5.4 Analysis on Electricity Consumption (Micro-level)

5.4.1 Objectives and Methodology of the Analysis

(1) Objectives

The micro analysis of the power consumption is intended as the basic investigation for the trial calculation of the energy saving potential or effect of energy saving measures through the analysis and measuring of energy consumption using measuring instruments.

(2) Methodology and Items of Analysis

Three sites are selected from the factories, buildings, and residences respectively, where the energy audit and a simple and practical experimental survey for energy saving measures are carried out using measuring instruments for analyzing applicable energy saving measures and energy saving potential.

The method of investigation and items of analysis are shown in the following table;

Table 5- 38 Method for Investigation and Items of Analysis at Each Site

	Site	Method of Investigation	Items of Analysis
Factory	Ceramic Factory A	Energy audit	• Power consuming pattern at major facilities *1 • Applicable energy saving measures • Energy saving potential by energy saving measures
	Vegetable Oil Factory B	Energy audit	• Power consuming pattern at major facilities *1 • Applicable energy saving measures • Energy saving potential by energy saving measures
	Glass Factory C	Energy audit	• Power consuming pattern at major facilities *1 • Applicable energy saving measures • Energy saving potential by energy saving measures
Building	Shopping Mall A	Energy audit	• Power consuming pattern at major facilities *1 • Applicable energy saving measures • Energy saving potential by energy saving measures
	Hotel B	Energy audit	• Power consuming pattern at major facilities *1 • Applicable energy saving measures • Energy saving potential by energy saving measures
	PAEW Office (one floor in multi-tenant building)	• Measuring power consumption • Experimental survey for energy saving	• Power consuming pattern at major facilities *1 • Applicable energy saving measures • Energy saving potential by energy saving measures
Residence	Residence A	• Measuring power consumption • Experimental survey for energy saving	• Power consuming pattern of whole site *1 • Experimental survey for energy saving *2
	Residence B	• Measuring power consumption • Experimental survey for energy saving	• Power consuming pattern of whole site *1 • Experimental survey for energy saving *2
	Residence C	• Measuring power consumption • Experimental survey for energy saving	• Power consuming pattern of whole site *1 • Experimental survey for energy saving *2

*1: Power consuming pattern is measured by measuring instruments.
*2: Experimental survey is implemented for verifying the effect using measuring instruments.

(3) Method of Energy Audit (Factories and Buildings)

At each surveyed site, the energy audit is carried out using the required measuring instruments and the trial calculation of the energy saving potential is made in consideration of the operation pattern of the energy consumption facilities, the operational efficiency of the facilities, energy losses, etc. Moreover, the power consumption pattern is measured for major energy consuming facilities, and the operational conditions are analyzed.

The questionnaire concerning the contents of energy consuming facilities, energy consuming conditions, etc. is submitted to each site in advance, an interview is performed on the contents of the filled questionnaire at the energy audit, and the required information is acquired for examining practical energy saving measures and energy saving potential.

(4) Method for Measuring Power Consumption (PAEW office and residences)

Since at the PAEW office and residences it was confirmed that measurement was possible using measuring instruments which the JICA Study Team possesses, the power consumption patterns are measured and the power consumptions as baseline use are analyzed.

(5) Method of Experimental Survey for Energy Saving (PAEW office and residences)

The following experimental surveys are carried out at the PAEW office and a residence. By comparison with the above baseline use, these activities can confirm the effect of energy saving measures which are practical and simple for spreading and raising awareness on the energy measures.

(PAEW Office)

- Change the power consumption of air-conditioners by setting temperatures to 22, 24 and 26 ºC respectively
- Change of the power consumption of lighting by lowering the illumination in corridors to 200 lx from 400 lx

(Residence)

- Have residents change power consumption habits via proactive energy-saving activities
- Change power consumption habits by installing a visualization monitor which displays the power consumption amounts in residences and utilizing the monitor

5.4.2 Results of Energy Audit

(1) Ceramic Factory A

(a) The Factory Outline

The products of this factory are ceramic tiles for building material and the products that are distributed to Oman as well as the neighboring countries. Its production lines are divided into two sub-factories and the No.1 to the No.3 plant are located at the first sub-factory and the No.4 plant is at the new factory. The annual production of the whole factory encompasses 13million m^2 of surface area and weighs approximately 400,000 tons.

(b) Energy Consuming Situations

The energy sources of the factory are electric power for the production lines, air compressors, chillers, lighting, etc. and natural gas for the tunnel kilns of calcining ceramic tiles. The annual consumption volumes are shown in the table below.

Table 5- 39 Annual Energy Consumption

Year	Electric Power kWh	Natural Gas Nm3
2010	27,386,000	19,556,989
2011	28,007,917	18,646,399

In addition, the following figures show the trend graphs of the monthly consumption of electric power and natural gas.

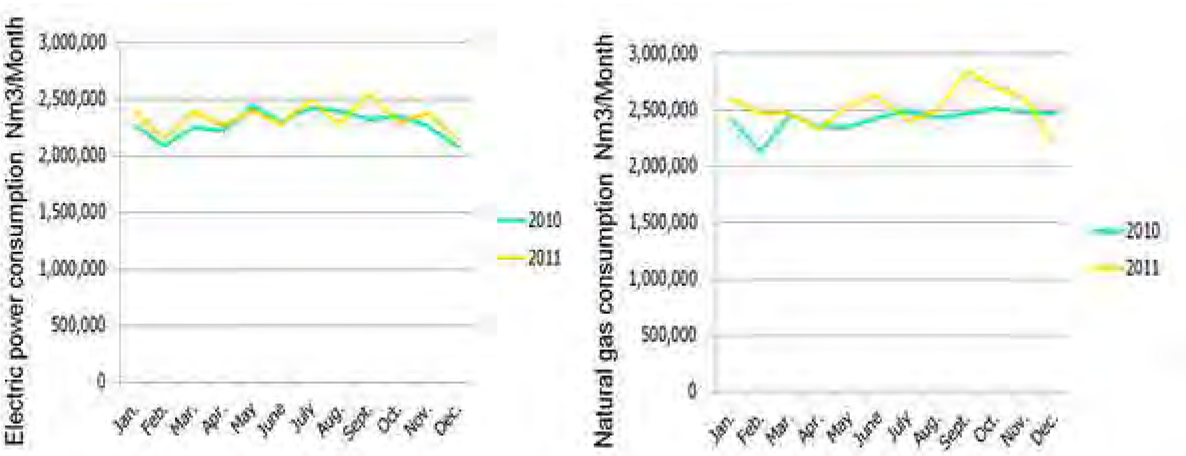


Figure 5- 39 Trend Graph of Monthly Consumption of Power and Natural Gas

(c) Results of Analyzing the Power Consumption Pattern at Major Facilities

The energy audit was targeted to the compressed air system because the compressors consume a large amount of power. In order to get the precise operating conditions of the compressors and measuring instruments, equipment such as the ultra-sonic air leakage detector and data logger are utilized and the energy conservation measures were examined based on the analyzed results of the acquired data. The schematic flow diagrams of the two compressed air systems with the leakage portions marked are shown in the figures below.

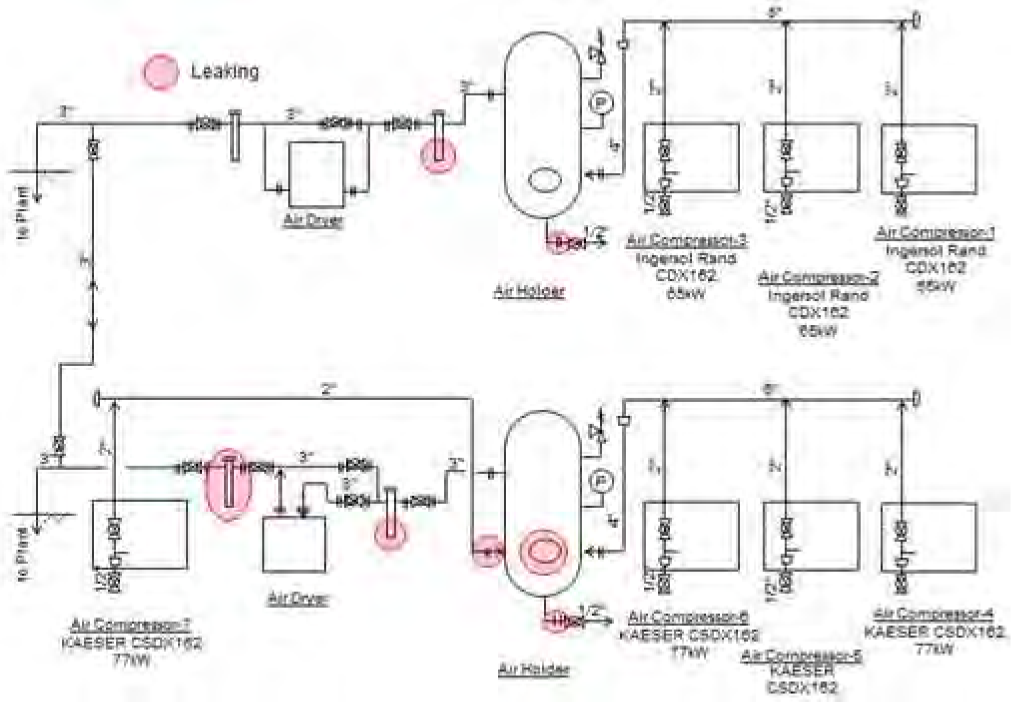


Figure 5- 40 Flow Chart of Compressed Air System in the First Factory

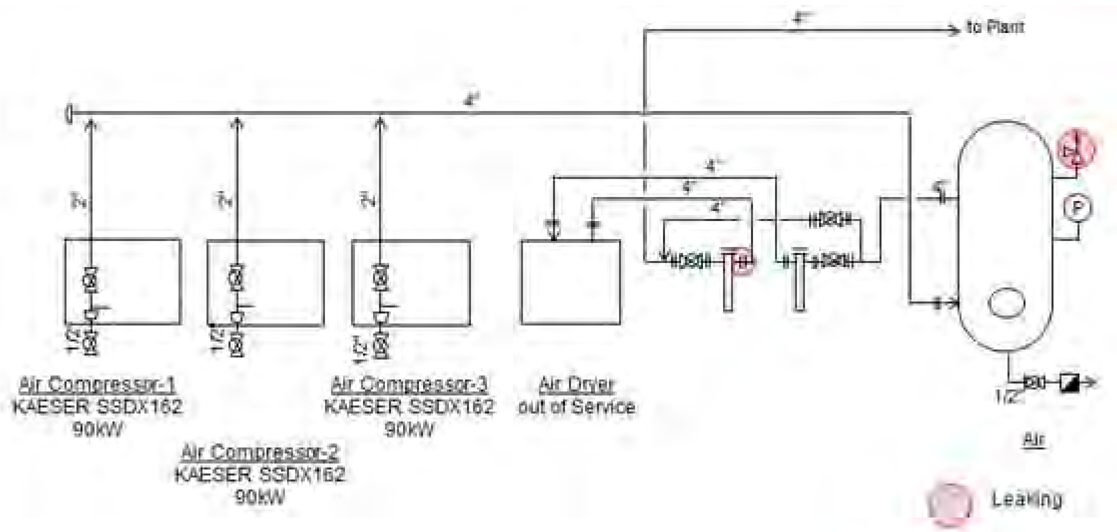


Figure 5- 41 Flow Chart of Compressed Air System in the New Factory

24 hours of the continuous measurement of the motor current of all the compressors and the discharge air pressure were carried out using a data logger with a pressure sensor and current sensors.

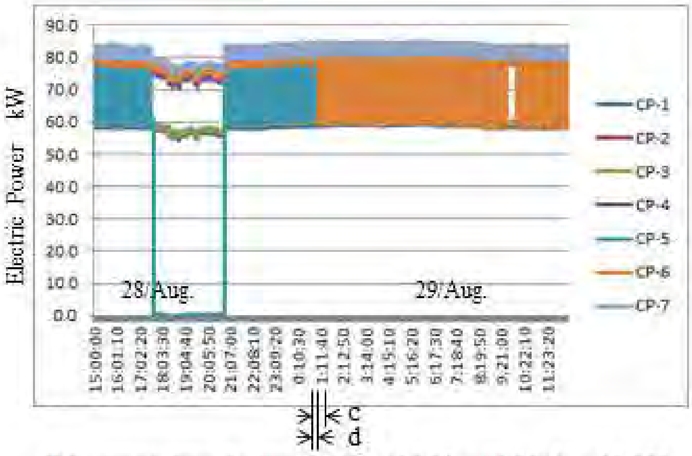
Measurement using data logger

10 channel data logger

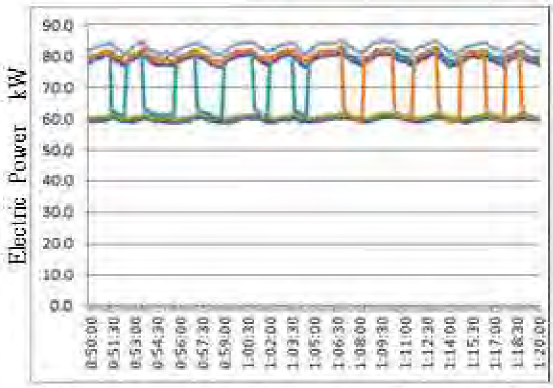
Current sensor

Pressure sensor

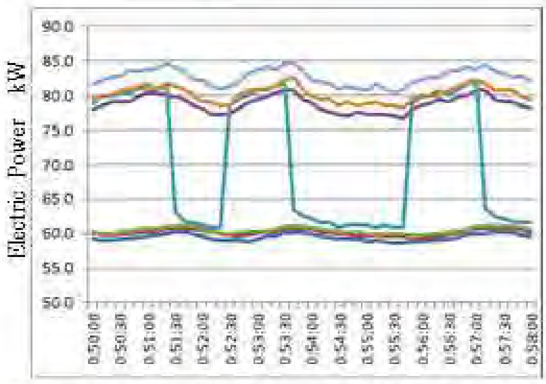
Figure 5- 42 Measurement of Operation Conditions of Air Compressor using Data Logger



[Measured data during 29/Aug. 15:00 and 30/Aug.12:00]

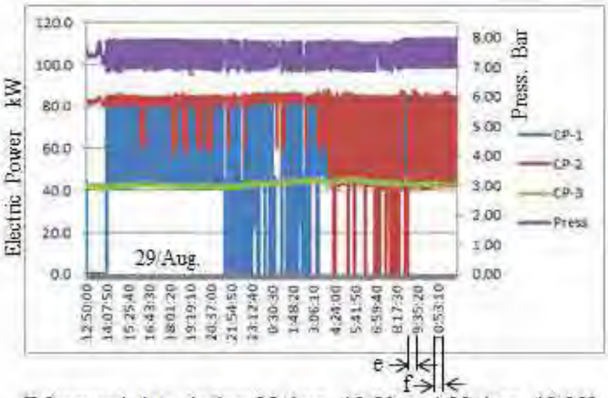


[Measured data during 29/Aug. 0:50 and 1:20 (c)]

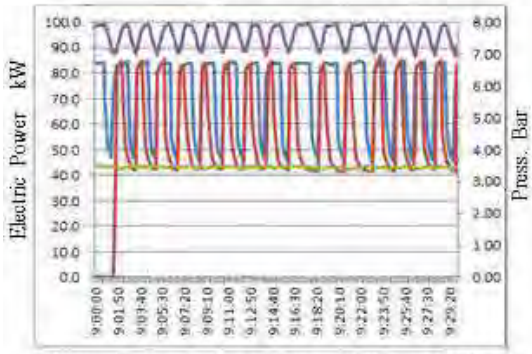


[Measured data during 29/Aug. 0:50 and 0:58 (d)]

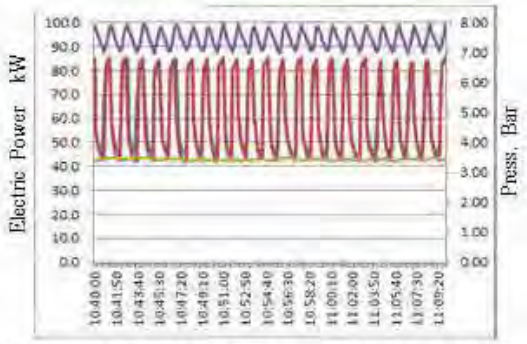
Figure 5- 43 Measurement Results of the Operating Conditions of 7 Air Compressors in the First Factor (Electric Power)



[Measured data during 28/Aug. 12:50 and 29/Aug. 12:00]



[Measured data during 29/Aug. 9:00 and 9:30 (e)]



[Measured data during 29/Aug. 10:40 and 11:10 (f)]

Figure 5- 44 Measurement Results of Operation Condition of 3 Air Compressors in the New Factory (Electric Power and Air Pressure)

The results of the analysis of the operating conditions and the improvements are as follows.

- First Factory (No.1-3 Plant)

  At present, six air compressors, out of a total of 7 units, are operating at full load and the remaining one air compressor controls the compressed air pressure by the load / unloads operation minus any backup standby compressors However, it is very important to keep at least one standby compressor in the event that the operating compressors experience unexpected trouble.

- New Factory (No.4 Plant)

  The set pressure of the air compressors is inadequate and given that the Cp-1 and Cp-2 sometimes repeats the onload / unload operations at the same time, by changing the setting of the pressure switches, the reduction of both unnecessary load operations and power consumption amount can be achieved.

(d) Applicable Energy Saving Measures

From the results of the energy audit, the recommendations on the applicable energy saving measures are shown below.

Table 5- 40 Recommended Measures for Energy Saving

No.	Item	Energy	Quantity of Reduction		Invest-ment	Payback Period	Remark
			MWh	RO	RO	Year	
1	Repair of parts that are leaking compressed air	Electric power	245	3,920	-	-	Investments are not considered due to maintenance.
2	Improvement of air blow	Electric power	92	1,450	2,000	1.1	
3	Lowering of compressed air pressure	Electric power	320	5,120	0	0	
4	Improvement of Lighting	Electric power	-	-	-	-	Impossible to estimate quantitatively

(e) Audit Findings

As a result of the energy audit, the energy saving potential to be achieved by implementing the recommended measures is estimated at 2.3 % for the whole of energy consumption as shown in the table below.

Table 5- 41 Energy Saving Potential per the Recommended Measure

Energy	Annual Consumption (in 2011)	Annual Reduction Quantity / Reduction Rate		Annual Reduction Amount	Invest-ment	Payback Period	Remark
		MWH	%	RO	RO	Year	
Electric power	28,008 MWh	657	2.3	10,490	2,000	0.19	Unit price of power: 0.016 RO/kWh

The energy saving potential indentified by the energy audit was not so large due to the following reasons. It is expected that more energy saving measures with potential could be unearthed in the whole factory if a detailed energy audit is executed.

- All the utility facilities were not surveyed due to time constraints.
- There were some items that could not be quantified.
- It was difficult to survey the industry-specific production facilities via a simple energy audit this time around.

(2) Vegetable Oil Factory B

(a) The Factory Outline

This factory produces various kinds of edible oil, and also plastic containers for the products are manufactured in the factory.

(b) Energy Consumption Situations

The energy sources of the factory are electric power for the production lines, air compressors, chillers, lighting, etc. and natural gas for the steam boilers. The annual consumption volumes are shown in the table below and its monthly trend graphs are shown in the figures below.

Table 5- 42 Annual Energy Consumption

Year	Electric Power kWh	Natural Gas Nm3
2010	29,393,265	5,647,683
2011	33,125,345	7,400,151

In addition, the following graphs reveal the trend of the monthly consumption of electric power and natural gas.

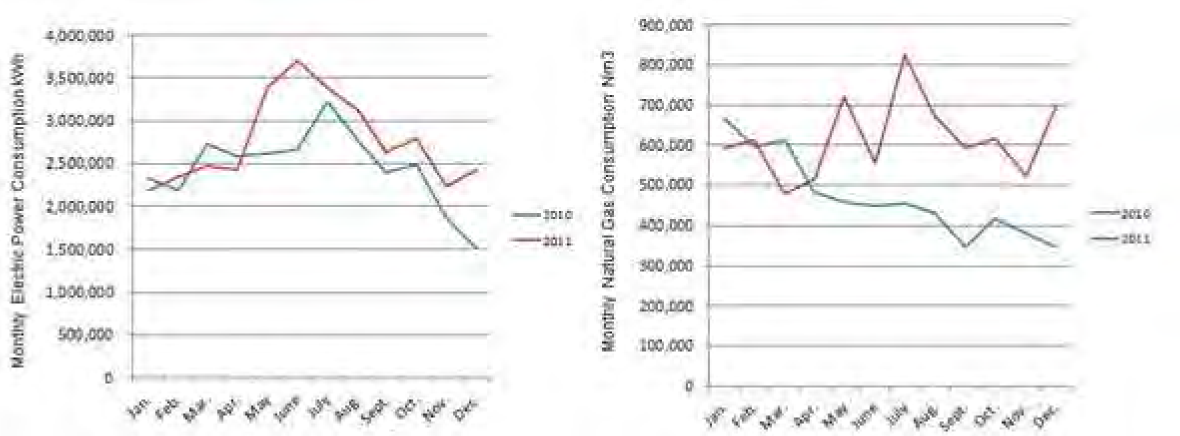


Figure 5- 45 Trend Graph of Monthly Consumption of Electric Power and Natural Gas

(c) Results of Analyzing the Power Consumption Pattern at Major Facilities

The factory has a total 14 air compressors comprised of low pressure air compressors for instrumentation and high pressure compressors for plastic bottle production. The operating conditions of 4 low pressure air compressors shown in the following figure were measured using a data logger with a pressure sensor and current sensors.

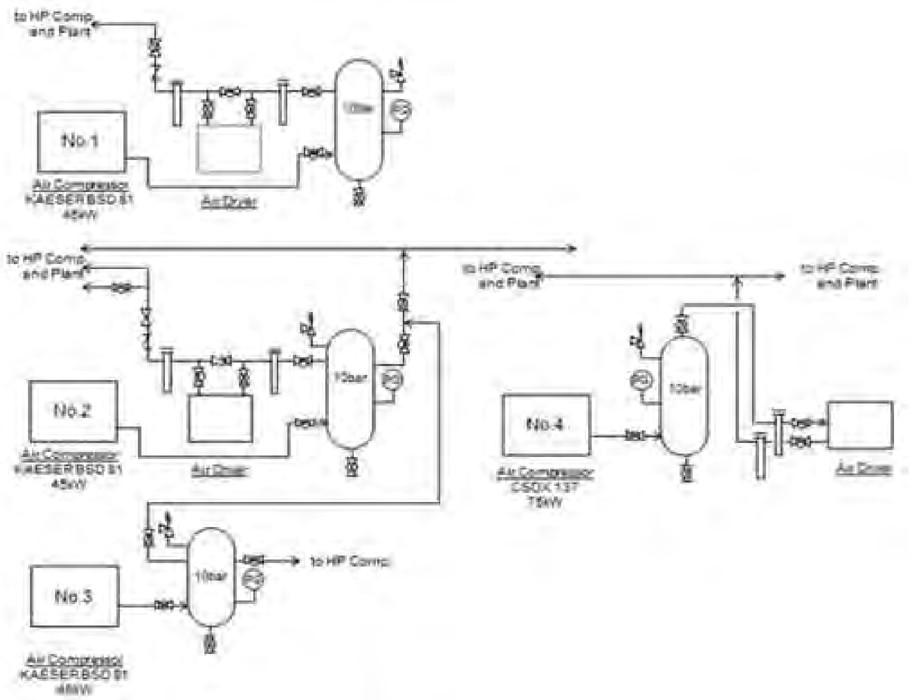
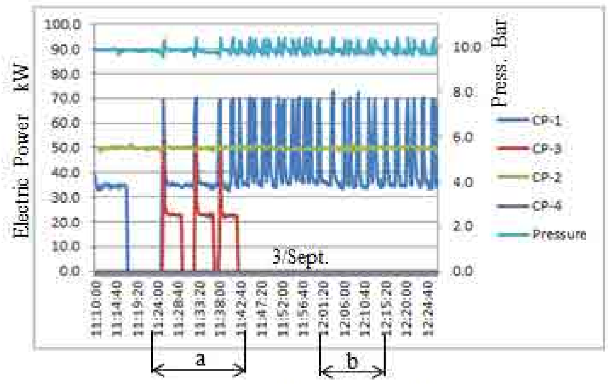
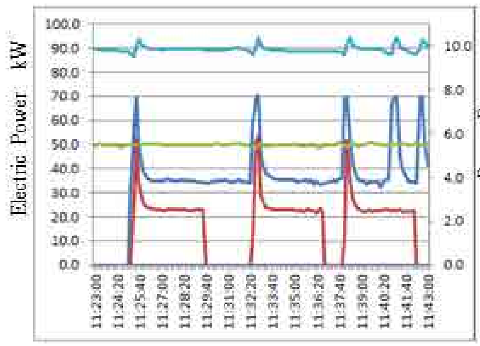


Figure 5- 46 Flow Chart of Compressed Air System (Measured Area)

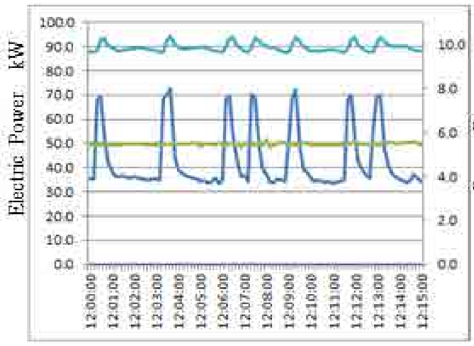
The measuring results are shown in the figures below.



[Measured data during 3/Sept. 11:10 and 12:30]



[Measured data during 3/Sept. 11:23 and 11:43 (a)]



[Measured data during 3/Sept. 12:00 and 12:15 (b)]

Figure 5- 47 Measurement Results of the Operating Conditions of 4 Low Pressure Air Compressors (Electric Power and Air Pressure)

From the results of analysis of the gathered data, the operation conditions and improvements are as follows.

- Each low pressure air compressor repeats load/unload/stop operations are conducted in accordance with the set pressure. In addition, there is a situation where the two air compressors start at the same time.
- The pressure of low pressure compressed air is about 10 Bar. A part of the low pressure compressed air is sent to boost-up the air compressors (pressure: 10 → 40 Bar) for the plastic container forming.
- There is a high pressure air compressor (pressure: atmospheric pressure → 40 Bar), and the high pressure air volume to be boosted up is relatively smaller in comparison to the low pressure air volume. Therefore, if there is any problem in the specifications of the boost up compressor, it is preferable to lower the pressure from the low pressure compressors in order to reduce power consumption.

(d) Applicable Energy Saving Measures

Based on the results of the energy audit, the recommendations on the applicable energy saving measures are shown below:

Table 5- 43 Recommended Measures for Energy Saving

No.	Item	Energy	Quantity of Reduction		Invest-ment	Payback Period	Remark
			Nm3 or MWh	RO	RO	Year	
1	Insulation of the non-insulated steam valves, etc.	Natural gas / Industrial water	46,700 Nm3	956	2,000	2.1	Only in the boiler room
2	Recovery of steam condensate	Natural gas / Industrial water	-	-	-	-	Impossible to estimate quantitatively
3	Periodical checking and repair of steam trap	Natural gas / Industrial water	-	-	-	-	Impossible to estimate quantitatively
4	Lowering pressure of compressed air for instruments	Electric power	-	-	-	-	Impossible to estimate quantitatively
5	Repair of compressed air leaking parts	Electric power	-	-	-	-	Impossible to estimate quantitatively
6	Improvement of lighting	Electric power	-	-	-	-	Impossible to estimate quantitatively

(e) Audit Findings

As a result of the energy audit, the energy conservation potential by implementing the recommended measures is estimated to be 0.6 % of the whole energy consumption as shown in the following table. However these measures are limited only to the boiler room, and these were items not able to be estimated quantitatively. Therefore, it is expected that the potential of further energy saving would be larger than this value.

As for electric power, there were no items that were able to be quantitatively estimated. However, it is expected that there are several areas where energy saving potential throughout the whole factory can be realized by promoting energy saving activities including the production facilities.

Table 5- 44 Energy Saving Potential by Recommended Measures

Energy	Annual Consumption (in 2011)	Annual Reduction Quantity / Reduction Rate		Annual Reduction Amount	Invest-ment	Payback Period	Remark
		Nm3 or kWh	%	RO	RO	Year	
Natural gas	7,400,151 Nm3	46,700 Nm3	0.6	957	2,000	2.1	Unit price of natural gas: 0.0205 RO/Nm3
Electric power	33,125,345 kWh	-	-	-	-	-	Unit price of power (ave.): 0.016RO/kWh

(3) Glass Factory C

(a) The Factory Outline

The factory is in an industrial area and produces glass bottles via a foaming process using compressed air at 8 production lines, and the annual production is 57,750 tons.

(b) Energy Consumption Situations

The energy sources which are consumed in this factory are electric power and natural gas. The electric power is used at the production facilities, air compressors, chillers, lightings, etc. and natural gas is used for melting raw glass. Those for each annual consumption are shown below.

Table 5- 45 Annual Energy Consumption

Year	Electric Power kWh	Natural Gas Nm3
2010	29,654,475	19,556,989
2011	28,430,836	18,646,399

In addition, about 30 % of the electric power is consumed at air compressors for the glass foaming process and instrumentation. Each capacity of these air compressors is as follows;

- Air compressors for glass foaming
  - Ingersol Rand turbo compressor 350 kW×3
  - Atlas Copco turbo compressor 500 kW×2
  - Ingersol Rand screw compressor 90 kW×2

- Air compressors for instrumentation
  - Ingersol Rand screw compressor　110 kW×2

The following figures show the trend of the monthly consumption of electric power and natural gas.

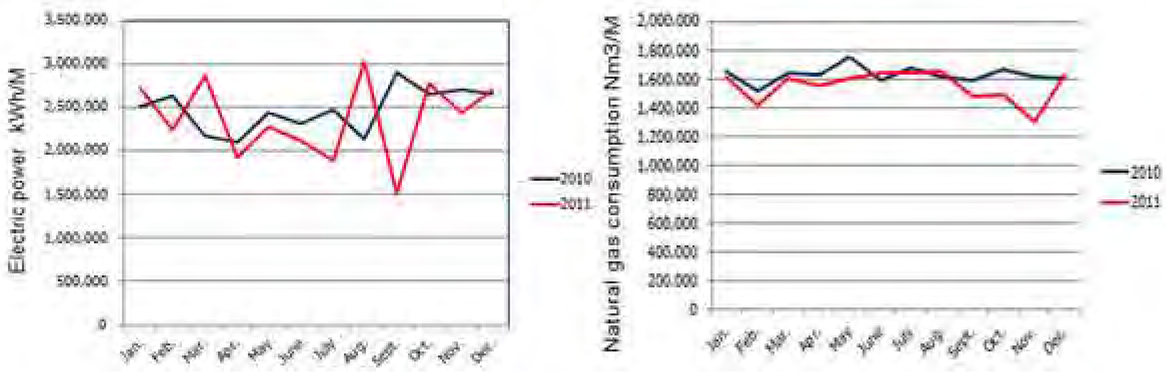


Figure 5- 48 Trend Chart of Monthly Consumption of Power and Natural Gas

(c) Results of Analyzing Power Consumption Pattern at Major Facilities

Continuous measurements were carried out using a data logger with the current sensors and a pressure sensor for all of the air compressors shown in the following schematic flow chart of the compressed air system.

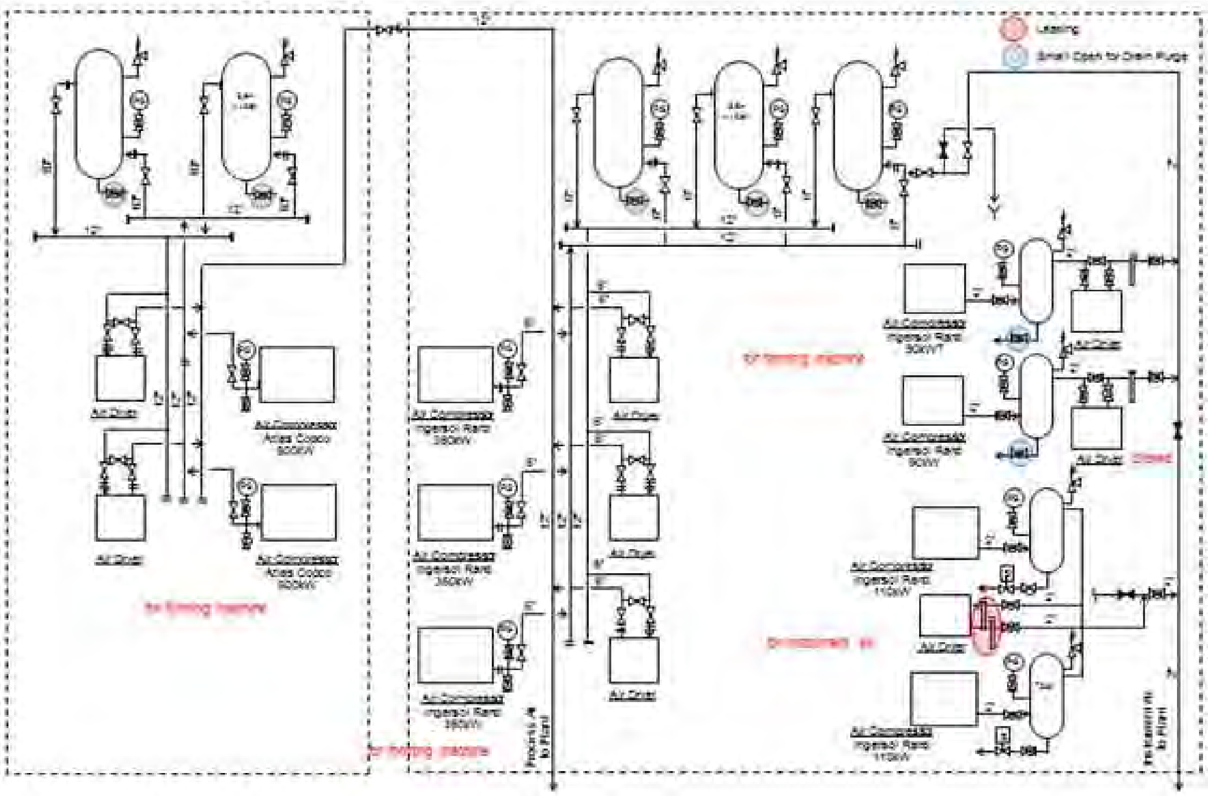


Figure 5- 49 Flow Chart of Compressed Air System

The measurement results are shown in the figures below.

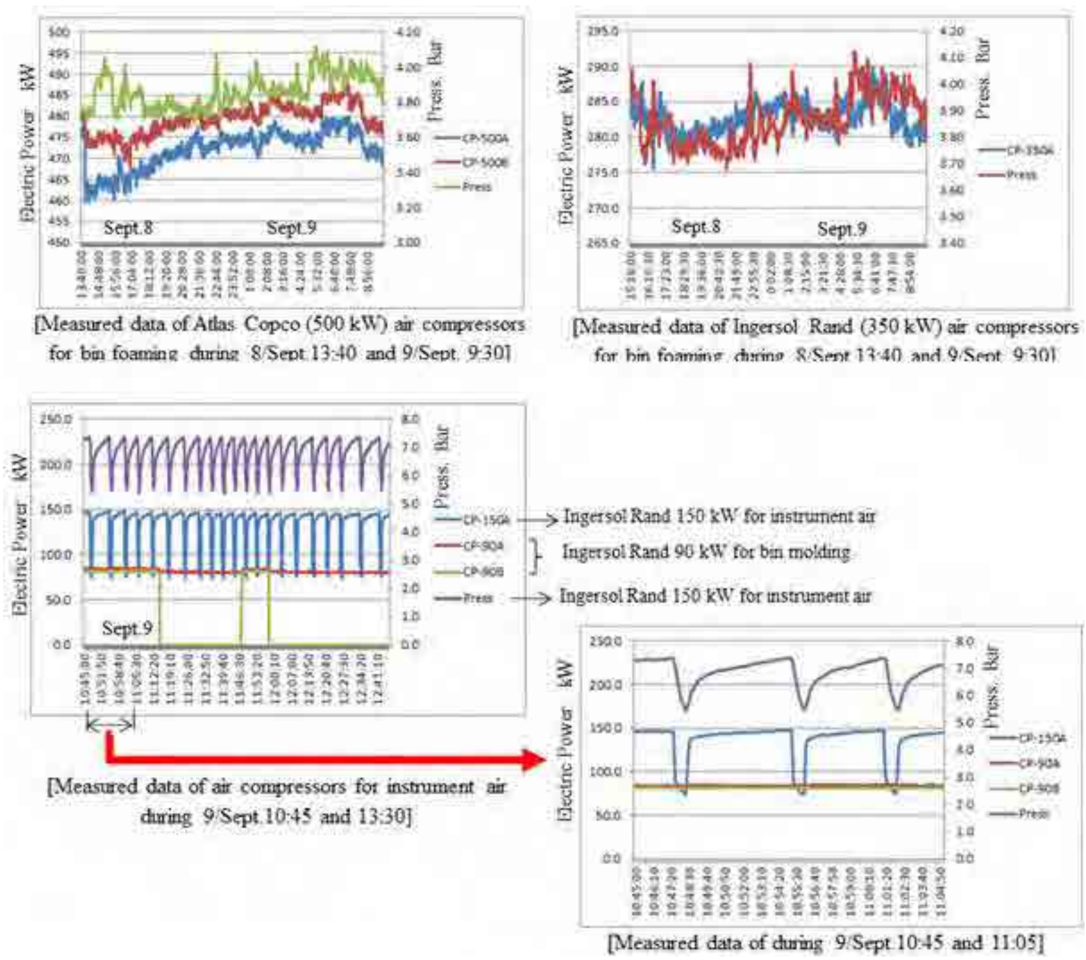


Figure 5- 50 Measurement Result of Operation Condition of 3 Air Compressors (Electric Power and Air Pressure)

Based on the results of analyzing the gathered data, the operating conditions and improvements are as follows;

- Depending on the operation conditions of the production facilities, the compressed air for the glass foaming is adjusted by changing the operation number of the air compressors. If the pressure becomes too high, the pressure is controlled by the spill-back. The pressure of the compressed air fluctuated within the range of 3.7 ~ 4.1 Bar (standard of operation pressure: 3.6 ~ 4.1 Bar). Therefore, the following energy conservation measures would be considered.
  - The average air pressure is higher than the required pressure (3.5 Bar) because of the current pressure control system, and the higher pressure requires much larger power consumption. So the remodeling of the pressure control system for maintaining constant pressure causes the corresponding reduction of the electric power consumption. The discharge air pressure of the 0.5Bar reduction allows for approximately 4 % power saving of the compressor.

- In the case of exceeding the upper limit of the pressure (4.1 Bar), the pressure is adjusted per the spill-back and it causes a loss of electric power correspondingly. Therefore, a considerable amount of electric power consumption would be reduced by introducing the inverter air compressors and improving the pressure control system.

- One air compressor is operated out of the two compressors for the instrumentation, and repeats the load and unload operations. In addition, the compressed air pressure range is 5.5 ~ 7.0 Bar.

(d) Applicable Energy Saving Measures

Based on the results of the energy audit, the recommendations on the applicable energy saving measures are shown below.

Table 5- 46 Recommended Measures for Energy Saving

No.	Item	Energy	Quantity of Reduction		Invest-ment	Payback Period	Remark
			MWh/y	RO	RO	Year	
1	Improvement of the compressed air system for glass foaming	Electric power	880	14,100	400,000	28	It would be better to examine the remodeling at the time of replacing them due to being worn-out because of the long payback period.
2	Repair of compressed air leaking parts	Electric power	31	500	0	0-	Investment is not considered due to maintenance.
3	Installation of air trap	Electric power	-	-	-	-	Impossible to estimate quantitatively
4	Improvement of lighting system	Electric power	-	-	-	-	Impossible to estimate quantitatively

(e) Audit Findings

As a result of the energy audit, the energy saving potential of electric power by implementing the recommended measures is estimated to be at about 3.2 % for the whole energy consumption as shown in the table below.

