah Auxilary Boiler Firing STs are efficient, because the prime energy is used for both power generators and desalination plants and the cost sharing in the contracts between the desalination plants and power generators are reflected.

Table 5- 1 Averaged Heat Rate of Power Plants in MIS in 2011

Power Plant Name	ACWA Barka	Ghubrah	Ghubrah Auxilary Boiler Firing	Kamil	Rusail	UPC Manah	Wadi Jizzi	Sohar Power	SMN Barka
Commissioning Year	2003	1978 -1995	1977 -1997	2002	1984 -2000	1996 -2000	1982 -1999	2007	2009
Type	CCGT	OCGT	ST	OCG T	OCGT	OCGT	OCGT	CCGT	CCGT
Maximum Available Capacity (Excuding Disal. Load) (MW)	450.0	378.5	96.9	297.0	686.6	273.3	324.6	589.8	450.0
Average Heat Rate (kJ/kWh)	8,876	12,431	5,607	11,88 3	12,214	11,928	12,552	8,995	8,876

CCGT: Combined Cycle Gas Turbine, OCGT: Open Cycle Gas Turbine

The following figure shows the relation between the commissioning years and the heat rates of the power plants in the MIS system including future power plants. OCGT (Open Cycle Gas Turbine) has the heat rate within the range of 11,000 – 14,000 kJ/kWh while CCGT (Combined Cycle Gas Turbine) has the heat rate within 6,000 – 9,000 kJ/kWh. All the power units that started operations from year 2000 are CCGT and the power generation of MIS system has been increasing its efficiency on a yearly basis.

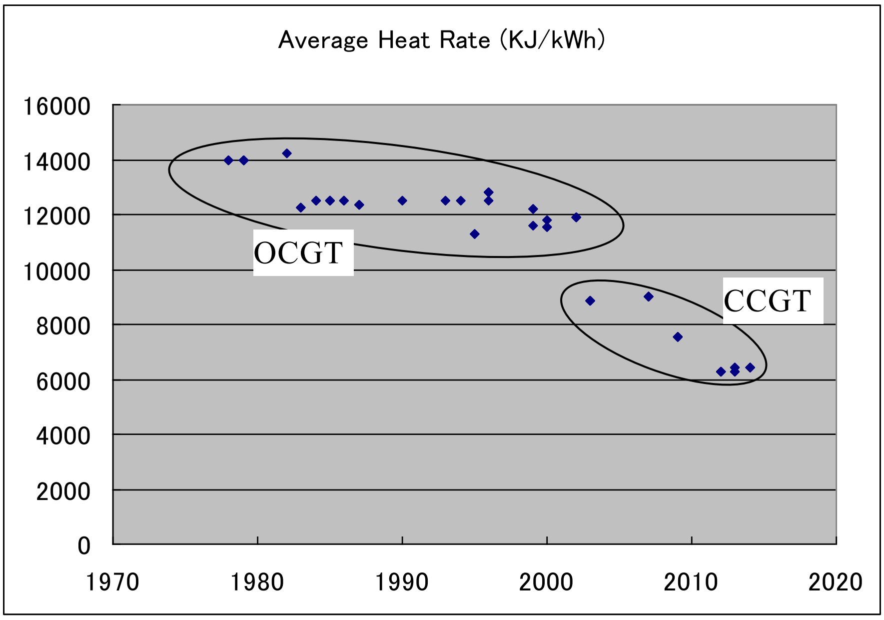


Figure 5- 1 Relation between the Commissioning Years and the Heat Rates of the Power Plants in MIS

The following figure shows the time trend of the averaged heat rate of the power plants in MIS in 2011. The heat rates are averaged over the units of the power plants and allocated to the power outputs of each power plant. As mentioned in the previous chapter, the allocation rates of the power outputs are approximately constant regardless of the time zones throughout the year. Its averaged value is calculated to be 10,087 kJ/kWh.

(Unit: kJ/kWh)

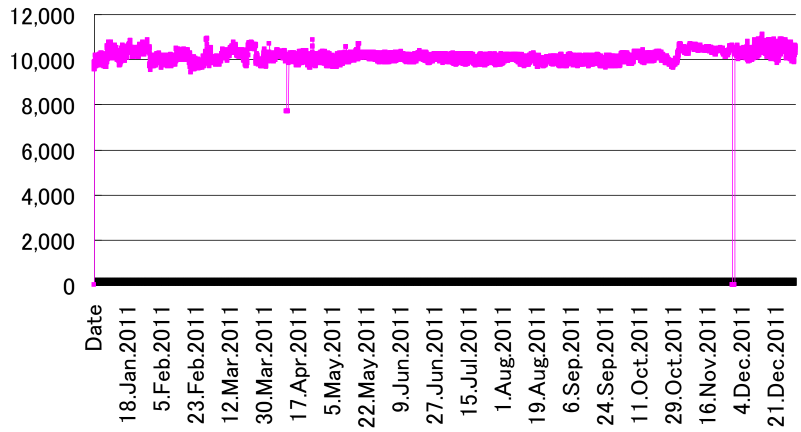


Figure 5- 2 Time Trend of the Averaged Heat Rate of the Power Plants in MIS in 2011

(b) Salalah System

The following table lists the power plants operated in the Salalah system in 2011 and their averaged values of the contracted heat rates. The DPC New Power Station (NPS) is the OCGT type and its efficiency is relatively low because of its large heat per kWh. IWPP started its operations from July 2011.

Table 5- 2 Averaged Heat Rate in Salalah System

Power Plant Name	DPC New Power Station (NPS)	IWPP
Type	OCGT	CCGT
Maximum Available Capacity (Excluding Disal. Load) (MW)	260	445
Average Heat Rate (kJ/kWh)	13,108	9,728

(2) Variable O&M Costs excluding Fuel Costs

The variable O&M costs excluding fuel costs are averaged to be 0.452 RO/MWh (1.175 US$/MWh) over the power plants operated in the MIS system in 2011. The averaged cost over OCGTs is 0.640 RO/MWh (1.664 US$/MWh). On the other hand, the averaged cost over the ones to be operated after 2012 such as BARKA3, SOHAR2, and SUR1 becomes 0.312 RO/MWh (0.812 US$/MWh). These values are approximately 1 % of the fuel costs.

(3) Fixed O&M Cost

OPWP recovers the cost of construction of power plants and the fixed portion of their O&M costs as the fixed cost per week related to the capacities of their unit and their operating ratios. The fixed costs are collected for the week when they are in stand-by operating status.

The averaged fixed cost over all the power stations in MIS that were operated in 2011 is 605 RO/Week/MW. The averaged cost per kW in the MIS system is estimated to be 1,380 US$/kW on the assumption of the expected possible operating ratio for each unit (90 %), its fixed cost, and the duration from the commissioning year to the expected decommissioning year.

On the other hand, BARKA3, SOHAR2 and SUR1 that are expected to be commissioned after 2012 are all CCGTs and their fixed costs lie within the range from 1,200 to 1,900 RO/Week/MW. The estimated cost per kW become around 2,300 to 3,700 US$/kW and its capacity averaged cost is 2,861 US$/kW which is higher than the averaged cost in the MIS system in 2001.

The following table summarizes the power generation costs in the MIS system.

Table 5- 3 Heat Rates and Cost of Existing and Future Power Generation in MIS System

Items	Unit	Averaged Value in 2011	Averaged Value of Existing OCGT	Averaged Value of CCGT after 2012
Heat Rate	kJ/kWh	10,087	12,222	6,375
Fuel Costs (evaluated from the price equivalent to the exported natural gas 10 US$/MMBtu = 397 US$/toe)	US$/kWh	0.096	0.116	0.060
Variable O&M Cost (excluding fuel costs)	US$/MWh	1.175	1.664	0.812
Fixed O&M Cost (including power plant construction costs)	US$/kW	1,380	1,501	2,861

5.1.2 Estimation of Generation Costs up to 2035

(1) Analysis Presumption

The OPWP formulated the prospected power procurement up to 2018. The JICA Study Team estimated the amount of power units required up to 2035 based on the peak power demand forecast up to 2035 obtained from OPWP.

- Power generation consists of OCGT and CCGT after 2019 in the same manner as in the years before 2018.
- The share of OCGT tends to decrease yearly. However, it will be still needed for the peak demand power supply due to its low fixed costs in spite of its high fuel costs. The share of the OCGT is assumed to be the same ratio as it will be in 2035, around 23.4%. This ratio is approximately the optimum ones as explained below.
- The following figure shows the load duration curve of the MIS system in 2011 created from the data obtained from OETC.

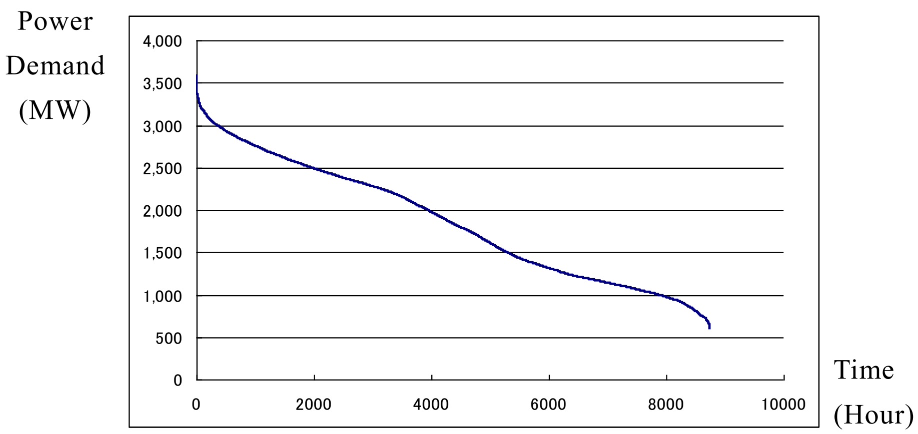


Figure 5- 3 Load duration curve of MIS system in 2011

- It is assumed that the power energy exceeding a certain amount will be supplied by OCGT and the remaining power energy will be supplied by CCGT. The lifetime of the power generators is assumed to be 20 years. The following graph depicts the total generation costs of the MIS system related to the ratio of the share of OCGT to the total generation capacity. The optimum point lies at the ratio of 25% of the OCGT. If the fuel cost is estimated to be 15 USD/MMBTU, the optimum ratio of CCGT moves to 21% and its result is almost the same as the case with 10 USD/MMBTU.

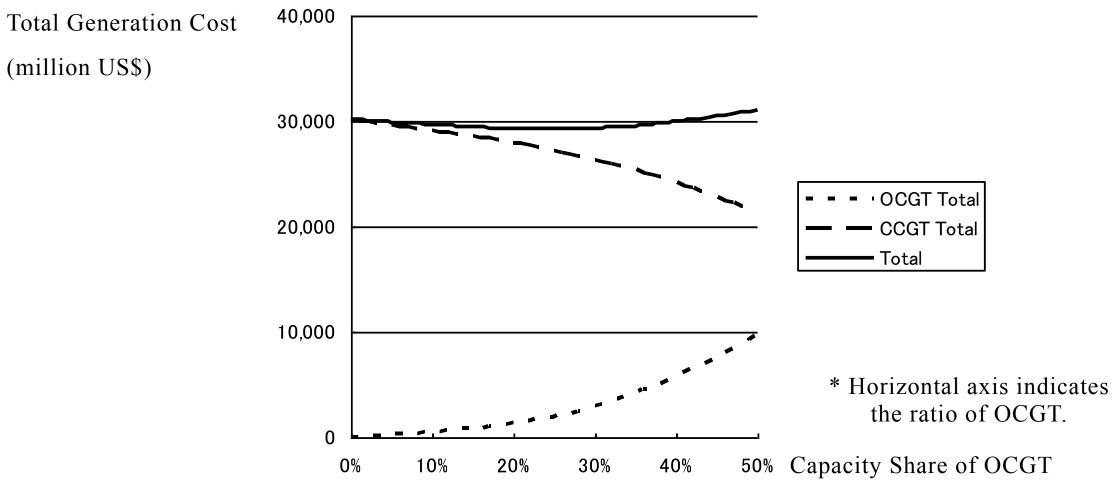


Figure 5- 4 Total Generation Cost of MIS System vs. Ratio of Shares of OCGT and CCGT

- The reserve margin of power generation is assumed to be around 20 %. The reserve margin of around 20 % is found to be needed from the results of the calculation on the condition that the duration of the periodical maintenance outage is 10 % of the year, the forced outage is 3 %, the number of units of the system is 70 to 100 and the allowable power shortage duration is one day per year.

(2) Estimated Amount of Power Generation

The following table shows the estimated amount of power generation up to 2035 per the abovementioned conditions.

Table 5- 4 Estimated Amount of Power Generation up to 2035 (MIS System)

			2012	2013	2014	2015	2016	2017
Peak Power Demand		MW	4,216	4,594	5,007	5,374	5,760	6,151
Energy Demand		MWh	20,727,170	22,671,940	24,331,367	26,211,287	28,144,931	30,079,339
OCGT	Capacity	MW	2,057	1,907	1,817	1,817	1,817	1,817
	Power Energy	MWh	2,443,473	1,276,690	483,788	524,872	565,441	605,955
CCGT	Capacity	MW	2,750	3,652	5,213	5,200	5,194	5,189
	Power Energy	MWh	18,283,697	21,395,251	23,847,579	25,686,415	27,579,490	29,473,384
Total Capacity		MW	4,807	5,559	7,030	7,017	7,011	7,006
Reserve Margin			1.14	1.21	1.40	1.31	1.22	1.14
			2018	2019	2020	2025	2030	2035
Peak Power Demand		MW	6,582	7,014	7,446	9,438	11,483	13,971
Energy Demand		MWh	32,139,380	34,209,714	36,274,196	45,883,835	55,824,701	67,919,285
OCGT	Capacity	MW	1,582	1,683	1,787	2,265	2,756	3,353
	Power Energy	MWh	430,405	241,738	256,326	324,231	394,477	479,941
CCGT	Capacity	MW	5,187	6,734	7,148	9,061	11,024	13,412
	Power Energy	MWh	31,708,975	33,967,977	36,017,869	45,559,604	55,430,224	67,439,343
Total Capacity		MW	6,769	8,417	8,935	11,326	13,780	16,765
Reserve Margin			1.03	1.20	1.20	1.20	1.20	1.20

(3) Estimated Generation Costs up to 2035

The averaged fixed and variable costs of OCGT and CCGT are estimated by averaging their costs according to their generation capacities (MW) and generated energy (MWh). The results are shown in the following table.

Table 5- 5 Averaged Generation Costs for Each Year

Year		2012	2013	2014	2015	2016	2017
Fixed Cost	US$/kW	2,279	2,395	2,510	2,509	2,509	2,508
Variable Cost	US$/kWh	0.0679	0.0644	0.0624	0.0624	0.0624	0.0624
Year		2018	2019	2020	2025	2030	2035
Fixed Cost	US$/kW	2,543	2,543	2,543	2,543	2,543	2,543
Variable Cost	US$/kWh	0.0620	0.0616	0.0616	0.0616	0.0616	0.0616

5.2 Power and Energy Demand Forecasts

5.2.1 Existing Power Demand Forecasts

(1) Power Demand Forecasts in the “7 Year Statement, Issue 6”

The power demand outlook in Oman are made by OPWP. It is described in the “7 Year Statement, Issue 6” to be published annually by OPWP in accordance with Condition 5 of AER. The JICA Study Team has received the latest “7 Year Statement, Issue 6” that was issued in March 2012. The statements include the power demand outlook from 2012 to 2018. The OPWP power demand outlook does not include the power demand of the whole country. Its targets are the MIS area (their distribution companies are Muscat, Majan and Mazoon distribution companies) and Salalah area (its distribution company is DPC). In 2010, these areas occupied 97 % of power demand in the whole country. The rest of the power demand, which is only 3 %, are in the rural areas (its power utility company is RAECO).

The power demand outlooks of MIS and Salalah in the "7 Year Statement, Issue 6" are as follows. As OPWP's power demand outlook assumes that they purchase power at a transmission outlet, the power demand is shown as the "net power production" that subtracts its own power use in power generation stations.

Table 5- 6 Power Demand Outlooks in "7 Year Statement, Issue 6" Published by OPWP

(Unit: TWh)

		2011	2102	2013	2014	2015	2016	2017	2018	18/11
MIS	High	19.00	21.30	23.60	25.90	30.20	35.70	38.20	41.00	11.6 %
	Base	19.00	20.70	22.70	24.30	26.20	28.10	30.10	32.10	7.8 %
	Low	19.00	20.40	21.40	22.70	23.90	25.50	26.80	28.20	5.8 %
Salalah	High	2.00	2.38	2.85	3.53	4.57	5.10	5.62	6.15	17.4 %
	Base	2.00	2.23	2.47	2.76	3.06	3.39	3.70	4.02	10.5 %
	Low	2.00	2.02	2.25	2.45	2.66	2.91	3.10	3.31	7.5 %
Total	High	21.00	23.68	26.45	29.43	34.77	40.8	43.82	47.15	12.2 %
	Base	21.00	22.93	25.17	27.06	29.26	31.49	33.8	36.12	8.0 %
	Low	21.00	22.42	23.65	25.15	26.56	28.41	29.9	31.51	6.0 %

(Source: "7 Year Statement, Issue 6" published by OPWP)

Table 5- 7 Peak Demand Outlooks in "7 Year Statements, Issue 6" Published by OPWP

(Unit: MW)

		2011	2102	2013	2014	2015	2016	2017	2018	18/11
MIS	High	3,845	4,320	4,827	5,325	6,173	6,908	7,458	8,059	11.2 %
	Base	3,845	4,216	4,594	5,007	5,374	5,760	6,151	6,582	8.0 %
	Low	3,845	4,115	4,396	4,676	4,947	5,227	5,501	5,791	6.0 %
Salalah	High	348	418	494	616	801	879	959	1,041	16.9 %
	Base	348	394	433	480	531	584	636	689	10.2 %
	Low	348	358	391	427	463	502	536	571	7.3 %
Total	High	4,193	4,738	5,321	5,941	6,974	7,787	8,417	9,100	11.7 %
	Base	4,193	4,610	5,027	5,487	5,905	6,344	6,787	7,271	8.2%
	Low	4,193	4,473	4,787	5,103	5,410	5,729	6,037	6,362	6.1 %

(Source: "7 Year Statement, Issue 6" published by OPWP)

(2) Current Situation of OPWP's Model Building (As of Sep. 2012)

The OPWP is formulating long term power demand outlooks away from the power demand outlooks in "7 Year Statements, Issue 6". The purposes of the long term power demand outlooks is to make a plan to stabilize the security of fuel supply for the power sector, and to clarify the roles of renewable energies, nuclear power and regional power grid systems for the diversification of future power supply.

As of Sep 2012, data collection is being continually conducted by OPWP staffs. The collected monthly data from 2005 are as follows;

- ✓ Power demand data,
- ✓ Power generation data,

- ✓ Power customer data,
- ✓ Population data (by age and by household),
- ✓ Economic data (GDP, inflation and so on),
- ✓ Meteorological data (temperature, sunshine and so on),
- ✓ Non-oil industry's sub-sector data（Petrochemical, Fertilizer, Iron, Oil refinery, LNG and so on）,
- ✓ Labor force data

The OPWP has a plan that the above monthly data will be added to the annual data, and have all of the data stored in their database. Generally speaking, the short and middle term demand forecasting model that aims to predict power demand for the next ten years frequently uses monthly and quarterly data. Therefore, it seems that OPWP's data collection aims at short term power demand forecasts in 7 Year Statements and long term power demand forecasts for power supply diversification. Furthermore, it sometimes happens that the model structures are different between the short term demand forecasting model and long term forecasting model. The procedures and outstanding points of the power demand forecasts in the 7 Year Statements are as follows.

- ✓ The power demand outlook in the near future is made with the accumulation from distribution company predictions.
- ✓ The power demand of the OPWP is the net production to subtract its own use of power consumption at power generation stations from the power generation amount.
- ✓ The power generation is calculated by using the power efficiencies of each power generation plant. The power supply from desalination plants is included.
- ✓ The power demand in RAECO is not included in the power demand outlooks of OPWP, because it is a small share in Oman's power demand and it fluctuates greatly. The power demand in RAECO fluctuates such as by moving the army and establishing new factories. It is not suitable to include such fluctuation into the power demand forecasting functions of RAECO in the model.
- ✓ Regarding the DPC power demand as well as RAECO, the power demand is quite uncertain due to introducing IPPs, constructing airports, industrial parks and so on.
- ✓ The desalination power is increasing at a high growth rate due to an increasing number of households, new power demand and well water pumping regulations.