Table 5- 47 Energy Saving Potential by Recommended Measures

Energy	Annual Consumption (in 2011)	Annual Reduction Quantity / Reduction Rate		Annual Reduction Amount	Invest-ment	Payback period	Remark
		kWh	%	RO	RO	Year	
Electric power	28,430 MWh	911	3.2	14,600	400,000	27	Unit price of power: 0.016 RO/kWh

Although the aforementioned energy saving potential is smaller than expected, it is possible to find out more if a detailed energy audit is conducted.

As for the item "Improvement of compressed air system for glass foaming", which is the largest item, it would be realistic to implement the recommended measures at the timing of the future replacement of the air compressors due to its deterioration, because the payback period of 28 years seems too long based on the current cheap electric power price (0.016 RO/kWh).

(4) Shopping Mall A

(a) Summary of the Facility

This large scale shopping mall in Muscat was originally opened in October 2001, and extensions were carried out in the east and west wings in 2007. There are 2 floors above grade, with interior car parks on the 1^{st} and 2^{nd} floors, electric rooms and chiller plant rooms are housed in outbuildings.

The mall houses about 150 small retails stores and a large scale supermarket, as well as a food court. The daily hours of business are 10 AM till 10 PM, except for Fridays and Saturday when the store is closed.

The shopping mall has a chiller plant for the air conditioning system that consumes high levels of electricity. This system is composed of 850 USRT turbo chiller units (5 units in total) with secondary chilled water pump systems; one to supply the supermarket and one for the other areas.

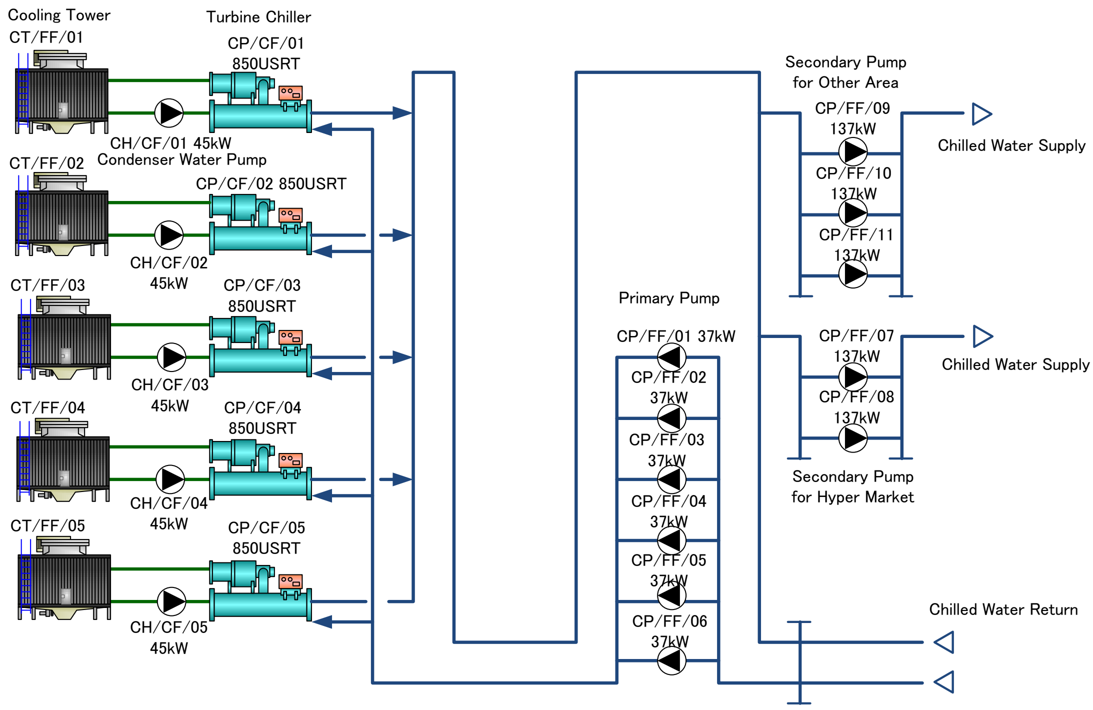
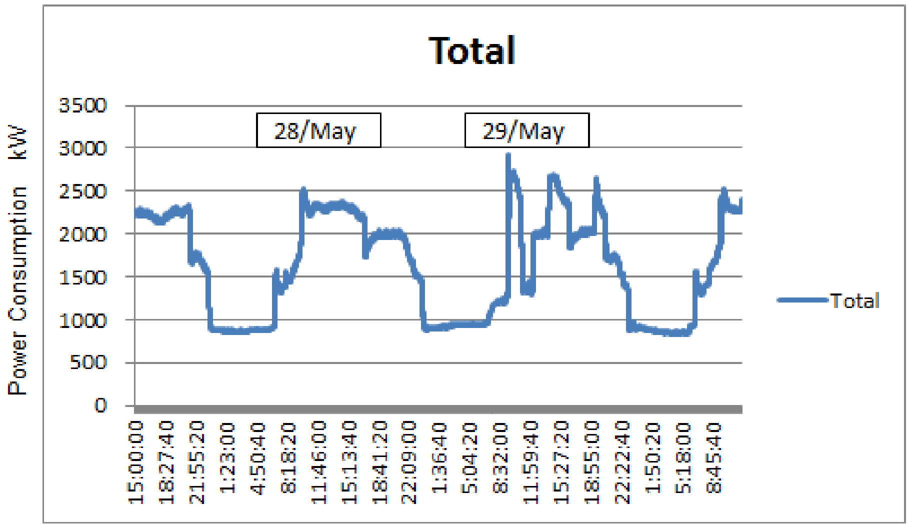


Figure 5- 51 Chiller Plant Diagram

(b) Analysis Results of Power Consumption Patterns for Main Equipment

The electrical energy for the sub transformers for the chiller system (5 systems) was measured at 10 second intervals. The results are shown in the graph below. The 850 USRT chiller power is 600 kW, and a total of 3 units (1 unit for TR1, 2 units for TR2) are in operation during business hours. Additionally, during the nighttime there is a base electrical power of approximately 1,000 kW, of which the chillers consume about 400 kW, and the remainder is taken up by TR4 and TR5 pumps and power for lighting.



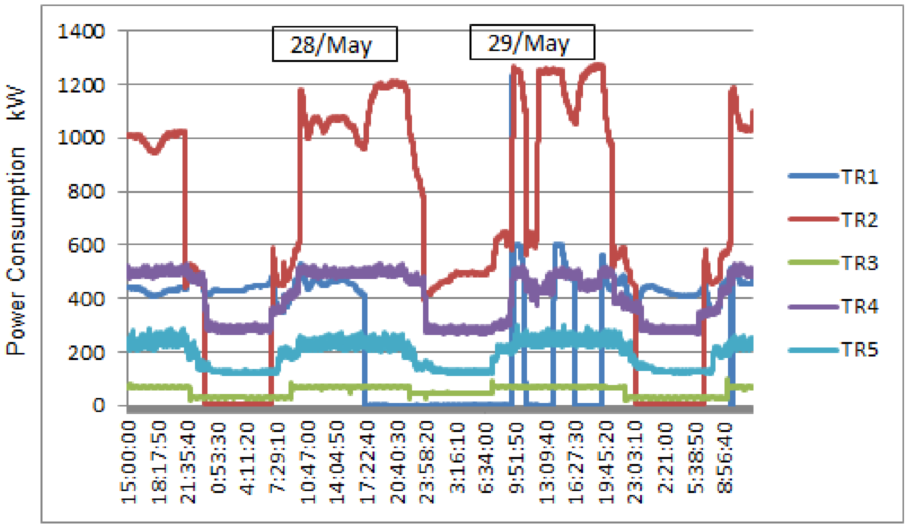


Figure 5- 52 Results of Chiller System Power Measurements

The graph below shows the power consumption for each TR at different times between May 27th 15:00 hours and May 29th 12:00 hours in 2012. On the 28th, the power consumption was 25,200 kWh. Only 1 chiller unit was in continuous operation overnight to reduce the cooling load for the start of business.

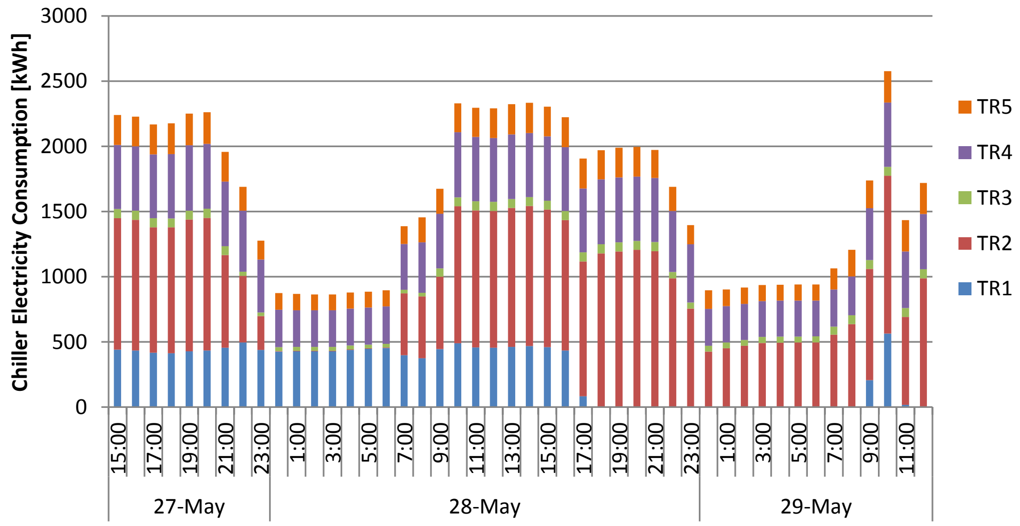


Figure 5- 53 Chiller Power Consumption at Different Times

(c) Applicable Energy Saving Measures

The results of the energy audit and proposals for applicable energy saving measures are shown below.

Table 5- 48 Applicable Energy Saving Measures

Item	Energy Saving Measures	Annual Reduction		Initial Investment (reference)	Investment Recovery Period (reference)	Remarks
		kWh	RO	RO	Year	
Chiller	Increase chilled water temperature in winter from (6->9°C)	103,900	2,078	None	None	Calculated based on estimated chiller power consumption
	Introduce VWV (Variable Water Volume) system (low load measure)	Insufficient info.				
	Introduce inverter turbo chiller	1,849,800	39,996	1,600,000	43	Calculated based on estimated chiller power consumption renewal of existing chillers are planned
	Introduce inverter control system for chilled water pumps	Insufficient info.				
AHU	Introduce CO_2 control system to reduce volume of fresh air intake (AH/R/09 Main mall grid)	Insufficient info.				
Lighting	Replace lights with LED units	104,200	2,084	101,000	48.5	

Note: Electrical power cost is 0.02 RO/kWh.

(d) Audit Findings

Based on the audit, the following observations were pointed out.

- Based on the power consumption measurements of the main equipment such as the turbo chillers and related pumps, we confirmed that 3 units are in operation during business hours, and the operating load factor of 1 chiller was over 80 %. This shows that for the cooling demand, the number of units in operation is appropriate and the load factor is high.

- Outside of business hours (during the night), power consumption was a little under 1,000 kW with 1 chiller unit and pump being in operation, and we believe that energy can be saved during the night by restricting the cooled area and relaxing temperature settings.
- Of the proposed energy saving measures, replacing chillers with highly efficient inverter turbo chillers（about a 25 ％ reduction in power consumption）offer the most benefits. Existing chillers would be replaced one at a time during the renewal period.
- Additionally, existing chillers temperature settings can be eased from 7°C to 9°C during the winter from December to February when the outside air temperature is lower to achieve about a 7 % reduction in power consumption. Replacing the existing fluorescent lights in the common areas in the shopping mall and passages with LED lights could achieve about a 35 % reduction in power consumption.

(5) Hotel B

(a) Summary of Facility

This large hotel is situated looking out over the sea, and has 280 guest rooms and large conference halls and banqueting halls. It was completed 15 years ago.

The hotel has a chiller plant for the air conditioning system that consumes high levels of electrical power. To prevent low performance during the day when solar and outside air temperatures are high, there is also an air intake cooler for the chiller based on the on-site drip type with large fans, as well as sunshades for the inlets. A steam boiler is installed as a heat source to supply steam for the hot water tank and laundry. In addition, there are 38 AHUs and about 780 fan coil units installed throughout the building.

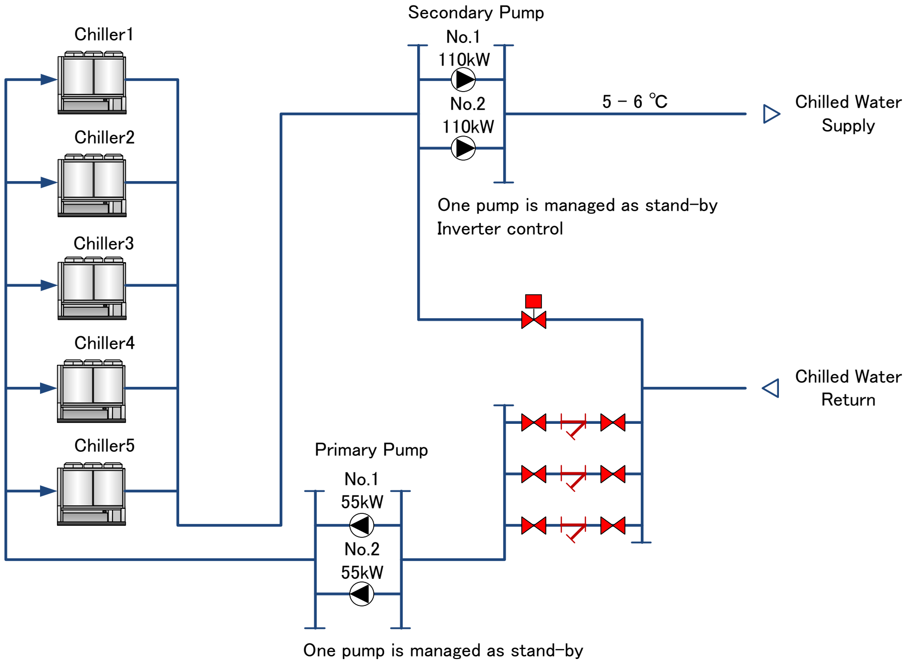


Figure 5- 54 Heat Source System Diagram

(b) Results of Analysis of Power Consumption Patterns for the Main Equipment

Power consumption for the chiller system sub transformer (5 systems) was measured every 10 seconds and the results are shown in the following figure. On June 3rd, peak power exceeded 1,600 kW during the daytime as well as at night. The evening peak can be explained by the banqueting hall being open for business. Additionally, we confirmed that the chillers were running regardless of whether it was day or night, consuming about 800 kW at night.

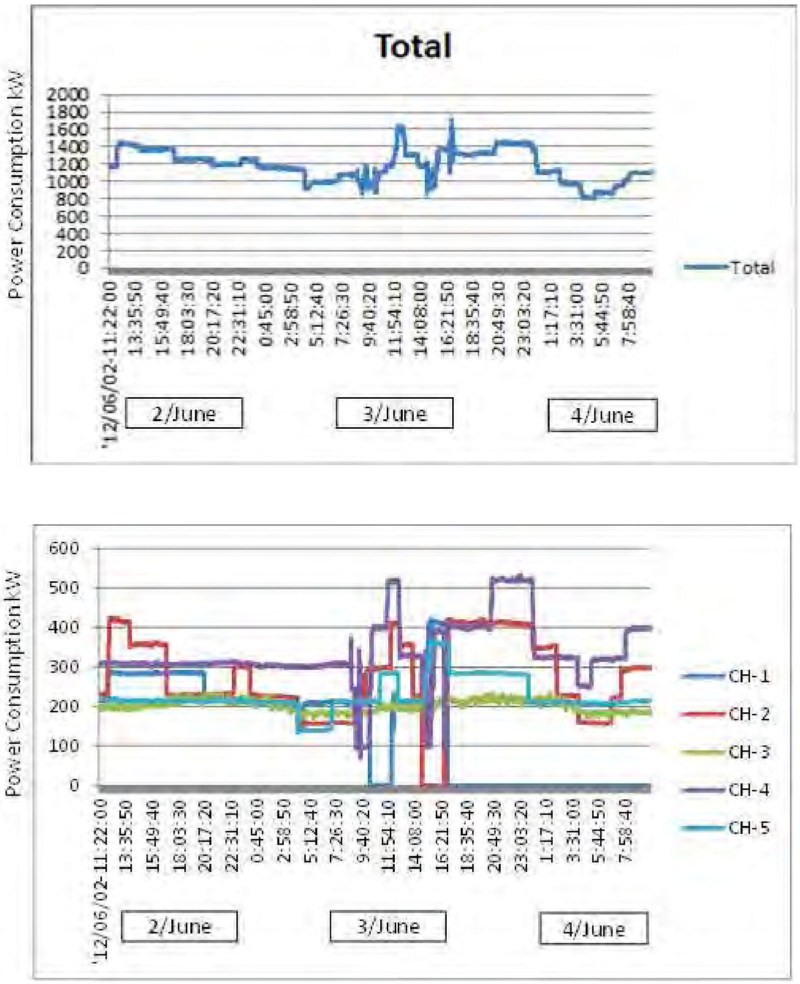


Figure 5- 55 Chiller System Power Consumption

The following chart shows the hourly power consumption on between June 2nd 12:00 and 4th 9:00 hours in 2012. The daily power consumption on June 3rd was 29,000 kWh. At night 3 to 4 units consume power and there is a little difference between the daytime and nighttime peaks and the power consumption trends are flat.

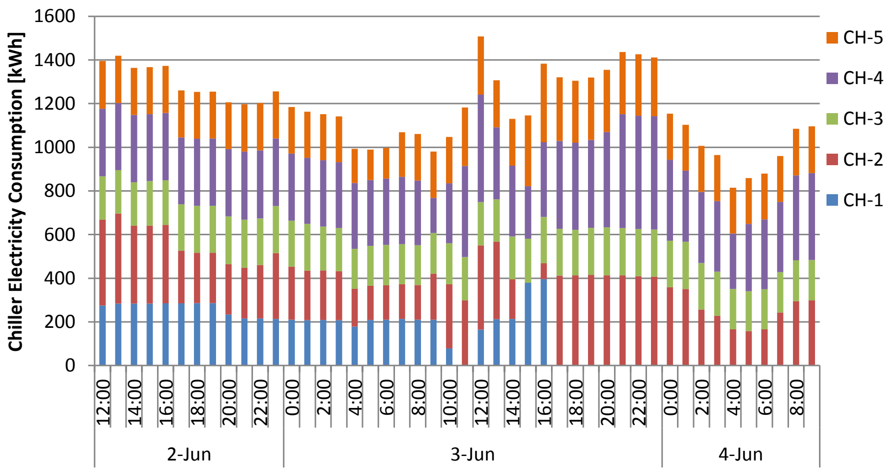


Figure 5- 56 Hourly Power Consumption of Chiller System

(c) Applicable Energy Saving Measures

Results of the energy audit and applicable energy saving measures are proposed below.

Table 5- 49 Hotel B - Proposals for Energy Saving Measures

Items	Energy Saving Measures	Annual Reduction		Initial Investment (reference)	Investment Recovery Period (reference)	Remarks
		kWh	RO	RO	Year	
Chiller	Increased chilled water temperature in winter (6->9°C)	232,000	1,160	None	None	Calculated based on estimated chiller power consumption
	Introduce VWV (Variable Water Volume) system (low load measure)	Insufficient Info.		32,500		
	Replace air cooled chiller with water cooled chiller (COP improvement)	Insufficient Info.		Insufficient Info.		
	Introduction of CO_2 control system for banquet hall	25,400	508	11,250	22	Calculated based on estimated chiller power consumption
AHU	Introduction of variable air flow system for the lobby (to reduce air flow at night)	52,000	102	6,250	6	Calculated based on estimated chiller power consumption
Steam System	Insulate un-insulated valves	880 kg-LPG		150		
	Routine inspection of steam trap	-	-	-		
	Install replacement highly efficient boiler		-	-		Boiler efficiency Min.5% up

Note: Electrical power cost is 0.02 RO/kWh

(d) Audit Findings

The following observations were pointed out during the audit.

- Based on the air cooled chiller and the related pump power consumption, regardless of whether it was day or night 4 to 5 chiller units were in operation, with a low operating load factor especially when 5 units were in operation. Introducing a chiller quantity control system to select the appropriate number of chiller units for the chilled water demand would be effective.
- As an energy saving measure, relaxing the chilled water temperature settings on the air cooled chiller (from 7°C to 9°C) should be a priority to reduce power consumption by about 7 %.
- Regarding the air conditioners, the lobby system is in operation 24 hours a day, and the banquet hall system is in operation for about 4 hours on most days. This simple energy saving measure would be effective for air conditioners with high operating rates.
- The introduction of variable air supply volume controls for the lobby area, and fresh air intake control based on the CO_2 density detection for the banquet hall would be effective energy saving measures.

5.4.3 Results of Power Consumption Measurement

(1) PAEW Office

(a) Summary of Facility

The PAEW office is located in a multi-tenant building and normally about 15-20 employees work in an office space of 350 m^2.

All air conditioning is provided by packaged units, with outside units installed in a central location on the roof. These packaged units are separate packaged units with one indoor unit per outdoor unit and a non-inverter specification. Regarding the power utility contract in Oman each tenant has a separate contract with the electrical power distributor. It is expected that there will be many packaged air conditioners in use for which power consumption can be clearly billed.

Table 5- 50 PAEW Office Summary

Occupied Floor		3^{rd} floor
Occupied Area		350 m^2
No. of Personnel		30
Distribution Boards		2 for lighting & power receptacle 2 for air conditioner on the roof
Lighting	Fixtures	600 square base lighting, Fluorescent lamp 3,800 lm/Fixture, 130 W/Fixture, 29 lm/W
	Lighting Levels	Desk: 500-700 lx, Corridor: 300-400 lx
Air Conditioning		9 package air conditioners, non-inverter type

Office

Outside units on rooftop

Figure 5- 57 Office

(b) Power Consumption Analysis

(i) Measurement Points

The measured area is separated into the Entrance (ENT) and Extension (EXT) for billing purposes, and based on the wiring of the 1^{st} floor substation the measurement points are:

ENT: Total of 3 points including air conditioning, lighting, power outlets;

EXT: 1 measurement point.

Office layouts and measurement points are shown below.

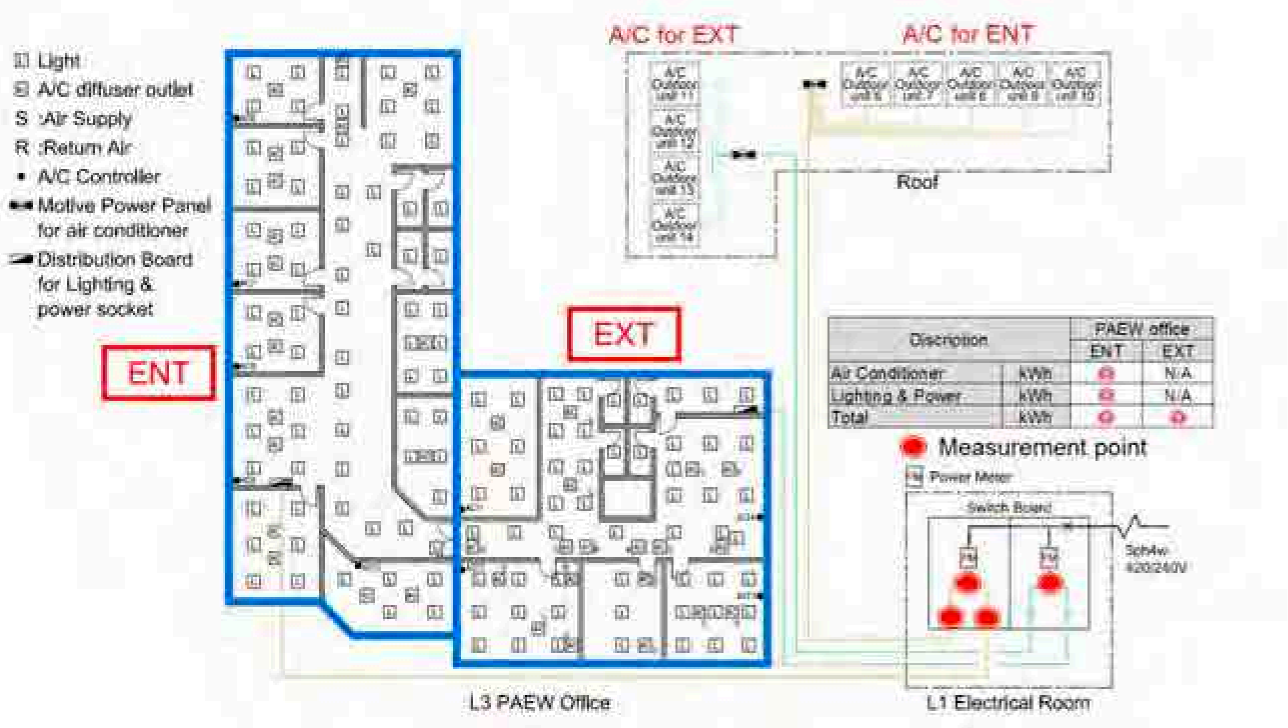


Figure 5- 58 Office Layout and Measurement Points

(ii) Results of Power Consumption Measurement

The power consumption measurements were carried out for 2 weeks roughly between May 20th (Sun) and June 4th (Mon) in 2012. By taking two separate measurements in the ENT area for the air conditioning system and lighting/power outlet systems, it was possible to calculate the breakdown of load power usage. The results were air conditioning 69 %, lighting and power outlets 31% and it was clear that air conditioning accounts for a large proportion.

Additionally, the result of the calculation of lighting power consumption in the ENT area, lighting accounted for 819 kWh (= 0.13 kWh x 70 fixtures x 10 hours x 12 days x 0.75 (demand factor of lighting: 75 %)), and it is assumed that there will be a breakdown of load power consumption for lighting: power outlet should be 2:1.

Therefore, a full breakdown of load power consumption should be air conditioning 69%, lighting 20 % and power outlets 11 %.

Table 5- 51 Results of Power Consumption Measurement

Discription			PAEW office			
			ENT (May 20 - June 4)		EXT (May 20 - May 27)	
Power consumption	Air Conditioner	kWh	2843	69%	N/A	N/A
	Lighting & Power	kWh	1248	31%	N/A	N/A
	Total	kWh	4091	100%	1262	100%
	Grand Total	kWh	5354			

The next graph shows the daily electrical power consumption. The total power consumption on weekdays was roughly from 450 kW/day to 500 kW/day. The PAEW staff are off work on Thursdays and Fridays, however, even on these days there is some power consumption. This is due to some staff working overtime on holidays or construction work being carried out.

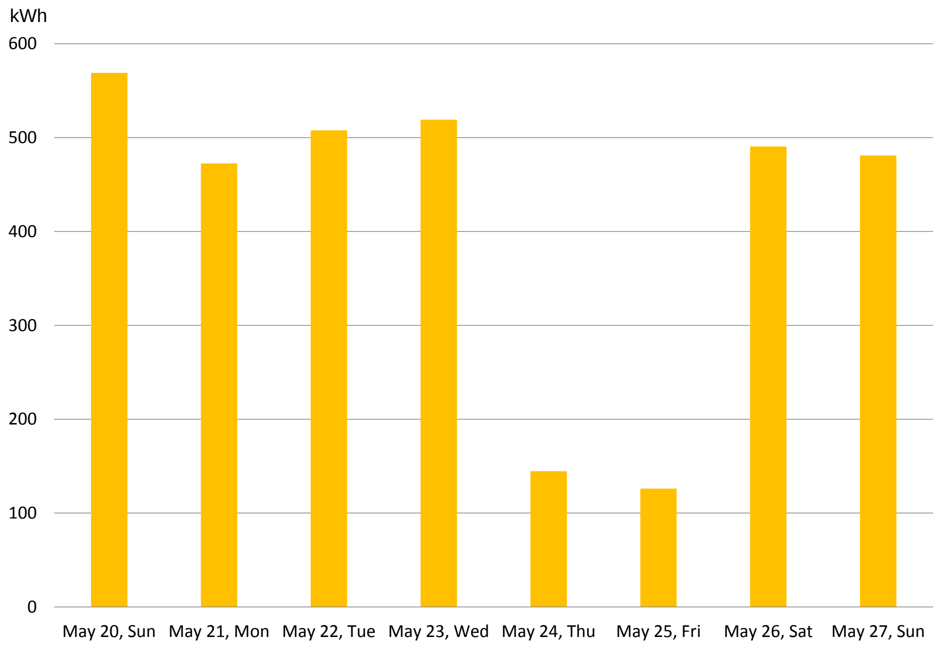


Figure 5- 59 Daily Power Consumption

Additionally the hourly power consumption from May 21st (Mon) to May 25th (Fri) in 2012 is shown below. It was also apparent that there were electrical loads late at night on May 21st and 24th. There is the possibility that air conditioning was unintentionally left running continuously throughout the night of the 24th till the following morning.

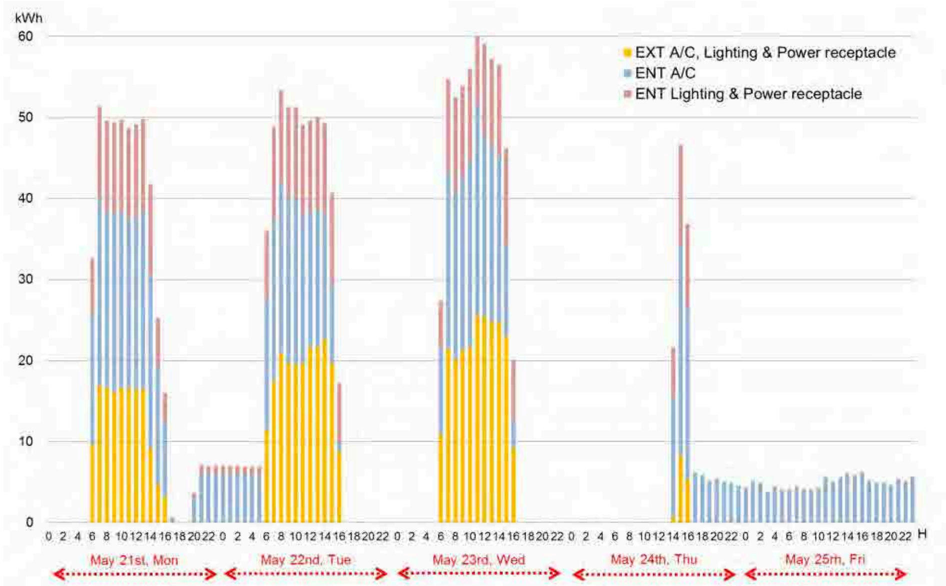


Figure 5- 60 Hourly Power Consumption

(iii) Lighting Measurement

Lighting in offices and corridors are provided by fluorescent light fixtures with aluminium louvers with average lighting levels of 500-700 lx at desktop height, and corridor lighting was about 300-400 lx. This is a high lighting level compared to the JIS lighting standards.

Furthermore, based on the light flux and power consumption of the lighting fixtures, it was clear that one fluorescent light delivers 29 lm/W, which is low compared to the highly efficient fluorescent lights used in Japan which deliver 100 lm/W.

(2) Residence A

(a) Basic Information

Residence A is situated in Muscat and has a floor space of about 300 m^2 and is occupied by a family of six. The following table shows the basic information.

Figure 5- 61 Residence A

Table 5- 52 Basic Information on Residence A

Address	Boucher
No of Families	1
No of Persons	6
Housing	2 Stories House Reinforced concrete without insulation Single Window Glass
Total Floor Area	300m2
No of Distribution Board	2 (for each floors)
No of Rooms	4 Bed Rooms 3 Living Rooms 1 Kitchen
Electric Appliance	9 Air Conditioners, setting temperature 16°C 8 Water Heaters 1 Refrigerators 2 TV Sets

(b) Analysis of Power Consumption

Power consumption was measured over a 2 week period from May 21st (Monday) to June 4th (Monday) in 2012. The total power consumption over the 2 week period was 1,640 kWh. Looking at the daily power consumption, the minimum power consumption was 80 kW/day while the maximum was 140 kW/day, varying on a day-to-day basis.

Furthermore, looking at days when power consumption was high, it is apparent that the peaks in power usage occur late at night. The family generally spends time in the living room until late in the evening, and it appears that the cause of this late night peak is due to members of the family returning to their bedrooms to retire for the night and switching on the air conditioners in several rooms at once.

However, a temperature logger was installed in the living room to measure the indoor temperature, and although the temperature setting was at 16°C, the actual temperature in the room was between 30°C to 35°C. We believe that either the packaged air conditioner unit is underperforming which would account for the failure to respond to the temperature settings.

The graphs below show the relationship between power consumption on days when it was high and indoor and outside temperatures during the period when measurements were carried out, as well as daily power consumption.

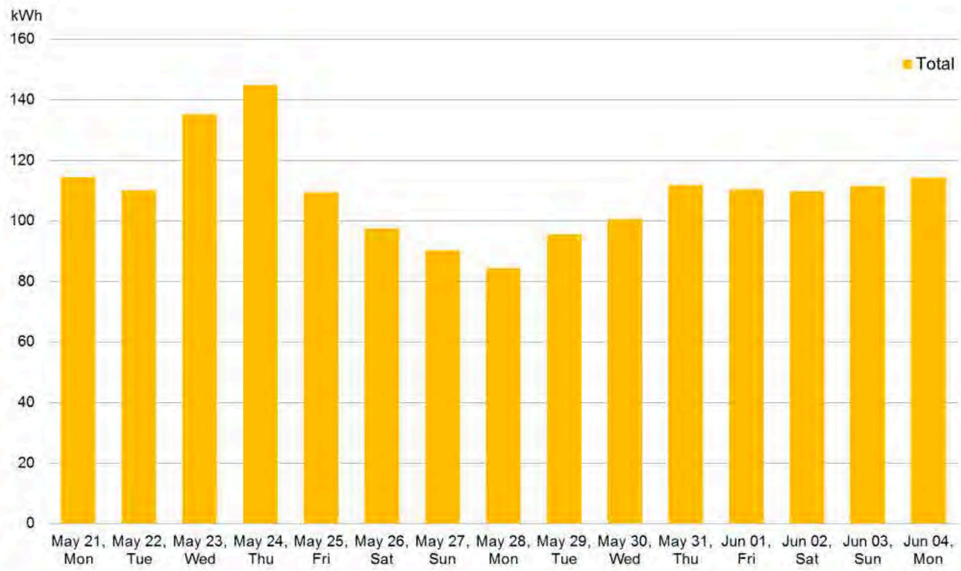


Figure 5- 62 Residence A Daily Power Consumption

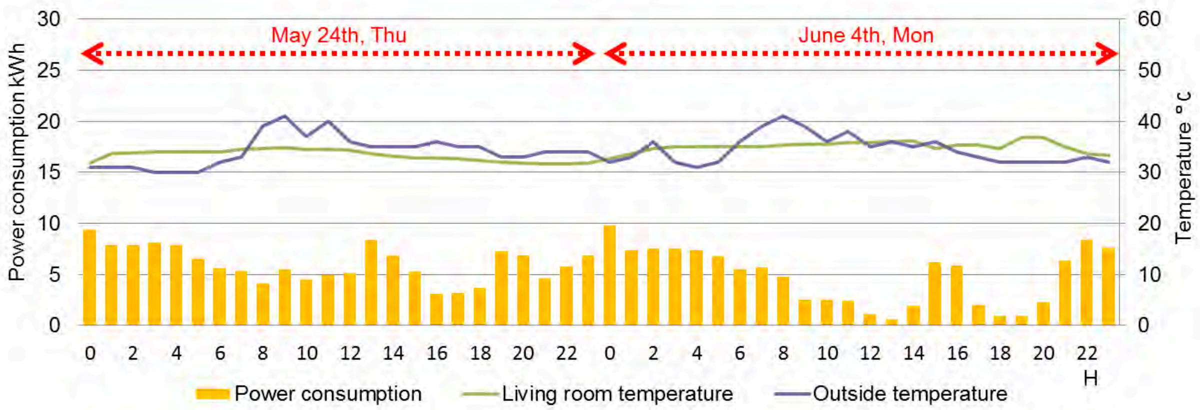


Figure 5- 63 Residence A Power Consumption at Different Times, Relationship between Inside and Outside Air Temperatures

(3) Residence B

(a) Basic Information

Residence B is situated in Muscat and has a floor space of 600 m^2 occupied by 3 families, a total of 1 person. The basic information is as follows.

Figure 5- 64 Residence B

Table 5- 53 Basic Information on Residence B

Address	Ghvbra
No of Families	3
No of Persons	14
Housing	3 Stories House Reinforced concrete without insulation Double Window Glass
Total Floor Area	600m2
No of Distribution Board	4 (for each floors, penthouse and kitchen)
No of Rooms	19 Bed Rooms 1 Living Rooms 2 Kitchens
Electric Appliance	12 Air Conditioners, setting temperature 16-18°C 10 Water Heaters 7 Refrigerators 4 TV Sets

(b) Analysis of Power Consumption

Power consumption was measured over a period of 2 weeks from May 21st (Monday) to June 4th (Monday) in 2012. The amount of power used over this 2 week period was 6,746 kWh. Looking at the daily power consumption, the minimum power consumption was 350 kW/day while the maximum was 500 kW/day, varying on a day-to-day basis.

Furthermore, looking at days when power consumption is high, it is apparent that peaks in power usage occur during the day and late at night. Residence B has a large number of occupants so there is a peak during the day. Additionally, the family generally spends time in the living room until late in the evening, and it appears that the cause of this late night peak is due to members of the family returning to their bedrooms to retire for the night and switching on the air conditioners in several rooms at once. Looking at the relationship between power consumption and temperatures, variations in power consumption are generally in proportion to outside air temperatures, and based on this the packaged air conditioners have a considerable impact on total power consumption.

However, temperature loggers were installed in the living rooms to measure the indoor temperature, and although the temperature was set at 16°C to 18°C, the actual temperature in the room was about 30°C. We believe that the packaged air conditioner unit is underperforming which would account for the failure to respond to the temperature setting.

The graphs below shows the relationship between power consumption on days when it was high and indoor and outside temperatures during the period when measurements were carried out, as well as daily power consumption.

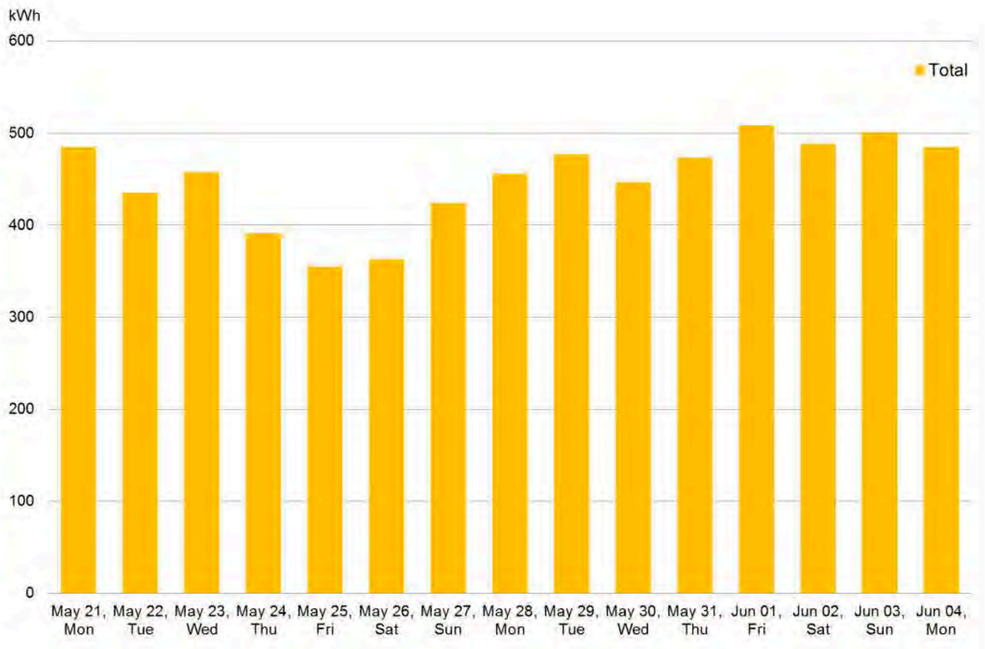


Figure 5- 65 Residence B Daily Power Consumption

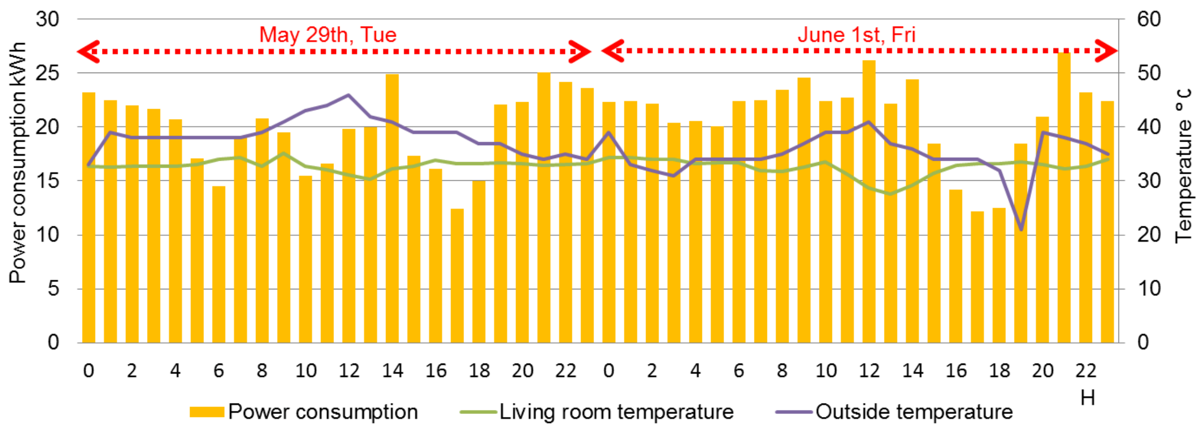


Figure 5- 66 Residence B Power Consumption at Different Times, Relationship between Inside and Outside Air Temperatures

(4) Residence C

(a) Basic Information

Residence C is situated in Muscat, and has a total floor space of 300 m^2 occupied by a family of 11. The basic information is as follows.

Figure 5- 67 Residence C

Table 5- 54 Basic information on Residence C

Address	Alaathiba
No. of Families	1
No. of Persons	11
Housing	3 Stories House Reinforced concrete without insulation Single Window Glass
Total Floor Area	300m2
No of Distribution Board	3 (for each floors)
No. of Rooms	10 Bed Rooms 2 Living Rooms 1 Kitchen
Electric Appliance	13 Air Conditioners, Setting temperature at daytime: 17ºC, at nighttime: 18-19ºC 11 Water Heaters 4 Refrigerators 2 TV Sets

(b) Analysis of Power Consumption

Power consumption was measured over a 2 week period from May 21st (Mon) to June 4th (Mon) in 2012. The total power consumption over the 2 week period was 2,376 kWh. Looking at the daily power consumption, minimum power consumption was 120 kW/day while the maximum was 170 kW/day, varying on a day-to-day basis.

Furthermore, looking at days when power consumption was high, it is apparent that the peaks in power usage usually occur late at night. As with Residences A and B, the family generally spends time in the living room until late in the evening, and it appears that the cause of this late night peak is due to members of the family returning to their bedrooms to retire for the night and switching on the air conditioners in several rooms at once.

However, a temperature logger was installed in the living room to measure the indoor temperature. The temperature setting was between 16°C to 19°C and the actual temperature in the room was between 26°C to 30°C, which was a better response to the temperature settings than at the other residences.

The graphs below show the relationship between power consumption on days when it was high and indoor and outside temperatures during the period when measurements were carried out, as well as daily power consumption.

The graphs below show the relationship between power consumption on days when it was high and indoor and outside temperatures during the period when measurements were carried out, as well as daily power consumption.

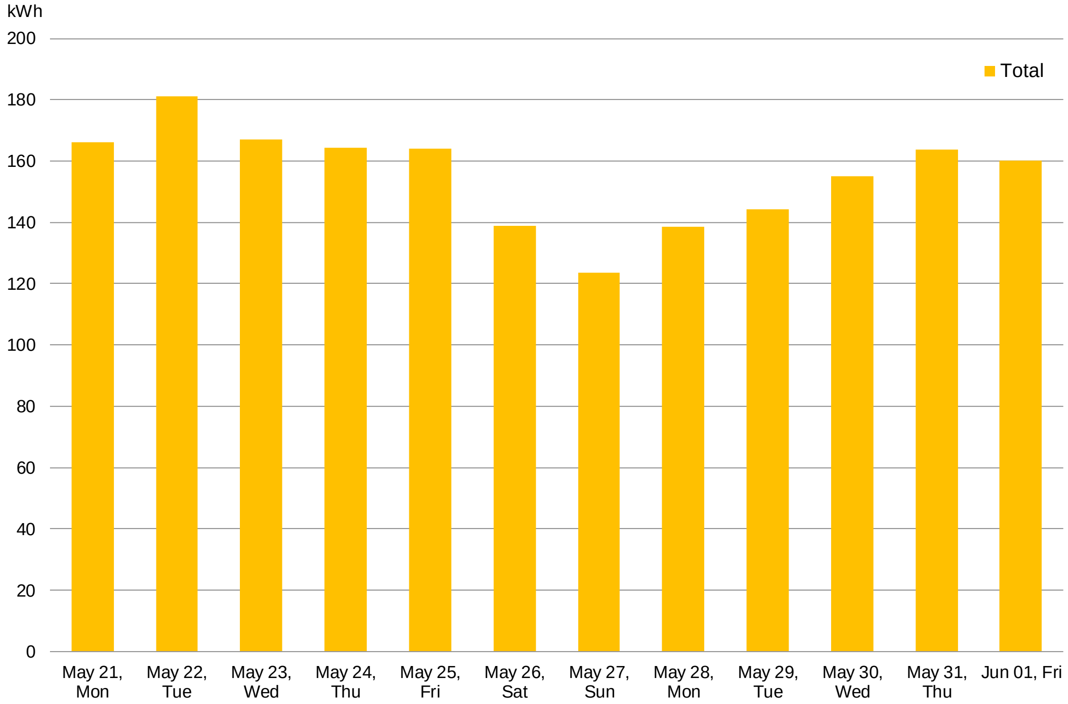


Figure 5- 68 Residence C Daily Power Consumption

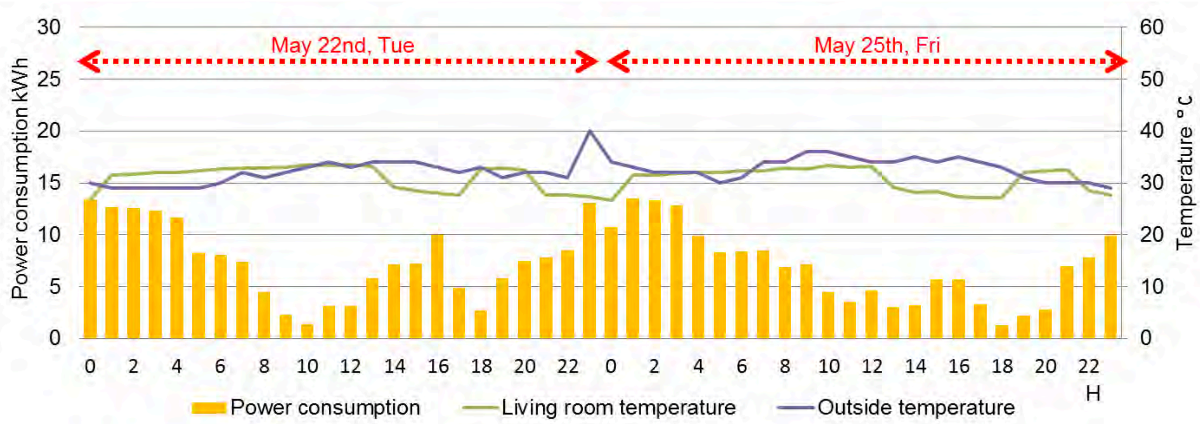


Figure 5- 69 Residence C Power Consumption at Different Times, Relationship between Inside and Outside Air Temperatures

(c) Electric Power Consumption Measurements in the Cold Season

In order to make a hot/cold season comparison of electric power consumption, power consumption at Residence C was measured in the cold season from December 3rd to 8th in 2012. The following figures show the measurement results compared with the ones in the hot season.

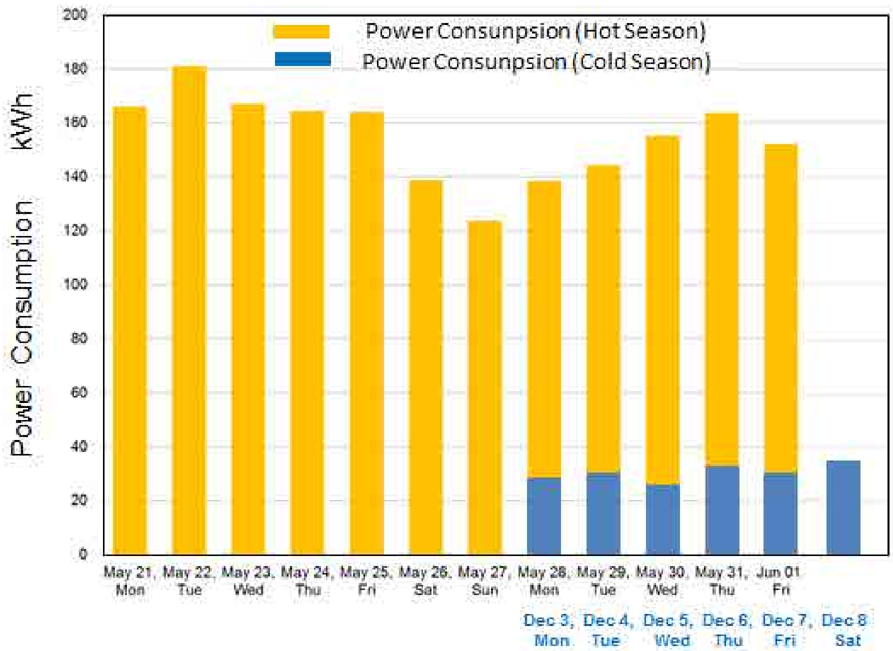


Figure 5- 70 Daily Power Consumption in the Hot Season and the Cold Season at Residence C

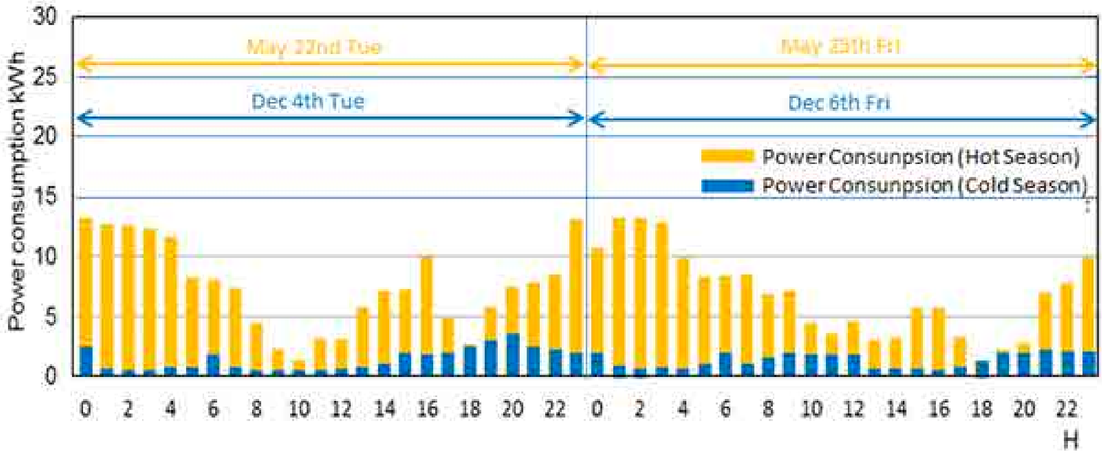


Figure 5- 71 Hourly Power Consumption in the Hot Season and the Cold Season at Residence C

A comparison of the power consumption in the hot season and cold season showed that the amount in the cold season is only about 20 % of the hot season. The difference in electric power consumption between the hot season and the cold season is mainly due to air conditioning usage, and in the case of Residence C, it is estimated that around 80 % of electric power is used for air conditioning in the hot season.

(5) Summary of Measurement Results at Residences

(a) Comparison with Residences in Japan

By reviewing the results of measurements at Residences A, B and C, a comparison with a typical residence in Japan was carried out. Regarding the average power consumption for August, in Oman it is about 10 times that of a household unit in Japan. However, the total floor spaces of residences are different so it is not easy to make an evaluation. Therefore, other comparisons, the monthly power consumption for the equivalent floor space and for an individual person was also made. Still it was found that power consumption in Oman was very high at 4 times that of a typical case in Japan.

Table 5- 55 Summary of Measurement Results

Description			Residence				
			In Oman				In Japan
			A	B	C	Average in Oman	Average in Japan
Information	Total floor area	m2	300	600	300	400	94.13
	Family		1	3	1	1.7	1
	Person	No	6	14	11	10.3	2.42
Power consumption	Total (A&B:15 days, C:12 days)	kWh	1640	6746	1867	3418	N/A
	Daily	kWh/D	109	450	124	228	13
	Monthly	kWh/M	3280	13492	3733	6835	410
	Monthly per floor area	kWh/M/m2	11	22	12	17	4
	Monthly per person	kWh/M/P	547	964	339	661	169
	Monthly per family	kWh/M/F	3280	4497	3733	4101	410

(Source: Ministry of Internal Affairs and Communications for data in Japan)

(b) Breakdown of Power Consumption by Usage

During this survey, we carried out interviews regarding several rooms within the residences, a rundown of electrical appliances and running times. Based on this and data from power measurements, power consumption was categorized according to use as shown below (total power used by air conditioning was calculated by deducting the assumed power consumption of other appliances based on operating conditions, from the total consumption).

This result showed that the amount of power used for air conditioning accounted for an average of 71 % which is considerably large.

Table 5- 56 Breakdown of Power Consumption by Usage

Description			Residence							
			A		B		C		Average	
Power consumption	Total of 15 days	kWh	1640		6746		1867		3418	
	Lighting	kWh	144	9%	396	6%	115.2	6%	218.4	6%
	Power Receptacle	kWh	144	9%	396	6%	115.2	6%	218.4	6%
	Refrigerator	kWh	126	8%	882	13%	401	21%	469.7	14%
	TV sets	kWh	72	4%	144	2%	62	3%	92.67	3%
	Air Conditioner	kWh	1154	70%	4928	73%	1173	63%	2418	71%

Lighting= (rooms numbers & kitchen numbers)* 100W* 12hours* 15days
Power Receptacle= (rooms numbers & kitchen numbers)* 100W* 12hours* 15days
Refrigerator= numbers* 350W *24hours *15days
TV sets= numbers* 200W *12hours *15days
Air Coditioner= Total - above
For residence C, 1st floor is vacancy, it is calculated that number of bed rooms are half of the table

5.4.4 Results of Experimental Survey on Energy Saving

(1) PAEW Office

(a) Changes in Power Consumption with Temperatures set at 22℃, 24℃, 26℃

(i) Measurement and Survey Points

During the period from May 28th (Monday) to May 30th (Wednesday) in 2012, tests were carried out targeting the EXT area. The EXT area air conditioning is composed of a total of 4 packaged units numbered from AC11 to AC14. In addition to measuring the power consumption of each outside unit, temperature loggers were installed in each area to measure the indoor temperatures. The areas and points where measurements were carried out are shown below.

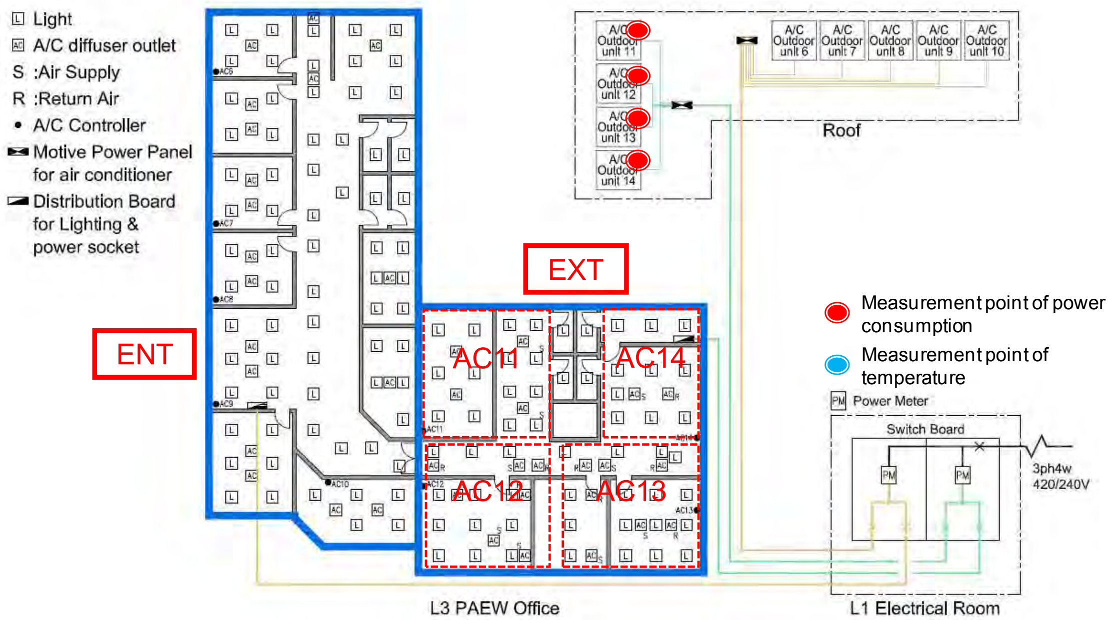


Figure 5- 72 Measurement Points

(ii) Survey Results

The results of measuring the power consumption while changing the indoor temperature settings each day from 22°C, 24°C and 26°C showed that each time there was a 2°C increase, power consumption was reduced by an average of 20 %. Based on this, for each 1 degree increase in the temperature setting between 22°C to 26°C, power consumption could be reduced by an average of 10 %. It was found that except in the case of AC12, the indoor temperatures accurately reflected the temperature settings. However, regarding AC12 and AC13, based on the above measurement points, the air conditioning zoning should be modified to match the existing partitioning of the office space in order to achieve power consumption reductions.

The results of the power consumption measurements based on set temperature checks, the power consumption temperature settings for each air conditioner, the inside and outside temperatures are shown below.

Table 5- 57 Results of Power Consumption Measurement based on Set Temperature Checks

Description				PAEW office air conditioner									Outside temp
				AC12		AC13		AC14		AC11		Ave	
Power consumption (kWh)	May 28th	Mon	Set Temp 22°C	27.0	100%	43.0	100%	19.8	100%	33.7	100%	100%	38°C
6am - 4pm	May 29th	Tue	Set Temp 24°C	21.1	78%	26.8	62%	21.7	110%	23.3	69%	80%	41°C
	May 30th	Wed	Set Temp 26°C	17.6	65%	11.9	28%	16.6	84%	14.1	42%	54%	37°C

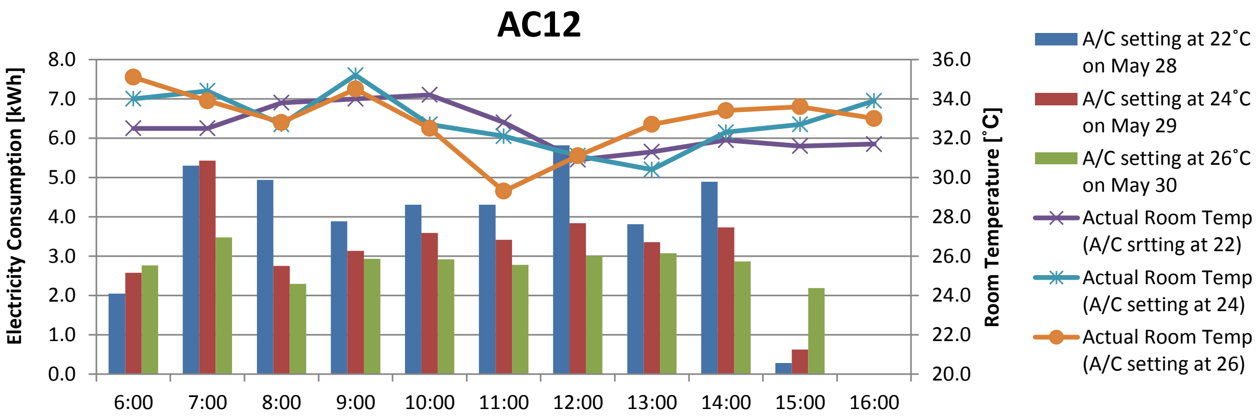


Figure 5- 73 AC12 Power Consumption at Different Times, Relationship between Inside and Outside Air Temperatures

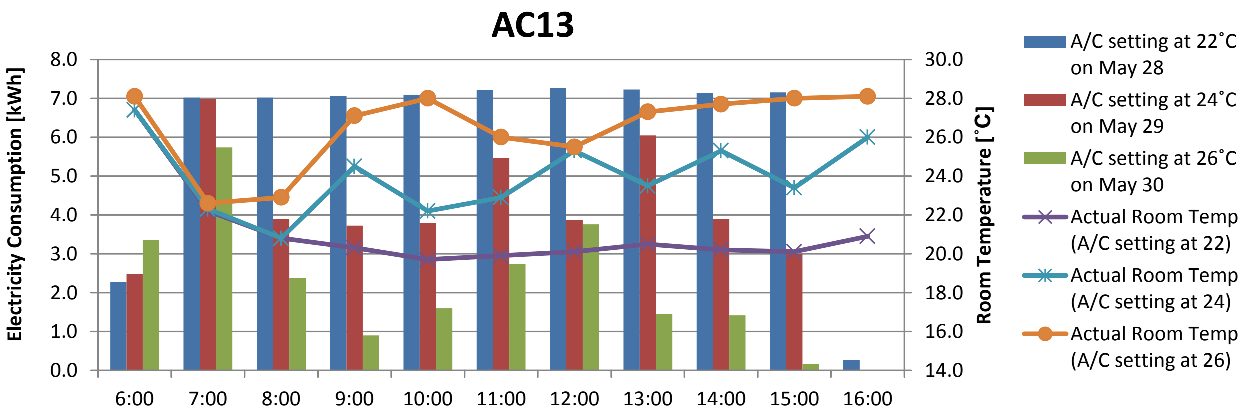


Figure 5- 74 AC13 Power Consumption at Different Times, Relationship between Inside and Outside Air Temperatures

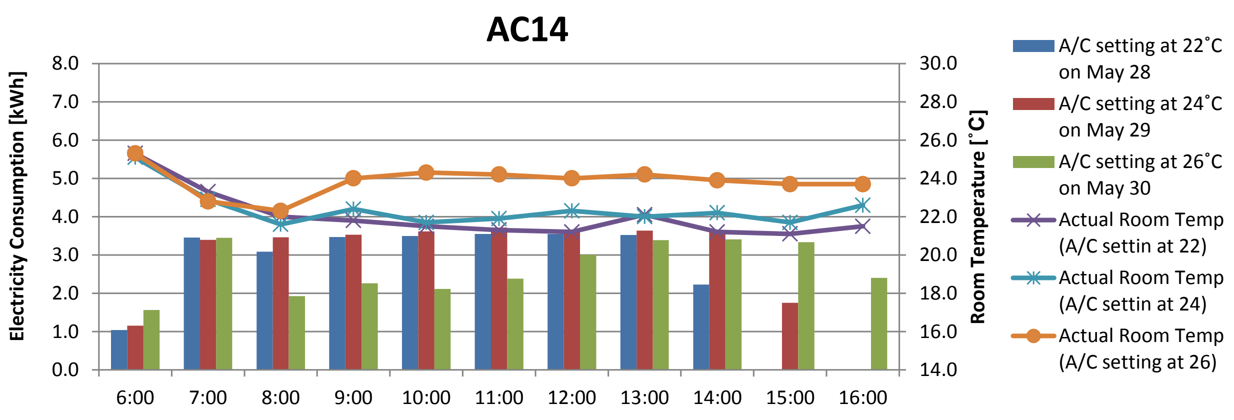


Figure 5- 75 AC14 Power Consumption at Different Times, Relationship between Inside and Outside Air Temperatures

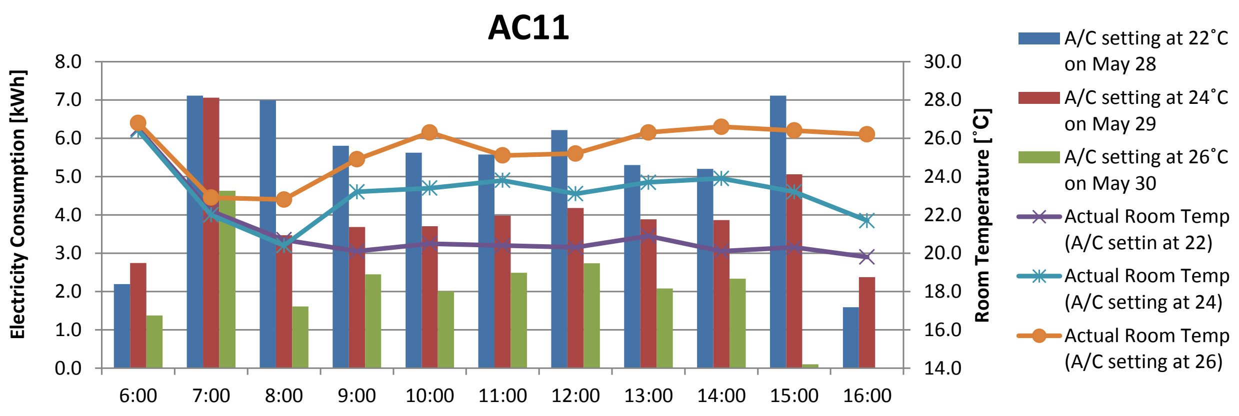


Figure 5- 76 AC11 Power Consumption at Different Times, Relationship between Inside and Outside Air Temperatures

(iii) Views of Occupants on the Temperature Settings and Comfort Levels

The results of the interviews with the occupants regarding their views on the above survey based on changes to temperature settings are shown below.

The general opinion was that it is comfortable up to a setting of 24°C.

Table 5- 58 Views of Occupants on Surveys

Days	Description		Male1	Male2	Female1	Female2
May 28th	Air Conditioner	Set Temperature: 22 °C	1	2	1	1
May 29th	Air Conditioner	Set Temperature: 24 °C	2	1	1	2
May 30th	Air Conditioner	Set Temperature: 26 °C	4	3	3	3

1. Large improvement 2. OK 3. Some discomfort 4. Intolerable

(b) Changes in Power Consumption when Corridor Lighting Levels are Reduced from 400 lx to 200 lx.

(i) Survey Results

On June 5 (Tuesday) 2012, a survey was carried out to confirm power consumption changes by dropping the corridor lighting (fluorescent) levels from 400 lx to 200 lx. The results showed that halving lighting levels achieved a 30 % power consumption reduction.

In Japan, the design lighting level for corridors is from 100 lx to 200 lx.

Table 5- 59 Power Consumption based on Changes in Lighting Levels

Description				PAEW office lighting		
				Total	Ave	
Power consumption (kWh) 9:00 - 14:00	May 20th	Sun	Corridor Illuminance: 400lx	68.2	68.6	100%
	May 21st	Mon		68.1		
	May 22nd	Tue		67.9		
	May 23rd	Wed		67.7		
	May 26th	Sat		68.2		
	May 27th	Sun		81.2		
	May 28th	Mon		66.6		
	May 29th	Tue		68.6		
	May 30th	Wed		68.1		
	June 2nd	Sat		67.3		
	June 3rd	Sun		65.1		
	June 4th	Mon		66.8		
	June 5th	Tue	Corridor Illuminance: 200lx	47.8	47.8	70%

(ii) Views of the Occupants on the Lighting Levels and Comfort Levels

The results of interviews with the occupants regarding their views on the above survey based on changes in lighting levels are shown below. Generally no-one raised any issues.

Table 5- 60 Views of Occupants on the Survey

Days	Description		Male1	Male2	Female1	Female2
June 5th	Lighting	Corridor IL luminance	N/A	2	1	2

1. Large improvement 2. OK 3. Some discomfort 4. Intolerable

(c) Summary

The results of the tests on easily implementable energy saving measures at the office confirmed that occupants could tolerate 24°C Office temperature settings. In this case there was a 20 % power consumption decrease to the 22°C setting. Additionally, air conditioning accounted for 69 % of the power consumption for the PAEW Office which results in an overall reduction of 14 %.

With regards to lighting, halving the 400 lx lighting levels reduced the lighting power consumption by 30 %. It can be assumed that lighting accounts for 20 % of the PAEW Office power consumption which results in an overall reduction of 6 %.

(2) Residences

(a) Changes in Power Consumption due to Energy Saving Activities

(i) Experimental Survey Procedure

From June 2nd (Sat) to June 4th (Mon) in 2012 occupants at Residences A, B and C were asked to carry out energy saving activities and the resulting changes in power consumption were checked. The measures were divided into air conditioning, lighting and television, and the occupants were asked to do the items on the following checklist.

Table 5- 61 Energy Saving Checklist

EE&C Activities		June 2nd	June 3rd	June 4th	Notes
Air-Conditioner	Turn off units in unused rooms				
	Close doors of rooms where the air-conditioner is in operation				
	Set temperatures at higher than usual levels				
Lighting	Turn off lights in unused rooms				
	Turn off lights in rooms with sufficient daylight				
Television	Turn off when not in use				
	Use energy saving mode				
Other	Switch off receptacle of electric appliances which are not in use				

(ii) Survey Results

Although occupants were asked to carry out the energy saving activities, in actuality they were only implemented at Residence B. The results of a power consumption analysis conducted during the energy saving survey showed that 4 % reductions were achieved at Residence B.

However, at Residences A and C, power consumption actually increased, in result of interviews conducted with Residence A and Residence B, it is thought that because the school summer holidays began on June 1st in 2012, the time spent by children at home during the day increased resulting in an increase in air conditioner usage and power consumption.

Table 5- 62 Result of Energy Saving due to Energy Saving Activities

Discription			Residence						Temp
			A		B		C		
June 1st	Not EE&C	kWh	110.4	0.0%	508.3	0.0%	160.0	0.0%	36°C
June 2nd	EE&C Activity	kWh	109.8	-0.5%	488.5	-3.9%	170.6	6.6%	38°C
June 3rd	EE&C Activity	kWh	111.5	1.0%	501.3	-1.4%	167.7	4.8%	38°C
June 4th	EE&C Activity	kWh	114.2	3.4%	484.7	-4.6%	171.3	7.1%	36°C

Table 5- 63 Residence B Energy Saving Activities

EE&C Activities		June 2nd	June 3rd	June 4th	Notes
Air-Conditioner	Turn off units in unused rooms	X	X	X	
	Close doors of rooms where the air-conditioner is in operation				
	Set temperatures at higher than usual levels	X	X	X	Usual: 16-18ºC
Lighting	Turn off lights in unused rooms	X	X	X	
	Turn off lights in rooms with sufficient daylight	X		X	
Television	Turn off when not in use	X		X	
	Use energy saving mode	X	X	X	
Other	Switch off receptacle of electric appliances which are not in use	X	X	X	Reduction of standby power consumption

(b) Changes in Power Consumption due to Installation of the Monitor which Shows a Visual Representation of Power Consumption and Implementation of Energy Saving Measures

(i) Survey Procedure

From August 27th (Mon) to September 8th in 2012, (Sat) power consumption was measured at Residence C and a monitor was installed from September 3rd (Mon) to September 8th (Sat) in 2012. The occupants were asked to carry out energy saving measures during that period and a survey was carried out to determine the results of the promotion of energy saving measures based on visual information. The monitor was installed in the living room where the family usually gathered. The visualization system and the screen are shown below.

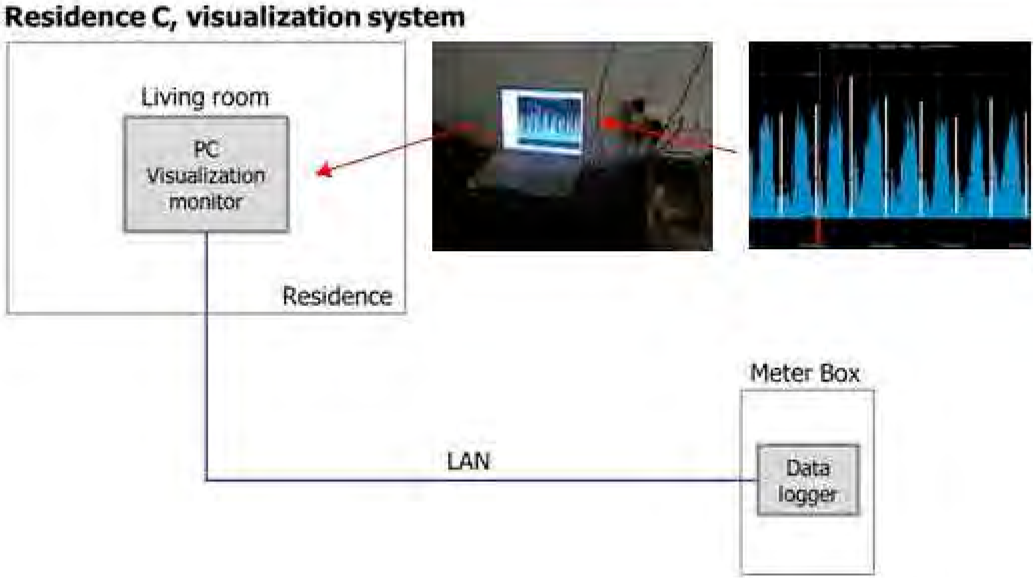


Figure 5- 77 Visualisation System Installed in Residence C

(ii) Survey Results

During the period when simple power consumption measurements were carried out with a visualization system installed to actively promote energy saving measures, calculations of power consumption at Residence C showed that although air temperatures were higher, a 9 % reduction in power consumption could be realised. The energy saving results and the details of the measures taken are shown below.

Table 5- 64 Measurement Results at Residence C

Event	Date		Power consumption (kWh)					Max Temp (°C)
			Total/day	Total/6days		Ave/6days		
Without visualization & EE&C activity	27	Mon	115.9	868.9		144.8		33
	28	Tue	168.2					33
	29	Wed	147.3					33
	30	Thu	142.2					32
	31	Fri	155.9					33
	1	Sat	139.3		-9%		-9%	34
With visualization & EE&C activity	3	Mon	125.2	788.0		131.3		33
	4	Tue	128.1					34
	5	Wed	128.6					34
	6	Thu	148.8					34
	7	Fri	140.7					39
	8	Sat	116.5					39

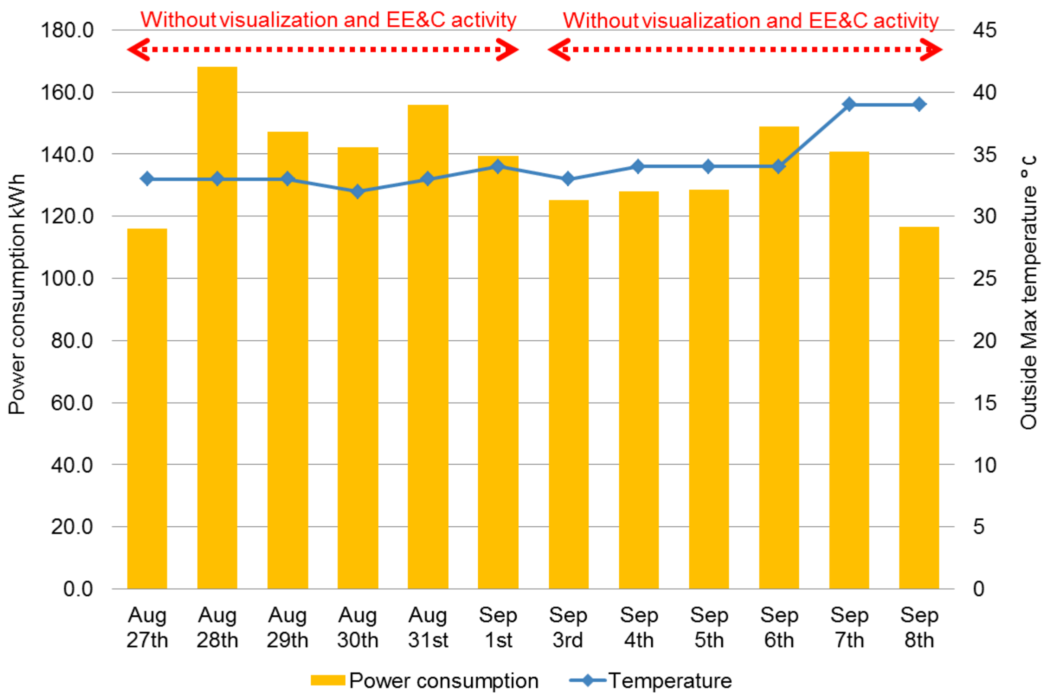


Figure 5- 78 Measurement Results for Residence C

Table 5- 65 Energy Saving Measures Taken at Residence C

EE&C Activities		June 2nd	June 3rd	June 4th	Notes
Air-Conditioner	Turn off units in unused rooms	X	X	X	
	Close doors of rooms where the air-conditioner is in operation				
	Set temperatures at higher than usual levels	X	X	X	Usual: 16-18°C
Lighting	Turn off lights in unused rooms	X	X	X	
	Turn off lights in rooms with sufficient daylight	X		X	
Television	Turn off when not in use	X		X	
	Use energy saving mode	X	X	X	
Other	Switch off receptacle of electric appliances which are not in use	X	X	X	Reduction of standby power consumption

(c) Summary

Based on the above experimental survey results, energy savings of 4 % were achieved by just asking occupants to carry out measures, but with the visualisation system installed to further promote energy saving, then the results were 9 %.

In this case the occupants were enthusiastic about the survey and cooperated. This was the main reason why energy saving was effective. Therefore, it is unlikely that the results of this survey can be applied across the entire residential sector.

However, based on these surveys, with the active development of a public awareness program, a 4 % energy saving potential can be achieved, and furthermore, with a visual breakdown of power consumption a further 5 % energy saving potential can be achieved.

The promotion of a public awareness program to increase the number of residences with similar levels of interest with those at the survey site, effectively combined with power consumption visualisation systems should be the future target to achieve the improved development of effective energy saving.

Table 5- 66 Effects of Visualisation on EE&C Activities

Requesting EE&C Activities with Visualization	9 % Saving
Requesting EE&C Activities Actions without Visualization	4 % Saving
Contribution of Visualization	5 % Saving

5.5 Potential Survey on Automatic Control System of Electric Appliances

Based on the previous micro analysis of the power consumption, the energy saving potential was sorted out using the following technologies which presume that the energy saving effect per automation is large.

(Residential Use)

- Inverter air conditioners
- Home Energy Management System (HEMS)

(Large Building Use)

- Control the number of heat source units for air conditioning
- Variable Air Volume (VAV) control
- CO_2 density control
- Occupancy sensor control for lighting
- Hf inverter lighting

5.5.1 Automatic Control Systems for Residence

(1) Inverter Air Conditioners

(a) Current Situation of the Inverter Air Conditioner Technology

Based on the micro audit of the power consumption, it is clear that peaks in power demand occur from late at night through to the early hours of the morning. It seems that one reason is the inability to adjust air conditioner power consumption, in spite of the fact that outside air temperatures drop during the hours of sleep and that there is a reduction in cooling loads. In the case of inverter air conditioners, when the cooling load drops, they automatically operate at lower speeds and reduce power consumption. It is expected that the diffusion of this technology throughout Oman would result in a major contribution to energy saving.

All air conditioning units in Omani residences are packaged units, and most of these are non-inverter models. These non-inverter air conditioner units consume considerably more power than inverter units, and it has been demonstrated that large reductions in energy consumption can be achieved when manufacturers change their models from the non-inverter type to the inverter type. While switching to inverter air conditioners is an ideal energy saving approach for Oman, the fact is inverter air conditioners have not been successfully exploited and without sales they have failed to achieve any reasonable degree of market penetration..