(3) Long Term Power Demand Outlook of OPWP

As of September 2012, OPWP has not started the model building. The model is for long term power demand forecasts from 2012 to 2035. One of the purposes to building the model is to analyze the diversification of power supply. Furthermore, it considers that renewable energies such as photovoltaic and solar heating are useful for power supply systems as substitutes to natural gas.

OPWP submitted the following tentative long term power demand to the JICA Study Team in June 2012.

Table 5- 8 Long Term Power Demand Outlooks of OPWP（Tentative Vision in June 2012）

	Power demand(TWh)				Peak demand（MW）			
	MIS	Salalah	Total	Growth Rate (%)	MIS	Salalah	Total	Growth Rate (%)
2011	19.0	2.0	21.0		3,845	348	4,194	
2012	20.7	2.2	23.0	9.6	4,216	394	4,610	9.9
2013	22.7	2.5	25.1	9.5	4,594	433	5,027	9.1
2014	24.3	2.8	27.1	7.7	5,007	480	5,487	9.2
2015	26.2	3.1	29.3	8.1	5,374	531	5,904	7.6
2016	28.1	3.4	31.5	7.7	5,760	584	6,344	7.4
2017	30.1	3.7	33.8	7.1	6,151	636	6,787	7.0
2018	32.1	4.0	36.2	7.0	6,582	689	7,270	7.1
2019	34.2	4.3	38.5	6.6	7,014	741	7,756	6.7
2020	36.3	4.6	40.9	6.2	7,446	793	8,239	6.2
2021	38.3	4.9	43.3	5.7	7,871	844	8,715	5.8
2022	40.3	5.2	45.6	5.3	8,288	893	9,181	5.3
2023	42.3	5.5	47.8	4.9	8,690	939	9,630	4.9
2024	44.1	5.8	49.9	4.4	9,075	983	10,058	4.4
2025	45.9	6.0	51.9	4.0	9,438	1,022	10,460	4.0
2026	47.7	6.2	54.0	4.0	9,816	1,063	10,879	4.0
2027	49.6	6.5	56.1	4.0	10,209	1,105	11,314	4.0
2028	51.6	6.7	58.4	4.0	10,617	1,150	11,766	4.0
2029	53.7	7.0	60.7	4.0	11,042	1,195	12,237	4.0
2030	55.8	7.3	63.1	4.0	11,483	1,243	12,727	4.0
2031	58.1	7.6	65.6	4.0	11,943	1,293	13,236	4.0
2032	60.4	7.9	68.3	4.0	12,420	1,345	13,765	4.0
2033	62.8	8.2	71.0	4.0	12,917	1,399	14,316	4.0
2034	65.3	8.5	73.8	4.0	13,434	1,455	14,888	4.0
2035	67.9	8.9	76.8	4.0	13,971	1,513	15,484	4.0
2018/11	11.1%	15.0%	11.5%		11.3%	14.6%	11.6%	
2035/18	4.5%	4.8%	4.5%		4.5%	4.7%	4.5%	

(Note1) Definition of power demand: Power demand = Final power demand + Transmission / Distribution loss
(Note2) The forecasted power demands up to 2018 are the same as 7 Year Statement, Issue 6 and the growth rate from 2025 onward is around 4 % per year. The growth rates during 2019 – 2023 are set by moving average method from 7 % in 2018 and 4 % in 2024.
(Note3) The preconditions such as population growth rate, GDP growth rate, crude oil and natural gas production and export outlooks are not specified in OPWP's outlook.

(4) Evaluation of Long Term Power Demand Outlook by OPWP

Through the interviews on OPWP's long term power demand outlook, the economic preconditions of the outlook can be estimated as follows;

- ✓ When comparing OPWP's power demand growth rate and the elasticity (power demand to real GDP) to the ones of the JICA Study Team model (2012 to 2035), the GDP growth rate used by OPWP can be calculated as shown in the following table.
- ✓ According to the following table, the average GDP growth rate of OPWP from 2012 to 2018 is estimated to be 6 % to 7 % per year and will be approximately 4 % per year after 2019.

Table 5- 9 Estimation of GDP Growth Rates Used by OPWP

	MIS+Salalah	Whole Country	Growth Rate	Elasticity	Growth Rate
	TWh	TWh	%		%
2011（Actual）	21.0	22	14.8	4.9	3
2012	23.0	24	9.6	1.6	6
2013	25.1	26	9.5	1.7	6
2014	27.1	28	7.7	1.3	6
2015	29.3	30	8.1	1.2	7
2016	31.5	32	7.7	1.1	7
2017	33.8	35	7.1	1.1	7
2018	36.2	37	7.0	1.0	7
2019	38.5	40	6.6	1.0	6
2020	40.9	42	6.2	1.0	6
2021	43.3	45	5.7	1.1	5
2022	45.6	47	5.3	1.1	5
2023	47.8	49	4.9	1.0	5
2024	49.9	51	4.4	1.0	4
2025	51.9	53	4.0	1.0	4
2026	54.0	56	4.0	0.9	4
2027	56.1	58	4.0	0.9	4
2028	58.4	60	4.0	0.9	4
2029	60.7	63	4.0	0.9	4
2030	63.1	65	4.0	0.9	4
2031	65.6	68	4.0	0.9	4
2032	68.3	70	4.0	0.9	4
2033	71.0	73	4.0	0.9	4
2034	73.8	76	4.0	0.9	4
2035	76.8	79	4.0	0.9	4

(Note1) The power demand in the whole country is calculated with the expression of 1.03*(MIS + Salalah). The additional demand with 3 % is power demand of RAECO.
(Note2) The elasticity in the model of the JICA Study Team is calculated by “Growth rate of final power demand / Growth rate of real GDP”.

5.2.2 Preconditions of Demand Forecasts by JICA Study Team

(1) Forecasting Objectives

The future power demand forecast that will be submitted by the JICA Study Team is the baseline to estimate future effects via EE&C measures. It is used for calculating the economic benefits of EE&C in a company with power generation costs.

At first, the baseline (Business as Usual case: BAU case) of power and energy demand is set using the model of the JICA Study Team. The EE&C effectiveness after implementing EE&C policies to be proposed by the JICA Study Team is calculated via the reduction of power and energy consumption between the scenarios with EE&C policies and the baseline without the policies.

(2) Methodologies for Demand Forecasting

The demand forecasting model of the JICA Study Team forecasts power, final energy demand and primary energy demand in Oman up to 2035 taking into account the preconditions of the future Omani population growth rate, social economic plan, industrial development policies, energy policy and international energy price predictions. The model is built on an econometric model development software named “Simple E. Expanded (SEEX)” that the Institutes of Energy Economics, Japan has developed. The forecasting model built by the JICA Study Team is one of the econometric models, and it consists of aggregated structural expressions with exogenous variables including the population growth rate, GDP growth rates and energy prices. The main preconditions of the demand forecasts are as follows.

Table 5- 10 Preconditions of the Demand Forecasts

Social economic preconditions (Omani Plan)	1) Population 2) Foreign exchanges 3) Sectoral GDP growth rates 4) Development plans of the Government
Energy activity preconditions (Omani plan)	1) International crude oil and Natural gas prices 2) Production predictions of crude oil and natural gas 3) Substitution of oil products by sector (Industry, transportation, residential) 4) Intensity changes (Energy consumption per population and GDP)
Power activity preconditions (Omani plan)	1) Power Development Plan (GCC, turbine, diesel) 2) Loss reduction measures 3) Power tariff policy (Tariff elasticity, load factor) 4) Renewable energies (Power supply plan) 5) Power efficiencies (Power generation per fuels) 6) Power ratios (Power consumption per final energy consumption) 7) Intensity changes based on current trends (Initial intensity)

(Source: JICA Study Team)

(3) Preconditions

The preconditions such as the population growth rate, GDP growth rate and future crude oil price are described in the sections of “3.2.1 Population Trends”, “3.2.4 GDP Outlook in Long Term” and “3.5.3 Future Prospects for Crude Oil Prices”. Thus, the other preconditions are described herewith.

(a) Fuel Consumption Rates by Generation Type

The following table shows the fuel consumption rates per generation type. The rates were calculated using the power generation and fuel consumption data in the IEA database. It seems that the rates in the following table are lower than the power efficiencies used in Oman, because the fuel consumption for other usages than power generation is included in these data.

The differences in the ways fuel consumption is calculated between the fuel consumption rates and power efficiencies in power stations are shown in the following expressions.

Case of fuel consumption rate:

Fuel consumption = Fuel consumption rate x Power generation

Case of power efficiency rate:

Fuel consumption = Power efficiency x Power generation + Fixed fuel consumption

Table 5- 11 Fuel Consumption Rates by Power Generators

	Fuel Consumption Rates during 2011-2035
Diesel	29 %
Gas Turbine	24 %
Gas Combined Cycle	42 %
Coal	39 %

(Source: JICA Study Team)

(b) Power Ratio

When looking at the energy consumption per sector, the share of the power consumption (ktoe) in all kinds of energy consumption (ktoe) is defined as the "power ratio". The historical trend of the power ratio shows a continuous increase in most of the countries. In the forecasting model, the sectoral power ratios in Oman are defined in the following table after analyzing Omani past power ratios and other country's power ratios. (The electrification rate and power ratio are different concepts.)

Table 5- 12 Power Ratios by Sector

(Unit: %)

Year	Agriculture	Industry	Commercial	Government	Transport	Residential
2005	4.9	16.1	100.0	100.0	0.0	73.1
2006	4.7	18.1	100.0	100.0	0.0	72.6
2007	4.6	17.6	100.0	100.0	0.0	64.0
2008	5.1	20.4	100.0	100.0	0.0	47.7
2009	5.5	22.2	100.0	100.0	0.0	46.4
2010	5.9	25.9	100.0	100.0	0.0	46.4
2011	6.1	28.4	100.0	100.0	0.0	46.6
2012	6.2	31.3	100.0	100.0	0.0	46.9
2013	6.4	32.2	100.0	100.0	0.0	47.1
2014	6.6	33.2	100.0	100.0	0.0	47.3
2015	6.8	34.2	100.0	100.0	0.0	47.6
2020	7.0	38.9	100.0	100.0	0.0	48.8
2025	7.9	40.8	100.0	100.0	0.0	54.6
2030	7.9	40.8	100.0	100.0	0.0	54.6
2035	7.9	40.8	100.0	100.0	0.0	54.6

(Note 1) Power conversion factor: 1kWh=860 kcal and the values in the above table from 2005 to 2011 are actual from 2005 to 2011

(Note 2) According to MOG data, gasoline and diesel oil are consumed in commercial and government sectors. It seems that these were used for transportation in these sectors, so these oil products are accounted in transportation sector.

(Note 3) According to IEA database, heavy oil is used in industry sector. However, the data list from MOG does not include the utilization of heavy oil in industry sector. Thus, the heavy oil consumption in industrial sector is not considered in the forecasting model, considering that it is residual oil from oil refinery plants.

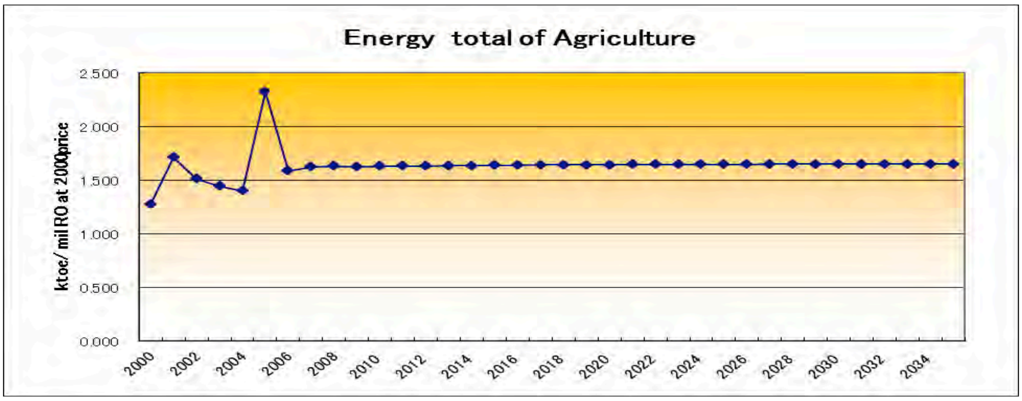
(Source: JICA Study Team)

(c) Energy Intensity

Energy consumption intensity (Energy Intensity) per sector is defined as the sectoral final energy consumption (power consumption + fossil energy consumption) divided by the sectoral GDP or population. In a similar way, the power consumption intensity (power Intensity) is the power consumption divided by the final energy consumption.

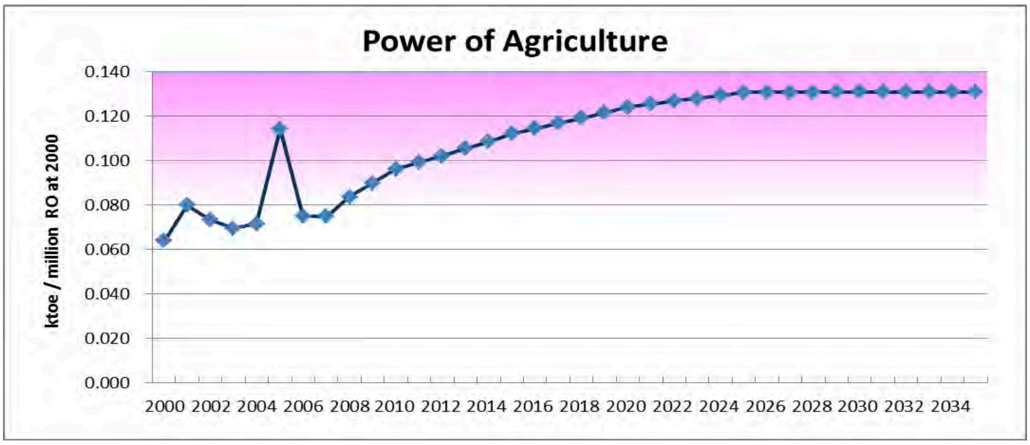
■ **Energy and Power Intensity of Agriculture & Fishery Sector**

The energy intensity is defined as the relative sectoral final energy consumption divided by the relative sectoral GDP. In the agriculture & fishery sector, the past energy intensities to the relative GDP from 2000 to 2010 are almost flat as shown in the following figure. It can be considered that the trend of the future intensities is maintained in case there is nothing to be done with any of the EE&C measures. While sectoral power consumption is in general experiencing a moderate increase in companies with an increasing relative power ratio. However the power consumption in the agriculture & fishery sector has not increased. It is the reason that the power ratio in that sector is too small.



(Source: JICA Study Team)

Figure 5- 5 Energy Intensity to GDP in the Agriculture & Fishery Sector

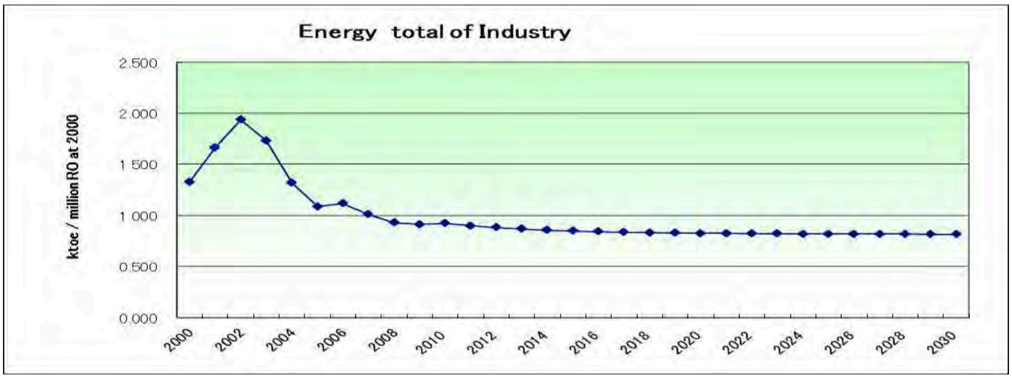


(Source: JICA Study Team)

Figure 5- 6 Power Intensity to GDP in the Agriculture & Fishery Sector

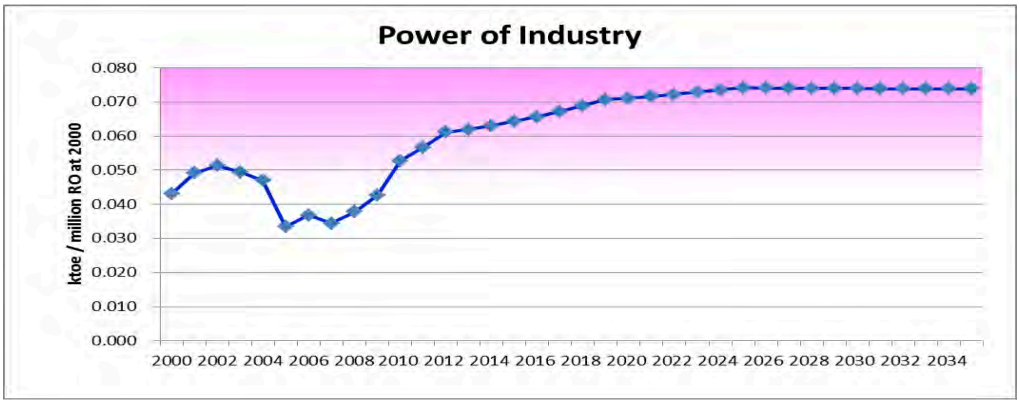
■ **Energy and Power Intensity of the Industry Sector**

In the industry sector, the energy consumption intensity is defined as the relative final energy consumption divided by the industrial GDP. The past energy intensities to the industrial GDP from 2000 to 2010 are on a decreasing trend. It means that energy efficiency in the sector has improved in the years. It can be considered that future energy intensities will not be improved unless there are EE&C voluntary minds and EE&C promotion policies. In the case where energy intensity will not improve any more, the trend will stabilize. On the other hand, the power consumption will increase in the company with the increasing power ratio in the industry sector. Adversely, the fossil energy intensity of the sector is slightly decreasing due to the increasing trend of the power ratio.



(Source: JICA Study Team)

Figure 5- 7 Energy Intensity to GDP in the Industry Sector

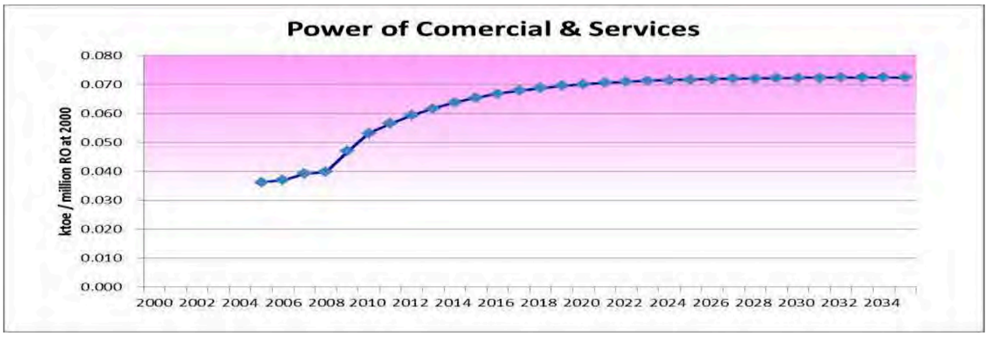


(Source: JICA Study Team)

Figure 5- 8 Power Intensity to GDP in the Industry Sector

■ **Power Intensity of Commercial Sector**

Regarding the energy intensity of the commercial sector, only power consumption intensity data exists, since the fossil energy consumption data of this sector from the MOG are accounted for in the transportation sector. The power intensity is defined as the power consumption in the commercial sector divided by the relative GDP. Although the past power intensities of commercial sector from 2000 to 2010 have increased moderately, the increasing trend of future intensities will stop if the power ratio does not increase in the future. At the same time, it will not decrease, unless there are people from EE&C willing to take proactive action and EE&C promotion policies. It means that the convergence of future power intensities in the commercial sector has stabilized.