However, from 2012, a Japanese manufacturer (Company A) began selling inverter air conditioners in the Middle East and Africa. Given that they have only been available for a short period and are expensive compared to non-inverter models, presently their trading activities has been restricted to only 3 % of the market. In the future, it can be expected to increase a diffusion of inverter air conditioner units via a decrease of their prices and the promotion of eco-friendly products.

(b) Inverter Air Conditioners Energy Saving Potential

The manufacturers of inverter air conditioners mention that they generally use 30 % less energy than non-inverter models. Regarding the inverter air conditioners developed by COMPANY A for areas like the Middle East where temperatures are very high, a fan needs to operate when the temperature exceeds a certain level in order to disperse the heat that collects in the outside unit's compressor. Considering the additional power required to operate this fan, we expect that the energy savings rate would be 20 % (compared to non-inverter units).

Based on a micro analysis of the power consumption mentioned in the previous section, it can be assumed that air conditioning accounts for 71 % of power consumption in residences. Based on these results it can be expected that the introduction of inverter air conditioners could achieve a 14 % reduction in total power consumption at residences.

Reduction in total power consumption in residences when inverter air conditioners are installed	**14%**

However, at major stores in Oman, the price difference between the inverter and non-inverter air conditioners manufactured by Company A is RO 75. So it would take 6.1 years to recover the initial investment based on an average 14% power consumption reduction at residences.

Average monthly power consumption at residences: 7,175 kWh/month*

Inverter air conditioner power consumption: 1,004 kWh/month (= 7,175 kWh x 14%).

Average residential electricity tariff: 15 Bz/kWh

Annual savings: 135 RO (= 1,004 kWh/month x 15 Bz/kWh x 9 months*)

Number years required to recover investment: 6.1 years (=75 RO x 11 ACs* / 135 RO)

* Using numerical values from the micro analysis of power consumption. Based on the premise that an average residence has 11 A/C units installed, operating 9 months a year.

(2) HEMS

Under the micro analysis of power consumption, promoting energy saving activities by installing a monitor showing a visual representation of energy saving effectiveness, it was possible to reduce the total power consumption at the residence by 9 %.

However, HEMS analyses power usage and learns the living patterns of occupants to carry out automatic controls to suit their lifestyle to achieve energy savings. The introduction of HEMS to automate energy saving activities should be at least as effective as the installation of visualization monitors to promote energy saving activities, offering a similar energy saving potential of about 9 % of total power consumption for residences.

Reduction in total power consumption at residences due to the installation of HEMS	**9%**

5.5.2 Automatic Control Systems for Building

(1) Control the Number of Heat Source Units for Air Conditioning

Based on the energy audit carried out at shopping centers and hotels, it was found that centralized heat source systems were installed and the air conditioning system was composed of several heat source units. It is believed that this type of system is widely used at shopping centres and hotels in other countries and it can be expected that similar systems are in use in Oman.

By controlling the number of units for air conditioning systems composed of several heat source installations means the automatic control to increase operating periods where equipment operates under the best conditions, where efficiency is close to the rated operations for the equipment, by sorting out heat source equipment based on the appropriate capacity and unit numbers and reducing the number of units in operation at low load times.

The micro analysis of power consumption confirms that, depending on the time of day, there are periods when the heat source equipment is at low load operations at both shopping centres and hotels. By introducing the control of the number of heat source units to improve operating efficiency, it should be possible to achieve a 10 % reduction in power consumed by heat source equipment.

Reductions in total power consumed by heat source equipment by controlling the number of heat source units	**10 %**

(2) Variable Air Volume (VAV) Control

In addition to the air conditioning heat source equipment, there are also the AHUs (Air Handling Units) supplying heating and cooling to each space. Based on a micro analysis of power consumption, it is proposed that VAV control technology can reduce the power consumption required for the AHU supply. This VAV control operates with temperature sensors and by providing variable control of the AHU supplied air flow, the power consumed by the fan can be reduced.

Based on the energy audit results for the hotel under the micro analysis of power consumption, it is expected that introducing a VAV control system for the AHU for the lobby system to reduce the air supply volume during the late night period can achieve 30% reductions in AHU power consumption, an effective energy saving technology for AHUs with variable loads.

Reductions in power consumed by AHUs using VAV control	**30 %**

(3) CO_2 Density Control

Generally, to maintain the proper indoor air CO_2 density and air purity, the AHU is equipped with functionality for fresh air intake. AHU fresh air intake is calculated based on the design level of the occupancy. However, spaces are not always occupied at full capacity and actual levels are often much lower. With automatic controls of CO_2, the indoor CO_2 density is measured and the fresh air intake volume can be automatically reduced when the rooms are below full capacity, in order to reduce cooling loads while still satisfying CO_2 density standards.

The micro analysis of power consumption showed that in shopping centres and hotels, the introduction of a CO_2 control system can achieve over 30 % reductions for the AHUs (that is a result based on the supposed fixed occupancy pattern for 1 day). Therefore, CO_2 density control is an effective energy saving technology for AHUs.

Reductions in power consumed by AHUs with CO2 density control	**30 %**

(4) Occupancy Sensor Control for Lighting

Given that there is a steady consumption of electrical power by the lighting systems throughout the year, the effectiveness of introducing lighting with occupancy sensors is considerable. The occupancy sensor control is not only for offices but can easily be installed in shopping centres, hotels and gardens.

Lighting with occupancy sensor controls can generally achieve 20 % reductions in lighting power. Based on a micro analysis, power consumption lighting at the PAEW office accounts for 20 % of total power consumption, therefore the introduction of occupancy sensors can achieve 4 % reductions in total power consumption for an office.

Reductions in total power consumed at an office by introducing occupancy sensor controls for lighting	**4 %**

However, where occupancy sensor control lighting at 12RO per unit is installed in the PAEW office, it takes 4.8 years to recover the initial investment.

PAEW office hourly power consumption: 52 kWh/hour*

PAEW office power consumption breakdown: air conditioning 69 %, lighting 20 %, power outlets 11 %*

PAEW office lighting hourly power consumption: 10 kWh/hour (=52 kWh x 20 %)

PAEW office lighting daily reduction in power consumption: 2 kWh/hour (=10 kWh x 20 %)

Annual reduction: 75 RO (= 2 kWh x 10 hours* x 250 days* x 15 Bz/kWh)

Cost recovery period: 4.8 years (=12 RO x 30 points* / 75 RO)

* Using numerical values based on the micro analysis of power consumption. Based on PAEW office business hours of 10 hours per day, 250 days per year and the installation of sensors installed in 30 locations.

(5) Hf Inverter Lighting

In Japan, Hf fluorescent lights are the main form of lighting, widely used to provide general illumination (uniform illumination of the entire space) with a high level of efficiency from 80 lm/W to 120 1m/W. Hf inverter lights have a built-in inverter controller which increases the frequency from 20 to 50 kHz which reduces flickering when the light is turned on and is also more efficient.

A micro analysis of power consumption revealed that lights in the PAEW office was at a low level of 29lm/W. Replacing this with Hf inverter lighting at 80 lm/W would achieve 63 % (= (80-29)/80) reductions in power consumed by lighting. Assuming that lighting accounts for 20 % of total power consumption in the PEAW office, we calculate that the introduction of Hf inverter lighting would achieve 12 % reductions in total power consumption for the office.

Reductions in total office power consumption with the introduction of Hf inverter lighting	**12 %**

Where the difference in price between the existing fluorescent light units and Hf inverter light units is RO 12, it would take 6.6 years to recover the additional investment.

PAEW office lighting hourly power consumption: 10 kWh/hour

Hourly reduction in power consumption with the introduction of Hf inverter lighting: 6 kWh/hour (=10 kWh x 63 %)

Annual reduction: 225 RO (= 6 kWh x 10 hours x 250 days x 15 Bz/kWh)

Cost recovery period: 6.6 years (=12 RO x 125 fixtures* / 225 RO)

* Using numerical values based on the micro audit of power consumption. Based on PAEW office business hours of 10 hours per day, 250 days per year and the replacement of light fixtures in 125 locations.

5.6 Energy Consumption Analysis by Site

5.6.1 Objectives and Targets of the Analysis

(1) Objectives

As described in Chapter One, an energy consumption analysis per site (energy user) aims to decide the targeted users for the Energy Management System (EMS). Although energy efficiency improvements have to be implemented by all kinds of energy users, however it is required that the number of targeted sites (energy consumption users) have to be selected in order that the EMS managing authorities have a high management and maintenance potential in consideration of their ability to handle costs, expenditures, the number of staff and budgets for the EMS.

In discussing the introduction of the EMS, it is usual to introduce the "threshold" based on the energy consumption of the sites (energy users).

After discussing the introduction of the EMS in Oman between C/P and the JICA Study Team, the JICA Study Team calculated, as a trial, the thresholds of power consumption of factories and the business and governmental buildings sampled by the distribution companies in Oman. The thresholds shown in this section are just referential in order that future EMS managing authorities decide their thresholds in Oman. When introducing thresholds for the EMS in Oman, the managing authorities should survey the power and energy consumption of the targeted sites (energy users) and decide the thresholds.

(2) Scope of the Analysis

The scope of the analysis is as follows;

- ✓ The energies consumed in the sites (energy users) consist of electric power and fuels. The EMS aims for basically energy efficiency improvements for all kinds of energy. Hence, the energy of thresholds target the summation of the power and the fuels after converting to primary energy.
- ✓ Three sectors, industry sector with factories, commercial sector with big buildings and government sector with their office buildings are targeted.
- ✓ There are many cases where countries before introducing EMS like Oman cannot prepare energy consumption data by sites (energy users). For calculating the energy consumption of both power and fuels by site (energy user), it is estimated using the power consumption data submitted by power companies and distribution companies.
- ✓ In the analysis, the thresholds are defined and the relative energy consumption is analyzed for industry (factories) and the commercial (business buildings) and government (office buildings) sectors.

5.6.2 Contents of the Analysis

(1) Power Consumption Data Collection by Site

(a) Required Data and the collection Results

For the data collection, the JICA Study Team had requested power consumption data per site in the industry sector (customers of mining and manufacturing), commercial sector (customers of commercials, banks, tourism, hotel and restaurant businesses) and government sector (customers of the government, hospitals, judicial offices and so on) to the distribution companies (MEDC, MZEC, MJEC and DPC). The contents of the requested data were site names, subsector names and the power consumption of large power consumers in 2010.

The following table shows the number of sites collected from the distribution companies. The items described in the data are company/organization names, annual power consumption (kWh) and the annual expenses by site.

Table 5- 67 Number of the Sites Submitted from the Distribution Companies

	MEDC	MZEC	MJEC	DPC	Total
Industry Sector	9	72	102	20	203
Commercial Sector	10	100	208	20	338
Government Sector	35	50	105	20	210
Total	54	222	415	60	751

(Note1) The values are the number of the sites

(Note2) The data of DPC are power consumption in 2011.The data of MJEC are power consumption from September in 2011 to August in 2012.

(Source: JICA Study Team)

(b) Outline of the Collected Data

The comparison between the power consumption of the sites and the total power consumption of the relevant sector is shown in the following table.

The summation of the power consumption from the distribution companies is 3.1 TWh in 2010, the total power consumption in the three sectors (industry, commercial and government) in Oman is 7.4 TWh. The share of the collected data occupied 41 % in 2010.

A detailed breakdown of the shares are the industry sector with 95 %, commercial sector with 22 % and government sector with 35 %. The share of industry sector is comparatively high. In general, the higher extraction rate data can show the higher precision for the survey and the analysis.

Table 5- 68 Power Consumption by Site and by Sector

	Power Consumption by Site	Power Consumption by Sector	Extraction Ratio
Industry Sector	1,466 GWh	1,540 GWh	95 %
Commercial Sector	749 GWh	3,470 GWh	22 %
Government Sector	860 GWh	2,424 GWh	35 %
Total	3,075 GWh	7,434 GWh	41 %

(Note1) The sectoral power consumptions are the whole country bases; the source is AER.

(Note2) The power consumption in industry sector does not include the power consumption to aluminum factories.

(Source: JICA Study Team)

(2) Analysis of the Data

(a) Setting Thresholds per Sector

Generally, the energy consumption per site in the industry sector is comparatively larger than other sectors, and conversely the energy consumption per site in the buildings and offices of commercial and government sectors is smaller than the industry sector.

By the above mentioned phenomenon, most of the energy consumption in the industry sector can be grasped by the small number of sites (energy users). However, it shows that the high coverage of energy consumption in the commercial and government sectors cannot be grasped unless a great number of the sites in the commercial and government sectors are collected. Therefore, it can be considered that the thresholds have to be set individually for industry, commercial and government sectors when introducing the EMS in Oman.

(b) Estimation of Energy Consumption (Power + Fuels) from Power Consumption

(i) Estimation of Final Energy Consumption by Site

Before estimating primary energy consumption, final energy consumption in the sectors has to be estimated. The final energy consumption is the total energy consumed by final energy users. As the data from the distribution companies is restricted to the power consumption per site, the final energy consumption including power and fuels by site can be estimated via the following expression.

Final energy consumption = Power consumption / power ratio

The power ratio in the expression is defined as the "Power consumption divided by final energy consumption". The final energy consumption includes the power and fuel consumption at the sites. Therefore, the power ratio is generally different among the sectors. Especially, power ratios in subsectors of the industry sector differ greatly. Their details are mentioned in the latter sections.

Meanwhile, power consumption in the commercial and government sectors have comparatively larger shares in the final energy consumption. As for fuel utilization, only LPG is used in the sectors for cooking and creating hot water.

By referring to IEA and MOG data, the power ratios in the commercial and government sectors can be defined at 90 %. It can be assumed that the other 10 % of their final energy consumption in the sectors is used in their business sites and offices as fuel.

(ii) Estimation of Primary Energy Consumption per Site

The primary energies in the session are energies such as crude oil and natural gas converted from final energy consumption as secondary energies such as power and oil products. Regarding the conversion from final energies to primary energies, the primary energy consumption from power consumption is defined by power consumption divided by power efficiency.

When assuming 30 % for the average power efficiency in Oman, it means that 30 % of the inputted energies to the power sector are converted to electric power. The following expressions can calculate primary energy consumption from final energy consumption.

Primary energy consumption = Power consumption / Power efficiency + Fuels

Fuels = Final energy consumption x (1 – Power ratio)

(c) Power Ratios per the Industrial Subsector

Per AER and IEA data, the power and fuel consumption in the whole country are clarified. According to the data, the average power ratio in the industry sector is 26 % in Oman. On the other hand, the power ratios in the industrial subsector cannot be grasped through looking at IEA and other Omani data. Therefore, regarding setting the power ratios in the industrial subsectors in Oman, it is assumed that after calculating the power ratios and/or referring to Japanese power ratios (the average power ratio is 28.3 % in Japan in 2010) of the industrial subsectors. As for the results, the power ratios in Oman and the setting reasons are described in the following table.

Table 5- 69 Power Ratios of Industrial Subsector in Oman

Subsector		Power Ratio (%)	Setting Reasons
Average Power Ratio of Industry Sector		26.0	From Omani power ratio of Industry sector
Subsector	Iron and steel	21.9	2.3 % reduced from Japanese relevant subsector
	Chemical and petrochemical	21.9	2.3 % reduced from Japanese relevant subsector
	Non-ferrous metals	67.4	2.3 % reduced from Japanese relevant subsector
	Non-metallic minerals	21.4	2.3 % reduced from Japanese relevant subsector
	Transport equipment	72.2	Applied Japanese power ratio to the relevant subsector
	Machinery	72.2	Applied Japanese power ratio to the relevant subsector
	Mining and quarrying	4.5	Power: AER data Fossil : IEA data
	Food and tobacco	31.2	Applied Japanese power ratio to the relevant subsector
	Paper, pulp and printing	34.2	Applied Japanese power ratio to the relevant subsector
	Wood and wood products	31.2	Applied Japanese power ratio to the relevant subsector
	Construction	1.6	Applied Japanese power ratio to the relevant subsector
	Textile and leather	31.2	Applied Japanese power ratio to the relevant subsector
	Non-specified (industry)	90.0	For setting, technical service companies assumed
	Others	70.0	For setting, assembly companies assumed

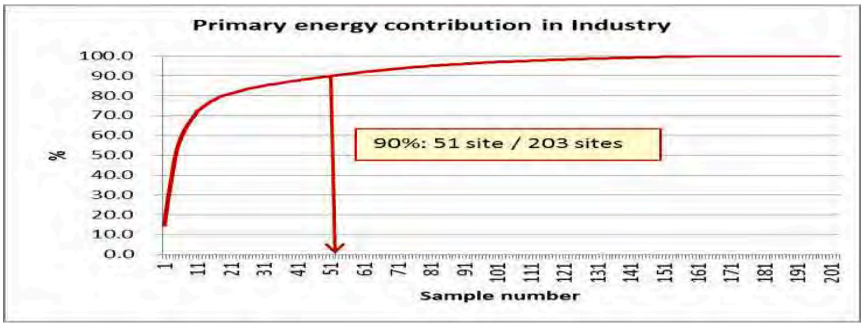
(Note) Power ratio in industry sector is 28.3 % and Oman's is 26.0 %, the difference is 2.3 % in 2010. When calculating the power ratio in Omani subsectors, the difference is used in the table.

(Source: JICA Study Team, having referred to IEA 2011 Statistics and AER Statistics)

(3) Calculation of Thresholds

(a) Threshold for the Industry Sector

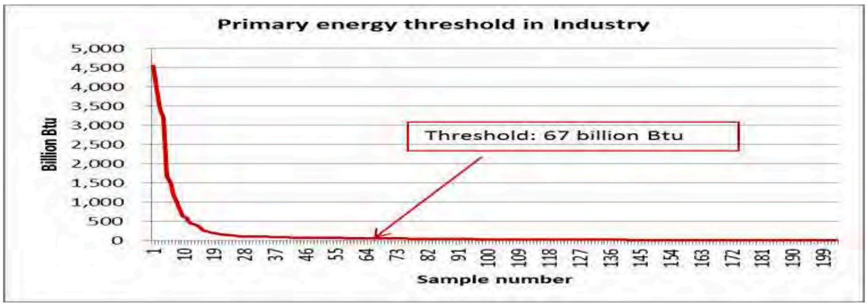
The number of collected sample data for achieving a threshold in the industry sector is 203 sites from the distribution companies, and the primary energy consumption of the sampling sites is estimated by the power consumption data of the sites. The following figure is that the horizontal axis shows the number of sampling sites to be arranged in descending order of primary energy consumption and the vertical axis is the coverage ratio (maximum 100 %) of the primary energy consumption in the sample sites. In the industry sector, 90% of primary energy consumption is covered by 51 sites in the total number of the sampling sites (203 sites).



（Source: JICA Study Team）

Figure 5- 79 Number of Sites in the Industry Sector and Coverage of Primary Energy Consumption

The following figure shows the position of the ranked 51st site by primary energy consumption among the total sampling sites. The primary energy consumption with 67 billion Btu (around 1,700 toe) of the ranked 51st site becomes the threshold for industry sector. By the threshold, the coverage of the primary energy consumption in Industry sector is 90 %.



（Source: JICA Study Team）

Figure 5- 80 Primary Energy Consumption and Number of the Sites in the Industry Sector

When calculating the number of sites over the threshold with 90% coverage in the industry sector of Oman, the results are shown in the following table. The sampling data do not include the whole targeted sites in Oman. When estimating the number of the whole targeted sites in Oman, it is 54 sites with an extraction ratio of 95 %. The extraction ratio is calculated by the ratio of the primary energy consumption of the sampling sites and the total primary energy consumption of the industry sector in Oman.

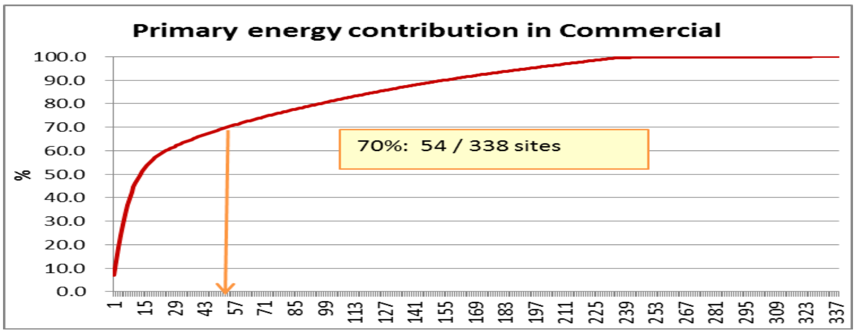
Table 5- 70 Threshold of the Industry Sector

Items	Values
Number of samples	203 sites
Average power ratio	26 %（Power consumption / Final energy consumption）
PEC of sampling sites	31.2 trillion Btu (780 ktoe)
Coverage ratio of PEC	90 % coverage of PEC at 51th site
Threshold	67.0 billion Btu (1,700 toe)
PEC of Industry sector	32.8 trillion Btu (820 ktoe)
Number of site over the threshold in the country	54 sites

(Note) PEC: Primary energy consumption (Source: JICA Study Team）

(b) Threshold for the Commercial Sector

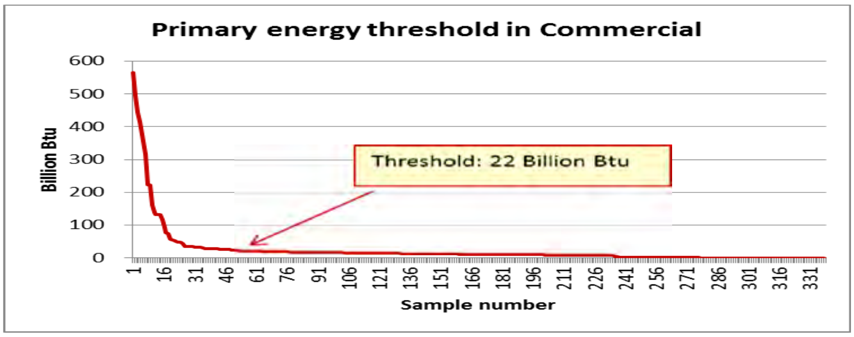
The number of collected sampling data for creating a threshold in the commercial sector is 338 sites from the distribution companies and the primary energy consumption of the sampling sites is estimated per the power consumption data of the sites. The following figure shows the relation between number of sampling sites and the coverage ratio of the primary energy consumption. In the commercial sector, 70 % of the primary energy consumption is covered by 54 sites in the total number of sampling sites (338 sites).



(Source: JICA Study Team)

Figure 5- 81 Number of the Sites in Commercial Sector and Coverage of Primary Energy Consumption

The following figure shows the position of the ranked 54th site by primary energy consumption among the total sampling sites. The primary energy consumption with 22 billion Btu (around 550 toe) of the ranked 54th site becomes the threshold for the Commercial sector. By the threshold, the coverage of the primary energy consumption in the Commercial sector is 70 %.



(Source: JICA Study Team)

Figure 5- 82 Primary Energy Consumption and Number of the Sites in Commercial Sector

When calculating the number of the sites over the threshold with a 70 % coverage 70 in the commercial sector of Oman, the results are shown in the following table. The sampling data does not include the whole targeted sites in Oman. When estimating the number of whole targeted sites in the commercial sector of Oman, it is 276 sites by using the 22 % extraction ratio.

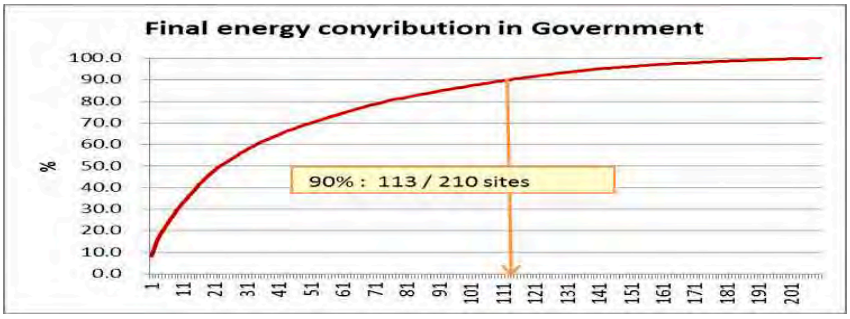
Table 5- 71 Threshold of the Commercial Sector

Items	Values
Number of samples	338 sites
Average power ratio	90 % (Power consumption / Final energy consumption)
PEC of sampling sites	8.0 trillion Btu (200 ktoe)
Coverage ratio of PEC	70 % coverage of PEC by 54sites
Threshold	22.0 billion Btu (550 toe)
PEC of Industry sector	41.0 trillion Btu (1,000 ktoe)
Number of site over the threshold in the country	276 sites

(Note) PEC: Primary energy consumption (Source: JICA Study Team)

(c) Threshold for the Government Sector

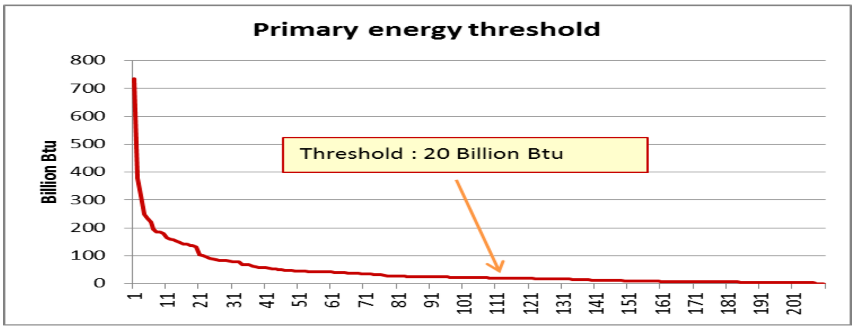
The number of collected sampling data for creating a threshold for the government sector is 210 sites from the distribution companies and the primary energy consumption of the sampling sites is estimated by the power consumption data of the sites. The following figure shows the relation between the number of sampling sites and the coverage ratio of primary energy consumption. In the government sector, 90 % of primary energy consumption is covered by 113 sites in the total number of sampling sites (210 sites).



(Source: JICA Study Team)

Figure 5- 83 Number of Sites in Government Sector and Coverage of Primary Energy Consumption

The following figure shows the position of the ranked 113th site by primary energy consumption among the total sampling sites. The primary energy consumption with 20 billion Btu (around 500 toe) of the ranked 113th site becomes the threshold for the government sector. By the threshold, the coverage of the primary energy consumption in the government sector is 90 %.



(Source: JICA Study Team)

Figure 5- 84 Primary Energy Consumption and Number of the Sites in the Government Sector

When calculating the number of sites over the threshold with a 90 % coverage in the government sector of Oman, the results are shown in the following table. The sampling data does not include the whole targeted sites in Oman. When estimating the number of whole targeted sites in the Government sector of Oman, it is 380 sites by using the extraction ratio of 35 %.

Table 5- 72 Threshold of the Government Sector

Items	Values
Number of samples	210 sites
Average power ratio	90 % (Power consumption / Final energy consumption)
PEC of sampling sites	9.2 trillion Btu (230 ktoe)
Coverage ratio of PEC	90% coverage of PEC by 113sites
Threshold	20.0 billion Btu (500 toe)
PEC of Industry sector	30.9 trillion Btu (770 ktoe)
Number of site over the threshold in the country	380 sites

(Note) PEC: Primary energy consumption (Source: JICA Study Team)

(d) Threshold and Number of Targeted Sites

The number of targeted sites of the EMS is shown in the following able. When calculating the thresholds for industry, commercial and government sectors, the coverage ratios of 90 %, 70 % and 90 % are assumed for the sectors. As for the results, the total number of targeted sites with the coverage ratios is 710 sites. However, the coverage ratios have to be decided after examining whether the number of total sites (710) is controllable or not per the managing authorities of the EMS.

Table 5- 73 Threshold and Number of the Targeted Sites in EMS

	Threshold		Coverage Ratios of PEC	Estimation of Number of Targeted Sites
Industry Sector	67,000 MM Btu	1,700 toe	90 %	54 sites
Commercial Sector	22,000 MM Btu	550 toe	70 %	276 sites
Government Sector	20,000 MM Btu	500 toe	90 %	380 sites
Total				710 sites

(Note) PEC: Primary energy consumption (Source: JICA Study Team)

(e) Sensitive Analysis of the Relation between Thresholds and Number of Targeted Sites

The results of the sensitive analysis on the relation between the sectoral thresholds and number of the total sites are shown in the following table. At the same time, the coverage ratios to the sectoral primary energy consumption are simulated.

Table 5- 74 Sensitive Analysis on Thresholds and Number of the Targeted Sites

	Thresholds		Coverage of PEC	Number of Targeted Sites	Number of Sampling Sites
	MM Btu	toe	%	Sites	Sites
Industry Sector	20,000	500	97	115	109
	30,000	750	96	100	94
	40,000	1,000	95	85	79
	50,000	1,250	93	70	68
	60,000	1,500	91	60	58
	70,000	1,750	88	45	44
Commercial Sector	20,000	500	72	320	63
	25,000	625	68	200	40
	30,000	750	64	180	35
	35,000	875	61	140	27
	40,000	1,000	60	130	25
	50,000	1,250	58	110	22
Government Sector	20,000	500	90	380	113
	25,000	625	83	280	84
	30,000	750	81	260	77
	35,000	875	78	230	70
	40,000	1,000	70	220	64
	50,000	1,250	68	150	46

(Note) PEC: Primary energy consumption

(Source: JICA Study Team)

5.7 Analysis of the Electricity Tariff

5.7.1 Objective of the Analysis

As discussed in Chapter 4, in the electric power in Oman, the costs of power generation and power transmission are recovered using the wholesale electricity tariff (Bulk Supply Tariff) and the Transmission Use of System Charge that OPWP and OETC respectively are billing to the distribution companies (DisCos), and then DisCos recovers these upstream costs and their own costs of power distribution with the retail tariff billed to customers. The unit rates of BST and the transmission charge are revised every year based on their actual costs, and BST adopts the time-of-use rate setting taking into account the actual costs and the system load in each time zone of the year as described in 5.3.

In the meanwhile, the unit rates of the retail tariff have not been revised for years, and furthermore, these rates are constant regardless of time (Note: the retail tariff for industrial customers sets different rates between the summer and other seasons, and the retail tariff for residential customers has progressively increased unit rates as the customers consume more electricity, but these tariff systems do not mean that they appropriately reflect the power supply-demand balance of the time). In other words, there's a discrepancy in the tariff structure between wholesale electricity and the retail tariff.

Given that the current retail tariff is not sufficient for DisCos to recover the total costs of electricity supply, the government provides them subsidies to make up for the deficiency to sustain the profitability of DisCos. In addition to that, there's also "hidden subsidies" for reducing the cost of power supply, that is, the price of fossil fuels for power generation is set lower than the international price.

It can be pointed out that, due to these issues pertaining to the retail electricity tariff, the behaviors of electricity consumption may not be made in an economically rational manner, and that there's a possibility of excessive electricity consumption especially during peak hours.

Needless to say, the electricity tariff also assumes the characteristics as the cost for providing public infrastructure services, thus it is necessary to pay attention not only to the economic rationality but also to the social requirements of the country. Nevertheless, taking them into consideration, implementing the tariff system that complies with economic rationality as much as possible will serve as an incentive to control the power demand, especially the peak demand.

In this section, this Study analyzes the problems concerning the current retail electricity tariff in Oman, and then argues what this Study should propose with regard to the tariff incentives for the demand control.

5.7.2 Results of the Analysis

(1) Comparison between the Unit Costs of Supply and the Retail Tariff's Unit Rates

(a) Parameters for Calculating the Costs of Supply

Here the costs of supply for every hour in 2011 (8,760 hours) in the MIS grid are compared with the unit rates of the retail tariff (Bz/kWh). The following parameters are referred to in calculating the costs of supply.

- Power generation costs: As discussed in 5.3, the current wholesale tariff (BST) is supposed to reflect the generation costs in each time zone appropriately, thus this is applicable to this analysis. The BST rates in 2012 are adopted because the BST in 2012 is considered to reflect the status of the system load in 2011 better than the BST in 2011.
- Power transmission costs: The power transmission-related expenditures, which are found in the financial statements of the three DisCos, are summed up (about 2.9 Bz per power sales to customers). For simplicity, the average unit costs (= total costs divided by the total electricity sales) are used constantly, regardless of the difference in load pattern among sectors.
- Power distribution costs: All the other expenditures in the DisCos' financial statements than the power procurement costs (generation) and the transmission-related expenditures are summed up (about 4.2 Bz per power sales to customers). Given that the DisCos have miscellaneous revenues besides the electricity sales and they partially recover the accrued costs, these revenues are

subtracted from the distribution costs.

- Others: While the BST is billed for the electricity at the point of supplying to DisCos, there's a loss on the distribution system before reaching the customers. A loss-equivalent cost (12 %) is added to each hour's BST rate.

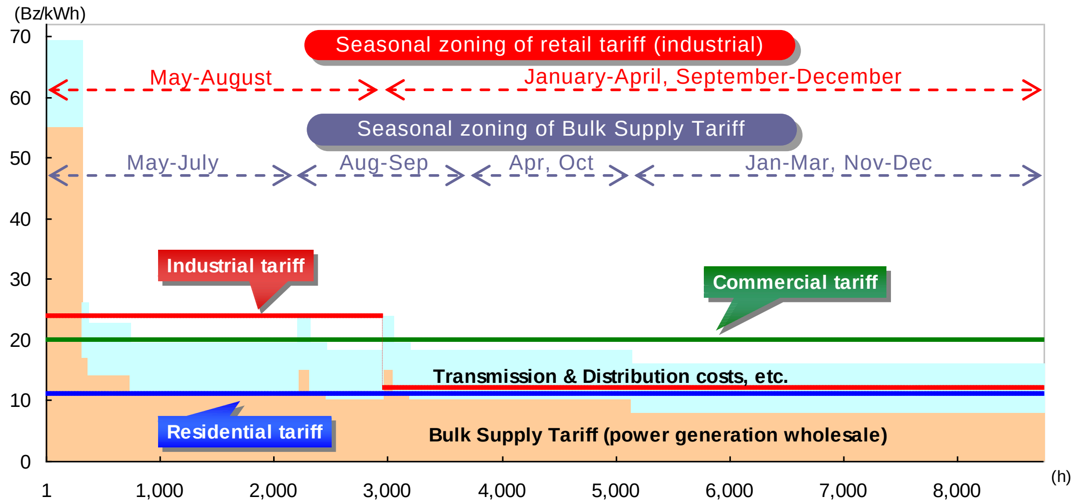
  To be more accurate, the different loss rate should be considered among different sectors, considering the difference in the voltage of supply and the non-technical loss rates, but here the same rate was applied to all the sectors. Likewise, the same unit costs of transmission and distribution were applied to all the sectors regardless of the difference of the voltage of supply.

  The analysis of the profit and loss of each sector, where the total costs of supply are allocated among sectors more specifically considering the difference in the voltage of power supply and the load pattern, is shown in the following section (4).

(b) Results of the Comparison between the Costs of Supply and the Retail Tariff

The following figure summarizes the comparison between the hourly costs of the supply per electricity sales and the retail tariff's unit rates for each sector in the MIS area in 2011 (8,760 hours). In this figure, 8,760 hours are grouped into several time zones with the same tariff rates and the costs of supply in the following manner:

- The retail tariff and the wholesale tariff (BST) have a different definition of time zones and they are not in total conformity.
  - Retail tariffs for industrial customers set different rates between the period from May to August and the remaining period, the former (24Bz/kWh) being twice of the latter (12 Bz/kWh)
  - The BST sets the highest rates for the period "from May to July", and the rates are differentiated from higher to lower in the following order: "August-September", "April and October", and "January-March and November-December"
- Therefore, 8,760 hours are segmented into the "May-August" and "the remaining months" to follow the definition of the retail tariff, and then further segmented into the subgroups of months as follows:
  - The first group is segmented between "May-July" and "August"
  - The second group is segmented into "September", "April and October", and "January-March and November-December".
- In each of the aforementioned subgroups, the time zones are arranged in the descending order of the BST unit rates.



(Note) The sum of the light-red coloured bars (BST) and the light-blue coloured bars (transmission and distribution costs and others) indicates the hourly costs of supply per electricity sales (Bz/kWh) whereas the blue, green and red-coloured horizontal bars indicate the retail tariff's unit rates (Bz/kWh).

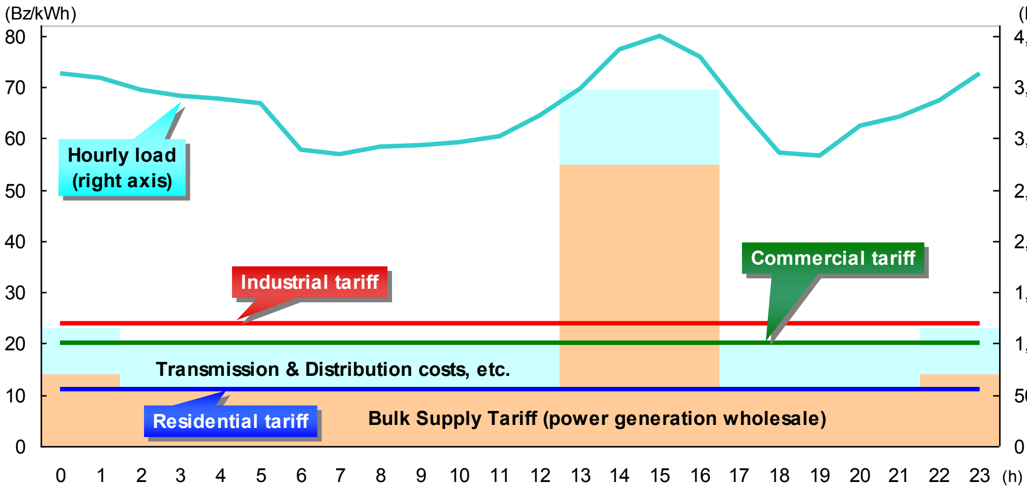
Figure 5-85 Hourly Costs of Supply per Electricity Sales and Retail Tariff' Unit Rates for Each Sector in 2011 (MIS Grid)

The characteristics of each sector's balance between the unit rate and the cost of supply that can be observed from the above figure are as follows:

- Industrial tariff: The unit rate from May to August (24 Bz/kWh) is set high enough to recover the costs of supply during this period, except during the daytime peak hours when the high costs of supply cause a huge loss. The unit rate in the remaining period (12 Bz/kWh) is set at a low level to barely only recover the generation costs. The total revenue throughout the year is not able to recover the total costs of supply.
- Commercial tariff (20 Bz/kWh): From May to July, the unit rate is lower than the costs of supply in the peak hours (both in the daytime and nighttime) and even in the off-peak hours it's barely balanced, thus the revenue throughout this period is not able to recover the total costs of supply. In the remaining period, the unit rate mostly exceeds the costs of supply (except for some peak hours in August and September).
- Residential tariffs (considering the progressively increasing unit rates with usage, this Study assumes the average unit rate to be 11 Bz/kWh, a little higher than the minimum unit rate 10 Bz/kWh): The revenue is constantly lower than the cost of supply throughout the year.

(c) Comparison between the Costs of Supply and the Retail Tariff on the Day of Annual Peak Load

The following figure illustrates the hourly costs of the supply per electricity sales, the retail tariff's unit rates, and the system load curve on the day of the annual peak load (18th June 2011). The difference of the load between the daytime peak hours and off-peak hours is a little more than 1,000 MW, which is equivalent to a little more than a quarter of the peak load (4,000 MW). In terms of the unit costs of supply, the costs in peak hours are more than triple that in the off-peak hours.



(Source: JICA Study Team's Estimation (costs of supply), OETC (load curve))

Figure 5- 86 Hourly Costs of Supply per Electricity Sales, Retail Tariff's Unit Rates, and the System Load Curve on the Day of Annual Peak Load (18th June 2011, MIS Grid)

(d) Observations on the Level of Retail Tariff Rates

The above analysis indicates that the current retail tariff's unit rates are not designed rationally to recover the costs of supply. This is especially typical for the residential demand, which accounts for about half of the total electricity sales but the unit rate is set far below the costs of supply.

The tariff system is designed like the one in Japan, which sets the unit rates based on the appropriate cost allocation, the unit rates for residential demand becomes by nature higher than those for other sectors because almost 100% of the residential demand is supplied at low-voltage thus more costs related to low-voltage distribution should be added (Note: The trial profit and loss estimation in the above table does not consider the difference in the voltage of supply, thus the average costs for residential demand, whose share during the summer daytime peak load is relatively small, are slightly lower than those of other categories).