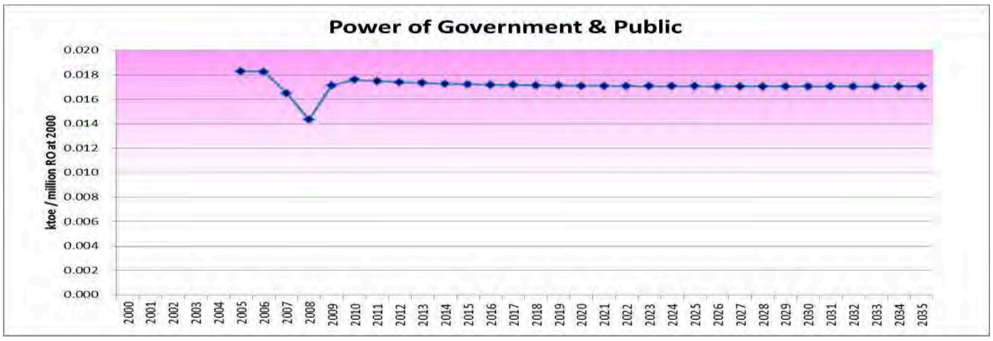


(Source: JICA Study Team)

Figure 5- 9 Power Intensity to GDP in the Commercial Sector

■ **Power Intensity of Government Sector**

Regarding the energy intensity of the government sector, only power consumption intensity data exists, since the fossil energy consumption of this sector are accounted for in the transportation sector. The power intensity is defined as the power consumption in the government sector divided by the nationwide GDP. The future power intensities of the government sector have converged to a constant level, unless there are EE&C people willing to take proactive action and EE&C promotion policies. It means that the convergence of the future power intensities of the government sector have stabilized.



(Source: JICA Study Team)

Figure 5- 10 Power Intensity to Country GDP in the Government Sector

■ **Energy Intensity of Transportation Sector**

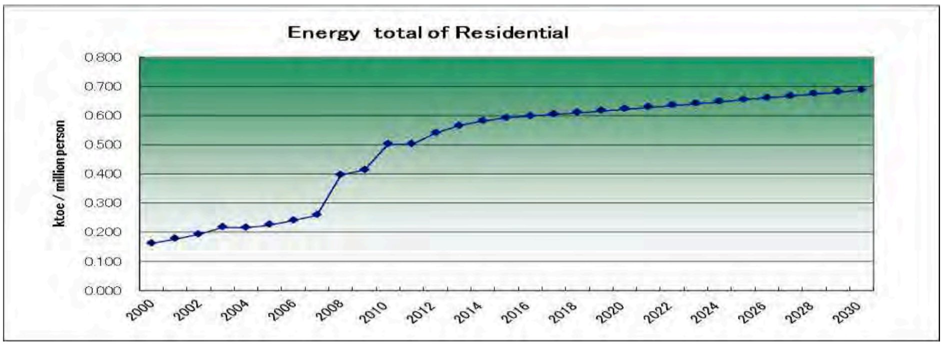
As for the transportation sector, only fossil energy consumption intensity data exists, since it has not used electric power in the past years. The gasoline, diesel oil, jet fuel and heavy oil are pointed out as energies in the transportation sector. The energy consumption intensity in the transportation sector is defined as the energy consumption divided by the national GDP. The energy consumption intensities to the national GDP increased in the company via the dissemination of transportation facilities in recent years. However, after 2015, the dissemination of high performance vehicles in Oman will yield fuel efficiency improvements nationwide. As a result, energy consumption efficiency will improve in the future.

(Source: JICA Study Team)

Figure 5- 11 Energy Intensity to GDP in the Transportation Sector

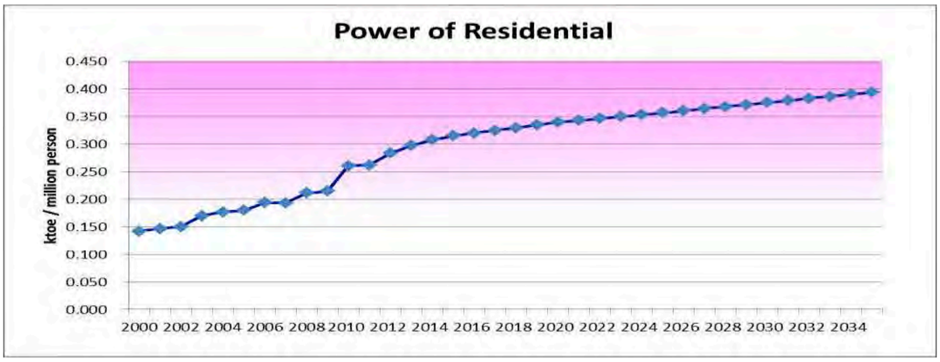
■ **Energy Intensity of Residential sector**

The energy consumption intensity in the residential sector is defined as the relative final energy consumption divided by the Omani population. The past energy consumption intensities to the population from 2000 to 2010 have increased as shown in the following figure. As the energy consumption intensity has a strong relation to population and national income, it can be considered that the energy consumption in the residential sector of Oman will increase in the future. As power consumption intensities to the population in developed counties has constantly increased, the average growth rate of the energy consumption intensity for the Omani residential sector is set at 1 % per year. In consideration of the increasing energy intensities at 1 % per year and the increasing power ratio up to 2020, the power consumption intensities of the residential sector will increase 1.5 % per year and fossil energy intensity will increase 0.5 % per year.



(Source: JICA Study Team)

Figure 5- 12 Energy Intensity to Population in the Residential Sector



(Source: JICA Study Team)

Figure 5- 13 Power Intensity to Population in the Residential Sector

(d) Demand Elasticity to the Energy Price

In case of Japan, the elasticity of economic indicators to the energy prices are in the range of minus 0.1 to minus 0.6 as shown in the following table. The elasticity of the Japanese large consumer's power demand to the power tariff is minus 0.28. IEA introduces another example where the elasticity of the energy demand to energy prices are from minus 0.3 to minus 0.5.

Table 5- 13 Elasticity of Economic Indicators to Energy Prices in Japan (1978～1999)

Sector	Economic indicator	Elasticity
Industry	Index of industrial production	-0.64
Residential	Private consumption	-0.15
Commercial	GDP	-0.44
Power	Large scale power consumption	-0.28
Total of Japan	GDP	-0.51

(Source: "Analysis on variation of energy demand by energy prices" Hyogo Kenritsu University, Akihiro Amano)

In the case of Oman where power tariffs and the energy price are comparatively low compared to their other consumer prices, the elasticity of energy demand and power demand to the energy price and power tariff generally is low compared to other developed countries.

Therefore, the following elasticity of minus 0.1 is selected for the demand forecasting model of the JICA Study Team. It means that Omani power and energy demand do not suffer a negative impact from the power tariff and energy price hike.

Table 5- 14 Elasticity of Power and Energy Demand to Power Tariff and Energy Price

Sector	2011	2012	2015	2020	2025	2030	2035
Agriculture & Fishery	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
Mining & Industry	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
Commercial & Services	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
Government & public	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
Residential	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1

(Note) The elasticity are set separately for power demand and fossil energy demand in the model.
Fossil energy prices are real price at the year of 2010.
Power demand is affected by future tariff and the relative elasticity

(Source: JICA Study Team)

Table 5- 15 Power Tariff Estimation in Oman (MEDC)

		2011	2012	2103	2014	2015	2020	2025	2030	2035
Industry	RO/MWh	18.6	19.8	19.8	20.1	20.4	21.9	23.0	24.1	25.3
Commercial	RO/MWh	23.2	24.8	24.8	25.2	25.5	27.3	28.7	30.1	31.6
Residential	RO/MWh	14.5	15.5	15.5	15.7	15.9	17.1	17.9	18.8	19.8

(Note) The sectoral power tariffs are representative values defined by Category 1 and Category 2 of MEDC tariffs.
There is an assumption that natural gas price in Oman also will increase due to an increase in international crude oil price. Thus, future power tariffs of MEDC are set with elasticity 0.7 to crude oil price.

(Source: JICA Study Team)

(e) Power Development Plan

The power development plan (PDP) from 2012 to 2018 in the model is quoted from the "7 Year Statement, Issue 6". As power and energy demand forecasting in the project are targeted up to 2035, the gas-combined cycles are prepared for additional power generation capacity after 2019 in company with meeting the power demand increase. In Oman, there are three power supply territories (MIS, Salalah, Rural areas). Most of the power supply capacity is concentrated in the MIS area.

5.2.3 Power Demand Forecasts by JICA Study Team

(1) Sectral Power Demand Forecasts

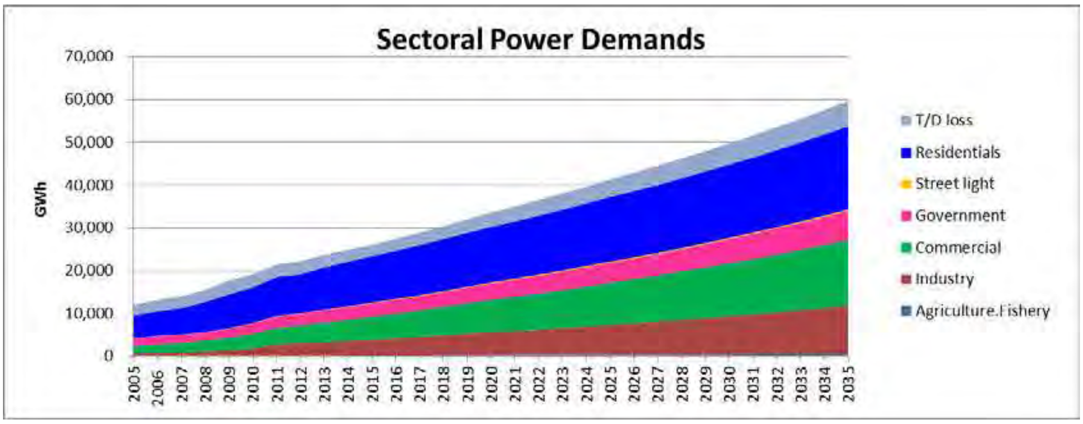
(a) Power demand

The results of the sectoral power demand forecasts are as follows. In the following table, the power demand is defined as the summation of final power demand and transmission and distribution losses (T/D loss) from transmission and distribution companies. The power demand under this definition increases from 22 TWh in 2012, where the total of the sectoral demand is 19 TWh, to 60 TWh in 2035, where the total of sectoral demand is 54 TWh. The scale factor based on 2010 to the power demand in 2035 is 3.1 times, while the one based on 2012 is 2.7 times in 2035.

Table 5- 16 Sectoral Power Demands and T/D Loss

	Unit	2010	2012	2015	2020	2025	2030	2035
Total	GWh	19,200	22,270	26,040	33,610	41,380	49,790	59,770
Agriculture & Fishery	GWh	210	260	300	370	430	470	520
Industry	GWh	1,540	2,810	3,540	5,210	6,960	8,870	11,270
Commercial & Services	GWh	3,470	4,150	5,410	7,580	9,810	12,390	15,410
Government & Publics	GWh	2,390	2,690	3,080	3,860	4,660	5,640	6,830
Street Light	GWh	120	140	180	230	270	300	320
Residential	GWh	8,400	9,080	10,930	13,000	15,110	17,140	19,440
T/D Loss	GWh	3,070	3,140	2,600	3,360	4,140	4,980	5,980

(Source: JICA Study Team)



(Source: JICA Study Team)

Figure 5- 14 Trends of Sectoral Power Demand Forecasts

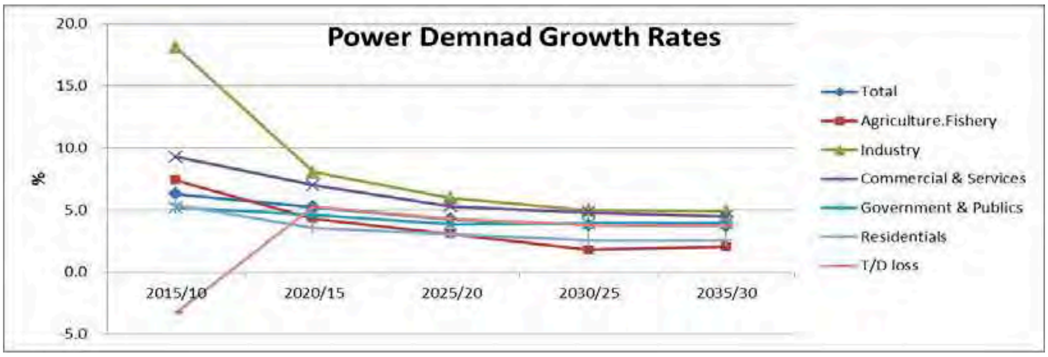
(b) Sectoral Power Growth Rates

The results of the sectoral power demand growth rates are shown in the following table. The growth rates of the power demand including T/D losses are 7.7 % per year from 2010 to 2015, 5.3 % per year from 2015 to 2020, 4.2 % per year from 2020 to 2025, 3.8 % per year from 2025 to 2030 and 3.7 % per year from 2030 to 2035. The growth rate of the Industry sector during the whole term is the highest in all the sectors.

Table 5- 17 Growth Rates of Sectoral Power Demands

	Unit	15/10	20/15	25/20	30/25	35/30	20/10	35/20	35/10
Total	%	6.3	5.2	4.2	3.8	3.7	5.8	3.9	4.6
Agriculture & Fishery	%	7.4	4.3	3.1	1.8	2.0	5.8	2.3	3.7
Industry	%	18.1	8.0	6.0	5.0	4.9	13.0	5.3	8.3
Commercial & Services	%	9.3	7.0	5.3	4.8	4.5	8.1	4.8	6.1
Government & Publics	%	5.2	4.6	3.8	3.9	3.9	4.9	3.9	4.3
Street Light	%	8.4	5.0	3.3	2.1	1.3	6.7	2.2	4.0
Residential	%	5.4	3.5	3.1	2.6	2.6	4.5	2.7	3.4
T/D Loss	%	-3.3	5.3	4.3	3.8	3.7	0.9	3.9	2.7

(Source: JICA Study Team)



(Source: JICA Study Team)

Figure 5- 15 Growth Rates of Sectoral Power Demands

When looking at the growth rates of power demands from 2010 to 2015, the industry sector displays high and rapid growth. It is 18.1 % per year. As well as the industry sector, the commercial sector and street light utilization also shows comparatively higher growth rates than other sectors. The growth rates are 9.3 % per year for the commercial sector and 8.4 % per year for street light utilization.

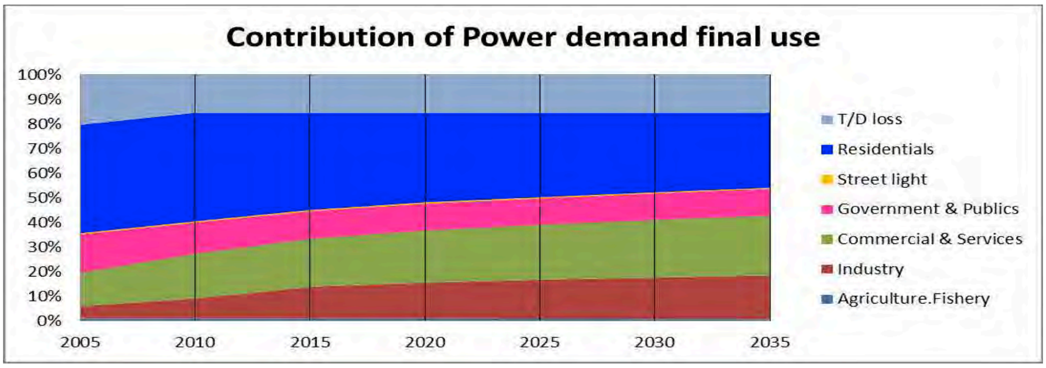
During 2015 - 2020, the growth rate of the industry sector is 8.0 % per year, the commercial sector is 7.0 % per year, and the street light utilization is 5.0 % per year. These sectors and utilization are at higher growth rates than other sectors.

During 2020 - 2035, the industry sector is 5.3 % per year, the commercial sector is 4.5 % per year and the average growth rate of the whole country is 3.9 % per year. The growth of Omani power demand will stabilize in the future.

Furthermore, the sectors with lower growth rates than the average growth rate after 2020 are agriculture & fishery sector (2.3 % per year) and residential sector (2.7 % per year).

(c) Contribution of Sectoral Power Demands

The contribution of sectoral power demand is shown in the following figure. Power consumption contributions in the residential sector change from 40 % in 2012 to 32 % in 2035. Adversely, the contribution of the industry sector increases from 12 % in 2012 to 19 % in 2035, and the commercial sector also increases from 18 % in 2012 to 26 % in 2035. As a result, the summation of industry and commercial contributions is 30 % in 2012, and it increases to 45 % in 2035. It means that the contribution exceeds the residential sector in 2035.



(Source: JICA Study Team)

Figure 5- 16 Contribution of Sectoral Power Demands

As mentioned above, it is important that EE&C measures and governmental policies tackle higher demand growth in industry and the commercial & service sectors and street lights should be preferentially introduced in Oman.

(2) Regional Power Demand Forecasts

(a) Power Demand per Region

The following table shows the power demand forecasts per region (MIS, Salalah and Rural). The contributions of MIS regional power demands were 89 % in 2012. However, they will slightly decrease to 87 % in 2035. On the other hand, the contribution of Salalah increases from 9 % in 2012 to 10 % in 2035. Furthermore, the rural area will increase its contribution from 2.5 % in 2012 to 2.7 % in 2035.

Table 5- 18 Regional Power Demand Forecasts

(Unit: GWh)

		2010	2012	2015	2020	2025	2030	2035
Total	MIS	16,870	19,730	22,990	29,620	36,280	43,420	51,860
	Salalah	1,892	1,977	2,386	3,152	4,037	5,041	6,308
	Rural	462	556	651	829	1,052	1,304	1,607
	Total	19,223	22,262	26,027	33,600	41,369	49,765	59,775
Agriculture & Fishery	MIS	190	240	270	340	390	430	480
	Salalah	10	9	10	12	14	16	18
	Rural	13	13	14	17	20	23	26
	Total	213	261	294	368	424	468	523
Industry	MIS	1,210	2,420	3,080	4,600	6,170	7,870	9,970
	Salalah	328	379	447	589	765	970	1,266
	Rural	6	10	12	17	22	28	37
	Total	1,544	2,809	3,539	5,206	6,957	8,869	11,273
Commercial & Services	MIS	3,110	3,670	4,740	6,570	8,410	10,530	13,010
	Salalah	293	368	510	770	1,061	1,405	1,819
	Rural	74	110	156	238	334	450	587
	Total	3,476	4,148	5,406	7,579	9,805	12,384	15,415
Government & Publics	MIS	2,040	2,340	2,680	3,370	4,040	4,840	5,800
	Salalah	359	367	428	548	684	845	1,045
	Rural	118	126	141	170	208	253	308
	Total	2,517	2,833	3,249	4,088	4,932	5,937	7,153
Residential	MIS	7,590	8,230	9,920	11,780	13,640	15,410	17,420
	Salalah	601	619	752	917	1,109	1,301	1,529
	Rural	210	228	263	304	362	420	489
	Total	8,400	9,077	10,934	13,001	15,112	17,131	19,438
T/D Loss	MIS	2,730	2,830	2,300	2,960	3,630	4,340	5,180
	Salalah	301	235	239	316	405	505	632
	Rural	42	70	65	83	105	130	161
	Total	3,072	3,135	2,604	3,359	4,140	4,975	5,973

(Source: JICA Study Team)

(b) Regional Power Demand Growth Rates

The results of the regional power demand growth rate forecasting are shown in the following table. The growth rate of MIS is the highest in the whole country. The MIS growth rate is the same as the growth rate of the country nationwide. In the years from 2010 to 2020, the growth rate of MIS is 5.8 % per year, Salalah is 5.2 % per year and in the rural areas is 6.0 % per year. And in the years from 2020 to 2035, the growth rate of Salalah is 4.7 % per year and the growth rate of the rural areas is 4.5 % per year respectively. The growth rates of Salalah and the rural area are higher than the MIS growth rate at 3.8 % per year. It means that the growth rates of the Salalah and the rural areas are higher than MIS after 2020.

Regarding the industry sector, the above trends are clearer in the years from 2010 to 2020, the growth rates during the term are MIS at 14.3 % per year, Salalah at 6.0 % per year and the rural areas at 10.6 % per year.

In the years from 2020 to 2035, the growth rates are MIS at 5.3 % per year, Salalah at 5.2 %

per year and the rural areas at 5.5 % per year. From 2020 onward, it can be said that the growth rate gaps among the three regions become narrower than the ones in the years before 2020.