The fact that the unit rate for residential demand is set much lower than that for industrial and commercial demands implies that this rate was set taking into account the social and political considerations, not appropriately reflecting the costs of supply.

(2) Subsidization from the Government to DisCos

(a) Subsidization to DisCos in the MIS Area

The wholesale electricity tariff (BST) and the transmission charges are set at a level so that they can recover their respective costs. Therefore, the sustainability of the power generation (OPWP) and transmission (OETC) businesses are assured as stand-alone business entities.

However, the power distribution business (DisCos) is not able to attain the profit-loss balance only with revenue from electricity sales, which is too low to recover the total costs of supply including the upstream costs of generation and transmission.

In order to maintain the financial soundness of the DisCos, the AER calculates a Maximum Allowed Supply Revenue (MASR) for each licensed supplier every year and subsidizes the gap from their actual revenue. The following table shows the summary of the subsidization to the DisCos in the MIS area (Note: numbers up to 2011 are the actual results and those in 2012 are prospects), published by AER. The Underlying Economic Subsidy Requirement is formulated as the difference between the Underlying Economic Costs and the Permitted Tariff Revenue.

In comparison with the Study Team's estimation in the above table, the "Costs of Electricity Supply" and the "Revenue from Electricity Sales" correspond to the Underlying Economic Cost and the Permitted Tariff Revenue respectively. The reason why the latter two are higher than the former two respectively is that the Study Team's estimation subtracts the miscellaneous revenues (revenues other than electricity sales) from the costs (i.e. deducted from both revenues and cost) while AER's document includes them in the revenue (i.e. added to both sides), and that the Underlying Economic Cost in AER's document also includes the approved profit of DisCos, which is counted out in the JICA Study Team's estimation.

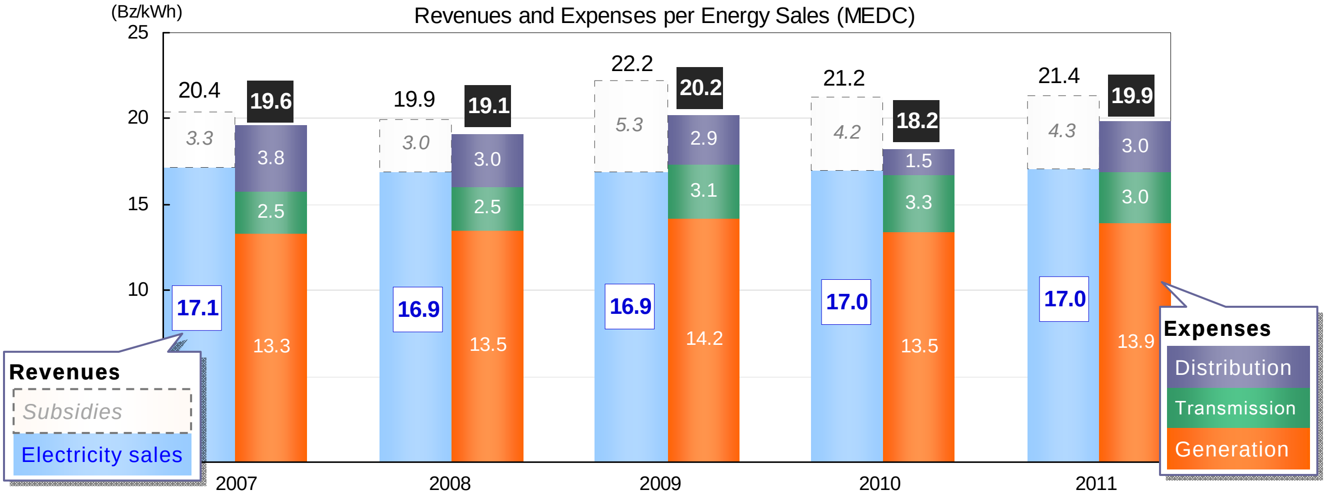
Table 5-75 Total Costs of Supply, Revenues and Subsidies in MIS Area

Economic Cost (RO m)	2006	2007	2008	2009	2010	2011	2012 (e)
PWP (MAR excluding Kt)	140.5	144.5	161.2	177.6	198.3	222.5	252.3
OETC (MAR excluding Kt)	26.5	27.9	31.5	38.5	41.4	44.0	46.3
Muscat (MAR excluding Kt)	22.8	23.8	23.9	32.3	34.9	38.8	55.5
Majan (MAR excluding Kt)	16.6	17.8	19.6	26.0	28.0	30.8	40.2
Mazoon (MAR excluding Kt)	23.0	24.2	27.6	37.5	41.2	45.2	62.6
Underlying Economic Cost	**229.6**	**238.2**	**263.8**	**311.9**	**343.8**	**381.3**	**457.0**
Permitted Tariff (& other) Revenue	143.1	153.9	179.8	201.5	227.1	259.9	292.6
Underlying Economic Subsidy Requirement	**86.5**	**84.3**	**84.0**	**110.4**	**116.7**	**121.5**	**164.4**
Total Units Supplied (GWh)	9,194	9,778	11,317	12,714	14,122	16,374	18,308
Underlying Economic Cost / kWh Supplied	25.0	24.4	23.3	24.5	24.3	23.3	25.0
Customer Revenue / kWh Supplied (bz/kWh)	15.6	15.7	15.9	15.9	16.1	15.9	16.0
Underlying Subsidy / kWh Supplied (bz/kWh)	9.4	8.6	7.4	8.7	8.3	7.4	9.0

(Source: AER Annual Report 2011)

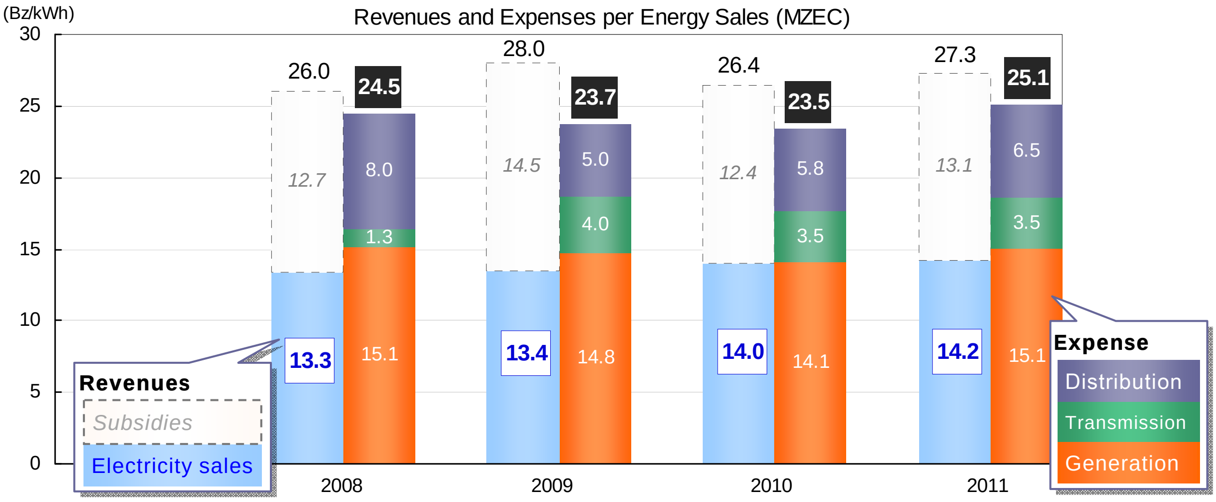
(b) Profit and Loss Balance of Each Disco in MIS Area

The following three graphs show the historical trend of each DisCo's revenues and expenses per electricity supply based on the DisCos' financial statements. The light-blue bars on the left-hand side indicate the revenue from electricity sales and the bars on the right-hand side indicate the power generation costs, transmission costs, and distribution costs respectively from the bottom. Miscellaneous revenues (revenues other than electricity sales) are subtracted from the distribution costs. All three DisCos are not able to recover costs only with electricity sales and rely on subsidies (bars with the dotted line on the left-top) to gain profit. Among these three DisCos, MEDC is in a relatively better position, because the share of commercial and government demand in electricity sales is higher, which helps to raise the average revenue per electricity sales, and the higher population density contributes to reducing the costs of supply. MEDC's revenues are almost able to recover the generation and transmission costs but the revenues of MZEC and MJEC barely recover the generation costs only.



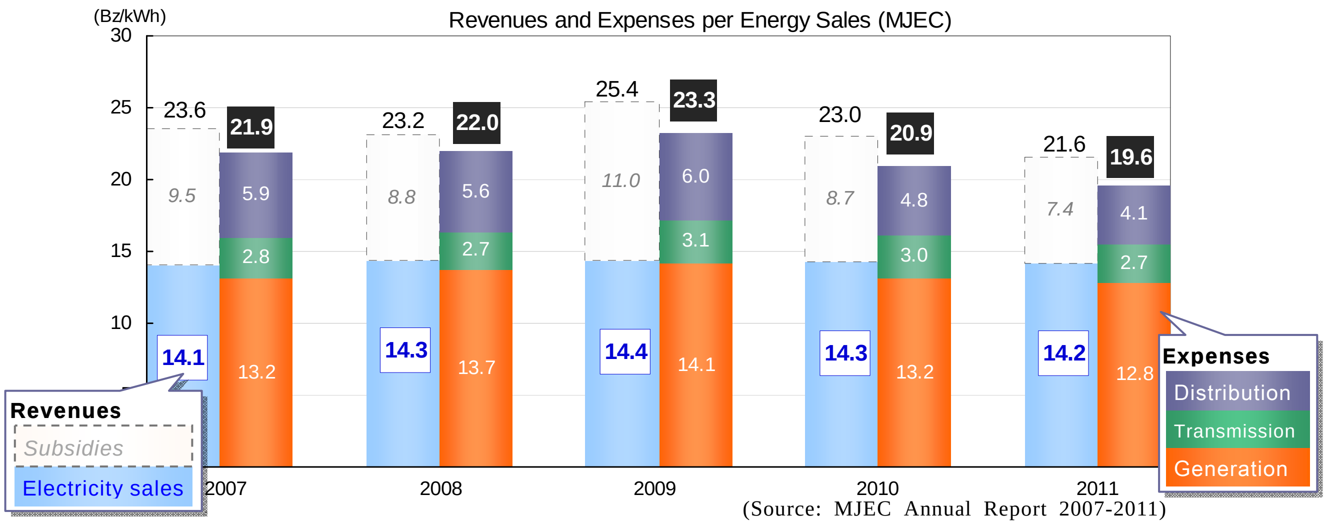
(Source: MEDC Annual Report 2008-2011)

Figure 5- 87 Revenues and Costs per Electricity Sales (MEDC)



(Source: MZEC Annual Report 2009-2011)

Figure 5- 88 Revenues and Costs per Electricity Sales (MZEC)



(Source: MJEC Annual Report 2007-2011)

Figure 5- 89 Revenues and Costs per Electricity Sales (MJEC)

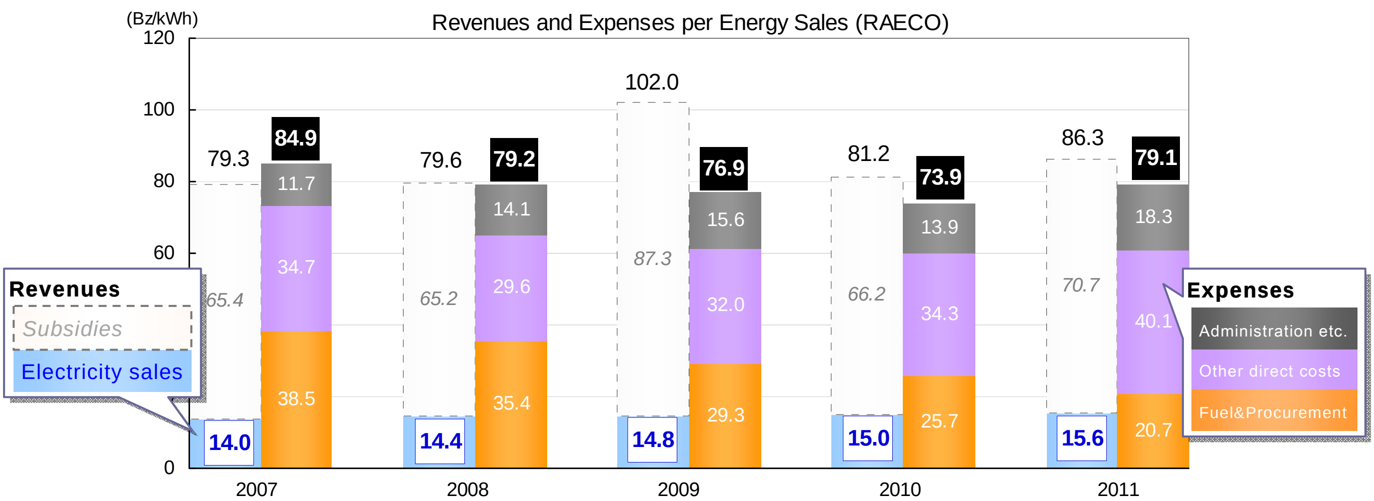
(c) Subsidization to RAECO

In the supply area of RAECO, where electricity is supplied with diesel generators and isolated grids, and according to AER's document, the average costs of supply are high at about 90 Bz/kWh but only about 20 % is recovered by revenue from electricity sales (17-18 Bz/kWh) and the subsidies cover the remaining 80 %. The Study Team's analysis using RAECO's financial statements show that the costs of supply per electricity sales are around 80 Bz/kWh and the average revenues per sales are around 15 Bz/kWh, which is also about 20% of the costs. According to the financial statements analysis, its revenue is insufficient even to recover the power generation costs.

Table 5-76 RAECO's Costs of Supply, Revenues and Subsidies

	RAEC Subsidy million RO							RAEC Revenue & Subsidy Bz/kWh						
Million RO	***2006***	***2007***	***2008***	***2009***	***2010***	***2011***	***2012 e***	***2006***	***2007***	***2008***	***2009***	***2010***	***2011***	***2012 e***
Customer Revenue	3.5	3.8	5.4	6.5	7.3	8.7	**10.0**	14.3	14.5	17.3	17.7	17.6	18.9	**18.9**
Subsidy	16.6	18.3	23.7	27.6	29.7	30.5	**41.6**	68.0	69.1	76.2	74.9	71.0	66.0	**79.0**
Economic Cost	20.1	22.2	29.1	34.1	37.0	39.2	**51.6**	82.3	83.6	93.5	92.6	88.6	84.9	**97.9**

(Source: AER Annual Report 2011)



(Source: RAECO Annual Report 2007-2011)

Figure 5- 90 Revenues and Costs per Electricity Sales (RAECO)

(d) Total Subsidies to the Power Distribution Business

DPC's structure of revenues and costs is quite different from other DisCos, and its revenue is derived not from electricity sales to customers but from OPWP, which allows for the concession of electricity supply to DPC, as a reward for operating electricity supply facilities (Note: Originally the concession provider was the Ministry of Housing Electricity and Water when DPC started operations but was later succeeded by OPWP). Therefore, the subsidies to DPC's power supply are provided indirectly via OPWP, and according to AER's document, about a 41 million RO subsidization was needed for DPC in 2011. The following table, showing the subsidy requirements to DPC together with those to the MIS area (105.4 million

RO) and RAECO (30.5 million RO), indicates that 176.9 million RO was required in all of Oman to subsidize the power distribution business, on average 9.6 Bz/kWh per electricity supply. When this amount is simply added to the current electricity tariff, its equivalent to raising the average electricity tariff (about 15 Bz/kWh: MIS area, 2011) by about 60% (about 1.6 times), and the residential tariff (about 11 Bz/kWh, in considering the progressively increasing rates) by about 90% (a little less than twice).

Table 5-77 Total Subsidization to Power Distribution Business in 2011

	2011 Subsidy Baiza/KWh Supplied					2011 Subsidy RO per Account[1]				
	Muscat	Majan	Mazoon	RAEC	DPC	Muscat	Majan	Mazoon	RAEC	DPC
Subsidy per KWh/Account	2.7	6.8	11.7	66.0	24.6	84	216	202	1,347	644
Subsidy mRO	18.6	32.5	54.3	30.5	41.0	18.6	32.5	54.3	30.5	41.0
GWh/'000 Accounts	6,931	4,799	4,645	462	1,669	222	150	269	23	64

(Source: AER Annual Report 2011)

(3) Analysis of Each Sector's Profit and Loss

This Study then tried the estimation of the annual profit of each sector in the MIS area by referring to the sector breakdown of hourly load (see Section 5.3) and the financial statements of the DisCos.

Here the tariff categories other than Residential, Commercial, and Industrial (i.e. Government, Agriculture & Fisheries, Ministry of Defense, and Tourism) are assumed to have the same load pattern and tariff rates as the commercial sector and are classified as "Commercial & Government etc." It also needs to be noted that the revenue are calculated by multiplying the unit rates by the hourly load estimated by the Study Team, thus the total sum does not match the total amount of three DisCo's financial statements.

In allocating the costs of supply among sectors, it was taken into account that the difference of the voltage level of supply affects the costs of supply (e.g. the customer that receives the electricity supply at middle voltage or higher does not need to share the costs related to the low-voltage distribution facilities). However, because sufficient data of the breakdown of voltage of supply for each sector was not available, this Study estimated the ratio as follows referring to the limited information obtained from OETC and DisCos:

- Residential: Low voltage 100 %
- Commercial, Government etc.: Middle voltage 20 %, Low voltage 80 %
- Industrial: High voltage (transmission line) 25 %, Middle voltage 75 %

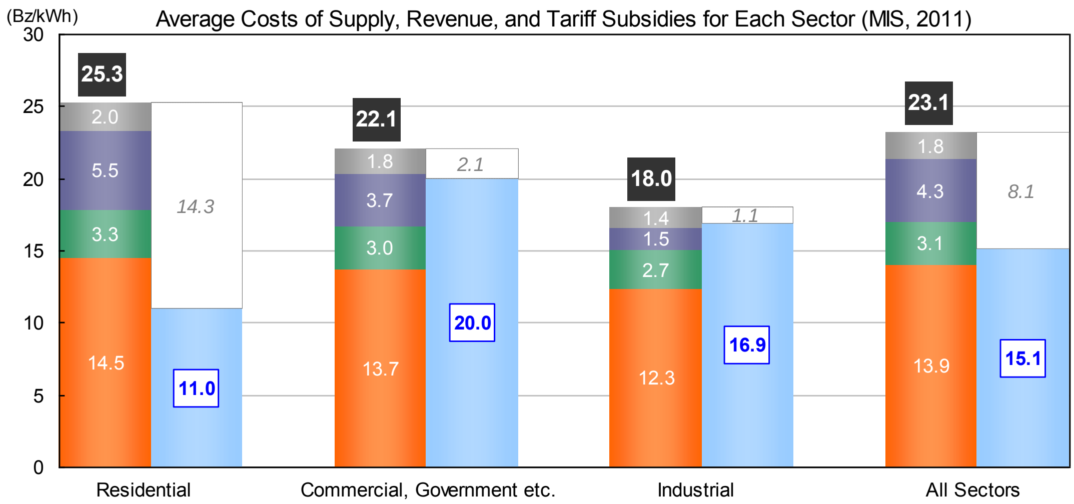
The information was not available either regarding the breakdown of the distribution costs among middle-voltage facilities (to be allocated to customers receiving at MV and LV only), low-voltage facilities (to be allocated to LV customers only), and customer-related costs (meter reading, billing, customer services etc., to be allocated in proportion to the number of customers). Therefore, this Study assumes this ratio to be 53 %:19 %:28 %, referring to the information that a Japanese power utility used for calculating the electricity rates. The appropriate return on equity in calculating the disbursement of subsidies to DisCos was also taken into account.

The results of the analysis are shown in the following table and graph. The analysis results imply that the revenue recovers about 90 % of the annual costs of supply in the "Commercial & Government etc." and the Industrial categories, but the cost recovery stands at less than 50% in the Residential category. The deficit shown here also means the subsidy requirements to make up for the gap between the costs of supply and the electricity tariff.

Table 5-78 Trial Estimation of Profit and Loss of Each Sector (MIS Area, 2011)

	Residential	Commercial& Government etc.	Industrial	**Total**
Electricity Sales (GWh)	8,224	5,934	2,216	**16,374**
Revenue from Electricity Sales (1,000 RO)	90,469	118,687	37,410	**246,567**
Costs of Electricity Supply (1,000 RO)	207,893	131,063	39,811	**378,767**
Loss (1,000 RO)	**-117,424**	**-12,375**	**-2,400**	**-132,200**
Revenue/Costs	**43.5%**	**90.6%**	**94.0%**	**65.1%**
Revenue per Electricity Sales (Bz/kWh)	11.0	20.0	16.9	**15.1**
Costs per Electricity Sales (Bz/kWh)	25.3	22.1	18.0	**23.1**
Loss per Electricity Sales (Bz/kWh)	**-14.3**	**-2.1**	**-1.1**	**-8.1**

(Source: JICA Study Team's Estimation (Profit and Loss), AER (Electricity Sales))



(Source: JICA Study Team's Estimation)

Figure 5- 91 Average Costs of Supply, Revenue, and Subsidy Requirements per Electricity Supply for Each Sector

(4) Subsidization to the Fuel Cost

Besides the tariff subsidies that are provided to DisCos to compensate for the gap between the costs of supply and the revenues of DisCos, another type of subsidies for the electricity tariff also needs to be noted. These "hidden subsidies", or fuel subsidies, are to mitigate the gap between the domestic fuel prices and the international prices (see the right figure).

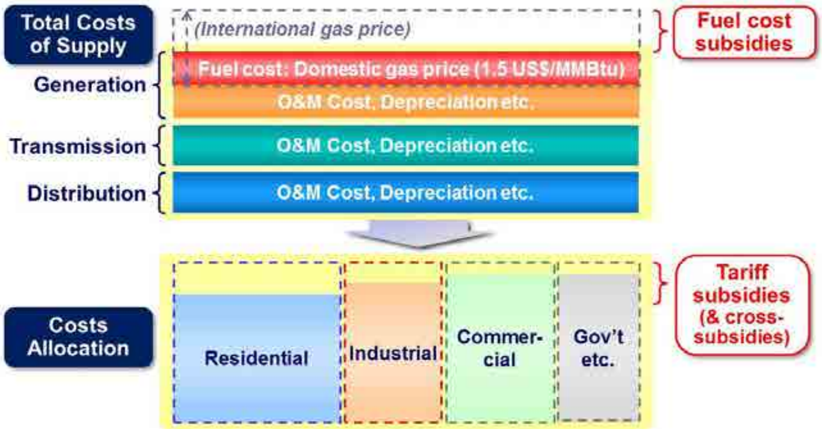
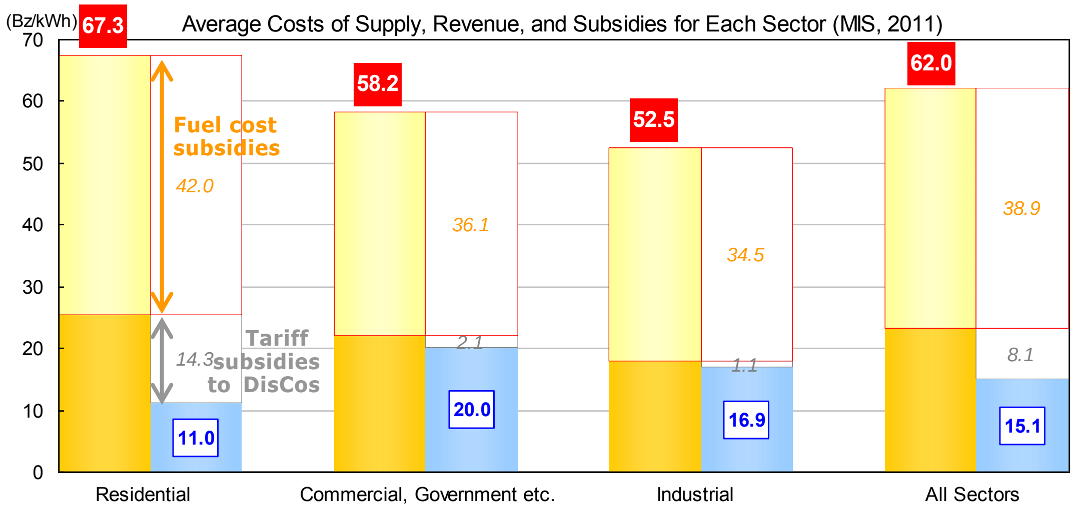


Figure 5- 92 Two Types of Subsidies to Electricity Tariff

According to the hearings of Omani stakeholders, the domestic price of natural gas for power generation is set at 1.5 US$/MMBtu. In the meanwhile, the gas prices in the international market have been around 10 US$/MMBtu recently, which is more than six times the domestic price. This 8.5 US$/MMBtu difference can be regarded as the "hidden subsidies" and the following figure shows the costs of power supply including these subsidies:



(Source: JICA Study Team's Estimation)

Figure 5- 93 Average Costs of Supply (including Fuel Cost Subsidies) and Revenue per Electricity Supply for Each Sector

If both the tariff subsidies and the fuel cost subsidies are abolished and the total cost is appropriately recovered by the electricity tariff, the residential tariff (about 11 Bz/kWh, considering the progressively increasing rates) needs to be raised by about 6 times the average electricity tariff of all sectors (about 15 Bz/kWh: MIS area, 2011) by about 4 times respectively.

The abolition or reduction of these subsidies will help to mitigate the burden of the national budget, and moreover, the raised electricity tariff is expected to stimulate the reduction of electric power demand that might have been consumed excessively so far. As an issue to be challenged in the future, these subsidies should be all abolished and the electricity tariffs should be set in conformance to economically rational rules so that the demand should be appropriately formed in response to the prices.

However, it also needs to be considered that a drastic increase in electricity tariffs may critically affect the national livelihood and industrial activities, which may deteriorate the national economy even if only temporarily. The policy on subsidies should be discussed by carefully taking into account the advantages and disadvantages, but because it is far beyond this Study's scope of works to comprehensively discuss the country's social and economic policies, this Study does not go further than pointing out the necessity to review the subsidy policies from the mid- and long-term aspects.

5.7.3 Issues Pertaining to the Current Tariff System and Discussions on Electricity Tariff Reforms in Oman

(1) Issues Pertaining to the Current Tariff System in Oman

Based on the results of the analyses presented in the previous sections, this section discusses the problems regarding the current electricity tariff systems in general. The objective of this Study is to propose the DSM tariff systems on the conditions that the current tariff system is maintained, thus making a specific proposal on the reforms of total tariff system as a whole is out of the scope of this Study. Nevertheless, because the current tariff structure is not necessarily rational and the total review of the tariff system will need to be made in the long run, this section argues the issues regarding the tariff system in general and the future directions of the tariff reforms not confining to the Scope of this Study.

Some of the stakeholders in the electric power sector in Oman have already recognized the necessity to deal with the problems concerning the electricity tariff and there already exist preceding studies in the electricity tariff reforms. In 2007 a consulting firm KEMA was entrusted by AER to conduct a study on the electric power tariff in Oman and prepared a study report "Cost Reflective Tariffs for Industrial and Large Commercial Customers", which proposes the restructuring of the retail tariff system so that the tariff rate is set to reflect the costs of supply, as well as another study report "Subsidy Impact Assessment" that discusses the status of subsidies to the electricity tariff. These reports (draft) were made public on AER's Website (hereinafter these two reports are collectively referred to as the "KEMA report"). Following this KEMA report, the AER started appealing for public comments on designing the Cost Reflective Tariff in October 2009 ("Public Consultation on proposals for the Cost Reflective Tariffs for Commercial and Industrial consumers of Electricity", hereinafter referred to as the "Public Consultation").

The problems of the tariff system in Oman identified by the Study Team are very similar to those that were pointed out by the KEMA report, thus the descriptions in the KEMA report are occasionally quoted in discussing them.

(a) Irrational Categorization of Customers

The current tariff system sets seven customer categories, namely Residential, Industrial, Commercial, Government, Agriculture & Fisheries, Tourism and Ministry of Defense. The first four categories account for 97 % of the total electricity sales (2011, total Oman). As also pointed out by the KEMA report, this categorization is not driven by the notion that the difference in consumption behaviour causes different costs thus different pricing is necessary, but is made with an intention to control tariff subsidies. Setting many categories can cause different billing to customers whose load profile is identical but whose tariff categories are different. Above all, there is little reason to justify the differentiation between the Commercial and the Government customers in terms of consumption behaviour and in Japan these customers are grouped in a same category called "Power for Business Use". In Oman, a flat rate 20 Bz/kWh is applied to the Commercial customers whereas the progressively increasing unit rates are used for billing to the Government customers. Therefore the billing to the Government customers is lower than that to the Commercial customers when the customer's monthly consumption less than 12,500 kWh and inversely when the monthly consumption is more than that. There is no justification either to differentiate the Tourism customers from the Commercial in terms of their consumption behaviour. Furthermore, only the customers in the tourism sector with monthly consumption 7,000 kWh or less are eligible for this tariff, thus its applicability is limited to small hotels and the share in the total electricity consumption is only 0.2%.

The KEMA report suggests that the customer categorization is reduced to three, i.e. Industrial, Commercial and Residential. Though the KEMA report does not elaborate on how to classify the remaining four categories (Government, Ministry of Defence, Agriculture & Fisheries, Tourism), but considering the similarity of the load pattern, including into Commercial may be justified. The KEMA report does not completely exclude the possibility of setting another category than these three, it points out that reasons should be explained explicitly, e.g. subsidization to this sector is indispensable from a policy perspective.

(b) Lack of Tariff Setting in Accordance with the Voltage Level of Supply

The costs of supplying customers at a higher voltage should not factor in the costs related to the facilities to supply at a lower voltage. Therefore, as also pointed out by the KEAM report, the tariff must be differentiated even within a same customer category depending on the voltage of supply in order to reflect the costs of supply to the tariff. It also needs to be taken into account that the loss rate in supplying at a higher voltage is lower than in supplying at a lower voltage.

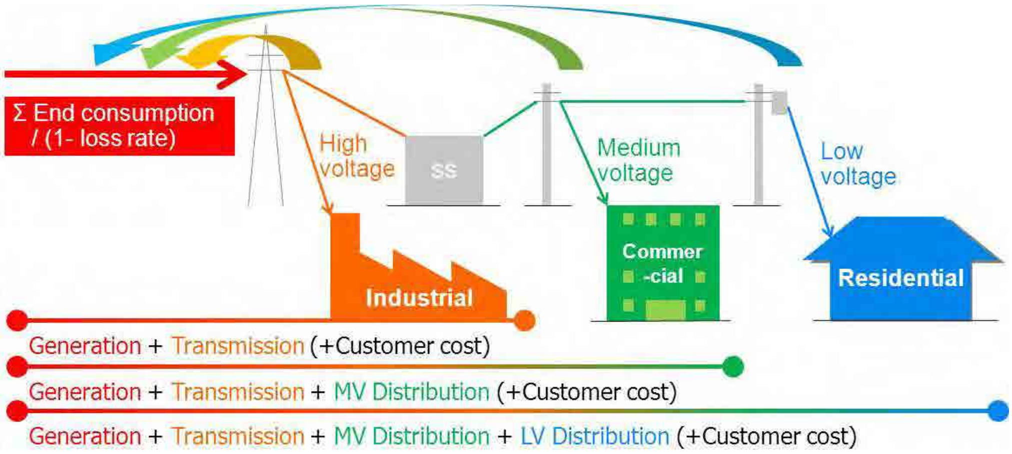


Figure 5- 94 Voltage Level and the Costs of Supply (Image)

The KEMA report proposes to set different tariff rates depending on the voltage level of supply for the three tariff categories as follows.

- Industrial: 132 kV, 33 kV, 11 kV (the KEMA report suggests that no separate industrial tariffs are charged for customers supplied at a low voltage, implying that small factories receiving a low voltage supply are included in the commercial sector)
- Commercial: 132 kV, 33 kV, 11 kV, 415 V
- Residential: Low voltage only (415 V)

The proposal to classify customers into three categories such as industrial, commercial, and residential, and to set different tariff rates for each voltage level to reflect the respective costs of supply are similar to the concept of cost allocation that has been adopted by Japanese tariff regulation. In Japan, besides the major three categories namely “business use” (commercial etc.), “industrial use”, and low voltage (mostly residential), some other customer categories are provided such as “agricultural use” and “temporary use” (for construction works shorter than on year etc.), but these differentiation can be justified because their consumption behaviour is obviously different.

According to the Public Consultation, the billing to the customers receiving electricity from the transmission lines counts out the costs of supply deriving from the distribution facilities thus is differentiated from the billing to the customers receiving from the distribution lines, but differentiating the tariff rates between MV (33kV, 11kV) and LV (415V) is not considered. The customers receiving at the MV need to install their own transformers for using the equipment working with lower voltage whereas the customers receiving at the LV utilize the power utility’s transformer that steps down the electricity from MV to LV, therefore applying the same tariff rates is the cross-subsidization between these two groups (unfair for the former). It is not practical in the accounting of the power distribution business in general to segment strictly the costs in accordance with the voltage level, but as a future challenge, the tariff rates should reflect the difference in the distribution costs depending on the voltage level of supply by developing a methodology to estimate the cost breakdown.

(c) Lack of Two- (Three-component) Tariff (Only Consisting of the Energy Charge)

As seen in the tariff table in 4.3.4, the electricity retail tariff (Permitted Tariff) in Oman only consists of the energy charge depending on the customer's electricity consumption (kWh) for all the categories. The KEMA report proposes to introduce a three-component tariff system consisting of the energy charge, the demand charge, and the standing charge.

The costs of supplying electricity can be grouped into the following three types according to the main cost drivers.

- Costs deriving from the volume of the generated and transmitted electricity;
- Costs for forming and maintaining the facilities of power supply;
- Costs for customer management (e.g. metering and billing);

Theoretically the tariff rates should be designed so that these three groups are recovered in relation to each customer's consumption (per kWh: energy charge), maximum demand (per kW: demand charge), and evenly per customer account (standing charge). In the actual practice, the share of the three components does not totally match that of the corresponding costs, and in many cases this three-component structure is simplified into a two-component system by unifying the demand and the standing charge components "basic charge" (for recovering the fixed costs besides recovering the variable costs with the energy charge).

Introduction of the two- (three-) component tariff system consisting of the energy charge and the demand charge is expected to help controlling the peak load of the total system because it favours the customers with the higher load factor (same consumption but lower maximum demand) thus the customers are motivated to reduce the maximum demand.

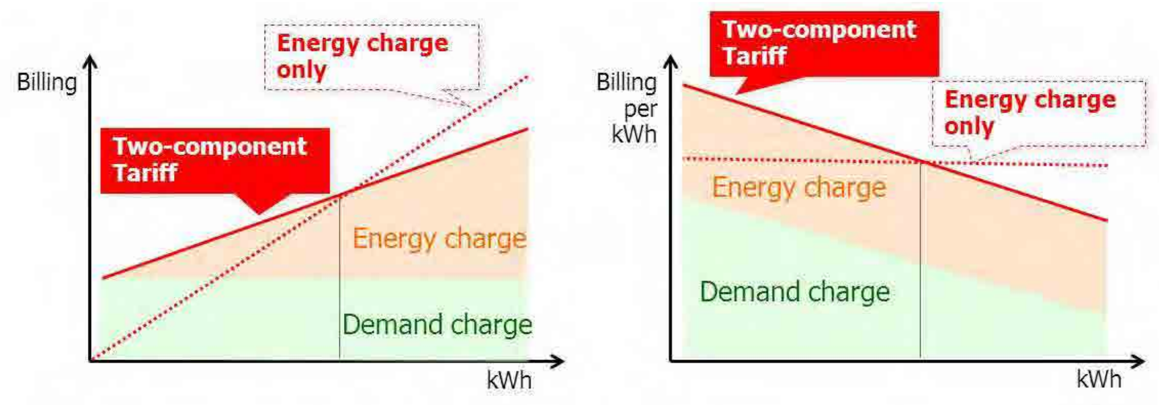


Figure 5- 95 Billing with Two-Component Tariff (Image)

Collecting and analyzing the customer's load profile data is indispensable in order to estimate how the billing will be after shifting from the energy charge-only tariff structure to two- (three-) component tariff structure as accurately as possible. At this moment the available data are far from sufficient to serve for this, and this is one of the biggest hurdles for implementation.

As also discussed in the KEMA report, installation of the demand meter at the customer's premises is required for billing the demand charge. In Japan, for small low-voltage customers to whom the demand meters is yet to be installed, billing of the basic charge is made depending on the total capacity of the equipment used by the customer or depending on the main circuit breakers. The KEMA report, in the meanwhile, suggests that the costs of supply that correspond to the demand charge component may be recovered as a part of the energy charge considering that increasing the fixed portion of the residential tariff is disadvantageous for small households.

The Public Consultation presents a tariff model in which the transmission costs are recovered in proportion to the customer's maximum demand while the generation and the distribution costs in proportion to the customer's electricity consumption. As a future challenge, it is worth considering the billing so that the distribution costs deriving from power supply facilities are recovered according to the customer's maximum demand.

(d) Time-Differentiated Pricing

As specified in the previous section, the current electricity retail tariff does not consider the tariff-differentiated pricing except for the industrial tariff that only sets different rates between summer and other seasons, though the wholesale tariff (BST) provides different rates among seasons and time-zones.

The KEMA report proposes to introduce the Time-of-Use (TOU) pricing in the retail tariff that follows the BST's time-differentiated pricing. The Public Consultation also presents a formula of the CRT that is linked to the BST. The KEMA report projects the applicability of the TOU tariff as follows.

- For customers supplied at 132 kV, a demand meter that can record their hourly load is already installed, thus a TOU tariff to follow BST's pricing can be implemented.
- For customers supplied at 33 kV and 11 kV, though hourly load metering cannot be made at this moment, the differentiated pricing of an energy charge among more than two time-zones which is currently applied to industrial customers, is preferred (installation of a demand meter that can record a customer's hourly load in the same way as 132 kV customers is recommended as the next step).
- Time-of-use (TOU) pricing for the customers supplied at low voltage will be left for future consideration.

Five years have already passed since the KEMA report and according to the Study Team's hearings on DisCos, installation of digital meters fit for TOU tariff has seen a progress, such as the MEDC's plan to install a digital meter for top 2,000 large customers, the applicability of TOU tariff to customers supplied at MV (33kV, 11kV) has become easier technically.

(e) Subsidized Tariff Rates

As also discussed in the previous section, the electricity tariff rates in Oman are set at a very low level due to the types of subsidies, the one provided to DisCos for making up for the revenue from electricity sales that is insufficient to cover the costs of supply, and the other, called "hidden subsidies", for controlling the fuel cost for power generation far below the international market price.

The KEMA report calls the former the “direct subsidies” and the latter the “indirect subsidies” respectively. The direct subsidies are expected to be removed by implementing the CRT, and this concept is taken over by the Public Consultation. However, it states that the applicability of the CRT is confined to large customers such as industrial and commercial and the existing Permitted Tariff will remain valid for small customers, hence the subsidization will be needed for them (especially residential).

The KEMA report states that it “does not deal with indirect subsidies” and the Public Consultation has no explicit description regarding this, which implies that this is an issue that should be discussed apart from the introduction of the CRT.

(f) Others

In addition to the aforementioned, the KEMA report points out that the penalization against the customer’s reactive power is not sufficient. According to the Study Team’s hearing on DisCos, the industrial customers with the power factor less than 90% are subject to the commercial tariff so that the annual billing becomes higher than applying the industrial tariff. However, switching to another tariff category may not be an appropriate penalty against low power factor and because no specific plan appears to exist regarding how frequent and accurate the power factor of the existing customers is investigated, the validity of the penalization remains doubtful.

(2) Current Status of Introducing the Cost Reflective Tariff

The JICA Study Team considers that the Cost Reflective Tariff (CRT) proposed by the KEMA report are in principle appropriate, because a proposal is made to conform to a concept to design the electricity tariff as economically rational as possible within the framework of tariff regulation. In addition, the KEMA report proposes a new tariff structure considering the industrial structure of the electric power sector in Oman and the status of facility installation, thus its feasibility is also well considered.

Furthermore, the KEMA report proposes a time-differentiated pricing in the retail tariff for the customers with a demand meter that follows the pricing of the wholesale tariff (BST), i.e. TOU tariff shall be applied to these customers. When the Cost Reflective Tariff is put into practice as proposed by the KEMA report, this will also cover a part of the “electricity tariff system that serves for load levelling” to be proposed by this Study.

As the next step to follow the KEAM report, the AER started appealing to the public consultation on the detailed design of the CRT (“Public Consultation”) in October 2009. Whereas the KEMA report proposed a comprehensive reform of the electricity retail tariff, the Public Consultation focuses on the introduction of a new retail tariff for large commercial and industrial customers that is linked to the BST, leaving the current Permitted Tariff unchanged (at least not revised at once) for the small customers including the residential. The CRT aims at achieving the following two objectives:

- Setting tariff rates to reflect the costs of supply
- Setting differentiated pricing among seasons and time-zones to meet the status of power demand and supply

As shown in the analysis results in 5.7.2, the total billing to the industrial and commercial customers is relatively high to be able to recover the costs of supply to some extent, thus the main challenge for implementing the CRT is the second point, i.e. how to rebalance the tariff rate among the seasons and time-zones. However, as for residential customers, the tariff rates constantly fall below the costs of supply and the inevitable reflection of the costs of supply will cause a huge residential tariff increase. Probably the scope of the tariff reforms was narrowed for its early implementation, considering that the comprehensive revision of the electricity tariff system will inevitably cause a huge social impact.

In the same way, the breakdown of the power distribution costs by the voltage level of supply and the introduction of the two- (three-) component tariff system may be counted out prioritizing the early implementation because it will take time for collecting and analysing the necessary data.

According to the Study Team's hearing on the AER, the plan to implement the CRT was discussed specifically between 2011 and 2012, but they concluded to postpone this plan because it's not the right time yet. Given that making a decision to revise the electricity tariff is not under the jurisdiction of the AER but requires an approval of the Council of Ministers, careful considerations and the lead time may be needed to discuss its actual implementation.

Taking the aforementioned into consideration, this Study assumes that the implementation of the CRT still remains undecided and proposes DSM tariff incentives that are in line with the discussions that have been made in Oman so far.

5.7.4 Designing the TOU Tariff Model

As discussed in the previous section, there already has been a discussion within AER to implement the Cost Reflective Tariff (CRT) that comprises the element of the TOU tariff, but it was decided to postpone this plan because it's not the right time yet.

This JICA Study also considers proposing tariff incentives to reduce the peak load. However, proposing a TOU tariff that is similar to the CRT may have difficulty at this moment in gaining consensus from all the stakeholders on the roadmap for implementation.

As a step forward towards the discussion on the TOU tariff beyond this uncertainty, the JICA Study Team considers that a technical argument on how to design the TOU tariff system helps to make the discussion points for future implementation clearer. This section, therefore, presents a sample of TOU tariff model on the condition that the existing tariff system is basically maintained.

(1) Preconditions in Designing the TOU Tariff Model

The following preconditions are taken into account in designing the TOU tariff model.

- TOU as optional tariff:
  In order to lower the hurdle for implementation, this TOU tariff model is offered as an optional tariff besides the current tariff as a "Standard Tariff" so that customers can freely choose between two options, i.e. not replacing the current tariff with the new TOU. The abolition of subsidies to the electricity tariff, which were discussed in 5.7.2, therefore remains to be tackled in the long run. The adoption of the three-component (or two-component) tariff, which was proposed by the KEMA report, is not considered for making the comparison with the "Standard Tariff" easy.
- Billing neutrality:
  Here the TOU tariff is introduced as an optional tariff, thus if the TOU rates are too high compared to the "Standard Tariff", very few customers will choose the TOU and the expected peak shift effect will become small. On the contrary, if the TOU rates are too low, the customers may be too much encouraged to shift to TOU, i.e. many customers will benefit from the reduced billing without too much effort for peak shift and for the DisCos it will result in a larger disadvantage of the reduced revenue than the advantage of the improved load factor.
  Therefore, it is desirable to design the TOU tariff by mainly targeting the largest cluster of customers in terms of the load factor, so that their billing on the TOU tariff may be a little higher than that of the "Standard Tariff" but becomes lower with a small load shift from peak hours to off-peak hours.
- The economically rational rate setting reflecting the costs of supply in each time zone:
  In general, the larger the margin between the high unit rate in peak hours and the low unit rate in off-peak hours becomes, the more the customers are motivated to shift their loads. However, setting an extremely large margin that cannot be justified economically may not be appropriate and hardly acceptable from a social perspective. Like the wholesale electricity tariff (BST) that sets unit rates to reflect the load level at each time zone, the retail tariff should be designed to provide TOU rates that are consistent with the costs of supply of each time zone.
- Simplicity of tariff structure:
  In the meanwhile, too much complicated time-zone segmentation for rate-setting, even though they are strictly harmonious with the costs of supply, may prevent the customers from understanding how to properly shift the load among the time zones and the price signal may not function as expected. Time-zoning should be simplified as much as possible to be acceptable to the customers.

The following sections present the TOU tariff model formulated by the JICA Study Team based on the annual load curve on the MIS grid, the BST tariff and so on.

(2) Time-zone Segmentation for the TOU Tariff Model (MIS Grid)

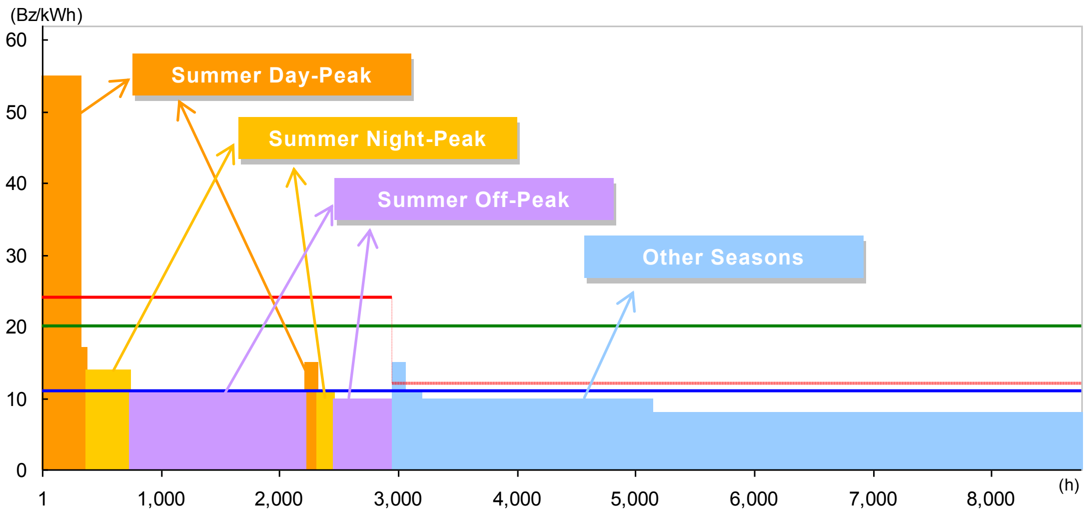
(a) Definition of Seasons and Time Zones

The BST in the MIS area divides the 12 months into six groups such as "January-March", "April", "May-July", "August-September", "October", and "November-December", and then segments each of them into four time zones to set unit rates. In the meanwhile, the current retail tariff for industrial customers sets different rates for the period of "May-August" and the remaining period, that is, the definition of seasonal zones is different from the BST's.

For easy comparison with the "Standard Tariff", is TOU tariff model adopts the same definition of seasonal zones as that of the current retail tariff, i.e. the "Summer Season" from May to August and "Other Seasons" (see also the figure "Hourly Costs of Supply per Electricity Sales and the Retail Tariff' Unit Rates for Each Sector in 2011 (MIS Grid)" in 5.7.2).

Then the "Summer Season" is further classified into three time zones, and together with a single time zone in the "Other Seasons", four time zones are defined as follows:

- Summer Day-Peak: from the 13^h to the 17^h, all the days from May to August
- Summer Night-Peak: from 22^h to 2^h, all days from May to August
- Summer Off-Peak: 2^h to 13^h and 17^h to 22^h, all days from May to August
- Other Seasons: All days long from January to April and September to December

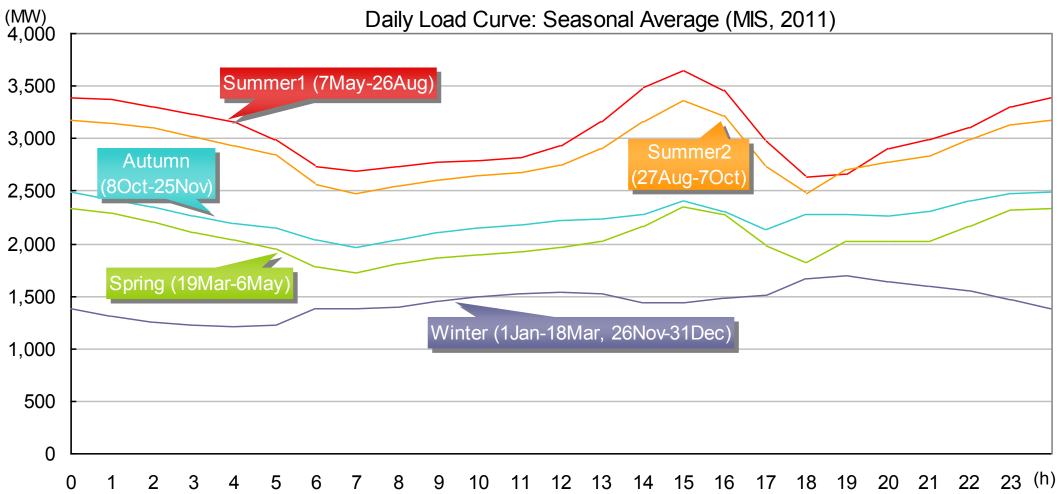


(Source: JICA Study Team)

Figure 5- 96 Classification in Four Time Zones for TOU Tariff's Rate Setting (MIS Grid)

Regardless of the months and the days-of-week during the "Summer Season", all the BST rates in the Summer Day-Peak exceed those in the Summer Night-Peak, and those in the Summer Night-Peak exceed those in the Summer Off-Peak, thus it is justified to group them among these three time zones for simplicity. During the "Other Seasons", the BST rates in some hours in September are priced high, but because their margin over the remaining ones is not significantly high and their duration is short, setting another time zone for them does not need to be considered.

The TOU tariff in Japan is set at "Nighttime" time zone throughout the year, because the load level in the nighttime during the summer (low-load hours during the high-load season) is lower than the daytime in the spring and autumn (high-load hours in the low-load season). In the case of the MIS grid, the load fluctuation among seasons is much larger than the load fluctuation within a day (i.e. the lowest load during the summer is still higher than the highest load during the winter) thus the time-of-use rate setting in the low-load seasons, i.e. “Other Seasons”, is not needed.

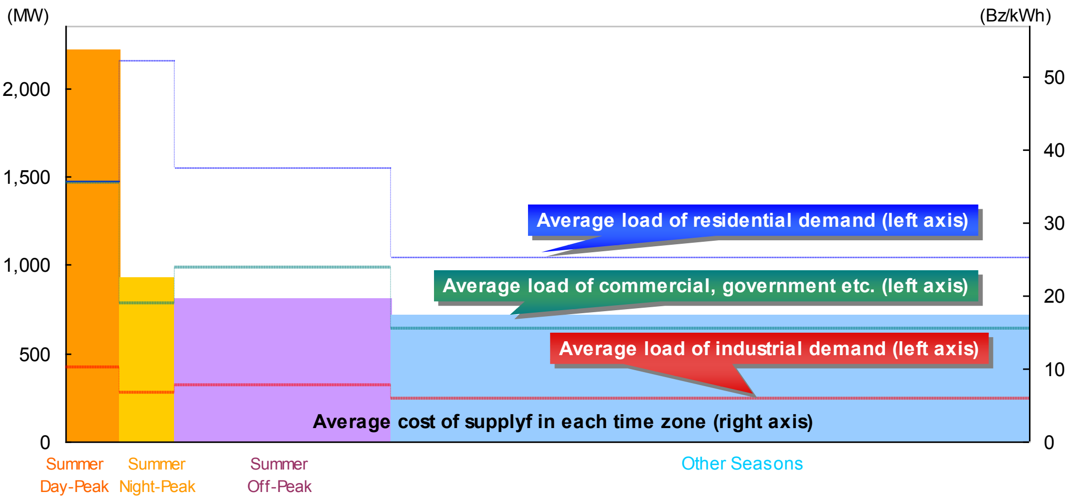


(Source: OETC Data, touched up by the JICA Study Team)

Figure 5- 97 Average Daily Load Curve in Each Season (MIS Grid)

(b) Average Hourly Load of Each Sector

The annual load data of each of the residential, industrial, and “commercial, government etc.” sectors are also arranged into the aforementioned four time zones. The following figure shows each sector’s average load in each of the four time zones. As for the industrial and “commercial, government etc.” sectors, the average load of the Summer Day-Peak is much higher than that of the Summer Night-Peak and the Summer Off-Peak, which implies the possibility that setting a good margin between the tariff rate in the Summer Day-Peak and the remainder may stimulate the customers’ voluntary peak load shift. Regarding the residential sector, the average loads of Summer Night-Peak and Summer Off-Peak are higher than the Summer Day-Peak even in the current situation, therefore the potential of the peak shift from the Day-Peak to the remaining hours may be relatively small.



(Source: estimated by the JICA Study Team)

Figure 5- 98 Each Sector's Average Load in Each of the Four Time Zones (MIS Grid)

(3) TOU Tariff Model for Industrial Customers (MIS Grid)

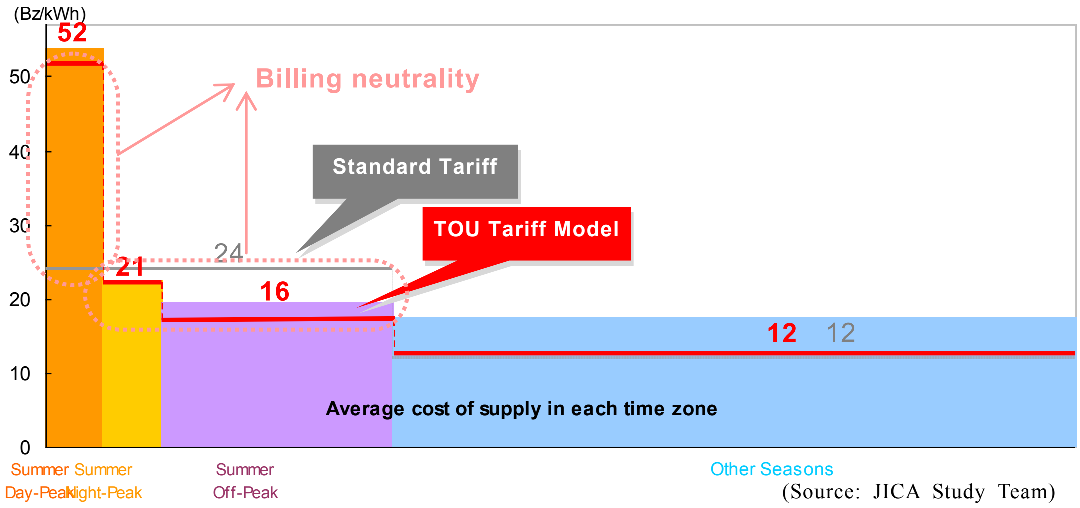
Then this Study sets out to design the TOU tariff model, which takes into consideration the consistency with the costs of supply (e.g. BST) in each time zone and the billing neutrality with the "standard Tariff".

As for the industrial customers, the "standard Tariff" already sets the differentiated unit rates between the "Summer Season" (24 Bz/kWh) and "Other seasons" (12 Bz/kWh), and, as analyzed in 5.7.2, the latter is too low to recover the costs of supply. Therefore, the TOU does not need to set a much lower rate during this period and the same 12 Bz/kWh as in the "Standard Tariff" is applied.

In order to maintain the billing neutrality with the "Standard Tariff", the TOU tariff rate in the "Summer Season" should be set higher in the Summer Day-Peak and lower in the Summer Night-Peak and Summer Off-Peak than the "Standard Tariff".

In conclusion, the unit rates of the TOU tariff model for industrial customers are set as follows.

- Summer Day-Peak: 52 Bz/kWh (Standard Tariff: 24 Bz/kWh)
- Summer Night-Peak: 21Bz/kWh (Standard Tariff: 24 Bz/kWh)
- Summer Off-Peak: 16 Bz/kWh (Standard Tariff: 24 Bz/kWh)
- Other Seasons: 12 Bz/kWh (Standard Tariff: 12 Bz/kWh)



(Source: JICA Study Team)

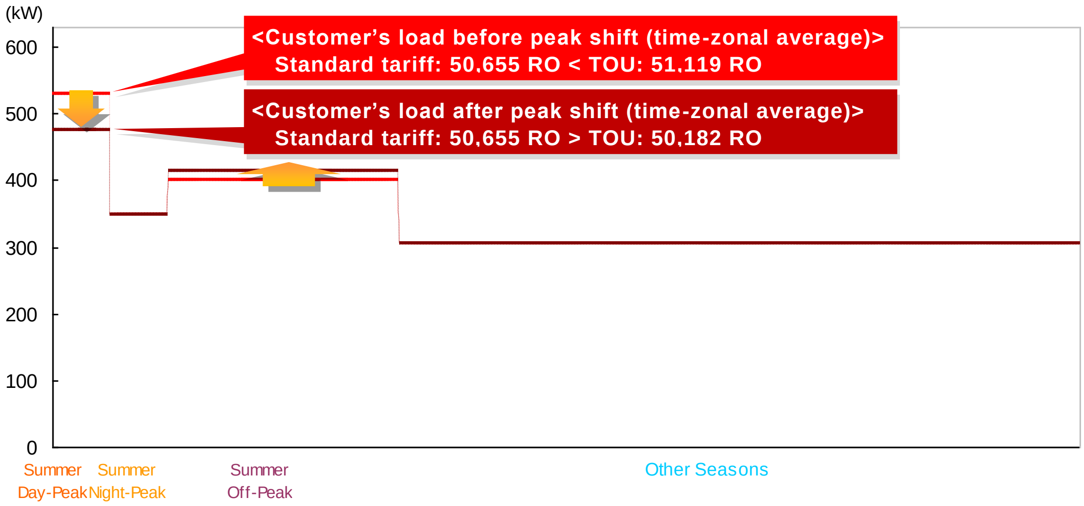
Figure 5- 99 TOU Tariff Model for Industrial Customers (MIS Grid)

Assuming the "model customer" of the industrial sector, the annual billing of the TOU tariff is calculated and compared to the "Standard Tariff". The "model customer" has the same load pattern as the average of the industrial sector in the MIS grid (i.e. the shape of its load curve is the same as that of the estimated annual load curve of the total industrial sector) and its annual consumption is 3,000 MWh. The annual billing of these two tariffs is formulated as follows. In this case, the billing of the TOU tariff is a little higher.

- Standard Tariff: 24 Bz/kWh x 1,221 MWh + 12 Bz/kWh x 1,779 MWh = 50,655 RO
- TOU Tariff: 52 Bz/kWh x 260 MWh + 21 Bz x 171 MWh + 16 Bz/kWh x 789 MWh + 12 Bz/kWh x 1,779 MWh = 51,119 RO

If this customer reduces the average consumption of the Summer Day-Peak by 10% and shifts the same to the Summer Off-Peak hours (without changing the total consumption in a year, i.e. 3,000 MWh/year), the annual billing of the Standard Tariff remains unchanged, i.e. 50,655 RO, but the billing of the TOU tariff is reduced by a little less than 1,000 RO and becomes lower than the "Standard Tariff".

- TOU Tariff (after peak shift): 52 Bz/kWh x 234 MWh + 19 Bz x 171 MWh + 16 Bz/kWh x 815 MWh + 12 Bz/kWh x 1,779 MWh = 50,182 RO



(Source: JICA Study Team)

Figure 5- 100 Comparison of Annual Billing to a Model Customer of the Industrial Sector (MIS Grid)

(4) TOU Tariff Model for Commercial Customers (MIS Grid)

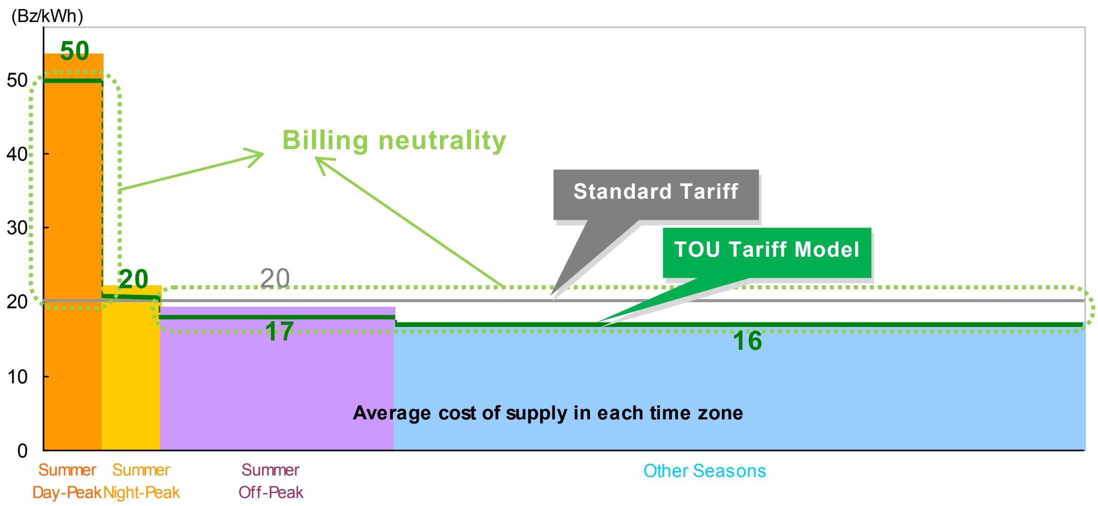
Likewise, this Study sets out to design the TOU tariff model for commercial customers.

The "Standard Tariff" for commercial customers sets the rate at 20 Bz/kWh constantly throughout the year, which is not sufficient to recover the costs of supply during the "Summer Seasons" but yields profit in "Other Seasons". Therefore, the TOU tariff model's billing neutrality with the "Standard Tariff" is attained by lowering the TOU tariff model's unit rate in "Other Seasons". However, given that the possibility of peak shift from "Summer Season" to "Other Seasons" is very limited, especially for commercial customers whose price elasticity is smaller than that of industrial customers, its unit rate is set at 16 Bz/kWh, which is not lower than the average costs of supply during this period.

The unit rates of the TOU tariff model in the three time zones in the "Summer Season" are adjusted so that they are consistent with the costs of supply and maintain billing neutrality.

The unit rates of the TOU tariff model for commercial customers are set as follows

- Summer Day-Peak: 50 Bz/kWh (Standard Tariff: 20 Bz/kWh)
- Summer Night-Peak: 20 Bz/kWh (Standard Tariff: 20 Bz/kWh)
- Summer Off-Peak: 17 Bz/kWh (Standard Tariff: 20 Bz/kWh)
- Other Seasons: 16 Bz/kWh (Standard Tariff: 20 Bz/kWh)



(Source: JICA Study Team)

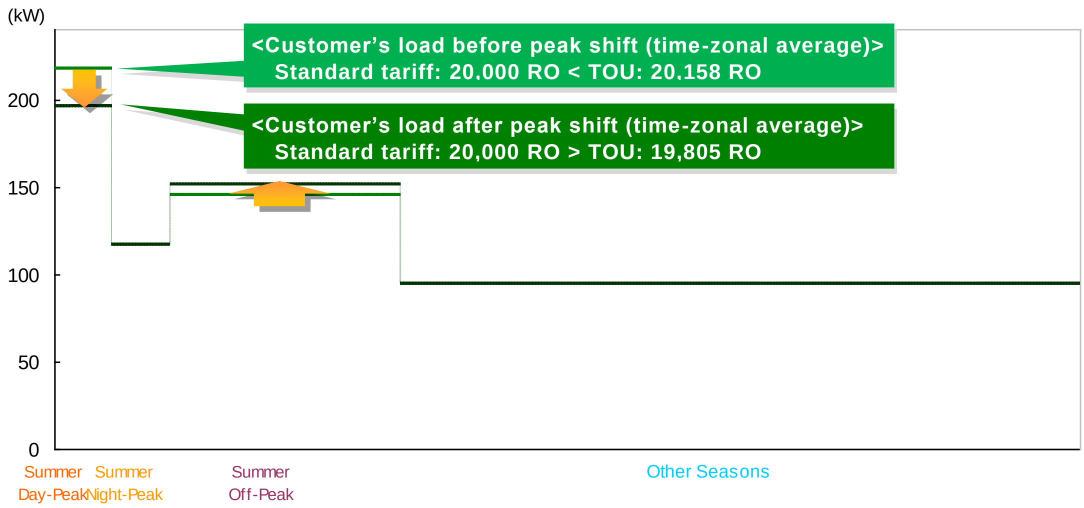
Figure 5- 101 TOU Tariff Model for Commercial Customers (MIS Grid)

Assuming a "model customer" of the commercial sector, the annual billing of the TOU tariff is calculated and compared with the "Standard Tariff". The "model customer" has the same load pattern as the average of the commercial sector in the MIS grid (i.e. the shape of its load curve is the same as that of the estimated annual load curve of the total commercial sector) and its annual consumption is 1,000 MWh. The annual billing of these two tariffs is formulated as follows. In this case, the billing of the TOU tariff is a little higher.

- Standard Tariff: 20 Bz/kWh x 1,000 MWh = 20,000 RO
- TOU Tariff: 50 Bz/kWh x 107 MWh + 20 Bz x 57 MWh + 17 Bz/kWh x 287 MWh + 16 Bz/kWh x 549 MWh = 20,158 RO

In the same way, if this customer reduces the average consumption in the Summer Day-Peak by 10% and shifts the same to the Summer Off-Peak hours (without changing the total consumption in a year, i.e. 1,000 MWh/year), the annual billing of the Standard Tariff remains unchanged, i.e. 20,000 RO, but the billing of the TOU tariff is reduced by about 350 RO and becomes lower than the "Standard Tariff".

- TOU Tariff (after peak shift): 50 Bz/kWh x 96 MWh + 20 Bz x 57 MWh + 17 Bz/kWh x 297 MWh + 16 Bz/kWh x 549 MWh = 19,805 RO



(Source: JICA Study Team)

Figure 5- 102 Comparison of Annual Billing to a Model Customer of the Commercial Sector (MIS Grid)

(5) The Way Forward

The TOU tariff model presented in this section is only a sample. Various models of TOU tariffs can be designed by changing the preconditions such as the segmentation of seasonal zones and time zones, mainly targeted customer clusters (load factor and load curve), and the parameters such as “the customer benefits from reduced billing by …% by shifting the peak load by …%”.

Furthermore, as explained in 5.7.3, gaining a consensus on the roadmap for implementing the TOU tariff may be difficult at this moment. Therefore, there is the possibility that the TOU tariff model presented in this section will be adopted as it is.

Nevertheless, every stakeholder in the power sector in Oman is showing a positive response more or less towards the implementation of the TOU tariff sometime in the future. Therefore it is worth identifying the issues to be considered for future implementation via a discussion on a specific TOU tariff model that helps to make the discussion points clearer.

Based on the argument in this section, the specific discussion points in designing the TOU tariff will be described in 7.5 of Chapter 7.

(6) Designing TOU Tariff Model in the Salalah Area (Reference)

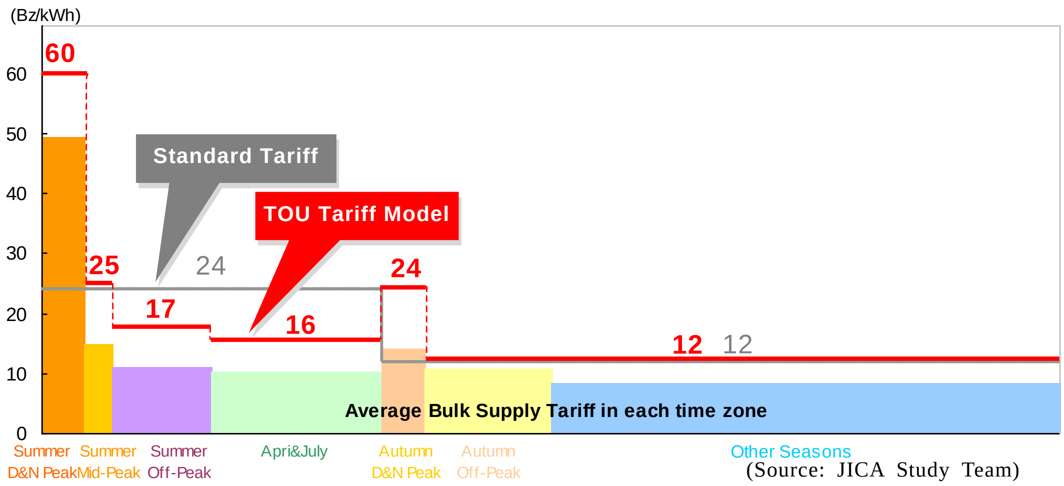
In the same way as was done with the MIS grid, the TOU tariff model for industrial and commercial customers in the Salalah area is designed, by using the parameters such as the annual load profile data of each sector and the costs of supply (Note: because the sufficient data to estimate the hourly costs of supply in the Salalah area including the transmission and distribution costs, the unit rates of BST are referred to as the costs of supply).

Here only the results of the trial calculation are presented. This model adopts six time zones for setting unit rates, more than the MIS TOU model that has four time zones, considering the peculiarity of the annual load curve of the Salalah grid that once drops during the late summer (July-August) and increases again in autumn (September-October).

Given that the load fluctuation of the Salalah grid is small compared to the MIS grid, both during the year and day, a larger margin needs to be set between the unit rate of the peak hours and off-peak hours in order for the customers to gain reduced billing benefits with the peak shift (e.g. 10% reduction of the peak load in this example).

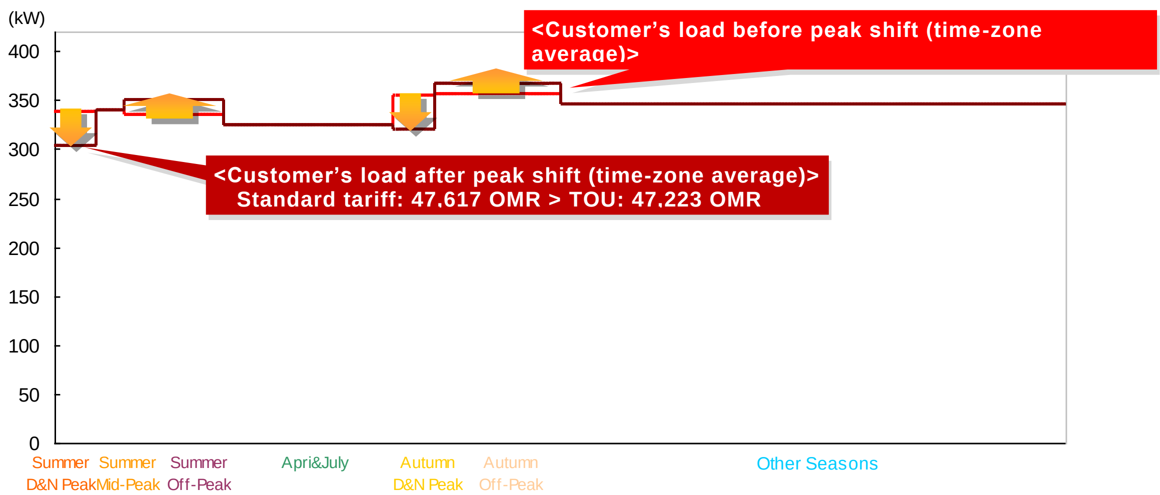
Furthermore, because of the small load fluctuation in a day, by having the same assumptions of the peak shift as in the MIS model, i.e. "the customer reduces the average consumption in the peak hours by 10 % and shifts the same to the off-peak hours", making the average load level of peak hours lower than off-peak hours. Probably there are only a few customers who dare to accept a peak shift like that.

For these reasons, the JICA Study Team concludes that even if the TOU tariff is implemented in Salalah area, only a few customers will choose the TOU and its peak shift effect may be limited.



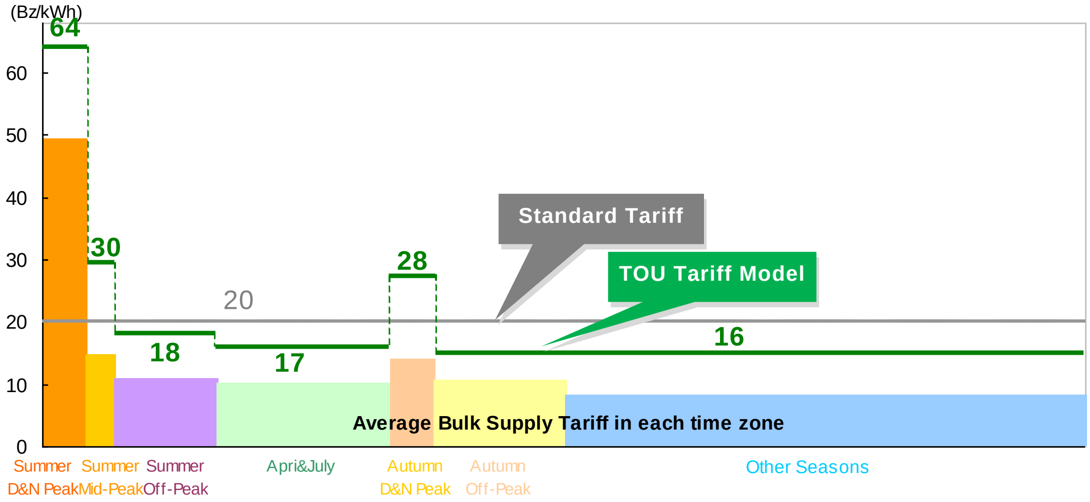
(Source: JICA Study Team)

Figure 5- 103 TOU Tariff Model for Industrial Customers (DPC Grid, reference)



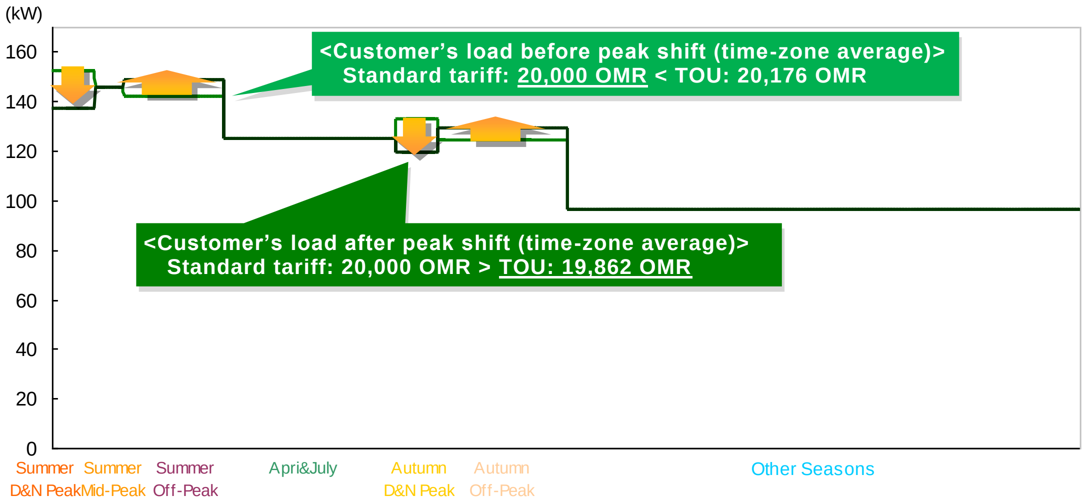
(Source: JICA Study Team)

Figure 5- 104 Comparison of Annual Billing to a Model Customer of the Industrial Sector (DPC Grid, reference)



(Source: JICA Study Team)

Figure 5- 105 TOU Tariff Model for Commercial Customers (DPC Grid, reference)



(Source: JICA Study Team)

Figure 5- 106 Comparison of Annual Billing to a Model Customer of the Commercial Sector (DPC Grid, reference)

5.8 Awareness Survey on Energy Efficiency and Conservation

5.8.1 Objectives and Methodology of the Survey

This survey aimed to collect basic information, attain a satisfactory awareness level along with a willingness to implement EE&C activities in order to consider effective measures and programs. It targeted general energy users, (i.e., residential, industrial, commercial, governmental, schools, and mosques) and grasped the actual performance of energy consumption devices, consumption patterns, energy management and activities for EE&C of these users. The survey was conducted via direct interviews and prepared questionnaires.

Table 5- 79 Contents of the Survey

Items	Contents
Consumer Information	• (Residential) Family composition, number of rooms • (Other) Working hours, floor area • Electricity consumption (kWh)
Electric Appliances *Air conditioners, lights, insulates etc	• Operating pattern and season of air conditioners • Types of installed lights • Insulation of building envelopes, roof and windows
Awareness of EE&C	• EE&C activities for lights • EE&C activities for air conditioners • Information tips of EE&C • Awareness level of E-portal (portal website of electricity)
Feasibility of the DSM Tariff (Industrial, Commercial)	• Feasibility of peak demand cut • Comments on the TOU tariff and demand adjustment contract

A local consultant determined the interviewees, conducted interviews and carried out an analysis of the interview results. Interviewees of the industrial and residential sector are selected from Muscat, Salalah, and Sohar in which there are industrial districts. Interviewees of other sectors, on the other hand, are selected from Muscat and Salalah.

Table 5- 80 Target of the Survey

Target	Breakdown of the Target	Area Location
Industrial (30 samples)	• Large • Middle • Small	• Muscat • Salalah • Sohar
Commercial (20 samples*)	• Office • Shopping Mall • Hotel • Hospital • University	• Muscat • Salalah
Government/Municipal (10 samples)	• Government • Municipal	• Muscat • Salalah
Schools (10 samples)	• Primary • Secondary	• Muscat
Mosques (10 samples)	• Large duma prayer mosque • Smaller	• Muscat
Residential (60 samples)	• Villas • Flats	• Muscat • Salalah • Sohar

* While 30 samples were initially planned, 20 samples, who give the valid answers, of 32 interviewees can be subjects in the survey.

5.8.2 Results and Analysis of the Survey

This subchapter introduces the results of the following items which are related to EE&C measures.

- Air Conditioners

- Insulation Materials
- Data Availability for the Energy Management System
- Investments in EE&C
- EE&C measures for AC
- EE&C Information Sources
- Awareness of the E-portal
- Interests in the DSM Tariff

(1) Air Conditioners

The following circle graphs show the operation patterns of ACs in each sector. As a result, the commercial sector has the longest operating time of ACs, and more than half of industry, government institutions, schools and mosques use ACs in working hours.

In the industrial sector, 50 % of the subjects answered that they use ACs during working hours. In fact, some of them need ACs to be operated all throughout the day for their production processes, but it seems that more than half of industrial subjects use ACs during working hours. In the commercial sector, 70 % answered that they use ACs 24 hours everyday or on working days and the operation hours are higher than other sectors. The ratio of those who use ACs during working hours are 80% at government institutions, 100 % in schools, 70% in mosques and this result shows that the operating times of the ACs in these sectors are shorter than industrial and commercial entities. 66% of the subjects from the residential sector answered that they use ACs everyday.