Table 5- 19 Growth Rates of Regional Power Demand

(Unit: %)

		15/10	20/15	25/20	30/25	35/30	20/10	35/20
Total	MIS	6.4	5.2	4.1	3.7	3.6	5.8	3.8
	Salalah	4.8	5.7	5.1	4.5	4.6	5.2	4.7
	Rural	7.1	5.0	4.9	4.4	4.3	6.0	4.5
	Total	6.2	5.2	4.2	3.8	3.7	5.7	3.9
Agriculture & Fishery	MIS	7.3	4.7	2.8	2.0	2.2	6.0	2.3
	Salalah	0.0	3.4	3.4	2.5	2.6	1.7	2.8
	Rural	1.8	3.4	3.6	2.7	2.6	2.6	3.0
	Total	6.7	4.6	2.8	2.0	2.3	5.6	2.4
Industry	MIS	20.5	8.4	6.0	5.0	4.8	14.3	5.3
	Salalah	6.4	5.7	5.4	4.9	5.5	6.0	5.2
	Rural	15.1	6.2	5.9	5.2	5.4	10.6	5.5
	Total	18.0	8.0	6.0	5.0	4.9	12.9	5.3
Commercial & Services	MIS	8.8	6.7	5.1	4.6	4.3	7.8	4.7
	Salalah	11.8	8.6	6.6	5.8	5.3	10.2	5.9
	Rural	16.1	8.9	7.0	6.1	5.5	12.4	6.2
	Total	9.2	7.0	5.3	4.8	4.5	8.1	4.8
Government & Publics	MIS	5.6	4.7	3.7	3.7	3.7	5.1	3.7
	Salalah	3.6	5.0	4.5	4.3	4.4	4.3	4.4
	Rural	3.7	3.8	4.1	3.9	4.0	3.8	4.0
	Total	5.2	4.7	3.8	3.8	3.8	5.0	3.8
Residential	MIS	5.5	3.5	3.0	2.5	2.5	4.5	2.6
	Salalah	4.6	4.1	3.9	3.2	3.3	4.3	3.5
	Rural	4.6	3.0	3.6	3.0	3.1	3.8	3.2
	Total	5.4	3.5	3.1	2.5	2.6	4.5	2.7
T/D Loss	MIS	-3.4	5.2	4.2	3.6	3.6	0.8	3.8
	Salalah	-4.5	5.7	5.1	4.5	4.6	0.5	4.7
	Rural	9.4	5.0	4.9	4.4	4.3	7.1	4.5
	Total	-3.3	5.2	4.3	3.7	3.7	0.9	3.9

(Source: JICA Study Team)

(3) Power Generation Forecasts

The power generation forecast of the whole country of Oman is shown in the following table. It is calculated from sectoral power demand, T/D losses, and power exports/imports. The power generators up to 2018 are based on the OPWP plan (7 Year Statement, Issue 6). From the year 2019 onward, it is assumed that gas-combined-cycles are installed when additional power generation capacities are required. Other assumptions are; the power is not traded as exports and imports between Oman and other countries, and power from renewable energies such as PV and wind power generators are assumed to be 1.2 % of the total power generation in 2020 and 1.8 % of the total power generation in 2035. (The percentages are decided by referring to the documents submitted by PAEW.) As a result, the required power generation is 25 TWh in 2012 and it increases to 67 TWh in 2035. The generation scale factor in 2035 is 2.7 times to the ones in 2012 (It is the same scale factor of the power demand).

Table 5- 20 Power Generation Forecasts

(Unit: GWh)

	2010	2012	2015	2020	2025	2030	2035
Power demand + Loss + Own Use	21,700	25,000	29,300	37,800	46,500	55,900	67,200
Import Power	0	0	0	0	0	0	0
Export Power	0	0	0	0	0	0	0
Total of Power Generation	21,700	25,000	29,300	37,800	46,500	55,900	67,200
Power from Diesel	2,500	2,240	850	1,080	1,290	1,370	1,500
Power from Gas Turbine	9,040	9,640	8,360	8,560	9,210	8,880	9,710
Power from Gas Combined Cycle	10,550	13,090	19,830	27,630	35,230	44,650	54,640
Power from Renewables	0	50	210	480	750	1,030	1,310

(Source: JICA Study Team)

(4) Peak Demand Forecasts

The results of the peak demand forecast are shown in the following table. When calculating peak demand from power demand, the load factors for each year are required. In the model, a 58% load factor is used for all the targeted years. In the whole country of Oman, it is forecasted that the peak demand (gross peak demand) in 2012 is estimated to be 5.0 GW and will increase to 13.2 GW in 2035. Regarding the net peak demand based on which OPWP creates purchasing contracts with power generation companies, it increases from 4.4 GW in 2012 to 11.8 GW in 2035. Therefore, the required power generation capacities increase from 5.4 GW in 2012 to 14.5 GW in 2035 under the condition of the reserve margin at 10% to the total capacity.

Table 5- 21 Peak Demand Forecasts

	Unit	2010	2012	2015	2020	2025	2030	2035
Load Factor	%	57.9	58.0	58.0	58.0	58.0	58.0	58.0
Gross Peak Demand	MW	4,280	4,924	5,758	7,432	9,148	11,008	13,217
Installed Capacity	MW	4,708	5,417	6,333	8,175	10,063	12,109	14,538
Net Peak Demand	MW	3,787	4,383	5,124	6,614	8,142	9,797	11,763
OPWP Contracted Capacity	MW	4,166	4,821	5,637	7,276	8,956	10,777	12,939

(Source: JICA Study team)

(5) Energy Consumption in the Power Sector

The results of the energy consumption forecast in the power sector are shown in the following table. From 2019 onward, many Combined Cycle Gas Turbines (CCGT) are installed as additional power generators, although some renewable energies are installed. Therefore, natural gas consumption increases in the power sector. The contribution of natural gas to all types of fuel consumption in the power sector was 87 % in 2012 and will increase to 96 % in 2035.

There are assumptions that natural gas will mainly be used as future fuel for the power sector, and coal power generation have not been considered.

Table 5- 22 Energy Consumption in the Power Sector

	Unit	2010	2012	2015	2020	2025	2030	2035
Diesel	ktoe	1,077	964	366	466	556	589	644
Natural Gas to Gas turbine	ktoe	3,241	3,454	2,995	3,069	3,299	3,182	3,479
Natural Gas to GCC	ktoe	2,160	2,680	4,061	5,657	7,213	9,142	11,188
Coal	ktoe	0	0	0	0	0	0	0
Total	ktoe	6,478	7,097	7,422	9,192	11,068	12,914	15,311
Diesel	trillion Btu	43	39	15	19	22	24	26
Natural Gas to Gas turbine	trillion Btu	130	138	120	123	132	127	139
Natural Gas to GCC	trillion Btu	86	107	162	226	289	366	448
Coal	trillion Btu	0	0	0	0	0	0	0
Total	trillion Btu	259	284	297	368	443	517	612
Diesel	%	17	14	5	5	5	5	4
Natural Gas to Gas turbine	%	50	49	40	33	30	25	23
Natural Gas to GCC	%	33	38	55	62	65	71	73
Coal	%	0	0	0	0	0	0	0
Total	%	100	100	100	100	100	100	100

（Note1） In the table, ”trillion Btu” is converted from “toe” in the above table.
（Note2） It is not guaranteed that only GCC type power generators will be installed for all additional capacities from 2019 onward, because Oman has to install more desalination plants in future. Therefore, Oman has to study a power development plan for the future after the year of 2019.

(Source: JICA Study Team)

5.2.4 Comparison of Power Demand Forecasts between OPWP and JICA Study Team

In this section, the tentative power demand forecasts by OPWP and power demand forecasts of the model created by the JICA Study Team are compared. (The compared power demand herein is the net power demand). The growth rate of the power demand forecasted by the OPWP is 7.7 % per year from 2011 to 2020 and the one by the JICA Study Team is 5.0 % per year during the same term. The original OPWP forecasts targets only MIS and Salalah areas, not the whole country. The OPWP power demand forecasts in the following table are converted to the whole country by using the conversion factor (multiplied by 1.03) of the current power demand between “MIS + Salalah” and the whole country.

Table 5- 23 Comparison of Power Demand Forecasts between OPWP and the JICA Study Team

	Power Demand (TWh)				Peak Demand (MW)			
	OPWP	Growth rate	JICA Study Team	Growth rate	OPWP	Growth rate	JICA Study Team	Growth rate
2011	21.6		21.6		4,319		4,319	
2012	23.6	9.6	22.3	3.2	4,748	9.9	4,844	12.2
2013	25.9	9.5	23.7	6.6	5,178	9.1	5,195	7.2
2014	27.9	7.7	24.9	5.0	5,652	9.2	5,484	5.6
2015	30.2	8.1	26.0	4.5	6,082	7.6	5,758	5.0
2016	32.5	7.7	27.4	5.3	6,534	7.4	6,066	5.4
2017	34.8	7.1	28.9	5.3	6,991	7.0	6,388	5.3
2018	37.2	7.0	30.4	5.3	7,488	7.1	6,726	5.3
2019	39.7	6.6	32.0	5.3	7,988	6.7	7,080	5.3
2020	42.1	6.2	33.6	5.0	8,486	6.2	7,432	5.0
2021	44.6	5.7	35.1	4.3	8,977	5.8	7,752	4.3
2022	46.9	5.3	36.5	4.3	9,456	5.3	8,081	4.3
2023	49.2	4.9	38.1	4.2	9,919	4.9	8,424	4.2
2024	51.4	4.4	39.7	4.2	10,360	4.4	8,779	4.2
2025	53.4	4.0	41.4	4.3	10,774	4.0	9,148	4.2
2026	55.6	4.0	42.9	3.7	11,205	4.0	9,496	3.8
2027	57.8	4.0	44.6	3.8	11,653	4.0	9,855	3.8
2028	60.1	4.0	46.2	3.8	12,119	4.0	10,226	3.8
2029	62.5	4.0	48.0	3.8	12,604	4.0	10,611	3.8
2030	65.0	4.0	49.8	3.8	13,108	4.0	11,008	3.7
2031	67.6	4.0	51.6	3.7	13,633	4.0	11,420	3.7
2032	70.3	4.0	53.6	3.8	14,178	4.0	11,846	3.7
2033	73.1	4.0	55.6	3.7	14,745	4.0	12,287	3.7
2034	76.1	4.0	57.6	3.7	15,335	4.0	12,744	3.7
2035	79.1	4.0	59.8	3.7	15,948	4.0	13,217	3.7
20/11	7.7		5.0		7.8		6.2	
35/20	4.3		3.9		4.3		3.9	
35/10	5.6		4.3		5.6		4.8	

（Note1）OPWP’s forecast is tentatively submitted to the JICA Study Team in June 2012.
（Note2）The power demand of JICA Study Team is calculated with “Final power demand + T/D loss”.

(Source: OPWP and JICA Study Team)

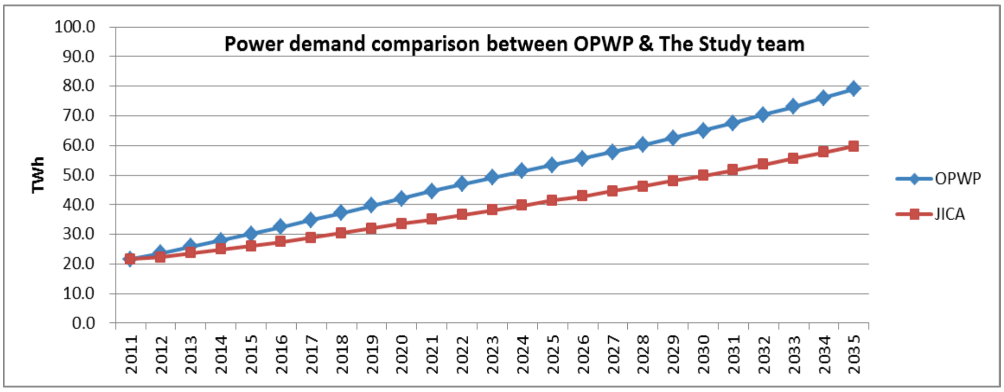


Figure 5- 17 Comparison of Power Demand Forecasts between OPWP and the JICA Study Team

Based on the above comparison, the following considerations of OPWP's power demand forecasts are observed.

- ✓ OPWP's power demands from 2011 to 2018 are the same as the "7 Year Statement, Issue 6" published in March 2012. So it is considered that EU monetary crises in 2012 are outside of the conditions necessary to conduct power demand forecasts. The differences between OPWP and the JICA Study Team are mainly due to the differences in future Omani economic circumstances from 2011 to 2020. (GDP growth rate of OPWP is estimated to be around 7 % per year, while the Study team is 5 % per year.)
- ✓ As well as power demand forecasts from 2011 to 2020, the growth rates of the peak demand are 7.8 % per year in the OPWP forecast and that of the JICA Study Team is 4.8 % per year.
- ✓ However, the growth rates of the power demand of OPWP and the JICA Study Team are together around 4 % per year in the further future from 2025 to 2035. There is no big difference between both during the term. The growth rate of the power demand is rather lower than the years from 2015 to 2025. It is caused by a decrease of future oil and gas production in Oman. The downward oil and gas production makes the Omani GDP growth rate smaller than the current level.

5.2.5 Final Energy Demand Forecasts

(1) Sectoral Final Energy Demands

The sectoral final energy demands are shown in the following table. The final energy demand is the summation of all kinds of energy consumption in the consumers. The final energy demand includes power, fossil fuels and woods/charcoal. (Woods/charcoal consumption is negligible in Oman)

The results of JICA Study Team's forecasts indicate that the final energy demand in Oman is 7.3 million toe in 2010, and increases to 21.1 million toe in 2035. The growth rates are 5.7 % per year from 2010 to 2020 and 3.4 % per year from 2020 to 2035. The growth rate during the whole term (2010 to 2035) is 4.3 % per year.

The final energy demand of the transportation sector occupies around half of the total final energy demand in recent years. It forecasted that the demand is 4.5 million toe in 2010 and 12.0 million toe in 2035. Furthermore, the growth rate is 4.0 % per year. For the forecast of the transportation sector, fuel efficiency improvements of vehicles are included. However, the fuel conversions from existing gasoline and diesel to methanol, hydrogen and electricity are not included, and also the transportation system changes from private vehicles to public transportation systems are not considered in the forecasting.

The second largest contribution to final energy demand is the residential sector. The residential sector consumes 19% of final energy demand in 2010 and most of them is power demand. Power consumption of the residential sector is 52 % of the total power consumption in 2010. Furthermore, it is forecasted to be 36 % of the total power consumption in 2035. The residential sector also consumes LPG other than power. The growth rate of the final energy demand in the residential sector is 3.2 % per year from 2010 to 2035 as well as power demand (the growth rate of the power demand is 3.4 % per year).

The sectors with the higher growth rates of the final energy demand are the industry, commercial and government sectors, and the growth rates are 6.5 %, 6.1 % and 6.2 % per year respectively.

Table 5- 24 Sectoral Final Energy Demand Forecasts

Final Energy Demand	Unit	2010	2012	2015	2020	2025	2030	2035
Total	1,000 toe	7,330	8,600	10,380	12,800	15,160	17,900	21,150
Agriculture & Fishery	1,000 toe	310	330	360	420	480	530	590
Industry	1,000 toe	510	690	840	1,150	1,500	1,930	2,480
Commercial & Service	1,000 toe	300	360	460	650	840	1,070	1,330
Public Sector + Others	1,000 toe	370	450	560	760	980	1,280	1,660
Transportation	1,000 toe	4,450	5,260	6,380	7,750	8,960	10,370	12,000
Residential	1,000 toe	1,390	1,510	1,780	2,070	2,400	2,720	3,090

(Source: JICA Study Team)

Table 5- 25 Sectoral Growth Rates of Final Energy Demands

Growth Rate	Unit	15/10	20/15	25/20	30/25	35/30	20/10	35/20	35/10
Total	%	7.2	4.3	3.4	3.4	3.4	5.7	3.4	4.3
Agriculture & Fishery	%	3.0	3.1	2.7	2.0	2.2	3.1	2.3	2.6
Industry	%	10.5	6.5	5.5	5.2	5.1	8.5	5.3	6.5
Commercial & Service	%	8.9	7.2	5.3	5.0	4.4	8.0	4.9	6.1
Public Sector + Others	%	8.6	6.3	5.2	5.5	5.3	7.5	5.3	6.2
Transportation	%	7.5	4.0	2.9	3.0	3.0	5.7	3.0	4.0
Residential	%	5.1	3.1	3.0	2.5	2.6	4.1	2.7	3.2

(Source: JICA Study Team)

(2) Final Energy Demand by Energy

The final energy demands by energy are shown in the following table. The growth rate of the total final energy demand is 4.3 % per year from 2010 to 2035. Regarding the demand per energy type, the growth rates of power and natural gas are comparatively high. Their growth rates are respectively 4.9 % and 6.4 % per year.

Especially, the final energy demands from 2010 to 2015 are increasing rapidly. The gasoline demand for vehicles (8.1 % per year), the natural gas demand for the industry sector (8.6 % per year) and the power demand (7.8 % per year) from 2010 to 2015 push up the total final energy demand.

The scale factor of the final energy demand is 2.9 times from 2010 to 2035 and it is 2.5 times from 2012 to 2035.

Table 5- 26 Final Energy Demand Forecasts by Energy

Final Energy Demand	Unit	2010	2012	2015	2020	2025	2030	2035
Total	1,000 toe	7,370	8,620	10,400	12,820	15,180	17,940	21,160
Gasoline	1,000 toe	2,060	2,510	3,040	3,690	4,270	4,940	5,720
Diesel	1,000 toe	2,120	2,410	2,890	3,490	4,020	4,640	5,340
Kerosene	1,000 toe	0	0	0	0	0	0	0
Jet Fuel	1,000 toe	450	500	610	740	850	990	1,140
Fuel Oil + Marine Fuel	1,000 toe	130	150	180	220	260	300	340
LPG	1,000 toe	690	750	860	980	1,140	1,300	1,480
Natural Gas	1,000 toe	530	650	800	1,100	1,440	1,920	2,510
Power	1,000 toe	1,390	1,650	2,020	2,600	3,200	3,850	4,630
Biomass	1,000 toe	0	0	0	0	0	0	0

(Source: JICA Study Team)

Table 5- 27 Growth Rates of Final Energy Demands by Energy

Growth Rate	Unit	15/10	20/15	25/20	30/25	35/30	20/10	35/20	35/10
Total	%	7.1	4.3	3.4	3.4	3.4	5.7	3.4	4.3
Gasoline	%	8.1	4.0	3.0	3.0	3.0	6.0	3.0	4.2
Diesel	%	6.4	3.8	2.9	2.9	2.9	5.1	2.9	3.8
Kerosene	%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jet Fuel	%	6.3	3.9	2.8	3.1	2.9	5.1	2.9	3.8
Fuel Oil + Marine Fuel	%	6.7	4.1	3.4	2.9	2.5	5.4	2.9	3.9
LPG	%	4.5	2.6	3.1	2.7	2.6	3.6	2.8	3.1
Natural Gas	%	8.6	6.6	5.5	5.9	5.5	7.6	5.7	6.4
Power	%	7.8	5.2	4.2	3.8	3.8	6.5	3.9	4.9
Biomass	%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

(Source: JICA Study Team)

5.2.6 Primary Energy Demand Forecasts

The primary energy forecasts are shown in the following table. The scale factor of crude oil and natural gas consumption is 2.4 times and 2.6 times respectively from 2010 to 2035. Crude oil domestic consumption becomes 19.0 million toe in 2035 from 7.9 million toe in 2010, and natural gas increases from 7.1 million toe (284 trillion Btu) in 2010 to 18.3 million toe (732 trillion Btu) in 2035.

The growth rates of crude oil and natural gas demand are 4.3 % per year and 4.5 % per year respectively from 2010 to 2020, and it is 3.1 % per year and 3.5 % per year respectively in the further future from 2020 to 2035. Furthermore, as the GDP growth rate in Oman is 4.0 % per year from 2020 to 2035, the crude oil and natural gas elasticity to the GDP are 0.77 and 0.87, respectively. It can be said that the elasticity becomes stable in Oman as a middle developed country.