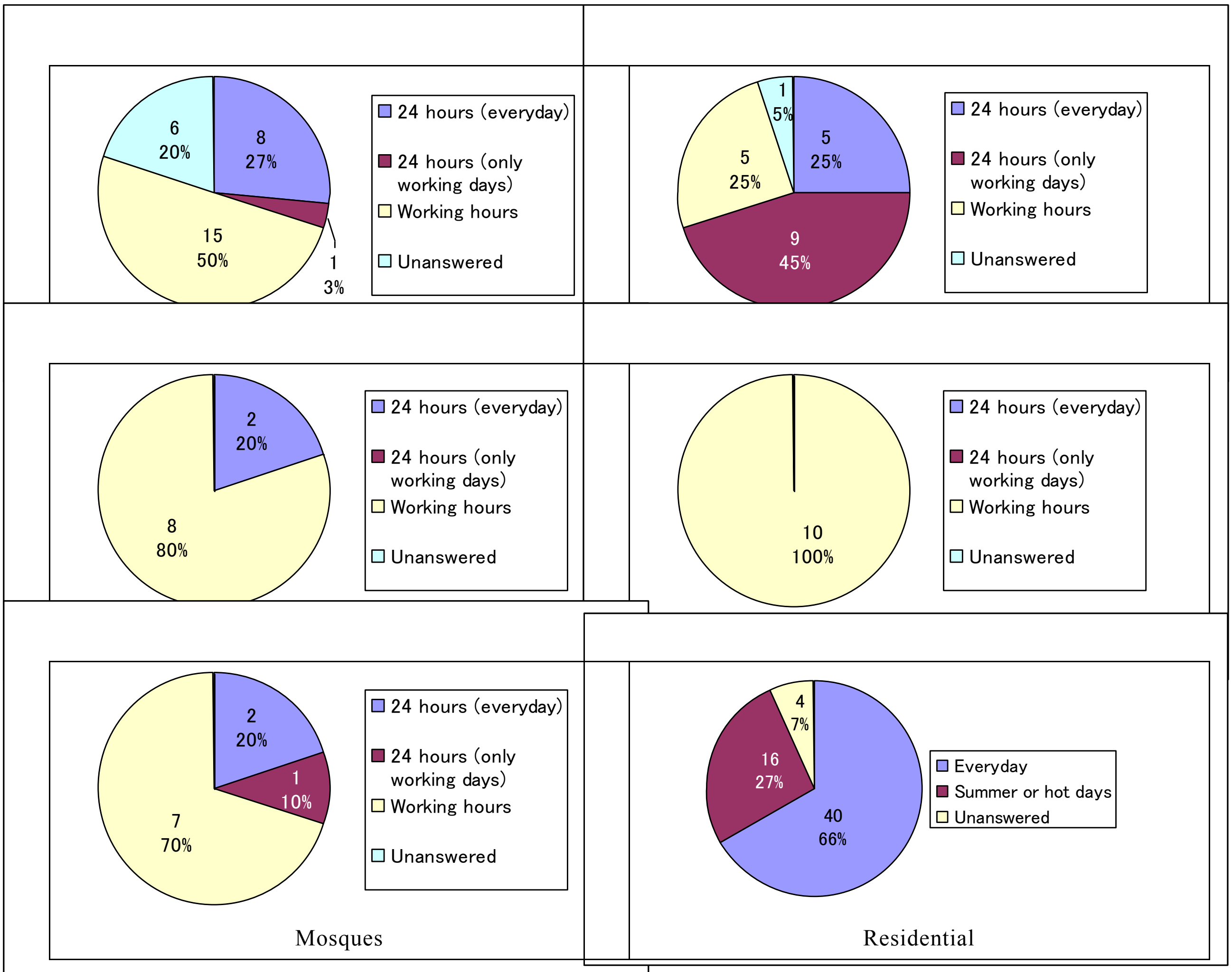
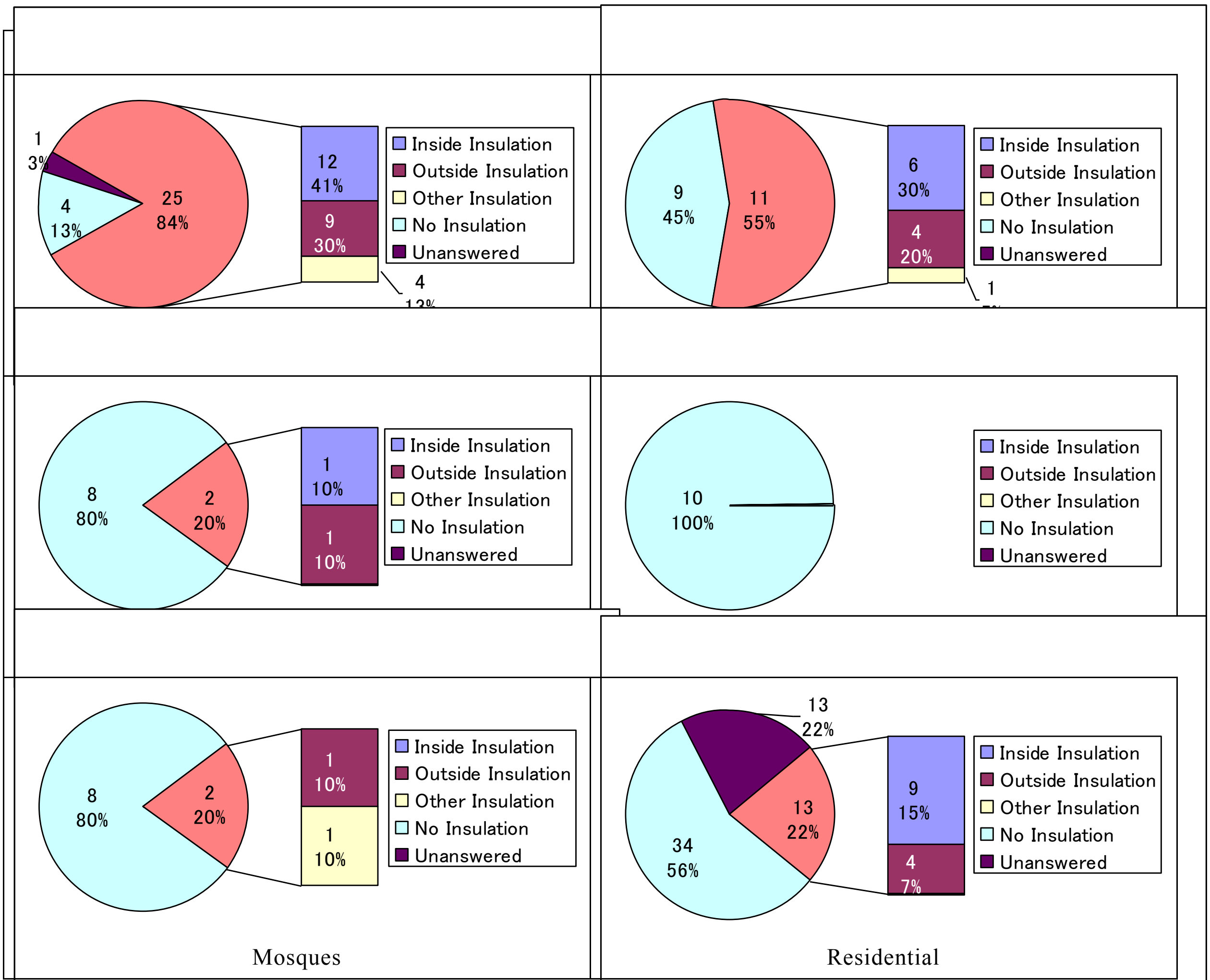


Figure 5- 107 AC Operating Pattern in Each Sector

(2) Insulation Materials

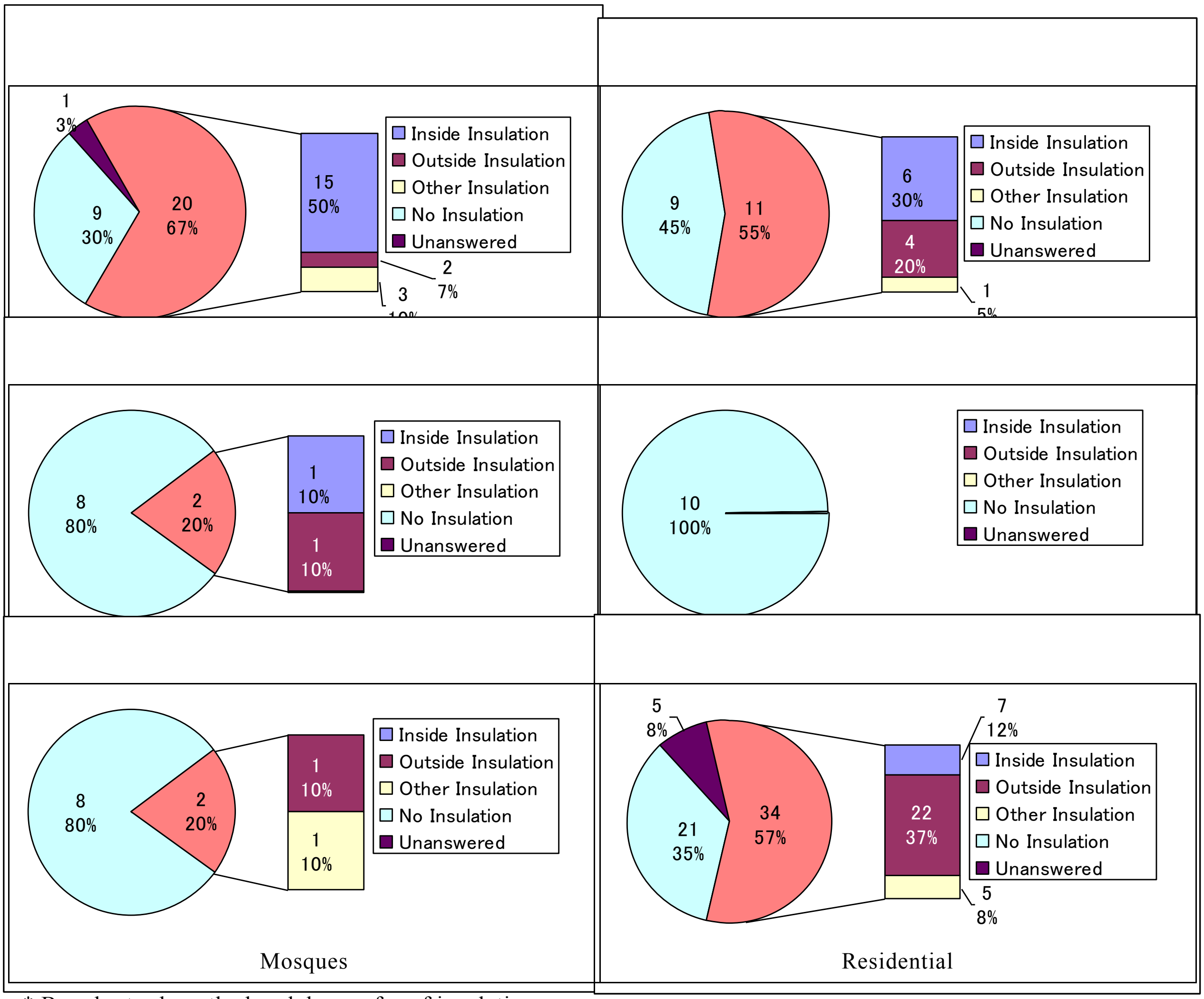
More than half of the building envelopes and roofs in industrial and commercial entities use insulation materials. In government institutions and mosques, on the other hand, 20% subjects have building envelopes and roofs with insulation materials, and no schools have insulating materials for building envelopes and roofs. In the residential sector, 20 % of building envelopes and more than half of the roofs use insulation materials.

With regard to windows, more than half of the subjects in each sector have single glazed windows, and normal glass is installed in many cases. More subjects in the residential sector tend to install low emissivity glass and heat reflective glass than in other sectors.



* Bar charts show the breakdown for building envelope insulation

Figure 5- 108 Building Envelope Insulation in Each Sector



* Bar charts show the breakdown of roof insulation

Figure 5- 109 Roof Insulation in Each Sector

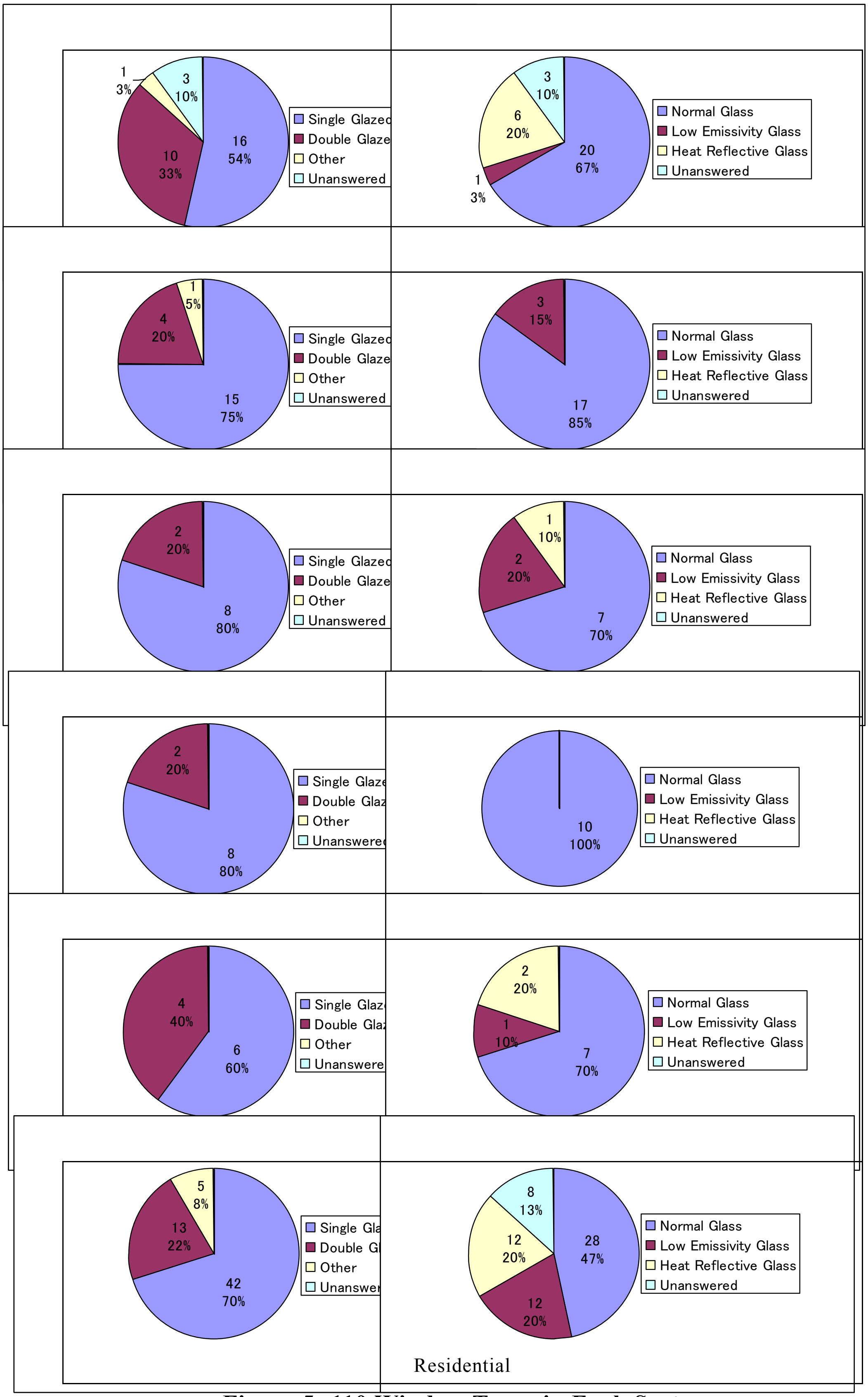
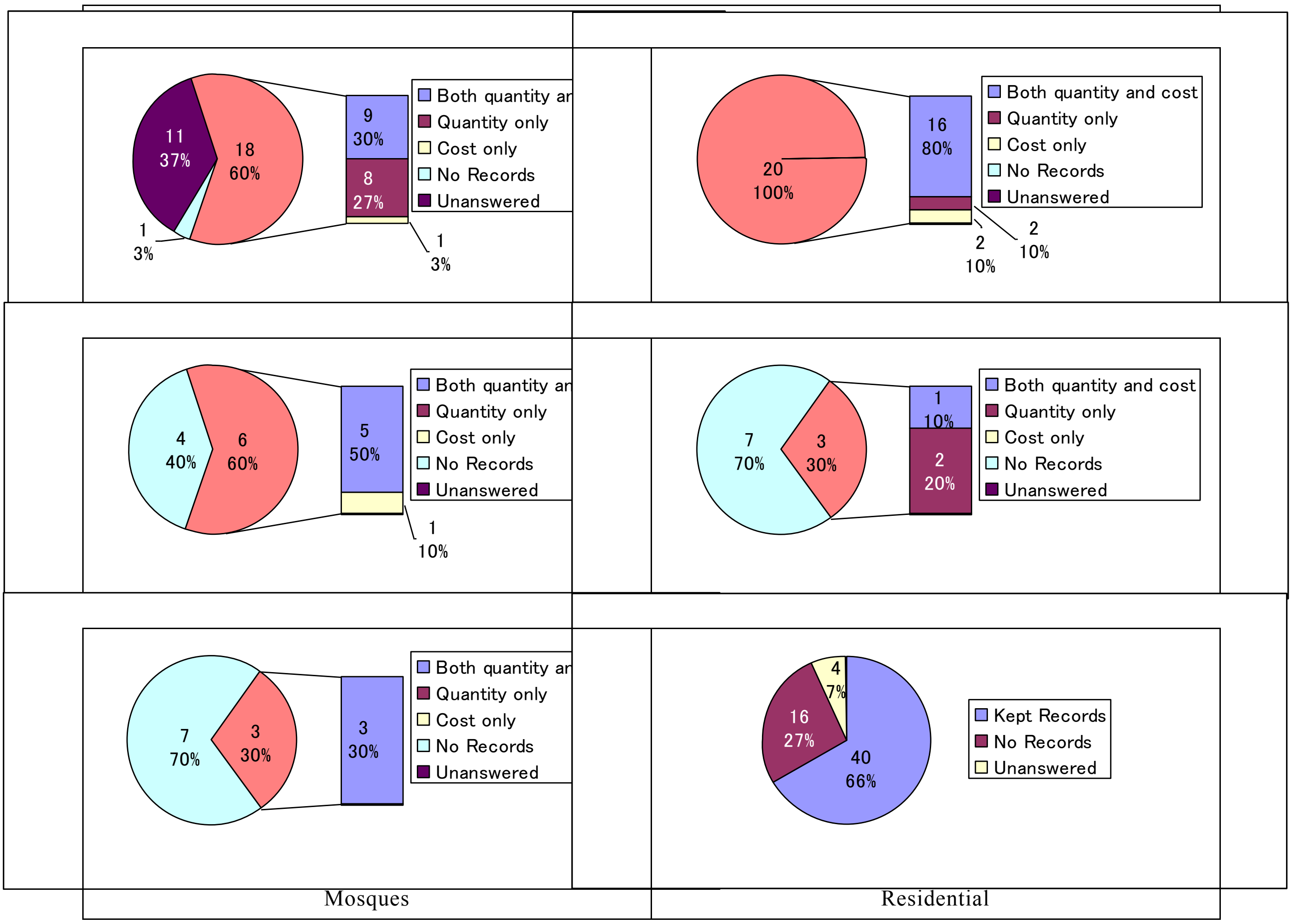


Figure 5- 110 Window Types in Each Sector

(3) Data Availability for the Energy Management System

Almost all of the subjects in both the industrial and commercial sector have kept their energy consumption data, and only 1 subject in industry answered clearly that it does not keep its data.

Only half of the subjects in government, schools and mosques have kept their energy consumption data. One reason considered is that the electricity users in such sectors are different from electricity payers.



* Bar graphs show the breakdown of energy consumption records

Figure 5- 111 Energy Consumption Records in Each Sector

(4) Investments in EE&C

About 20 % subjects in each sector answered that investments were made for EE&C. Furthermore, most subjects answered that they target “less than 1 year” or “1 – 3 year” for the pay-back period. This result implies that most users may not make investments without commeasurable incentives.

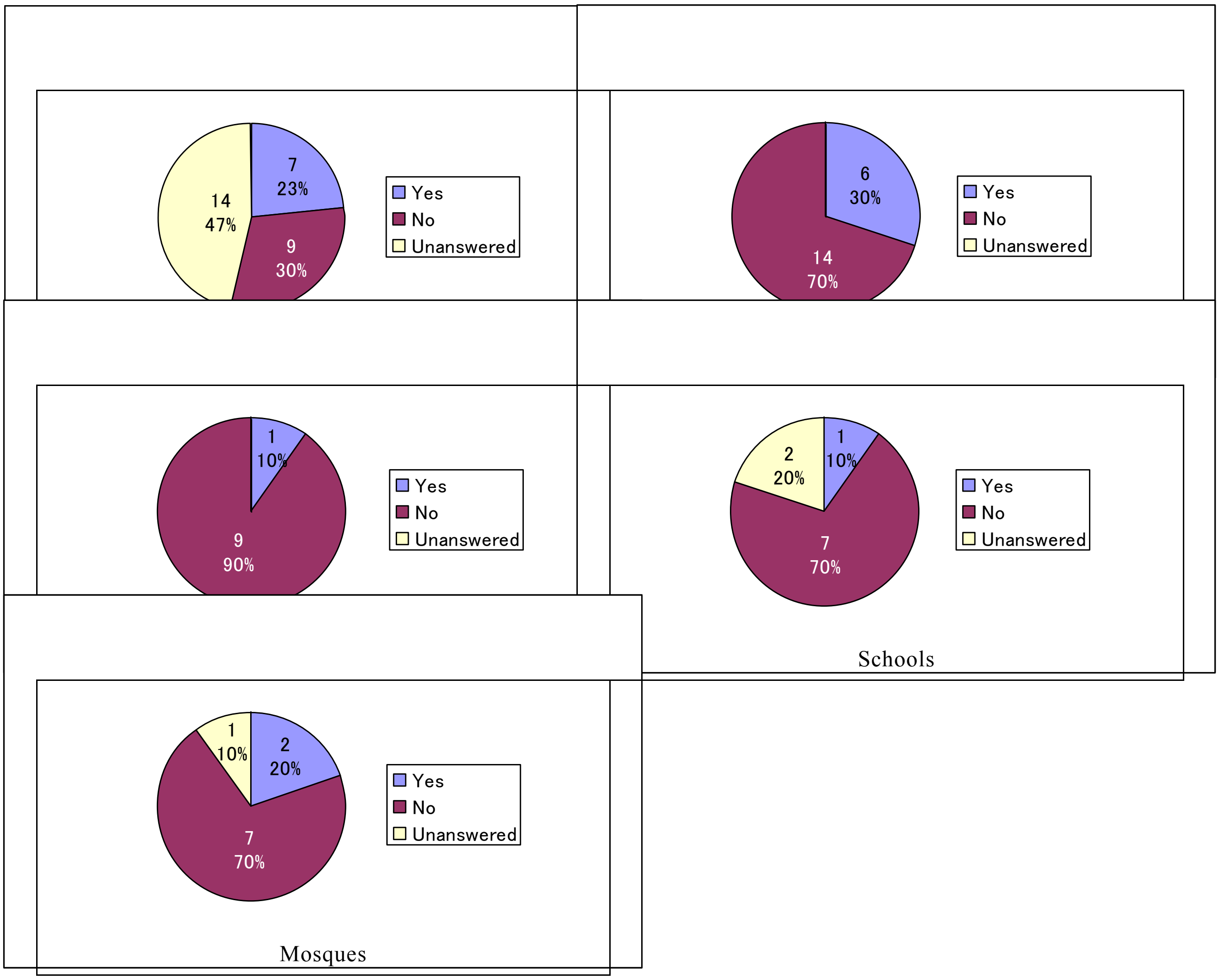


Figure 5- 112 Investments for EE&C in Each Sector

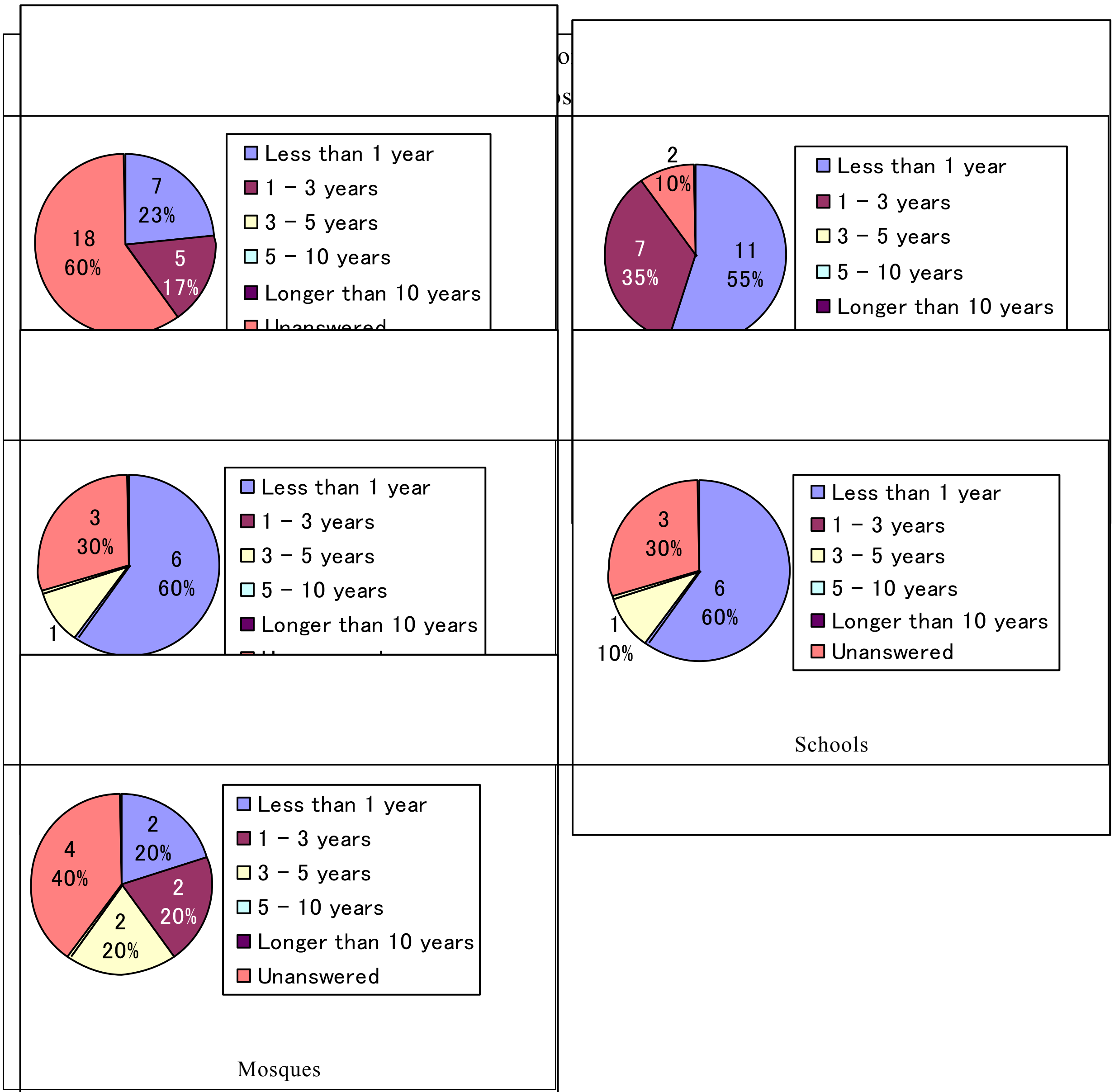


Figure 5- 113 Payback Period Targeted in each Sector

(5) EE&C measures of AC

The subjects in each sector tend to follow EE&C measures which do not need investments. The practice rates of “Close the windows/doors when ACs are operating”, “Stop ACs when nobody is in the room”, and “Stop ACs when the days are not hot” are higher than other activities because these activities are easier than other measures to implement. On the other hand, the practice rates of the activities which need investments such as replacements with efficient ACs are lower.

Question: Which of the AC energy efficiency measures have you adopted? (Multiple answers)

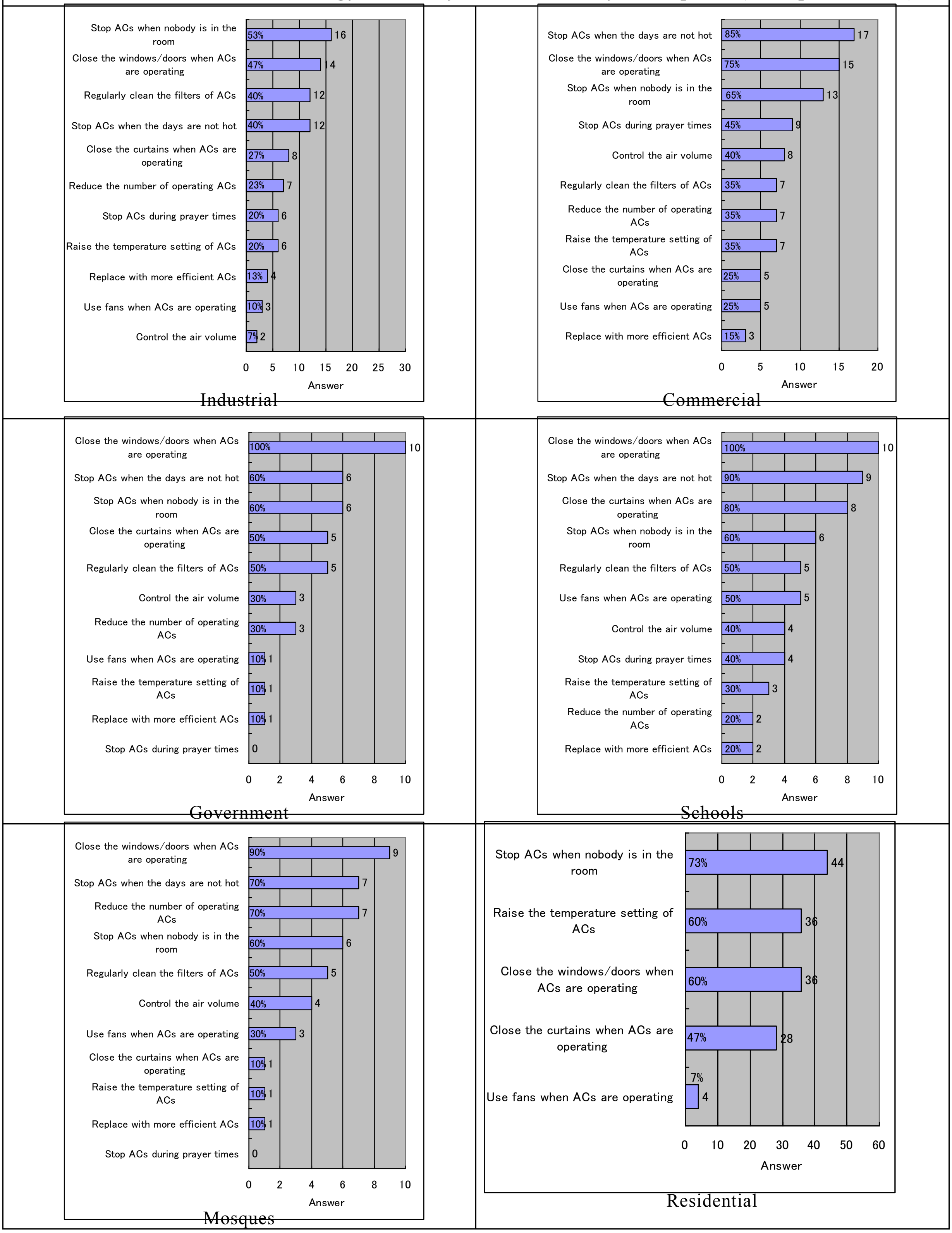


Figure 5- 114 EE&C Measures for Air Conditioners in Each Sector

(6) EE&C information Sources

The subjects in each sector were asked to give a maximum 3 answers about their EE&C information sources. The top answers given were from mass media such as TVs etc, which shows that PR campaigns are acknowledged in general. In the industrial and commercial sectors, the internet was in the higher rankings, which shows that these sectors are more active than other sectors when it comes to EE&C information gathering. In the residential sector, it seems that publicity activities are acknowledged because 47% of subjects recognize the EE&C brochures provided by the government and/or electric power companies.

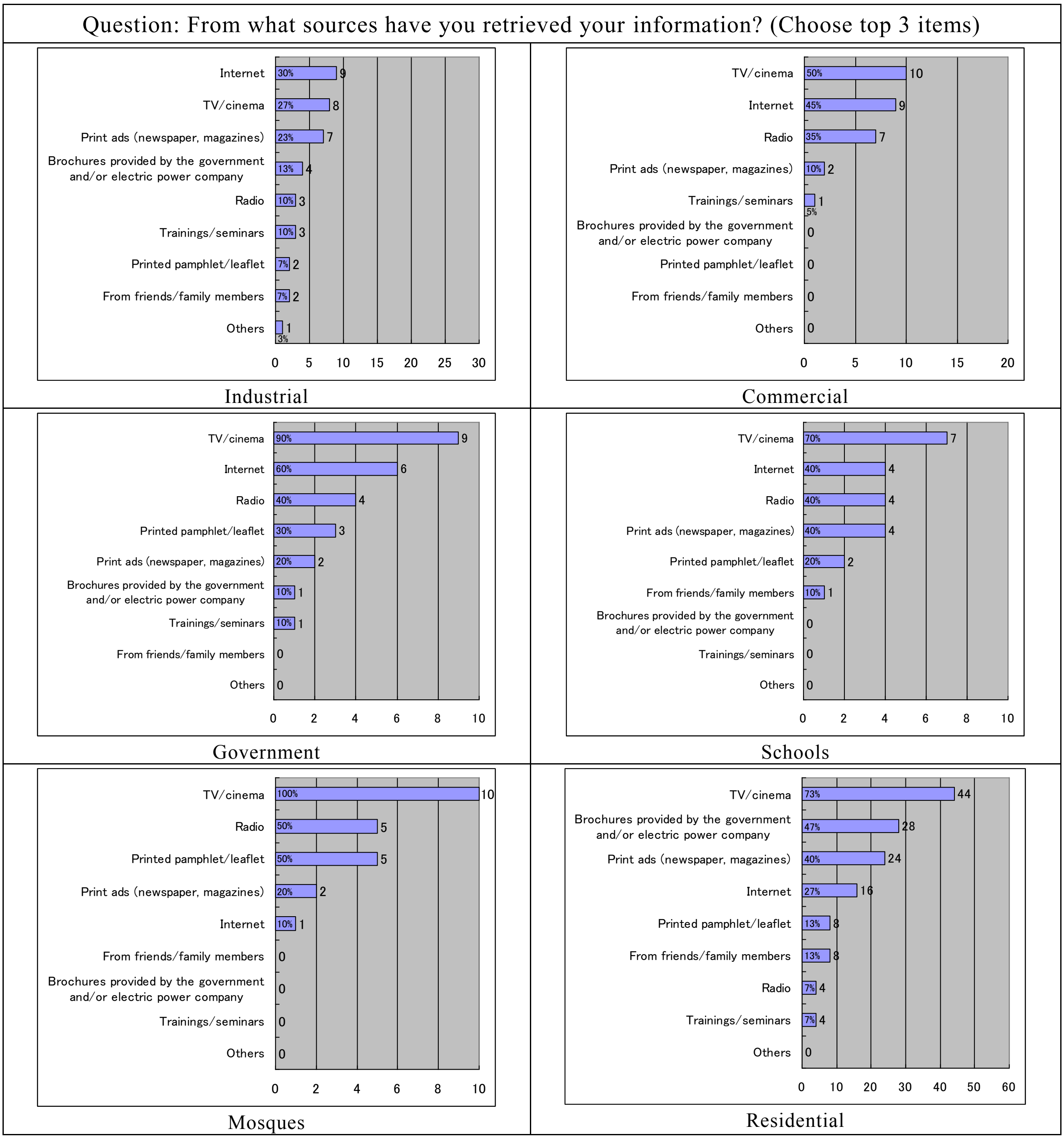


Figure 5- 115 Information Sources about EE&C in Each Sector

(7) Awareness of E-portal

The recognition of the E-portal was not so acknowledged through the survey, a few industrial and some residential subjects answered they know the E-portal. It cannot be ruled out that other staffs or families who are not interviewees in the survey are very familiar with E-portal, but it is possible to say that the E-portal was not highly-popularized.

Enhancing the contents of the E-portal is one of the important challenges because the subjects who use E-portal answered that their purpose of use is only for checking electricity consumption and bills.

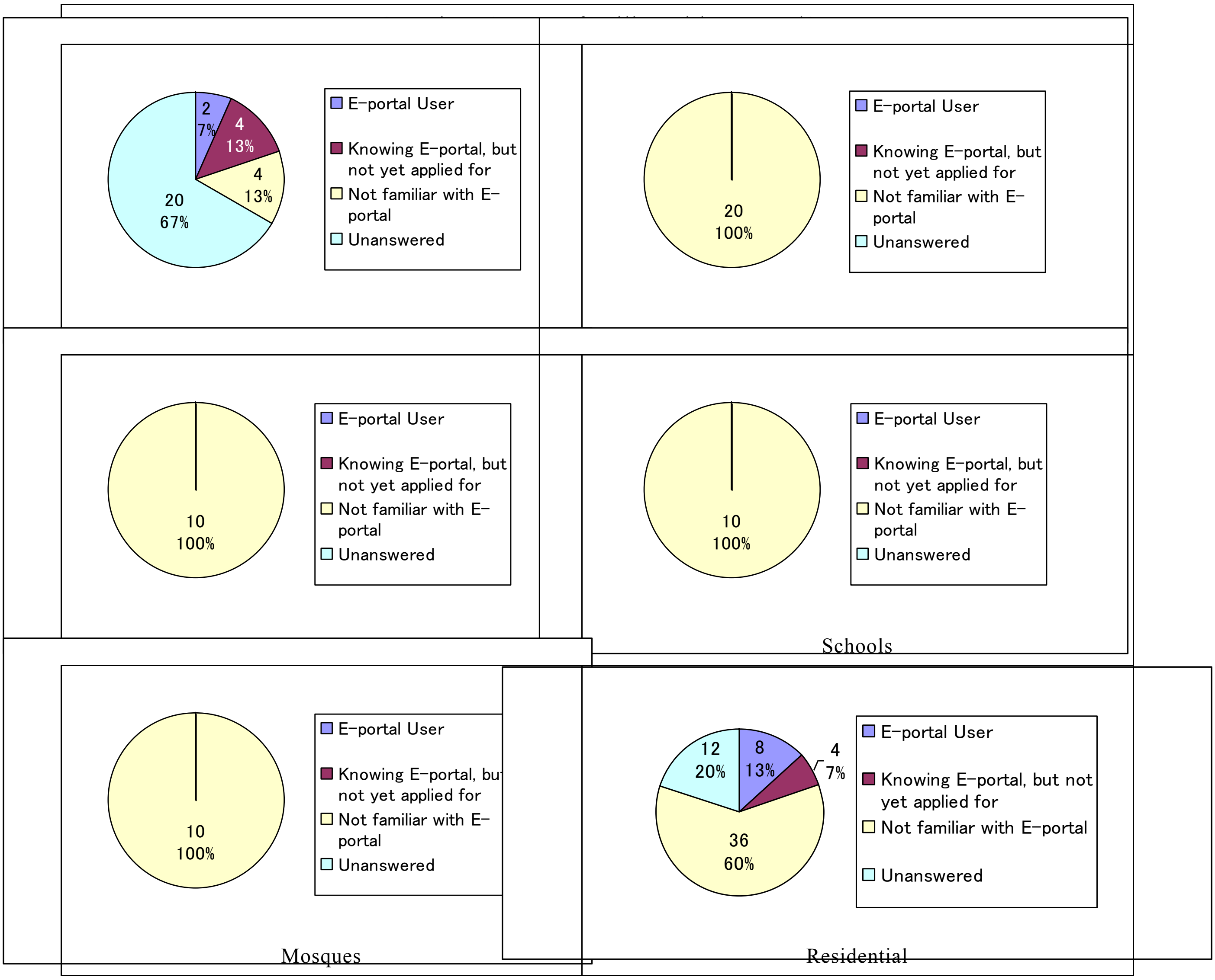


Figure 5- 116 Awareness of E-portal for Each Sector

(8) Interests in the DSM Tariff

The subjects who are interested in the DSM tariff were less than half although interviewers informed all of them of the system including its incentives etc. The main reasons are the difficult to change the production process and employment conditions, and cheaply priced electricity. Therefore, these difficulties may give subjects the impression that increased expenses due to operational changes are bigger than the DSM tariff incentives.

The rate of the subjects interested in the DSM tariff in the commercial sector is higher than in the industrial sector, but it is necessary to note whether the result shows the general trend because there is not a sufficient number of answers.