Table 5- 28 Primary Energy Demand Forecasts

Primary Energy Consumption	Unit	2010	2012	2015	2020	2025	2030	2035
Total	1,000 toe	15,058	16,890	18,636	23,119	26,759	31,680	37,510
Crude oil	1,000 toe	7,928	8,898	9,557	12,054	13,541	16,151	19,019
Natural gas	1,000 toe	7,130	7,987	9,060	11,024	13,153	15,440	18,379
Renewables	1,000 toe	0	4	18	41	65	89	112
Biomass	1,000 toe	0	0	0	0	0	0	0
Total	1,000 toe	15,058	16,890	18,636	23,119	26,759	31,680	37,510

(Source: JICA Study Team)

Table 5- 29 Average Growth Rates of Primary Energy Demand

Growth Rate	Unit	15/10	20/15	25/20	30/25	35/30	20/10	35/20	35/10
Total	%	4.4	4.4	3.0	3.4	3.4	4.4	3.3	3.7
Crude oil	%	3.8	4.8	2.4	3.6	3.3	4.3	3.1	3.6
Natural gas	%	4.9	4.0	3.6	3.3	3.5	4.5	3.5	3.9
Renewables	%		17.9	9.3	6.5	4.8	0.0	6.9	
Biomass	%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	%	4.4	4.4	3.0	3.4	3.4	4.4	3.3	3.7

(Source: JICA Study Team)

Table 5- 30 Contributions of Primary Energy Demand

Contribution	Unit	2010	2012	2015	2020	2025	2030	2035
Total	%	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Crude oil	%	52.6	52.7	51.3	52.1	50.6	51.0	50.7
Natural gas	%	47.4	47.3	48.6	47.7	49.2	48.7	49.0
Renewables	%	0.0	0.0	0.1	0.2	0.2	0.3	0.3
Biomass	%	0.0	0.0	0.0	0.0	0.0	0.0	0.0

(Source: JICA Study Team)

5.2.7 Considerations on Power and Energy Demand Forecasts

(1) Considerations of Power Demand Forecasts

- ✓ The residential sector has contributed significantly to the power demand in Oman. It is over a half share of the current total power demand. However, the future growth rates of the power demands are higher in the industry and commercial sectors and street light utilization than other sectors. As EE&C is more effective when facilities and equipment are introduced into factories and buildings, it can be considered that it is more effective when EE&C regulations are prepared for the investment of the new and updated factories and buildings in the industrial and commercial sectors and street lighting.

- ✓ Regarding the power supply sides, the reduction of T/D losses is effective to achieve power supply efficiency. Therefore, the reduction of the T/D losses by introducing EE&C measures is useful to achieve power supply efficiency.
- ✓ In Oman, the diversification of the power supply has been implemented in consideration of the global environment by introducing renewable energies which postpones the additional introduction of coal power plants. The Ministry of Environment and Climate Affairs makes an effort to establish CO2 emission regulations and formulate CDM projects for measures to tackle climate changes. The power business entities in Oman are also required to watch the directions of the ministry.

(2) Consideration of Energy Demand Forecasts (Natural Gas)

- ✓ The energy demand in Oman increased from 2008 to 2011 due to the construction rush since 2006. It was caused by the development of the industry sector and local development plans. It indicates that the Omani social structure is now changing to one with increasing fossil energy utilization in the social activities. In order to support changes, a comprehensive plan including natural gas utilization has to be prepared.
- ✓ Recently, LPG consumption in the residential sector has increased rapidly. According to the model of the JICA Study Team, future LPG demand exceeds the supply in Oman. Therefore, it is required that natural gas be supplied for complex houses and other big users in urban areas as a substitute for LPG energy.
- ✓ It is predicted that natural gas production will decrease as well as crude oil in the future. However, it has been said that there exist new natural gas reserves in Oman. As it is expected, new natural gas sources are available when new gas producing technologies are innovated, it is required that the related authorities of Oman keep an eye on new global technologies as they develop and emerge. .

5.3 Analysis of Electricity Consumption (Macro-level)

5.3.1 Objectives and Methodology of the Analysis

In order to estimate the potential of energy efficiency and conservation in all of Oman, this Study analyzes how electric power is consumed in which season and time zone by using the actual load data. It also needs to be noted that the load pattern differs significantly among sectors because of the differences in the main factors of power consumption.

The Study first analyzes the characteristics of the total system load based on the hourly load data of the power grids, and identifies the annual peak load that needs to be controlled, a task which has been given the highest priority. The importance to control the peak load depends on how sharply it rises. For this analysis, the hourly load data (24 hours x 365 days = 8,760 hours) of the MIS grid in the north and Salalah grid in the south are obtained from the system operators of theses grids, i.e. OETC and DPC respectively.

Then, the Study estimates the breakdown of the total system load by sector and also the breakdown between air-con demand and non air-con demand, in order to determine how electric power is sector is consumed by each sector in each season and time zone. Given that there is no preceding study to analyze the load profile of each sector systematically, the Study Team carry outs an estimation on its own using available data. To serve for this, the Study Team requested the major distribution companies, i.e. MEDC, MZEC, and MJEC in MIS area as well DPC in Salalah area, to select sample feeder lines as follows and to provide the hourly data of the load that is sent out from the substations to these feeders. These data are recorded in the Supervisory Control and Data Acquisition (SCADA) system that is installed at the substations.

- 11 kV feeders mainly supplying to residential customers
- 11 kV feeders mainly supplying to commercial customers
- 11 kV feeders mainly supplying to industrial customers
- 11 kV feeders mainly supplying to government customers

The load profile of each sector is formulated by using these data and then the sector's total load on the grid in each season and time zone is estimated by adjusting the load profile data to the statistics of annual power consumption and the hourly load data of the total system.

In Oman, the statistics of power consumption is classified into seven sectors in accordance with the electricity tariff categories. Among them, the three categories whose share in the total power consumption is very small, namely the Ministry of Defense, agriculture & fisheries, and tourism, are not analyzed as individual sectors but are included in the commercial or government sectors whose load patterns are considered similar. Furthermore, given that the commercial and government sectors are found to have a similar load pattern, these two are also grouped into one category, thus a sector analysis was conducted for the following three categories: “Residential”, “Industrial”, and “Commercial, Government etc.”

The annual load data shows that the load level during the winter is the lowest in a year (to be discussed in 5.3.2), thus air-con demand is considered the main factor that affects the the different load level among the seasons. Therefore, regarding the breakdown of the system load between the air-con demand and non air-con demand, this Study assumes that the load pattern during the winter is identical to the non air-con demand whereas the difference between this and that load pattern in the other seasons is the air-con demand.

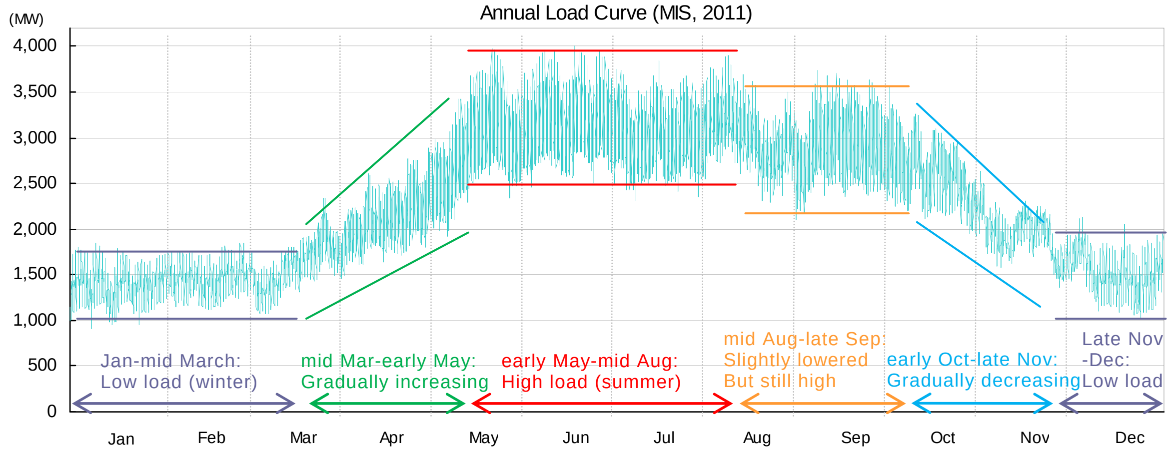
In this section, the scope of the load analysis is confined to the load data of the MIS and the Salalah grids, and RAECO is left out in the analysis. RAECO's share in the country's total power demand is as small as less than 3% and its power system is a group of small isolated grids, hence the effect of peak load reduction is considered to have little economic impact.

5.3.2 Results of Analyses

(1) Characteristics of the MIS System Load

(a) Annual Load Curve and Seasonal Characteristics

The following figure illustrates the annual load curve of the MIS grid in 2011.



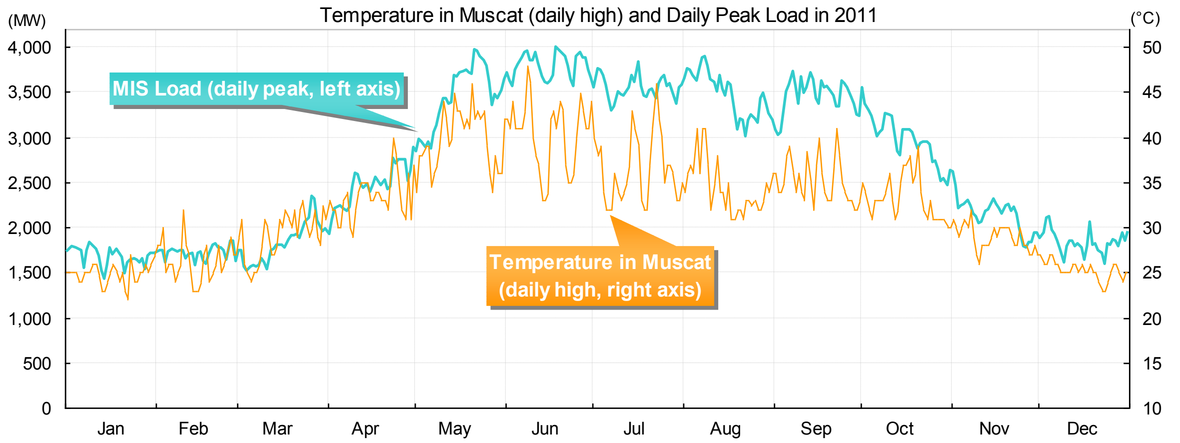
(Source: OETC Data, touched up by the JICA Study Team)

Figure 5- 18 Annual Load Curve of the MIS Grid in 2011 (Hourly Load Record)

The following seasonal characteristics can be observed from the yearly load fluctuation.

- From January to mid-March: staying at a low level
- From mid-March to early-May: gradually increasing
- From early May to mid-August: very high (the highest load in a year is observed between mid-May and late-June)
- From mid-August to late September: slightly lowered from the previous season but still maintaining a high level
- From early October to late November: gradually decreasing
- From early December to late December: as low as the beginning of the year

The system load sees the highest level in a year between mid-May and late June, when the highest temperature in northern Oman (e.g. Muscat) is also recorded. In the meanwhile, the system load stays at a low level between December and mid-March, when the temperature becomes the lowest in a year. Taking this into account, the air-con demand is considered the main factor that affects the different load level among the seasons. The following figure compares the daily peak of the MIS system load with the daily highest temperature in Muscat.



(Source: OETC (load data), Weather Underground http://www.wunderground.com (temperature))

Figure 5- 19 Daily Peak of the MIS System Load and the Highest Temperature in Muscat (2011)

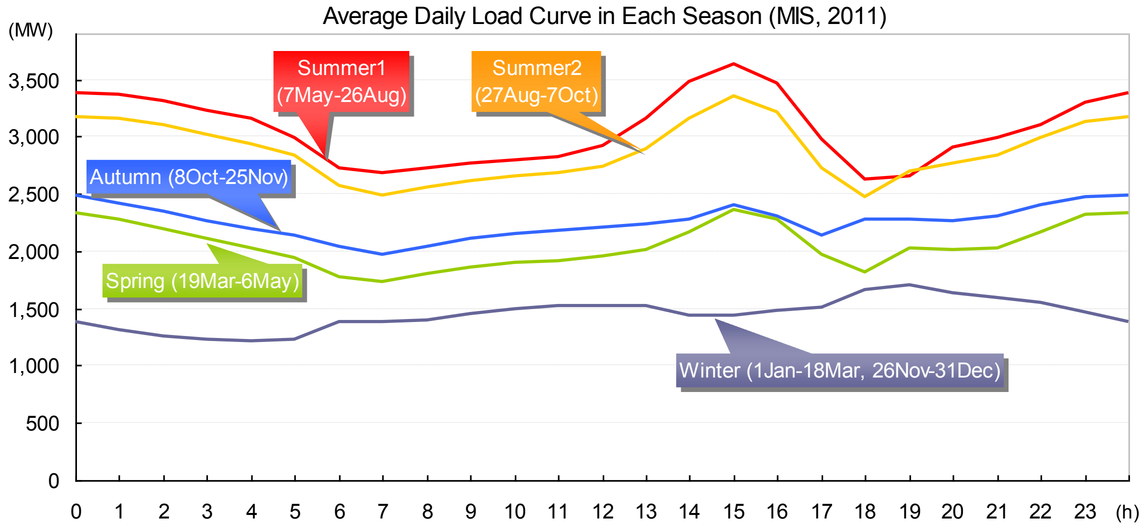
From January to mid-May, when the temperature gradually increases, the daily load is almost following this trend. Although the temperature starts decreasing from July, the load is maintained at a relatively high level, but from October it suddenly starts dropping sharply to catch up with the decreasing temperature. The same trend has been observed in the preceding two years (2009-2010). Assuming that there's no other major factor affecting the level of the system load, this trend may imply that once the consumers start using the air-con, the air-con demand may not decrease significantly until the temperature is lowered to a certain level.

Taking into account the difference of the load level among the seasons, this Study analyzes the annual system load by segmenting this into the following five seasonal zones. The seasonal segmentation is created at a period when the load level and the load pattern significantly changes, and a week from Saturday to Friday is the minimum unit of segmentation.

- Winter
  - From 1st January (Sat) to 18th March (Fri): 11 weeks (77 days, 1,848 hours)
  - From 26th November (Sat) to 31st December (Sat): 5 weeks (36 days, 864 hours)
- Spring
  - From 19th March (Sat) to 6th May (Fri): 7 weeks (49 days, 1,176 hours)
- Summer1 (early summer)
  - From 7th May (Sat) to 19th August (Fri): 15 weeks (105 days, 2,520 hours)
- Summer2 (late summer)
  - From 20th August (Sat) to 7th October (Fri): 7 weeks (49 days, 1,176 hours)
- Autumn
  - From 8th October (Sat) to 25th November (Fri): 7 weeks (49 days, 1,176 hours)

The wholesale electricity tariff (Bulk Supply Tariff: BST) in the MIS area, which is provided by OPWP, also classifies the twelve months into five seasonal zones to set different unit rates among the seasons, though the periods to segment the seasons are slightly different (see 4.3.2: January-March and November-December correspond to “Winter” in the Study Team’s analysis, April to “Spring”, May-July to “Summer1”, August-September to “Summer2”, and October to “Autumn” respectively). The concept of the five-season segmentation is widely accepted in the power sector in Oman.

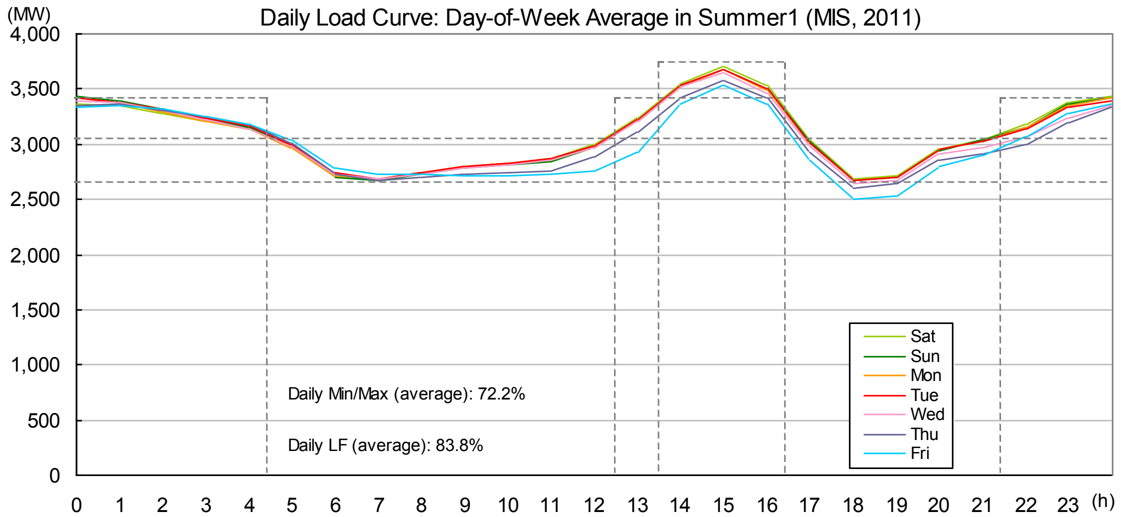
The following figure shows the average daily load curve in each of the five seasonal zones. Despite the difference in the load level, the shape of the load curve is similar among the seasons except for Winter, indicating two peaks in a day, i.e. daytime peak (14-16 h) and nighttime peak (0-1 h). In the summer (Summer1 and Summer1), the daytime peak becomes larger than the nighttime peak while in the spring and autumn these two are almost same or the nighttime peak is slightly higher. The daily load curve in the winter has a different shape from that of other seasons, with only one peak in the evening (18-19 h) and the load fluctuation in a day is smaller than in the other seasons.



(Source: OETC Data, touched up by the JICA Study Team)

Figure 5- 20 Average Daily Load Curve in Each Season (MIS Grid, 2011)

The following figure shows the average daily load curve of each day of the week during the early summer (Summer1). In countries like Japan, the difference in the economic activities between the weekdays and the weekend results in a significantly different level and shape of the daily load curve. However, in the MIS grid in Oman, though some minor differences in the daily load are observed between the weekdays and the weekend, such as the load level during the weekend (especially on Fridays) being slightly lower than weekdays and the increase of load in the morning is tardier. Also in other seasons, the difference between the weekdays and weekends is small.



(Source: OETC Data, touched up by the JICA Study Team)

Figure 5- 21 Average Daily Load Curve of Each Day of Week in Summer1 (MIS Grid, 2011)

(b) Time Zone Segmentation of the System Load

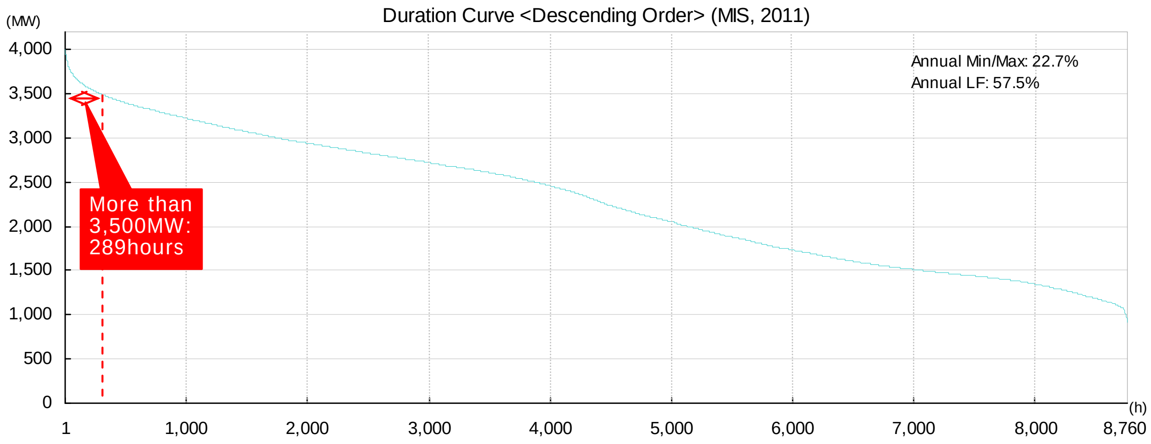
Following the analysis of the characteristics of the MIS system load in each season, the day of week, and hour of day, this Study then segments the annual load (8,760 hours) into the following 20 time zones. The allocation of the costs of the power supply in a year is tested based on this time-zone segmentation. This Study's time-zone segmentation is more complicated than that of OPWP's Bulk Supply Tariff in the MIS area (see 4.3.2), but the basic concept of the time-zone segmentation is almost the same.

Table 5- 31 Segmenting the Annual MIS Load into 20 Time Zones

		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Summer1	Weekday	Night Peak					Other								Day High	Day Peak			Other					Night Peak	
	Thursday															Th. Day Peak									
	Friday															Fr. Day Peak									
Summer2	Weekday	Night Peak					Other								Day High	Day Peak			Other					Night Peak	
	Thursday															Th. Day Peak									
	Friday															Fr. Day Peak									
Spring	All days	Night High			Other											Daytime High			Other					Night High	
Autumn	All days	Night High			Other											Daytime High			Other					Night High	
Winter	All days	Other																		High				Other	

(Source: JICA Study Team)

Then, the annual load (8,760 hours) is rearranged in descending order to create a duration curve, as shown in the following figure. At the left-top of the curve, i.e. during the time when the load level is very high, the curve's slope becomes very sharp, and there were only 289 hours when the system load recorded is higher than 3,500 MW. In other words, 500 MW power supply facilities, which is equivalent to more than 10 % of the total power supply necessary to meet the annual peak load (about 4,000 MW) is necessary to be ready only for about 3 % of the 8,760 hours in a year. The steeper the duration curve's slope at the left-top becomes, the more facilities are needed to be ready for only a short time, which leads to the inefficiency of the facilities operation and the increase of the costs of supply (fixed costs). The annual peak load in 2011 (4,000 MW) increased by about 11% from that in 2010 (3,613 MW), and there is the concern of a power supply shortage during the peak hours without the addition of power supply facilities. Hence, high priority must be given to controlling the peak load, especially preventing the steepness of the peak load during the summer daytime.



(Source: OETC Data, touched up by the JICA Study Team)

Figure 5- 22 Duration Curve of the MIS Grid in 2011

Another characteristic to be noted, which is unique to the duration curve of the MIS grid, is that its shape is not a smooth curve but is terraced with several bends due to the changing steepness (especially around 2,500 MW and 1,600 MW). The load level differs significantly among the seasons, and while the curve becomes moderate over 2,500 MW and below 1,600 MW because many hours fall within the same load range in the summer and winter respectively, the curve becomes steep during the intermediate seasons (spring and autumn) when the load level increases or decreases rapidly within a relatively short period. The following table arranges the load of 8,760 hours by 20 time zones and the load levels as the horizontal axis and vertical axes. This matrix indicates that the load exceeding 2,500 MW is observed mainly in the summer, the load between 1,600 MW and 2,500 MW mainly in the spring and autumn, and the load below 1,600 MW mainly in the winter.

Table 5- 32 Distribution of Hourly Load by 20 Time Zones and Load Levels (MIS Grid, 2011)

Hourly Load (MW)	Summer1						Summer2						Autumn			Spring			Winter		Total (hours)
	Daytime Peak			Night Peak	Day High	Other	Daytime Peak			Night Peak	Day High	Other	Day High	Night High	Other	Day High	Night High	Other	High	Other	
	Sat-Wed	Thu	Fri				Sat-Wed	Thu	Fri												
4,000-4,100	1																				**1**
3,900-4,000	11																				**11**
3,800-3,900	14	1	1																		**16**
3,700-3,800	36	2	2	1			2														**43**
3,600-3,700	36	10	5	24			4			1											**80**
3,500-3,600	42	9	11	52	1		18	1		4											**138**
3,400-3,500	34	8	8	117	14		13	1		7											**202**
3,300-3,400	25	8	12	145	15	7	19	3	3	37											**274**
3,200-3,300	11	2	3	153	16	34	14	5	3	48	2	1	1	4							**297**
3,100-3,200	2	3	6	102	14	102	12	2	6	57	4	8	1	4							**323**
3,000-3,100	3	2	2	69	18	143	9	3	6	60	14	18	6	15							**368**
2,900-3,000	3		1	39	3	206	6	1	7	63	4	55	10	16	7	3	1				**425**
2,800-2,900	1			16	3	238	2		2	34	8	93	8	17	13	5	10				**450**
2,700-2,800				6	2	232		2	2	18	4	105	14	20	22	12	12	1			**452**
2,600-2,700				6	1	213			1	13	2	116	7	19	43	6	17	3			**447**
2,500-2,600				4	1	124				1	1	106	9	9	64	13	15	8			**355**
2,400-2,500				1		49						85	3	11	65	14	35	17			**280**
2,300-2,400						18						39	10	10	55	13	29	33			**207**
2,200-2,300						8						19	9	17	78	14	23	51			**219**
2,100-2,200						6						1	9	40	92	13	22	78	2		**263**
2,000-2,100						1						1	25	36	75	16	20	101	4		**279**
1,900-2,000						1							14	15	90	17	21	119	13	9	**299**
1,800-1,900													7	5	99	12	24	113	37	28	**325**
1,700-1,800													10	5	51	8	13	128	91	69	**375**
1,600-1,700													1	2	23	1	3	74	139	143	**386**
1,500-1,600													3		7			41	108	390	**549**
1,400-1,500																		17	46	621	**684**
1,300-1,400																			11	402	**413**
1,200-1,300																			1	288	**289**
1,100-1,200																				239	**239**
1,000-1,100																				55	**55**
900-1,000																				16	**16**
	219	**45**	**51**	**735**	**88**	**1,382**	**99**	**18**	**30**	**343**	**39**	**647**	**147**	**245**	**784**	**147**	**245**	**784**	**452**	**2,260**	**8,760**

Note:
(orange) coloured cells indicate that <u>more than 60% of the time zone</u> falls in that load range
(yellow) coloured cells indicate that <u>more than 30% of the time zone</u> falls in that load range

(c) Cost Allocation among Time Zones (Comparison with BST's Unit Rates)

By using the time-zone segmentation and the duration curve, this Study tried the allocation of costs of supply among the 20 time zones. In order to make the cost allocation as accurate as possible, it also needs to be considered how the power plants with different unit costs are dispatched in each period. For simplicity, however, this Study assumes that the costs are the same regardless of the power plants and is almost balanced with the BST average.

Table 5- 33 Trial Allocation of Costs of Supply on MIS Grid among Time Zones

A. Allocation of Fixed Cost among Time Zones (1,000US$)

Fixed cost allocation (1,000US$)	Summer1						Summer2						Autumn			Spring			Winter		1,000 US$ /hour
	Daytime Peak			Night Peak	Day High	Other	Daytime Peak			Night Peak	Day High	Other	Day High	Night High	Other	Day High	Night High	Other	High	Other	
	Sat-Wed	Thu	Fri				Sat-Wed	Thu	Fri												
4,000-4,400	30,750																				**30,750**
3,600-4,000	19,957	2,647	1,629	5,091			1,222			204											**203.64**
3,200-3,600	6,081	1,158	1,216	14,246	1,332	1,187	2,027	290	174	2,809	58	29	29	116							**28.95**
2,800-3,200	2,563	527	597	8,401	983	8,542	1,158	187	316	3,639	374	2,048	304	655	234	94	129				**11.70**
2,400-2,800	1,618	332	377	5,430	650	9,959	731	133	222	2,534	288	4,337	436	850	1,581	392	665	214			**7.39**
2,000-2,400	1,313	270	306	4,406	527	8,278	593	108	180	2,056	234	3,878	671	1,307	3,081	653	1,103	1,750	36		**5.99**
1,600-2,000	1,034	212	241	3,469	415	6,523	467	85	142	1,619	184	3,054	680	1,156	3,667	694	1,156	3,427	1,350	1,175	**4.72**
1,200-1,600	797	164	186	2,675	320	5,029	360	66	109	1,248	142	2,354	535	892	2,853	535	892	2,853	1,645	7,096	**3.64**
800-1,200	769	158	179	2,580	309	4,851	348	63	105	1,204	137	2,271	516	860	2,752	516	860	2,752	1,587	7,933	**3.51**
400- 800	769	158	179	2,580	309	4,851	348	63	105	1,204	137	2,271	516	860	2,752	516	860	2,752	1,587	7,933	**3.51**
0- 400	769	158	179	2,580	309	4,851	348	63	105	1,204	137	2,271	516	860	2,752	516	860	2,752	1,587	7,933	**3.51**
Total	**66,418**	**5,784**	**5,088**	**51,458**	**5,155**	**54,072**	**7,602**	**1,058**	**1,458**	**17,721**	**1,691**	**22,513**	**4,203**	**7,555**	**19,673**	**3,915**	**6,525**	**16,500**	**7,791**	**32,071**	**338,250**
Supply(GWh)	**782**	**156**	**174**	**2,400**	**281**	**3,894**	**328**	**57**	**91**	**1,054**	**115**	**1,724**	**343**	**595**	**1,707**	**333**	**554**	**1,515**	**745**	**3,183**	**20,034**

B. Fixed Costs per MWh

Fixed cost per MWh	Summer1						Summer2						Autumn			Spring			Winter		Average
	Daytime Peak			Night Peak	Day High	Other	Daytime Peak			Night Peak	Day High	Other	Day High	Night High	Other	Day High	Night High	Other	High	Other	
	Sat-Wed	Thu	Fri				Sat-Wed	Thu	Fri												
US$/MWh	84.97	37.02	29.19	21.44	18.32	13.89	23.15	18.49	15.95	16.82	14.66	13.06	12.26	12.70	11.53	11.75	11.77	10.89	10.46	10.07	16.88
RO/MWh	**32.67**	**14.23**	**11.22**	**8.24**	**7.04**	**5.34**	**8.90**	**7.11**	**6.13**	**6.47**	**5.64**	**5.02**	**4.71**	**4.88**	**4.43**	**4.52**	**4.53**	**4.19**	**4.02**	**3.87**	**6.49**

C. Variable Costs per MWh

Energy	Summer1						Summer2						Autumn			Spring			Winter		Average
US$/MWh	15.52	15.52	15.52	15.52	15.52	15.52	15.52	15.52	15.52	15.52	15.52	15.52	15.52	15.52	15.52	15.52	15.52	15.52	15.52	15.52	15.52
RO/MWh	**5.97**	**5.97**	**5.97**	**5.97**	**5.97**	**5.97**	**5.97**	**5.97**	**5.97**	**5.97**	**5.97**	**5.97**	**5.97**	**5.97**	**5.97**	**5.97**	**5.97**	**5.97**	**5.97**	**5.97**	**5.97**

D. Total Costs per MWh

Total cost per MWh	Summer1						Summer2						Autumn			Spring			Winter		Average
	Daytime Peak			Night Peak	Day High	Other	Daytime Peak			Night Peak	Day High	Other	Day High	Night High	Other	Day High	Night High	Other	High	Other	
	Sat-Wed	Thu	Fri				Sat-Wed	Thu	Fri												
US$/MWh	100.49	52.54	44.71	36.96	33.84	29.41	38.67	34.01	31.46	32.34	30.18	28.57	27.78	28.22	27.04	27.26	27.29	26.41	25.98	25.59	32.40
RO/MWh	**38.64**	**20.20**	**17.19**	**14.21**	**13.01**	**11.31**	**14.87**	**13.08**	**12.10**	**12.43**	**11.60**	**10.99**	**10.68**	**10.85**	**10.40**	**10.48**	**10.49**	**10.15**	**9.99**	**9.84**	**12.46**

(Source: JICA Study Team)

The result of this trial cost is compared with the BST unit rates in 2012, as shown in the following figure. The seasonal segmentation has a slight difference between them, but here the average costs of supply in the "Winter" estimated by the Study Team are compared with the BST unit rates in January-March and November-December, "Spring" with April, "Summer1" with May-July, "Summer2" with August-September, and "Autumn" with October respectively.

The graphs indicate that the results of the costs are similar in general, despite some discrepancies such as the BST unit rate of daytime peak hours in the early summer (55 RO/MWh) being higher than the Study Team's estimation (43.17 RO/MWh), and the BST unit rate in winter (8 RO/MWh) being lower than the Study Team's estimation (9.45-9.63 RO/MWh). The results therefore can draw an inference that the BST unit rates are formulated in a similar way to the Study Team's trial costs, e.g. referring to the system load data in 2011. The reason why the BST unit rate of the daytime peak hours in the early summer are much higher than the Study Team's estimation is supposed to be that the BST calculation takes into account that the emergency diesel generators whose unit costs are very high are in operation during these hours while the Study Team's estimation assumes that all the power generators have the same costs, and so on.

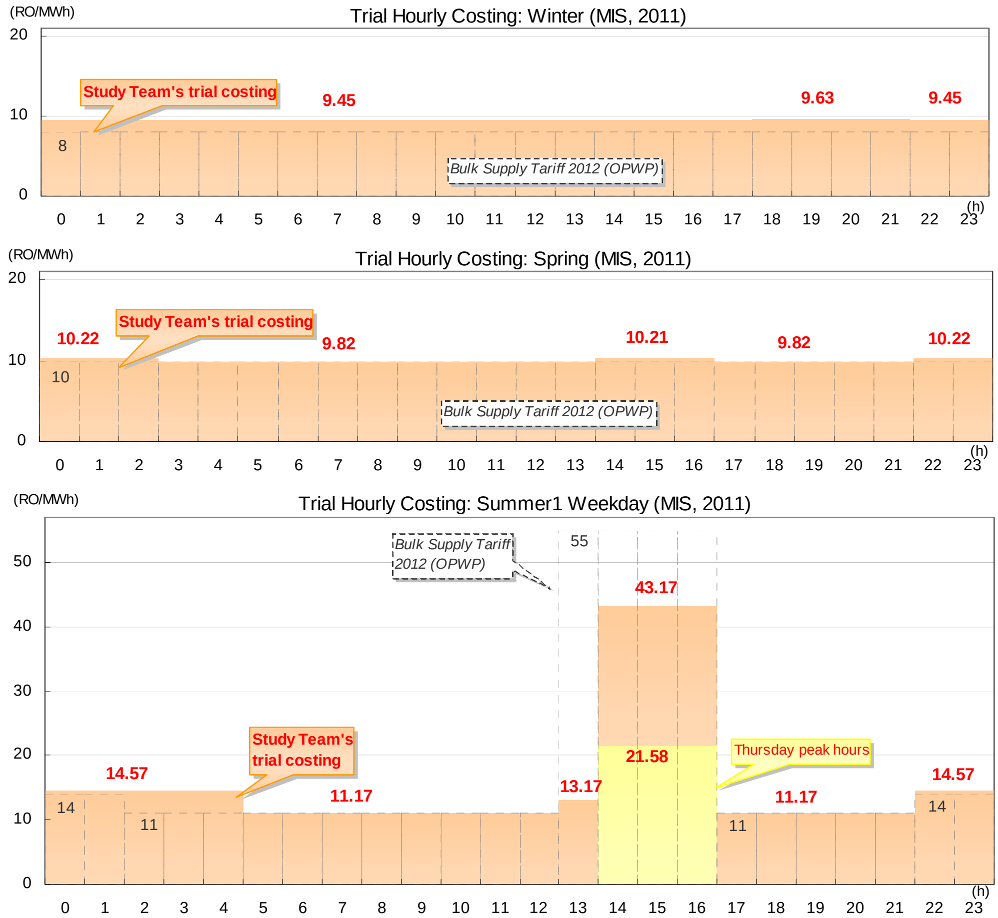


Figure 5- 23 Comparison between the JICA Study Team's Trial Costing and BST Unit Rates (MIS) (1/2)

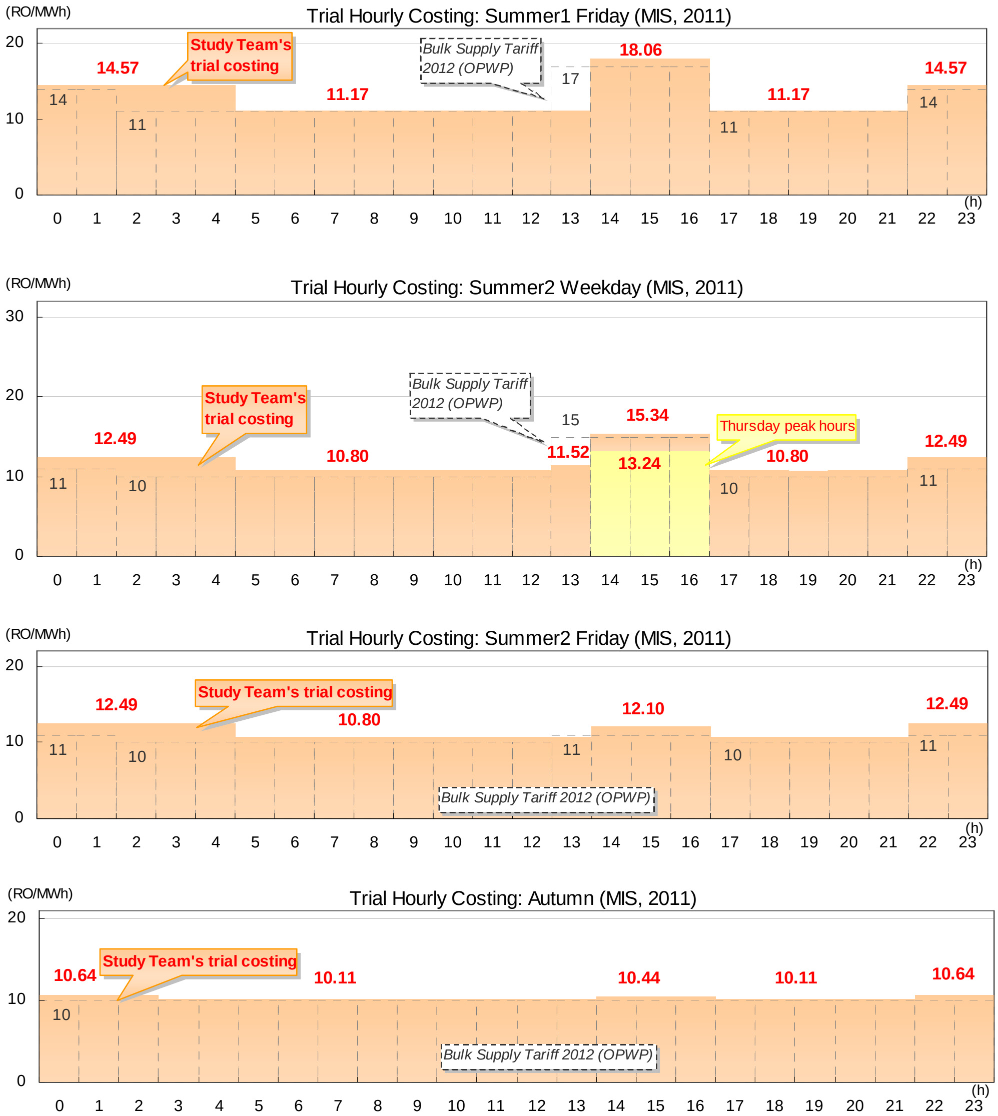


Figure 5- 24 Comparison between the JICA Study Team's Trial Costing and BST Unit Rates (MIS) (2/2)

Based on this analysis, the JICA Study Team concludes that the BST tariff that is currently applied to the MIS area basically follows the appropriate methodologies of cost allocation among the seasons and time zones. Hence, it is rational to use the BST unit rates as the power generation costs in designing DSM incentives in the retail tariff.

(2) The Estimated Breakdown of the MIS System Load by Sectors and between Air-con and Non Air-con Demands

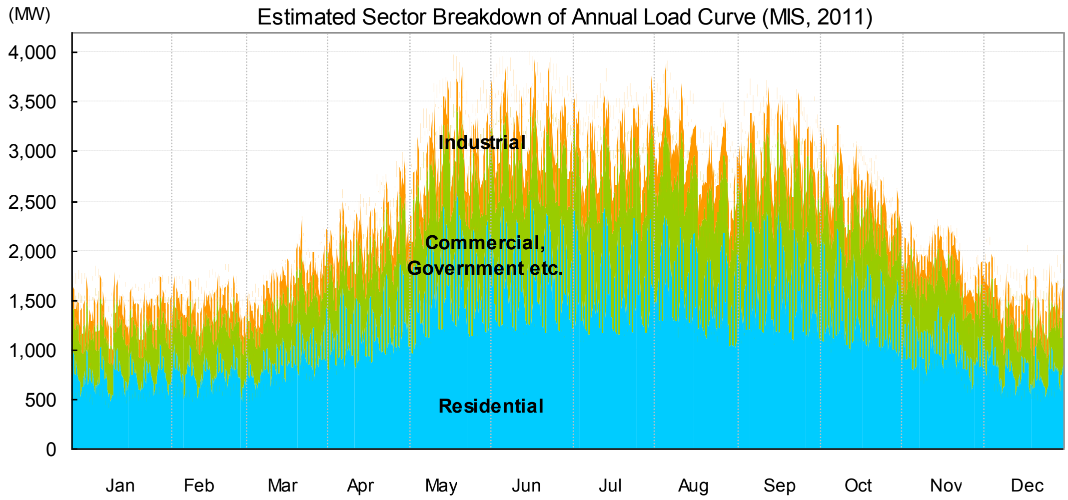
Then this Study estimates the breakdown of the annual system load of the MIS grid by sectors and the breakdown between the air-con and non air-con demands.