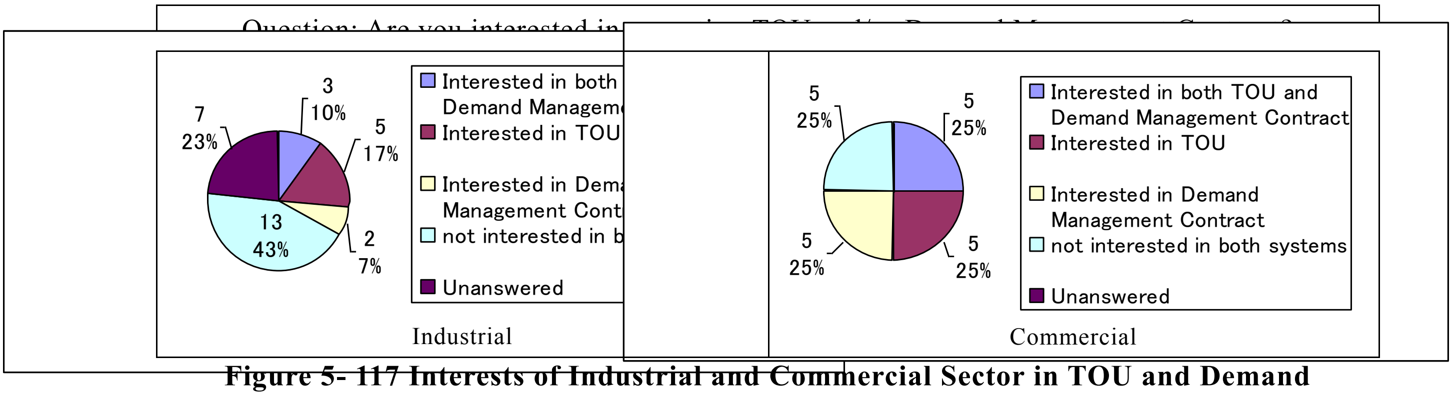
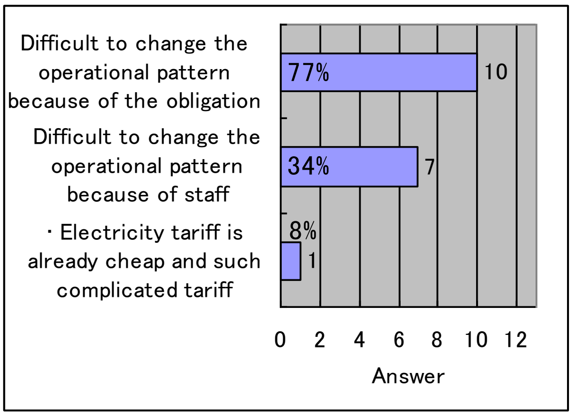
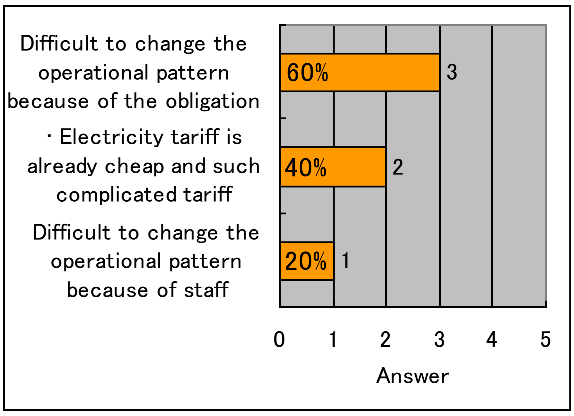


Figure 5- 117 Interests of Industrial and Commercial Sector in TOU and Demand Management Contract

Question: Why are you not interested in both TOU and the Demand Management Contract? (Multiple answer)



Industrial



Commercial

Figure 5- 118 The Reasons for lack of Interest in Both TOU and Demand Management Contract

(9) Feedback

The following contents for consideration of effective EE&C measures are extracted from the results of the survey.

Air Conditioners

- Industrial entities, government institutions, schools and mosques have a high percentage of operating patterns that use ACs during working hours, while the commercial sector, in which 70% of the subjects answered they use ACs in 24 hours, has a high percentage of AC operating patterns in 24 hours. This result indicates the possibility of unnecessary AC use, but this is not a complete fact to say. It is recommended that commercial enterprises supervise energy management because this sector requires a measurable amount of power.

- The improvement of AC efficiency in the residential sector will greatly contribute to EE&C because their AC operating time is longer than other sectors.

Insulate

- It is realized that industry has a high percentage of insulation materials and almost half of commercial enterprises are equipped with installed insulation materials. 20% of government institutions have insulates which are applied to new buildings. Although, it was thought that few residences installed insulates, it has been confirmed that 21% of residents have insulates.
- What is of paramount importance is to improve the penetration in commercial and residential sectors in consideration of comprehensive energy consumption.

Energy Management System

- Government institutions, schools and mosques have a high percentage of not having kept electricity consumption records and they are not very conscious of EE&C. Activities for improving EE&C in these sectors will contribute to raising awareness in the residential sector, and it is recommended that designation programs be developed in the public sector such as by having government institutions, schools and mosques lead EE&C.

Investments in EE&C

- 10-30 % users in each sector have experimented with investments in EE&C. Furthermore, most subjects answered that they target within 3 years for the pay-back period, and commeasurable incentives need to be established to encourage users to make investments in EE&C.

EE&C measures of AC

- Most in each sector follow EE&C measures. Some of the residential sector, which is considered to have a high percentage of AC energy consumption, follow EE&C practices.
- The ratio of energy consumption in the residential sector nationwide is assumed to be very high, and the portion of AC use is assumed the largest in all sectors. To promote EE&C in the residential sector, it is effective to establish triggers such as real time monitoring of electricity consumption and EE&C incentives, which encourages users to adopt EE&C, or introduce high efficient and/or automated control AC.

EE&C Information Sources

- Most in each sector obtain information about EE&C through the internet and TV.
- It is realized that the brochures provided by the government and/or electric power company are effective tools in the residential sector. The direct distribution of

brochures is advantageous in that it leads to face-to-face communication and allows for a clear introduction of EE&C activities clearly. A designation program with providing brochures and good communication will help to promote EE&C.

Awareness of E-portal

- The recognition of the E-portal was not so acknowledged. A challenge to enhance the contents of the E-portal, and advocate the benefits of using the E-portal will be needed.

Incentives of the DSM Tariff

- Interviews about the DSM tariff (TOU and demand management contract) were conducted for all industrial and commercial subjects. The number of subjects in commercial enterprises who answered they are interested in DSM is larger than in industrial entities. The main reason industrial users are not interested in DSM is that it is difficult to change their operations.
- While the TOU contract is of a permanent nature, the demand management contract is a request to save electricity on a temporary and/or emergency basis. It is possible to create a contract minus any significant changes in operations contingent on knowing in advance the effectiveness of the energy-saving equipment. If the benefits to be had are attractive enough, we believe this would represent sufficient expectation to move forward with this measure.

5.8.3 Challenges on the Awareness Survey

(1) Questionnaires

There was difficulty obtaining much detailed information via the interviews such as energy consumption data, capacities of the facility and EE&C activities. In many cases, the interviewees had difficulty understanding the meaning of the questions, although the interviewers took the time to explain. The two estimated reasons are that the originally planned questions are out of touch with the realities of energy use in Oman, and/or beyond the norm of energy users.

The questionnaires need to be updated based on the results so that they are in tune with the actual situation in Oman, when a similar survey is conducted continuously.

(2) Follow-up Survey

Interviewers tried to get more understanding through the survey and had evolved to the point where they were able to take flexible approaches which include several interviews for the same subjects and a demonstration to make interviewees more able to understand the contents of the interviews. When it comes time to conduct a similar survey, it is recommended that an outside firm experienced in conducting such surveys be hired.

5.9 Market Research on High-efficient Appliances

5.9.1 Objectives and Methodology

In September 2012, the market survey was conducted as a basic survey in order to design the scheme and effective dissemination programs for Minimum Energy Standards and Labeling System and its dissemination programs. It is implemented by interviewing retail shops and makers of home electric appliances regarding to the market trends of residential air-conditioners.

5.9.2 Results of the Survey

(1) Survey Results of Retail Shops for Home Electric Appliances

Survey results of three retail shops in Muscat by interview are shown below. There are several examples of maker original labels for advertisements and retail-shop original labels for easy purchase selection. However, the product efficiency based on the same standard is not displayed and not included in these labels.

Furthermore, as there is no information for the total cost of operation including running expenses, customers have no choice other than to select products on the brand name and product price.

Table 5- 81 Interview Result to Retail Shops regarding to Residential Air Conditioners

	E-MAX Electric Shop inside City Centre	Sales Floor of Lulu Shopping Centre	Panasonic Showroom in Qurum City Centre
Date	3rd September (Monday)	8th September (Saturday)	11th September (Tuesday)
Product Catalog	There are no catalogs prepared for all appliances on the sales floor. Furthermore, shops do not receive any catalogs from manufactures and importers. Salesclerks orally explain the performance etc. to customers.		It is a maker's independent showroom, preparing its own catalogs.
Maker Original Label	Maker original label displaying maker independent information including the expected energy conservation effect.  		
Shop Original Specification Display label	Displaying a maker name, price, output, guarantee period and manufactured country 	Generally displaying a price and brand name	
Criteria for Product Purchase Selection by Customers	• First priority of product selection is a brand name and followed by price • Japanese products are preferred but expensive.		
Efficiency Awareness	• Almost all customers are not concerned about efficiency attributed to a low electricity tariff.		
Education of Product Information to Salesclerks	• Implementing periodically		• Product briefing session • Holding education and training seminars for retail shop salesclerks
Sales Price Rage	• From RO 118 to RO 210 for hot-selling products of 18,000 Btu/h capacity (Results of 7 products surveyed)		
Installation Cost	• Installation cost of standard price zone is about 25 RO. There are some products including installation cost in price. (That is to say free installation cost.)		

(2) Survey Result of Sales Situation in Retail Shops

By visiting 3 retail shops, brand name, price, model number of displayed air conditioners are surveyed as of December 2012. Based on the visit survey, performance of the displayed products is checked through website of each manufacturer. Although window type air conditioners (all-in one type of indoor and outdoor unit) is displayed in each retail shop, the survey target is focused on split type.

(a) Sale Model Number by Makers in Surveyed Retail Shops

Sale model number by manufacturers in the surveyed retail shops is shown in the following table. Manufacturer number by country is also indicated; Japan 7, Korea 3, China 3 and others 4 companies.

Table 5- 82 Sale Model Number by Makers in Surveyed Retail Shops

Name of Retail Shop		E-MAX Electric Shop inside City Centre	Sales Floor of Lulu Shopping Centre	Sales Floor of Carrefour
Country	Maker			
Japan	J1	6	2	4
	J2	2	3	1
	J3	1	3	2
	J4	1		
	J5	1		
	J6	1		
	J7	1		
Korea	K1	4	1	7
	K2	2		6
	K3	1		1
China	C1	1	4	
	C2	1		
	C3	1		
USA	U1	1	2	
Sweden	SW1	1		2
Germany	G1		1	
Saudi Arabia	SA1	1		2
Total	17 Companies	26	16	25

(Source: JICA Study Team)

(b) Air Conditioner Performance

The following figures show the performance versus price distribution by refrigeration capacity, of which performance could be confirmed through website among displayed products in the retail shops.

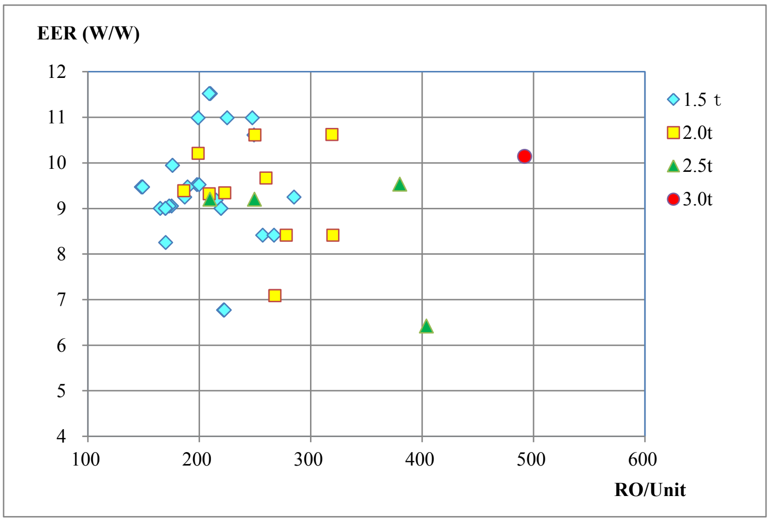


Figure 5- 119 Price by Refrigeration Capacity (EER Indication)

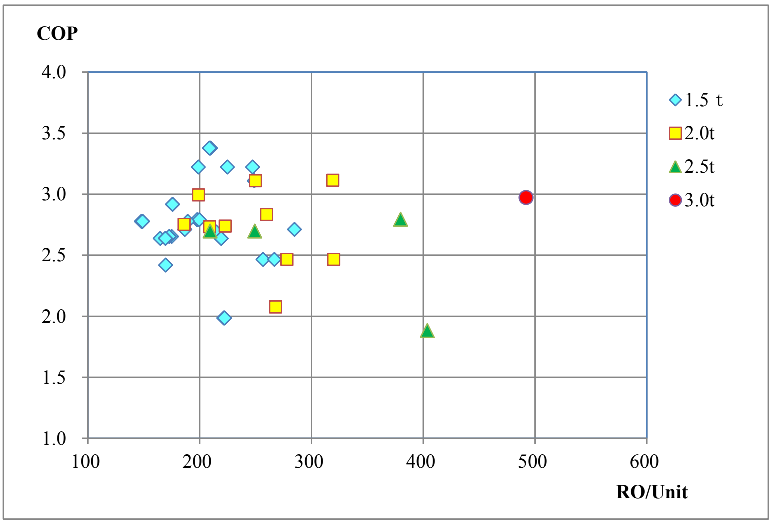


Figure 5- 120 Price by Refrigeration Capacity (COP Indication)

From the above survey result, the following points were found out.

- The refrigeration capacity of predominated air conditioners for the residential sector in the Oman market is 1.5 ton (18,000 Btu/h).
- Efficiency as indicated COP is almost within the range from 2.5 to 3.0.
- Although the displayed performance is not tested under the same condition, higher price products are not always high performance products from the viewpoints of customers.

(3) Interview Results with Manufacturers

Interview survey to two Japanese manufacturers of residential and business air conditioners was conducted regarding their sales activity and requests for the Minimum Energy Standards and Labeling System, if any.

Table 5- 83 Interview with Manufacturers regarding General Air Conditioner Information

	Company A	Company B
Core Sales Product	• Inverter air-conditioners for residence • Automatic control by motion sensor	• Business air-conditioners • (Under development) Inverter air-conditioners for residence
Sales Promotion Activity	• Participation to exhibition • Installation of ECO quiz boxes	-
Request an Energy Conservation Standard and Labeling System	• Display contents which can properly express inverter technology advantages	• Scheme establishment of neutral and fair test implementation is required, if an efficiency test is included. • Unannounced posterior test is required.

5.10 Survey on Possibility of Introduction of Smart Meter

5.10.1 Background and Objective

(1) Background

The following table shows the system losses (the sum of the technical losses and non-technical losses) of the three northern electricity distribution companies in MIS. Today, the distribution companies in Oman are working towards reducing system losses, but the system loss rate still indicates a high percentage.

Table 5- 84 System Losses of Distribution Companies of Oman (Unit: %)

	2009	2010
MEDC	19.4	16.4
MJEC	17.4	14.1
MZEC	17.66	15.32

(Source : EHC Annual Report 2010)

System losses (distribution system losses) consist of two elements. One are technical losses that are resistance losses, iron losses, copper losses, and the other one are non-technical losses such as power thefts, tampering etc.

Consequently, power sent from the primary substation does not always match the sum of the consumption at the customers' sides.

Smart meters contribute to reducing non-technical losses, but the distribution companies do not accurately grasp the non-technical loss rate including the system losses.

(2) Objective

The diffusion of smart meters requires a willingness to invest. Smart meters are not only one of the measures for EE&C, but also one of measures for non-technical loss reduction. Non-technical loss reduction may be one of the greatest incentives to invest in smart meters.

In this study, the JICA Study Team selected a model site supplied by DPC whose distribution losses had not been analyzed enough in comparison with the distribution companies in MIS, and calculated non-technical losses, and estimated the cost and benefit.

5.10.2 Outline and Methodology

(1) Outline

The following table shows the outline of the survey. The survey was conducted on the radial feeder that supplies to mainly the residential area in Mirbat, that is nearly 70 km eastward from Salalah, from the 28th of June, 2012 to the 28th of August, 2012.

Table 5- 85 Outline of Survey

<table>
<tr><td colspan="2">Period</td><td colspan="2">28/6/2012 - 28/8/2012 (2 months)</td></tr>
<tr><td rowspan="3">Substation</td><td>Name</td><td colspan="2">Mirbat Primary Substation</td></tr>
<tr><td rowspan="2">Location</td><td>Latitude</td><td>N 16°59′02.08″</td></tr>
<tr><td>Longitude</td><td>E 54°41′36.00″</td></tr>
<tr><td rowspan="4">Feeder</td><td>Name</td><td colspan="2">Hino Feeder</td></tr>
<tr><td>Type</td><td colspan="2">Radial</td></tr>
<tr><td>Main customers</td><td colspan="2">Residential</td></tr>
<tr><td>The number of customers</td><td colspan="2">58</td></tr>
</table>

(2) Methodology

The following table shows the calculation method of non-technical losses in this study. At first, all customers' monthly consumptions were read by the same-date-reading, and the system losses were calculated by deducting all the customers' consumption from the transmitted power from the primary substation during the study period. Then, the technical losses were calculated via a simulation using distribution system analysis software. After that, the non-technical losses were calculated by subtracting the technical losses from the system losses.

Table 5- 86 Method of Non-technical Calculation

Items	Methods
(1) Monthly metering on same date	Read all customers' monthly consumption on the same date
(2) Transmitted Power Measurement from Primary Substation	Measure the hourly transmitted power to the feeder at the primary substation by SCADA
(3) System loss Calculation	System loss was calculated by subtracting (1) from (2).
(4) Technical Loss Calculation	Input the parameters of the feeder (length and type of conductor and cable, transformer, load etc.) to the distribution system analysis software, and calculate technical losses
(5) Non-technical Loss Calculation	Non-technical losses was calculated by subtracting (4) from (3)

5.10.3 Calculation Result of the Survey on the Model Site

The following table shows the outline of the calculation result. The transmitted power from the Primary Substation to the feeder is 155,546 kWh, and the total consumption on the customer side 131,631 kWh. In this manner, the distribution system losses rate is 15.38 % (23,915 kWh). Furthermore, the technical loss rate is 7.09 % (11,026 kWh) with the distribution analysis software calculation, therefore, the non-technical losses are 8.29 % (12,899 kWh) by subtracting the technical losses from the system losses.

Table 5- 87 Result of Non-technical Calculation

	Items	Values	Remark
(1)	Period	2012/6/28-2012/8/28 (2 months)	
(2)	Transmit Power from Primary Substation to the Feeder	155,546 kWh	SCADA Metering Values at the substation
(3)	Total Consumption on the Customers' Side	131,631 kWh	Metered by DPC
(4)	Distribution System Losses	23,915 kWh	＝(2)－(3)
(5)	Distribution System Loss Rate	15.38 %	＝(4)／(2)
(6)	Technical Losses	11,026 kWh	by the simulation of analysis software
(7)	Technical Loss Rate	7.09 %	＝(6)／(2)
(8)	Non-technical Losses	12,889 kWh	＝(4)－(6)
(9)	Non-technical Loss Rate	8.29 %	＝(8)／(2)

5.10.4 Cost and Benefit Analysis on the Model Site

(1) Cost for Implementation of Smart Meters on the Model Site

The smart meter system such as the following figure is assumed for the cost estimation of the smart meters. The communication media is assumed to be General Packet Radio Service (GPRS), and the cost of the Meter Data Management System (MDMS) is omitted for easy calculation in this survey.

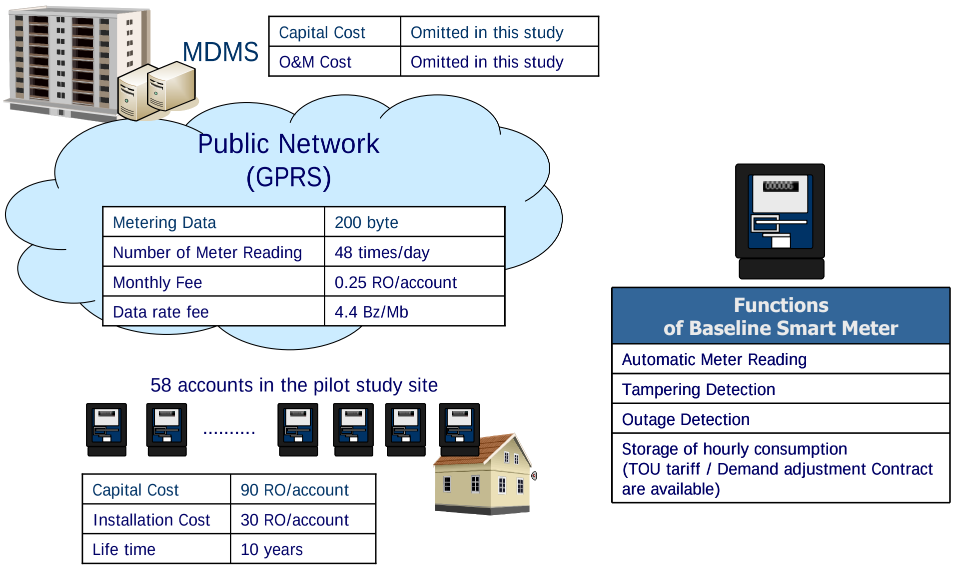


Figure 5- 121 Model Smart Meter System for Cost Estimation

The following table shows the implementation cost for the smart meters. It is assumed that the capital cost per meter is 90 RO, and the installation cost per meter is 30 RO. The lifetime of the smart meters is assumed to be 10 years, and the annual cost is calculated by dividing the capital cost by the lifetime. The annual communication cost per customer is estimated 3.05 RO with reference to the Oman telecom carrier tariff.

As a result, the annual capital cost for meters is 522 RO/year, the annual installation cost for meters is 174 RO/year, and the annual communication cost is 177 RO/year on the model site. Therefore, the total annual cost is 873 RO/year.

Table 5- 88 Cost for Implementation of Smart Meters

	Items	Values	Remark
(1)	Capital Cost for Smart Meter	90 RO/account	From hearing
(2)	Capital Cost for Installation of Smart Meters	30 RO/account	From hearing
(3)	Annual Communication Cost for a Customer	3.05 RO/account/year	Calculated by the data size, frequency, Oman mobile tariff (*)
(4)	The Number of Customers	58 accounts	
(5)	Annual Cost of Smart Meters on the Model Site	522 RO/year	＝((1)／Life time)×(4)
(6)	Annual Cost of Installation on the Model Site	174 RO/year	＝((2)／+Life time）×(4)
(7)	Annual Communication Cost on the Model Site	177 RO/year	＝(3)×(4)
(8)	Total Annual Cost	873 RO/year	＝(5)＋(6)＋(7)

（note*）The estimated condition is assumed as follows: Metering data is 200 byte/reading, Frequency of reading is once per 30 min, Monthly fee is 0.25RO/account, and data rate fee is 4.4 Bz/Mb from Omantel Mobi le Business Data tariff.

(2) Benefits of Implementing Smart Meters on the Model Site

The following table shows the benefits of implementing smart meters on the model site. In this study, the JICA study team focused the benefit for the distribution companies, and adopted the reduction of the non-technical losses and the cost of metering as the index of the benefit.

The annual total transmitted power is 800,464 kWh, therefore, the non-technical losses are 66,374 kWh by multiplying the annual amount of transmitted power by the non-technical loss rate. Assuming the non-technical losses would be nearly 0 %, the benefits of the non-technical loss reduction would be 996 RO/year, the reduced meter reading cost would be 290 RO/year, and the total annual benefit would be 1,286 RO/year.

Table 5- 89 Benefit for Implementation of Smart Meters

	Items	Values	Remark
(1)	Transmit Power from the Primary Substation to the Feeder	800,464 kWh	
(2)	Non-technical losses	66,374 kWh	=(1)×8.29%
(3)	Electricity Unit Price	15 Bz/kWh	
(4)	Accounts	58 accounts	
(5)	Unit Price for Meter Reading	5 RO/account / year	From hearing
(6)	Reduced Non-technical Losses by Smart Meters	66,374 kWh	=(2)
(7)	Benefit of Reduced Non-technical Losses	996 RO/year	=(3)×(7)
(8)	Benefit of Reduced Meter Reading Cost	290 RO/year	=(5)×(4)
(9)	Total Annual Benefit	1,286 RO/year	=(7)+(8)

5.10.5 Study Result

On the model site where the JICA Study Team studied this time, the total annual benefits by smart meters for the distribution company is 1,286 RO/year, the total annual cost is 873 RO/year. Hence, the implementation of smart meters in this site is feasible.

However, this result was calculated based on the assumption that non-technical losses will be reduced by nearly 0 %. The experiment to confirm the benefit of the reduced non-technical losses in the actual condition is recommended in a future study.

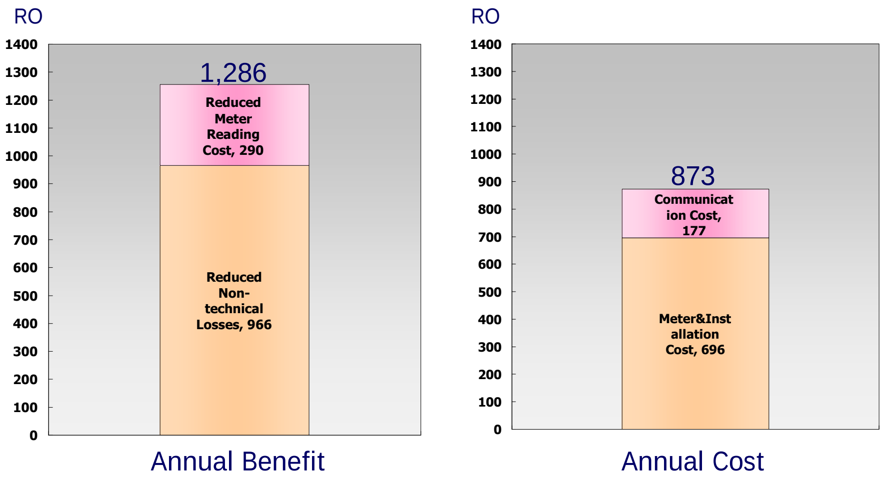


Figure 5- 122 Comparison of Annual Benefit and Cost of Smart Meters on the Model Site

5.11 Survey on Applicable EE&C Technology for Street Lighting

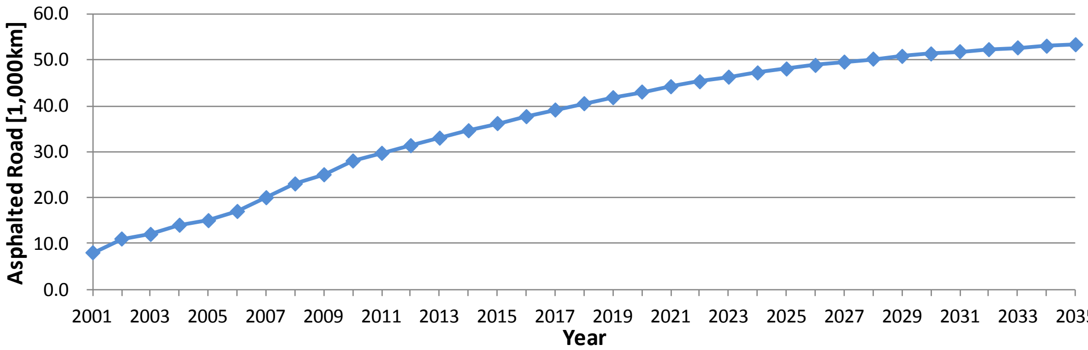
5.11.1 Background and Objective

(1) Background

(a) Power Demand of Street Lighting

Based on the road paving plan received from the Ministry of Transport and Communication, asphalted roadways have increased at a pace of about 3,000 km per year over the past 3 or 4 years. However, the future plan shows that the growth rate will be less than 2,000 km per year. Based on these trends, assuming the current pace of increase is maintained for about 5 years and then gradually decreases after that, the demand of asphalted roadways until 2035 is forecasted.

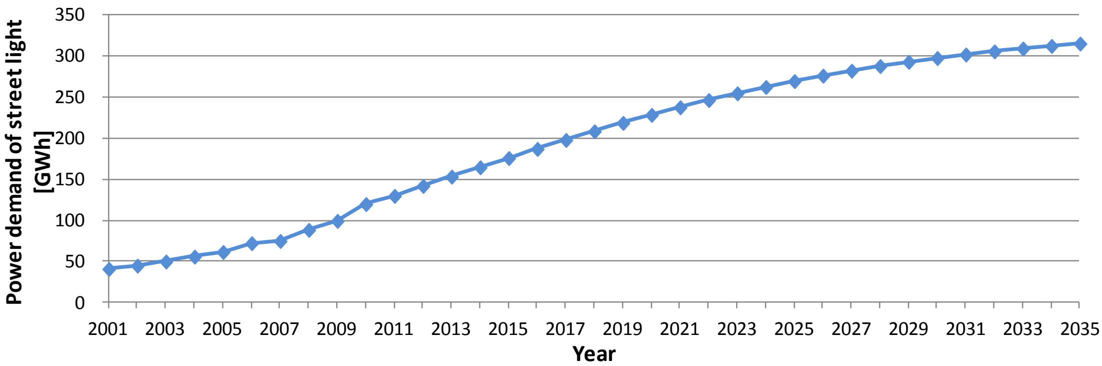
The forecasted asphalted roadways are shown below.



(Source: JICA Study Team)

Figure 5- 123 Forecasted Demand of Asphalted Roadways

The power demand for the street lighting, based on the forecasted asphalted roadway demand and the current street light power consumption, is forecasted as follows. As a result, the power demand in 2035 is forecasted at 316 GWh which is more than double of the power demand in 2010 (142 GWh). In this context, it is apparent that there is a strong necessity for the introduction of energy saving street light fixtures from now on.



(Source: JICA Study Team)

Figure 5- 124 Forecast Street Light Power Demand

(2) Objective

For the increased power demand of street lighting, the survey identifies the effective energy saving technology.

In the previous chapter, the dimming and LED technologies were confirmed as potential energy saving solutions for the street lighting in Oman. In this section, the energy saving potential for these technologies is calculated for a model city (Muscat Municipality).

5.11.2 Results of the Calculation of the Energy Saving Potential for Street Lighting in the Muscat Municipality

(1) Study Options

A comparison study for the following 5 options (A to E) is made.

Table 5- 90 Option Settings for Energy Saving Simulations

Option	Energy saving methods
A	**Existing lamps (HPSV) + dimming function (short period)** ・Install new dimming ballasts to existing lights. ・00: 00 ~ 06: 00: 50 % lighting (dimming pattern -1) ・18:00 ~ 00:00: 100 % lighting
B	**Existing lamps (HPSV) ＋dimming function (long period)** ・Install new dimming ballasts to existing lights. ・Outside rush hour: 50% lighting (dimming pattern -2) ・Rush hour: 100% lighting
C	**LED street light fixtures** ・Replace existing light fixtures, lamps with LED units. (continue to use light pole section)
D	**LED street light fixtures+dimming function (short period)** ・Replace existing light fixtures, lamps with dimmable LED light fixtures, and LED lamps (continue to use light pole section) ・00:00 ~ 06:00: 50% lighting (dimming pattern -1) ・18:00 ~ 00:00: 100% lighting
E	**LED street light fixtures+dimming function (long period)** ・Replace existing light fixtures, lamps with dimmable LED light fixtures, and LED lamps (continue to use light pole section) ・Outside rush hour: 50 % lighting (dimming pattern -2) ・Rush hour : 100 % lighting
Common Items	・The lighting period throughout the year is from 18:00 to 06:00. ・Total annual lighting period: 12 hours × 365 days = 4,380 hours ・Local lighting required for traffic safety are not subject to dimming, and about 20 % of all lighting types is local. ・Energy saving rates use the values heard from manufacturers.

(2) Overview of Existing Street Lighting in Muscat Municipality

The street lighting data for 2010 received from Muscat Municipality and the power consumption for the whole municipality calculated by the JICA Study Team are shown below.

However, because there is no tariff category for the street lighting in Oman, it was found that the data of power consumption for municipalities is not statistically recorded. As mentioned in Chapter 4, the street lighting power consumption data for 2010 received from MEDC reported a numerical value of 43.6 GWh. However, the calculation result for the power consumption of the street lighting in Muscat Municipality shows 37.2 GWh in the following table. Although there is not a big difference, the power consumption of the street lighting obtained from MEDC is not exactly equal to the calculation result from the data obtained from Muscat Municipality. It is surmised that there is a possibility that the data of Muscat Municipality contains the lighting demands for parking areas and souqs (local markets), etc. In this section, the calculation result based on the data received from the Muscat Municipality is used for the comparison study.

Table 5- 91 Existing Street Lighting Data in Muscat Municipality

Lamp type	Watt & Number				Muscat city								
					Main road		Internal road		Service road				
					No	MWh	No	MWh	No	MWh			
HPSV	70	W	x	1			6,109	0.6					
			x	2					85	0.0			
	250	W	x	1			4,906	1.6					
			x	2					1,074	0.7			
	400	W	x	1	996	0.5							
			x	2	1,550	1.6							
	600	W	x	1	303	0.2							
			x	2	209	0.3							
			x	4	940	2.9						合計	
Total of hourly power consumption [MWh]						5.6		2.2		0.7	→	8.5	[MWh]
Total of daily power consumption [MWh]						67.5		25.8		8.6	→	101.9	[MWh]
Total of annualy power consumption [GWh]						24.6		9.4		3.1	→	37.2	[GWh]

(Source: Muscat Municipality Data prepared by JICA Study Team)

Table 5- 92 Rush Hour Periods for Roads in Muscat Municipality

	Main Road	Internal Road	Service Road
Rush Hour period	7 am-11 pm	4 pm-9 pm	9 am-10 pm

(Source: Muscat Municipality Data prepared by JICA Study Team)

(3) Energy Efficiency of Light Fixture Unit

Three representative types of lamps were selected from the data of existing street lighting for Muscat Municipality, and a comparison study is carried out in the 20-year life cycle costs (equipment cost and total electricity charges) in case of each existing light fixture being replaced with Options A to E. The energy saving impacts by the options are also calculated comparing with the existing fixtures (that is indicated at 100 %). Electricity charge is taken as 0.06 RO/kWh in consideration of the international price.

Table 5- 93 Life Cycle Costs of Light Fixture Units

	Option		Present	Option A	Option B	Option C	Option D	Option E
	type	Lamp	HPSV	HPSV	HPSV	LED	LED	LED
		Dim	None	Dimming period-1	Dimming period-2	None	Dimming period-1	Dimming period-2
20 year life cycle costs [RO/20years]	70 W x 2		**1,397** (100%)	**1,299** (93%)	**1,243** (89%)	**1,026** (73%)	**957** (69%)	**914** (65%)
	250 W x 1		**2,018** (100%)	**1,769** (88%)	**1,620** (80%)	**1,300** (64%)	**1,109** (55%)	**994** (49%)
	400 W x 2		**6,096** (100%)	**5,260** (86%)	**5,100** (84%)	**3,836** (63%)	**3,188** (52%)	**3,065** (50%)

(Source: JICA Study Team)

(4) Comparison of Energy Saving Effects for the Whole Muscat Municipality

The energy saving effects (in comparison with existing equipment) in Options A to E for all the existing street lighting in Muscat Municipality are shown below. The capital payback period was calculated based on 2 cases: Current electricity charge at 0.01 RO/kWh and international price at 0.06 RO/kWh.

Table 5- 94 Energy Saving Efficiency for Each Option

Option		Present	A	B	C	D	E
Power saving measures	Lamp	HPSV	HPSV	HPSV	LED	LED	LED
	Dimming	None	Dimming period-1	Dimming period-2	None	Dimming period-1	Dimming period-2
Additional installation cost [RO]		-	9,774,700 (Attachment of dimming)	9,774,700 (Attachment of dimming)	6,912,400 (Replacement of lighting fixture)	9,144,800 (Replacement of lighting fixture)	9,144,800 (Replacement of lighting fixture)
Annual power consumption [GWh]		37.2	32.0	30.6	23.8	19.8	18.7
Annual power cost [RO/year] Unit cost: 0.06[RO/kWh]		2,231,000 (100%)	1,919,000 (86%)	1,836,000 (82%)	1,428,000 (64%)	1,187,000 (53%)	1,123,000 (50%)
Diffrence [RO] (Present - Option A to E)		-	312,000	395,000	803,000	1,044,000	1,108,000
Payback period [years] Unit cost: 0.06RO/kWh		-	**31.3**	**24.7**	**8.6**	**8.8**	**8.3**
Payback period [years] Unit cost: 0.01RO/kWh		-	**188.0**	**148.5**	**51.6**	**52.6**	**49.5**

(Source: JICA Study Team)

(5) Comparison of Life Cycle Costs with the Existing Street Lighting

The following table shows the 20 year life cycle costs when Options A to E are adopted for all existing street lighting in the Muscat Municipality.

Table 5- 95 Comparison of 20 Year Life Cycle Costs for Each Option

Option		Present	A	B	C	D	E
Lamp life	[h]	24,000	24,000	24,000	60,000	60,000	60,000
	[Year]	**6**	**6**	**6**	**14**	**14**	**14**
Times of replacement in 20 years [times]		4 (lamp) 1 (ballast)	4 (lamp) 1 (ballast)	4 (lamp) 1 (ballast)	2	2	2
Initial installation cost [RO]		7,032,400	9,774,700	9,774,700	6,912,400	9,144,800	9,144,800
Replacement cost in 20 years [RO/20 years]		11,421,100	11,421,100	11,421,100	5,911,600	5,911,600	5,911,600
Power cost[RO/20years] Unit cost: 0.06[RO/kWh]		44,618,000	38,372,000	36,716,000	28,556,000	23,737,000	22,459,000
Lifecycle cost[RO/20years] Unit cost: 0.06[RO/kWh]		**63,071,500** (100%)	**59,567,800** (94%)	**57,911,800** (92%)	**41,380,000** (66%)	**38,793,400** (62%)	**37,515,400** (59%)
Lifecycle cost[RO/20years] Unit cost: 0.01[RO/kWh]		**25,889,833** (100%)	**27,591,133** (107%)	**27,315,133** (106%)	**17,583,333** (68%)	**19,012,567** (73%)	**18,799,567** (73%)

(Source: JICA Study Team)

(6) Consideration for Energy Saving Technology for Street Lighting

(a) New Street Lighting

According to the above comparison study, LED street lighting is the best way due to the shortness of the payback period and low life cycle costs. However, as Oman is located in a high temperature area, there is a concern that the LED life span of the street lighting will not meet its full potential as guaranteed by manufacturers. At this moment, its durability is being tested in the Muscat Municipality.

According to Muscat Municipality, as of December 2012, at the test sites (3 locations in the municipality), maintenance costs have exceeded expectations even in a period of about 7 to 8 months. Thus any decision to adopt LED street lighting has not been made.

In this context, it is a realistic selection that the options of installing a dimming function (Options A and B) to the HPSV lights have been adopted at this moment.

(b) Existing Street Lighting

Regarding existing street lighting, it should be basically used to its full life potential. As an energy saving technology, an option adding a dimming function is also possible. However, this option requires some retrofitting of cables between the poles for the dimming function which would lead to additional construction costs compared to new installation. Therefore, it has been concluded that the existing street lighting system should continue to be used as it is.

It is noted that, according to Muscat Municipality, the street lighting currently in use in Muscat Municipality is of the type whereby a choke adjustment function can be added to each light. If such kind of street lighting is used, dimming by the choke adjustment function might be possible and thus the cable connection work between the poles can be avoided. (This type is not in use in Japan).