The results are summarized in the following table and figures. The air-con demand accounts for about 37 % of the annual system load from the grid, but at the annual peak load, its share increases to 63 %. On the day of the annual peak load (18th June), the commercial and government sectors take up almost a same large share as the residential sector during the daytime peak (15 h, 4,000 MW) whereas the residential sector has the overwhelming majority during the nighttime peak (0 h, 3,627 MW).

Table 5- 34 Estimated Breakdown of the MIS System Load by Sectors and between Air-con/Non Air-con Demands in 2011

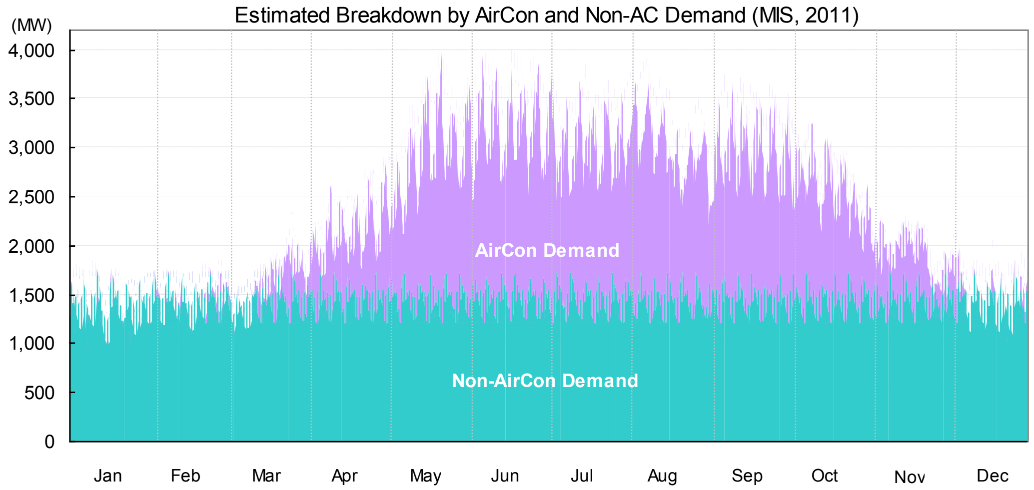
	Annual Supply from the Grid (GWh)			Annual Peak Load: 15h, 18th June (MW)		
	Non Air-con	**Air-con**	Subtotal	Non Air-con	**Air-con**	Subtotal
Residential	6,679	**4,203**	10,882	612	**1,152**	1,764
Commercial, Government etc.	4,053	**2,691**	6,744	615	**1,118**	1,733
Industrial	1,831	**577**	2,408	251	**253**	504
Total	12,563	**7,471**	20,034	1,477	**2,524**	4,000

(Source: JICA Study Team)



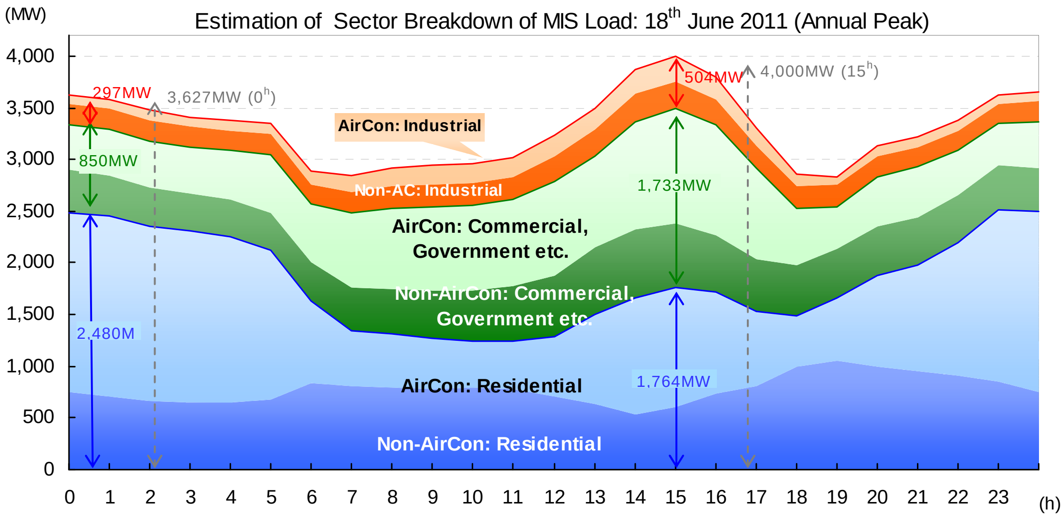
(Source: JICA Study Team)

Figure 5- 25 Estimated Breakdown of the MIS Annual Load Curve by Sectors (2011)



(Source: JICA Study Team)

Figure 5- 26 Estimated Breakdown of the MIS Annual Load Curve between Air-con and Non Air-con Demands (2011)



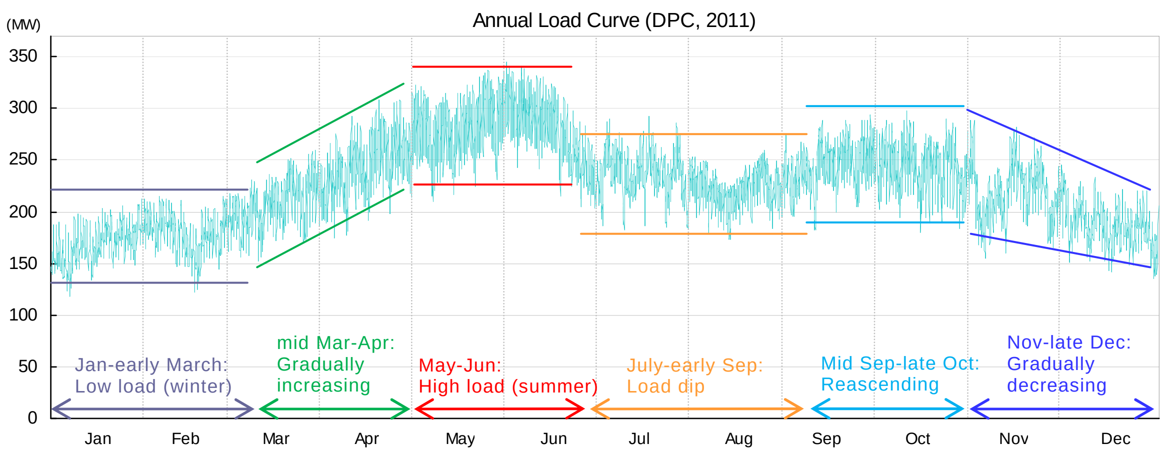
(Source: JICA Study Team)

Figure 5- 27 Estimated Breakdown of the MIS System Load by Sectors and between Air-con and Non Air-con Demands on the Day of Annual Peak Load

(3) Characteristics of the Salalah System Load

(a) Annual Load Curve and Seasonal Characteristics

The following figure illustrates the annual load curve of the Salalah grid in 2011.



(Source: DPC Data, touched up by the JICA Study Team)

Figure 5- 28 Annual Load Curve of the Salalah Grid in 2011 (Hourly Load Record)

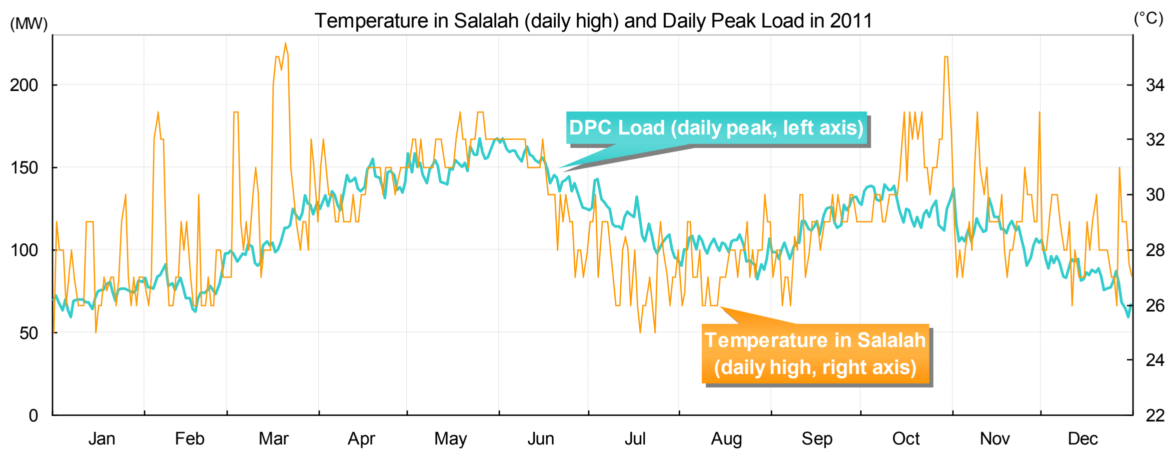
The overall characteristics of the Salalah grid's annual load curve are similar to that of the MIS grid, i.e. the load level during the winter is the lowest during the year. The load starts increasing from March, and after reaching the annual peak in the early summer (from late May to June) it starts decreasing gradually. However, some differences from the MIS grid are also observed as follows:

- The yearly load fluctuation is relatively small (the ratio of the peak and bottom load in a year: about four times for the MIS grid, about three times for the Salalah grid)
- After reaching the annual peak load in the early summer, the load significantly drops

and stays at a low level in July and August, then it increases again in September and October (Note: a similar trend is slightly observed in the MIS grid but it is not conspicuous compared to the Salalah grid)

The main factor behind these differences is the difference in weather conditions between northern Oman such as Muscat and southern Oman such as Salalah. The following figure compares the daily peak of the Salalah system load with the daily highest temperature in Salalah. Whereas the temperature in Muscat reaches the late 40's degrees Celsius, the temperature in Salalah remains at mid-30's degrees Celsius, and this difference is considered to strongly affect the difference of load fluctuation between them. It is also observed clearly that the temperature in Salalah rises again in September and October after decreasing in July and August (Note: The below figure indicates that the highest temperature in a year is recorded in March. However it needs to be withheld to judge its accuracy considering the insufficient development of weather statistic data in rural Oman).

Like the case of the MIS grid, it has also been observed that the system load does not decrease in the late summer as much as the temperature does. However, the gap between the trends of the temperature and the system load is not significant compared to the case of the MIS grid, which is probably because the temperature in Muscat during the late summer fluctuates sharply so that the air-con demand does not sufficiently respond to the short-term drop of temperature while the temperature fluctuation in Salalah is much milder so that the air-con demand catches up with the changes in weather conditions. There was a comment from the DPC staff regarding the gap between the trends of the temperature and the system load (though not significant) that the late summer is a tourist season in Salalah. Thus, a massive migration of people from other regions takes place during this period, and the humidity during this period is very high and it may push up the air-con demand despite the decrease in temperature.



(Source: DPC (load data)、Weather Underground http://www.wunderground.com (temperature))

Figure 5- 29 Daily Peak of the Salalah System Load and Highest Temperature in Salalah (2011)

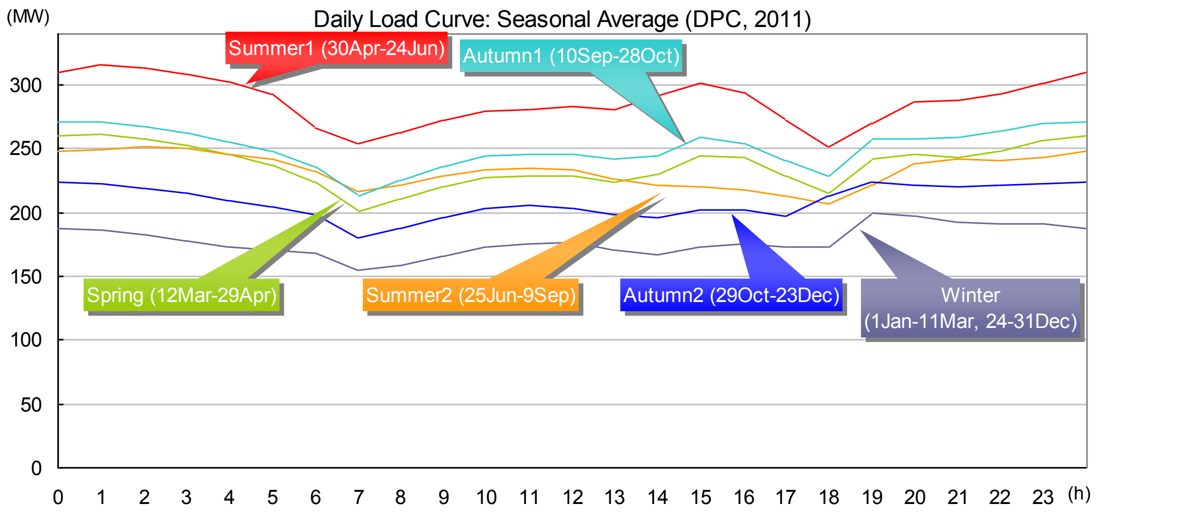
Considering the characteristics of the Salalah system load that it drops once during the late summer and rises again in autumn, this Study analyzes the annual system load by segmenting this into the following six seasonal zones. In the same way as the case of the MIS grid, the seasonal segmentation is made at a period when the load level and load pattern significantly changes, and a week from Saturday to Friday is the minimum unit of segmentation.

- Winter
  - From 1st January (Sat) to 11th March (Fri): 10 weeks (70 days, 1,680 hours)
  - From 24th December (Sat) to 31st December (Sat): 1 week (8 days, 172 hours)
- Spring
  - From 12th March (Sat) to 29th April (Fri): 7 weeks (49 days, 1,176 hours)
- Summer1 (early summer)
  - From 30th April (Sat) to 24th June (Fri): 8 weeks (56 days, 1,344 hours)
- Summer2 (late summer)
  - From 25th June (Sat) to 9th September (Fri): 11 weeks (77 days, 1,848 hours)
- Autumn1 (early autumn)
  - From 10th September (Sat) to 28th October (Fri): 7 weeks (49 days, 1,176 hours)
- Autumn2 (late autumn)
  - From 29th October (Sat) to 23rd December (Fri): 8 weeks (56 days, 1,344 hours)

OPWP started setting the wholesale electricity tariff (BST) from 2012, which classifies the twelve months into five seasonal zones to set different unit rates (see 4.3.2). January-March and November-December in BST corresponds to “Winter” and “Autumn2” in the Study Team’s analysis, April to “Spring”, May-June to “Summer1”, July-August to “Summer2” and September-October to “Autumn1” respectively. The BST sets the same late dates in January-March and November-December, but the Study Team’s analysis regards them as different seasonal zones, taking into account that the load level in November is still significantly higher than that in January-February and it continues decreasing until the end of December.

The following figure shows the average daily load curve in each of the six seasonal zones. The daily load curve takes a similar shape in Summer1, Autumn1, and Spring, having two peaks in the daytime (14-16 h) and nighttime (0-2 h), though the load level is different among these seasons. The daily load curve of the MIS grid also has two peaks except during the winter, but while the MIS grid sees its annual peak load in the summer daytime, the annual peak load of the Salalah grid comes in the summer nighttime (in 2011, the annual peak was recorded at 1 am, 31st May).

In Summer2, the daily peak load is also seen in the nighttime, but the peak load during the daytime has not been clearly observed, which is because the temperature during the daytime is low compared to the preceding and the following seasons. In Autumn2 and Winter, the load is almost flat from the evening (19 h) to late into the night, and this is the highest load in the day.



(Source: DPC Data, touched up by the JICA Study Team)

Figure 5-30 Average Daily Load Curve in Each Season (Salalah Grid, 2011)

(b) Time Zone Segmentation of the System Load

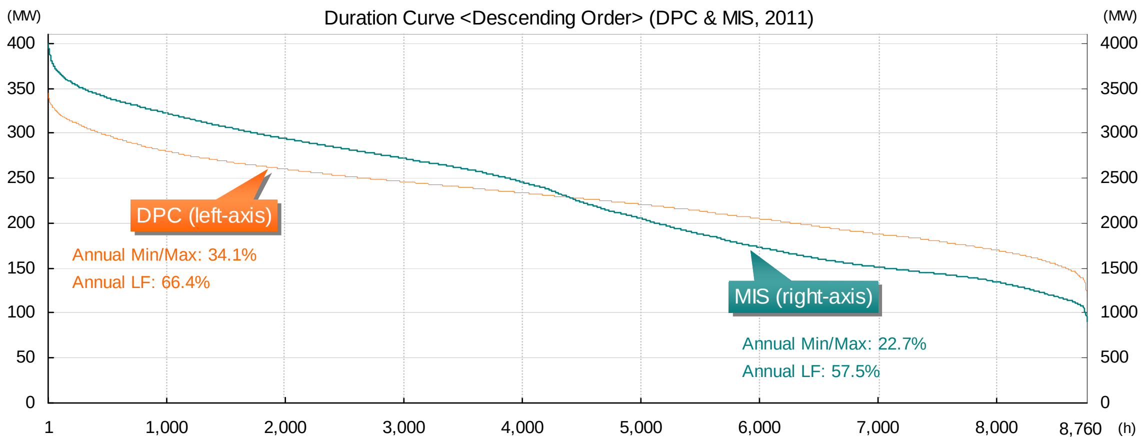
Following the analysis of the characteristics of the Salalah system load in each season, day of week, and hour of day, this Study then segments the annual load (8,760 hours) into the following 20 time zones. This Study's time-zone segmentation is more complicated than that of OPWP's Bulk Supply Tariff in Salalah area (see 4.3.2), but the basic concept of time-zone segmentation is almost the same.

Table 5- 35 Segmenting the Annual DPC Load into 20 Time Zones

		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Summer1	Weekday	Nighttime Peak					Night High	Other					Daytime High			Day Peak			Other			Nighttime High			Night Peak
	Friday															Fri Day Peak									
Autumn1	All days	Night High			Mid		Other									Daytime High			Other		Mid				Night High
Spring	All days	Night High			Mid		Other									Daytime High			Other		Mid				Night High
Summer2	All Days	High					Other																		High
Autumn2	All days	High			Other																High				
Winter	All days	Other																			High				

(Source: JICA Study Team)

Then the duration curve of the Salalah grid in 2011, along with that of the MIS grid for comparison, is shown in the following figure. Given that the power demand in the Salalah grid is about one-tenth that of the MIS grid, the scale is adjusted to one-tenth for easy comparison.



(Source: DPC and OETC Data, touched up by the JICA Study Team)

Figure 5- 31 Duration Curves of DPC Grid and MIS Grid in 2011

As also observed in the duration curve of the MIS grid, the duration curve of the Salalah grid has a steep slope at the left-top, but the slope of the duration curve in general is more moderate and its annual load factor (66.4 %) is smaller than that of the MIS grid (57.5 %). Unlike the duration curve of the MIS grid that is terraced with different slopes due to the different load levels among the summer (high load), spring and autumn (intermediate), and winter (low load), the duration curve of the Salalah grid has a smoother slope because of the moderate transition of load levels in the intermediate seasons. The following table arranges the load of 8,760 hours by 20 time zones and the load levels as the horizontal axes and vertical axes. In the matrix of the MIS grid, the number of hours when the system load was between 1,600 MW and 2,500 MW was fewer than when the load exceeded 2,500 MW (summer) and when it was below 1,600 MW (winter), but the matrix of the Salalah grid shows a smooth distribution from high-load hours to low-load hours.

Table 5- 36 Distribution of Hourly Load by 20 Time Zones and Load Levels (Salalah Grid, 2011)

Hourly Load (MW)	Summer1						Autumn1				Spring				Summer2		Autumn2		Winter		Total (hours)
	Night Peak	Day Peak	Night High	Day High	FrDay Peak	Other	Night High	Day High	Mid	Other	Night High	Day High	Mid	Other	High	Other	High	Other	High	Other	
340-350	5																				5
330-340	28	4																			32
320-330	52	17	1	1																	71
310-320	93	22	24	7																	146
300-310	61	44	42	24	1	9					12										193
290-300	44	27	62	39	3	36	5				15	2	4		3						240
280-290	33	10	34	36	3	64	53	1	10		26	7	16	1	15		10				319
270-280	15	7	31	23	3	89	44	23	53		18	13	30	6	40	11	17	4			427
260-270	4	1	15	9	6	87	59	35	97	30	17	17	44	22	53	42	29	6			573
250-260	1	11	10	9	3	71	18	27	67	114	24	11	23	50	86	102	19	18			664
240-250		1	4	7	3	46	10	26	38	123	25	18	49	50	114	221	41	51			827
230-240			1	7	2	33	8	15	27	88	29	21	42	66	78	246	47	72		1	783
220-230				3		7		14	2	86	21	18	57	84	56	280	47	95	12	6	788
210-220				3		5		5		50	7	18	22	92	17	221	59	67	34	20	620
200-210						1		1		30		10	6	68		145	78	100	91	68	598
190-200										15	1	10	1	59		73	54	130	108	146	597
180-190										3		2		28		35	36	125	79	307	615
170-180														13		10	11	116	47	290	487
160-170																		75	17	276	368
150-160																		32	2	197	231
140-150																		5		116	121
130-140																				45	45
120-130																				8	8
110-120																				2	2
	336	**144**	**224**	**168**	**24**	**448**	**197**	**147**	**294**	**539**	**195**	**147**	**294**	**539**	**462**	**1,386**	**448**	**896**	**390**	**1,482**	**8,760**

Note:
(orange) coloured cells indicate that more than 60% of the time zone falls in that load range
(yellow) coloured cells indicate that more than 30% of the time zone falls in that load range

(c) Cost Allocation among the Time Zones (Comparison with BST's Unit Rates)

In the same way as the MIS grid, this Study tried the allocation of costs of supply among the 20 time zones. Likewise, this Study assumes that the costs are the same regardless of the power plants and is almost balanced with the BST average.

The comparison of this trial costing with the BST unit rates in 2012 is summarized in the following figures.

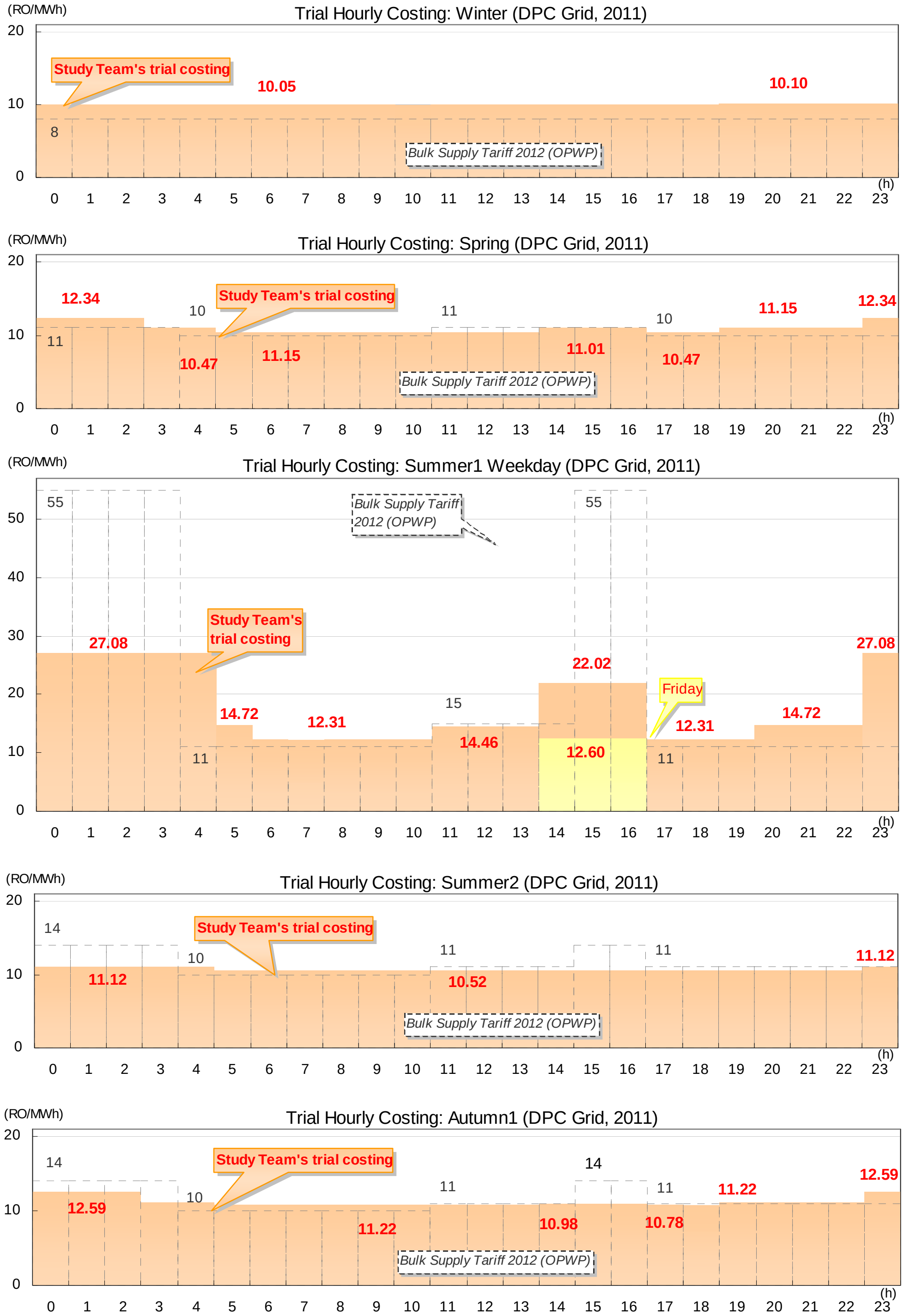


Figure 5- 32 Comparison between the JICA Study Team's Trial Costing and BST Unit Rates (Salalah) (1/2)

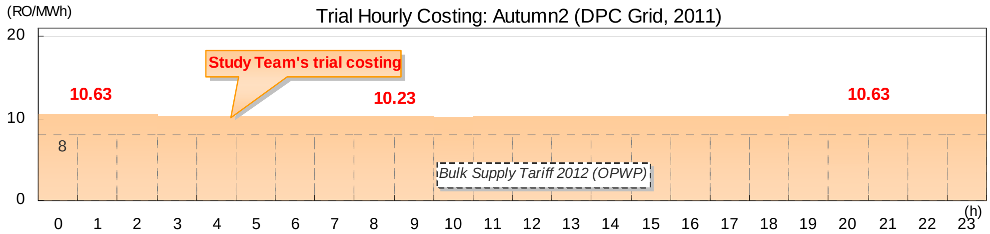


Figure 5- 33 Comparison between the JICA Study Team's Trial Costing and BST Unit Rates (Salalah) (2/2)

Compared to the Study Team's trial costing, the BST unit rate is priced much higher during the daytime peak in the early summer and lower in the winter and late autumn. In the Salalah grid, the load fluctuation is smaller than that in the MIS grid, and the number of power plants in operation is fewer, therefore the difference in power generation costs between the peak hours and off-peak hours should be smaller than that in the MIS grid. However, BST sets the same unit rate for summer peak hours (55 RO/MWh) and for winter (8 RO/MWh). Therefore, the JICA Study Team concludes that the BST unit rates in Salalah area are formulated in compliance with that in MIS, with minor adjustments in consideration of the different characteristics of the load curve between MIS and Salalah, rather than accurately reflecting the costs and load pattern of the Salalah grid.

(4) Estimated Breakdown of the Salalah System Load by Sectors and between Air-con and Non Air-con Demands

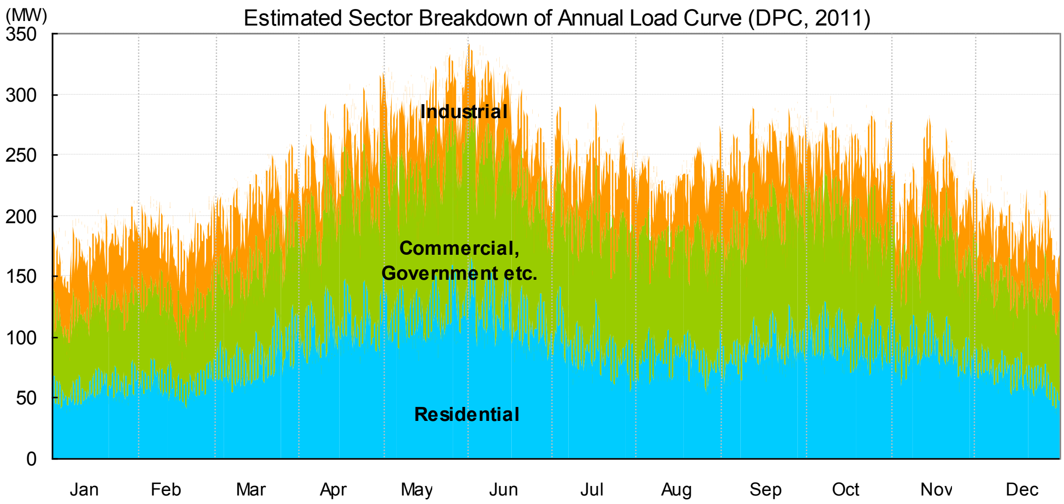
Then this Study estimates the breakdown of the annual system load of the Salalah grid by the sectors and the breakdown between air-con and non air-con demands. The hourly load data of sample 11 kV feeders are obtained from DPC, thus the estimation of the sector breakdown is made by using the sample data of 11 kV feeders that is respectively supplied to meet residential, commercial, industrial, and government demands, and adjusting them to fit the total system load curve. Then the breakdown between the air-con demand and non air-con demand is estimated, assuming that the load during the winter is identical with the non air-con demand and that the difference between this and the load patter in other seasons is the air-con demand.

The results are summarized in the following table and figures. Given that the weather conditions are more moderate than in the MIS area, the air-con demand accounts for about 28% of the annual system loads and about half of the annual peak load.

Table 5- 37 Estimated Breakdown of the Salalah System Load by Sectors and between Air-con/Non Air-con Demands in 2011

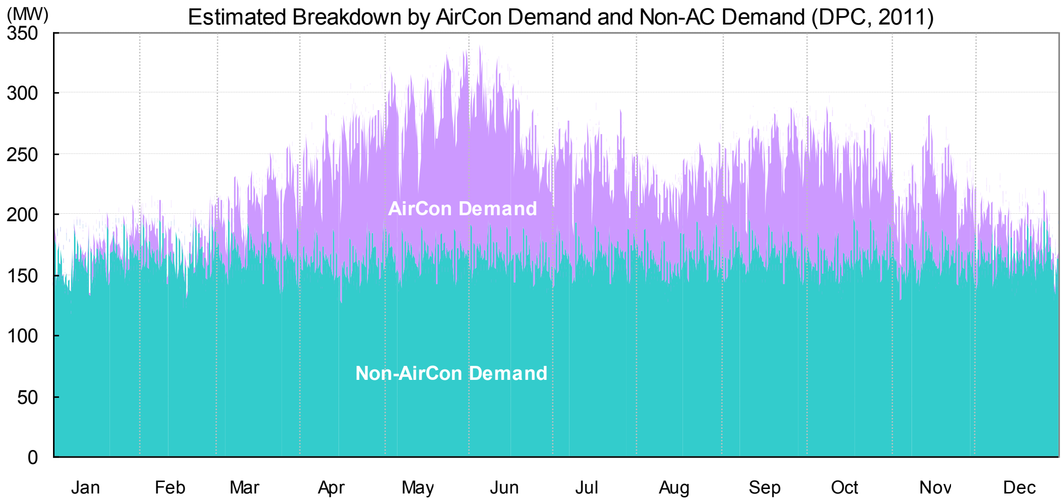
	Annual Supply from the Grid (GWh)			Annual Peak Load: 15th, 18th June (MW)		
	Non Air-con	**Air-con**	Subtotal	Non Air-con	**Air-con**	Subtotal
Residential	503	**282**	785	69	**98**	167
Commercial, Government etc.	558	**256**	814	60	**67**	127
Industrial	383	**15**	398	49	**2**	51
Total	1,445	**553**	1,998	177	**168**	345

(Source: JICA Study Team)



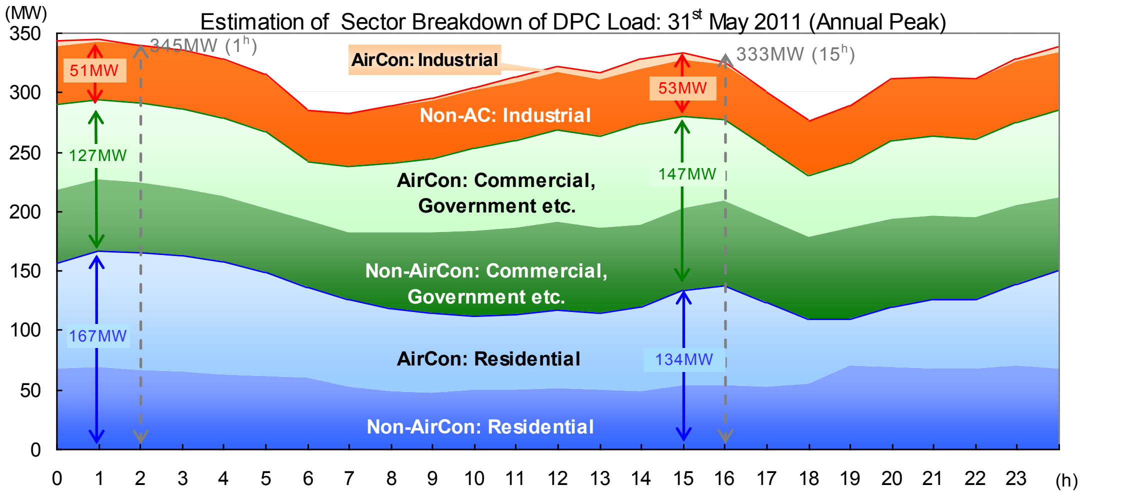
(Source: JICA Study Team)

Figure 5- 34 Estimated Breakdown of the Salalah System Load Curve by Sectors (2011)



(Source: JICA Study Team)

Figure 5- 35 Estimated Breakdown of the Salalah System Load Curve between Air-con and Non Air-con Demands (2011)



(Source: JICA Study Team)

Figure 5- 36 Estimated Breakdown of the Salalah System Load by Sectors and between Air-con and Non Air-con Demands on the Day of Annual Peak Load

(5) Considerations for Peak Load Reduction

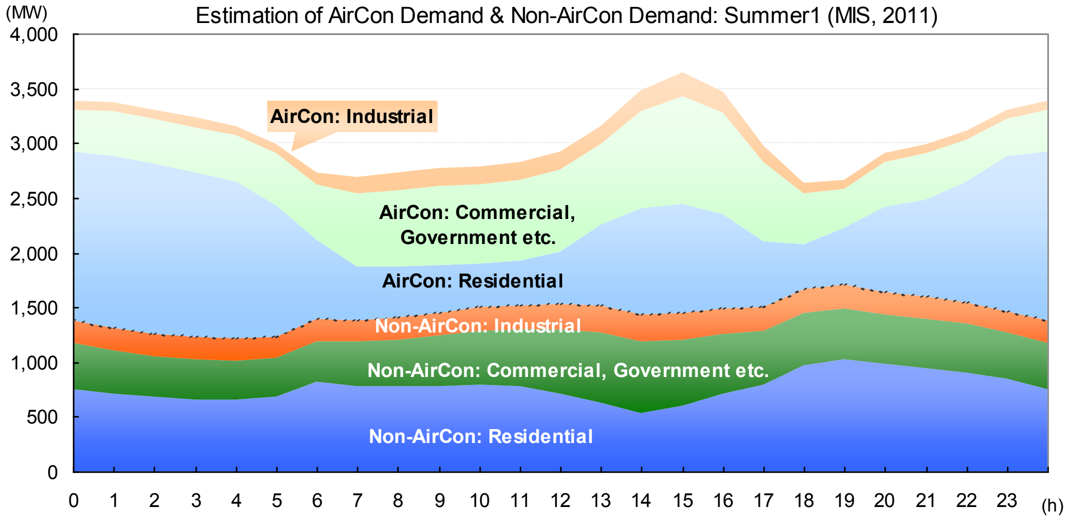
Measures for reducing the peak load can be roughly classified into the following two types.

- Reducing the overall power consumption by enhancing the awareness of energy saving, introduction of high-efficiency devices etc.
- Controlling the peak load by shifting the customer's demand (especially large customers) from peak hours to off-peak hours

Measures that deal with the first one may have a large potential and permanency of reducing energy consumption in general, but their drawback is uncertainty regarding to what extent the peak demand can be immediately reduced, and especially when the peak load reduction is immediately needed their efficiency cannot be accurately counted on. In the meantime, measures dealing with the second one may have energy consumption reduction limitations, but the imminent effect of the peak load reduction is to be expected.

In the MIS grid, the daytime peak load in the early summer (Summer1) is the highest in a year and the annual peak load in 2011 increased by more than 10 % from the previous year. The facilities for electric power supply need to be increased to meet the highest load of the year and it brings about an increase of fixed costs for newly added facilities. Therefore, determining how to control the peak load during the summer daytime for preventing the decrease of efficiency and the increase of costs of supply needs to be regarded as an imminent challenge.

The "commercial, government etc." and "industrial" sectors account for a large share in the summer daytime peak of the MIS system load and, after witnessing its daily highest in the summer afternoon (15h), the total system load decreases by about a quarter (about 1,000 MW) in three hours up to 18h. Taking this into account, the JICA Study Team considers that providing tariff incentives to motivate large customers belonging to the aforementioned sectors to shift their load from peak hours to off-peak hours may be effective in considerably reducing the peak load of the MIS system.

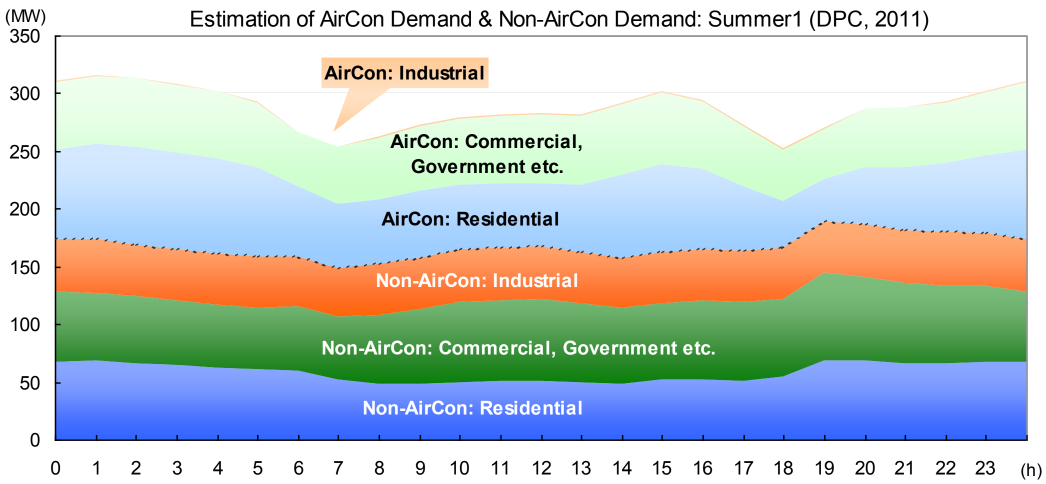


(Source: JICA Study Team)

Figure 5- 37 Average Daily Load Curve in Early Summer (Summer1) in 2011 (MIS Grid)

Furthermore, in the Salalah grid, a huge drop of the system load from 15h to 18h in the early summer (Summer1) is observed. However, given that the Salalah grid witnesses its highest load during the nighttime peak hours, the load shift from the daytime peak hours to the evening off-peak hours does not contribute to the reduction of the annual peak load of the total system.

The more important challenge for the Salalah grid is to reduce the peak load during the nighttime, but because the residential sector accounts for its largest share, the possibility of shifting the load from nighttime peak hours to other time zones is limited. Furthermore, the demand of the Salalah grid is as small as about one-tenth of the MIS grid, and the load fluctuation of the Salalah grid is also moderate. Therefore, the necessity and the effect of the peak load reduction using tariff incentives may be much smaller for the Salalah grid compared to the MIS grid.



(Source: JICA Study Team)

Figure 5- 38 Average Daily Load Curve in Early Summer (Summer1) in 2011 (Salalah Grid)