PN CER2272

REVISED FINAL REPORT

UPDATED GENERATION PLANNING FOR THE SAUDI ELECTRICITY SECTOR

Prepared for

Electricity & Cogeneration Regulatory Authority (ECRA)
Riyadh, Saudi Arabia

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SUMMARY

This is the revised final report of the study entitled *Updated Generation Planning for the Saudi Electricity Sector,* (CER2272, Phase II), started on May 1, 2005. The study was conducted by a project team from King Fahd University of Petroleum & Minerals (KFUPM), Dhahran, Saudi Arabia.

The purpose of this study was to prepare a plan for the expansion of electricity generation in the Kingdom of Saudi Arabia. The main objectives of this study are to develop a demand forecast for the Kingdom for the coming 15 years (2008 to 2023) and accordingly develop a viable Electricity Generation Plan for the same period.

The project consists of six tasks, namely, data collection, development of planning basis, development of electricity demand forecast, development of generation plan, development of generation cost estimates and reporting.

This report presents a plan for the expansion of Electricity Generation in the Kingdom of Saudi Arabia. A demand forecast for the coming 15 years (2008 to 2023) is developed to determine the generation requirements in the Kingdom. The demand forecast is based on the multiple regression analysis method. The historical annual energy and economic data, namely, population and gross domestic product (GDP) are used to determine customer elasticities. The peak demand forecast for the four operating areas: EOA, COA, WOA, and SOA, as well as the different isolated areas were calculated for high, most likely, and low growth scenarios.

The demand scenarios indicated that there was a clear need to develop generation plan that met the expected load. The plan as developed provides additional generation requirements with adequate supply reliability and within reasonable costs. It also takes into consideration the economic life of the existing generating units. The generation planning process was developed based on the information of the existing power system, the committed plans, the developed load forecast, and the available supply options. Data were collected for the Kingdom from the Ministry of Water & Electricity, Ministry of Planning, Electricity and Cogeneration Regulatory Authority (ECRA), Saudi Electricity Company, Saline Water Conversion Corporation (SWCC), and Independent Power Producers (IPP).

A Multi-Area Reliability Analysis Program (MAREL) was used to develop the generation plan. For the reference plan, the total generation additions, excluding the IWPP & IPP, are 34,454 MW. The figure includes 2,289 MW needed by the isolated power systems within the Kingdom. The cumulative present worth of capital investment to January 2005 at the base discount rate of 5 percent is MSR 44,811. A number of sensitivity analyses were carried out to study the impact of changing the discount rates on the reference generation plan. When the discount rate is changed to 3 percent, the investments change to MSR 55,024. The corresponding figure for a 10 percent discount rate is MSR 28,010. The effects of the annual capital escalation of 3% on the investment requirements of the reference generation plan are also considered. The cumulative present worth of capital investment to January 2005 at the base discount rate of 5 percent is MSR 61,600. When the discount rate is changed to 3 percent, the investments change to MSR 76,378. The corresponding figures for a

10 percent discount rate are MSR 37,590. The investment requirements for the changes in unit capital costs by ± 10% and ± 20% were also estimated at 3, 5 and 10 percent discount rates. When the unit capital cost is increased by 10% and 20%, the total investment requirement is MSR 49,292 and MSR 53,773 respectively at 5% discount rate. In the case of decreasing the unit capital cost by 10% and 20% at 5% discount rate the requirement is MSR 40,330 and MSR 35,849 respectively.

The study then developed generation plans when further transmission interconnections between SEC operating areas were proposed. Interconnection links between the COA & WOA and WOA & SOA were considered. The effect of the GCC grid on the Saudi system (EOA) is taken as a generation of 1600 MW capacity with a high level of availability. The commissioning year for the GCC grid is taken as 2008. This is referred to as the unified generation plan. The total plant additions under this plan are 31,296 MW. This is reduction of 3,158 MW. The cumulative present worth of capital investment to January 2005 at the base discount rate of 5 percent is MSR 41,346. When the discount rate is changed to 3 percent, the investments change to MSR 51,035. The corresponding figures for a 10 percent discount rate are MSR 25,532. The effects of the annual capital escalation of 3% on the investment requirements of the interconnected generation plan are also considered. The cumulative present worth of capital investment to January 2005 at the base discount rate of 5 percent is MSR 57,297. When the discount rate is changed to 3 percent, the investments change to MSR 71,417. The corresponding figures for a 10 percent discount rate are MSR 34,526. The investment requirements for the changes in unit capital costs by ± 10% and ± 20% were also estimated at 3, 5 and 10 percent discount rates. When the unit capital cost is increased by 10% and 20% the total investment requirement is MSR 45,480 and MSR 49,615 respectively at 5% discount rate. In the case of decreasing the unit capital cost by 10% and 20% the requirement at 5% discount rate is MSR 37,211 and MSR 33,077 respectively.

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SECTION 1 INTRODUCTION

1.1 BACKGROUND

This is the revised final report of the study entitled *Updated Generation Planning for the Saudi Electricity Sector,* (CER2272, Phase II), started on May 1, 2005. The study was conducted by a project team from King Fahd University of Petroleum & Minerals (KFUPM), Dhahran, Saudi Arabia.

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This study was done under a change order that was prepared in response to a request from the Electricity and Water Cogeneration Regulatory Authority (ECRA), Riyadh, for changing the scope of the work related to the project entitled *"Electric Energy Production Costing for the Saudi Electricity Sector"* (Project No. CER2272, Phase-II). The request is included in *Appendix A.*

A long-term electrification plan for the Kingdom of Saudi Arabia was developed in 1995 under the auspices of the General Electricity Corporation (GEC). The planning period covered was 1995 to 2020G. This plan was later updated by the GEC in 1998 and covered the period from 1998 to 2023. Since 1998, major restructuring processes have been taking place in the Kingdom's electricity and water desalination sectors. The Ministry of Water and Electricity (MOW&E) has been established to oversee the general progress in the sector. The regulatory authority, ECRA, is responsible to set and oversee the regulations covering the operation of this sector. Recently, the Kingdom has witnessed major developments in the production of natural gas which are expected to have a great impact on fuel supply and the long-term plan for the generation of electricity in the Kingdom. These factors have necessitated the development of a new master plan for the combined electricity and desalinated water producers for the Kingdom. This study will utilize and update the valuable data, and methodology which are reported in the preceding long-term plan.

1.2 ORGANIZATION OF THE ELECTRICTY SECTOR

As far as the electricity sector is concerned, the Kingdom of Saudi Arabia is divided into five geographical regions: Eastern, Central, Western, Southern, and Northern. In each of the Eastern, Central, and Western regions, there is an interconnected grid that feeds the major load centers of the region. In these three geographical regions, the isolated systems represent only a small percentage of the total load. In the Southern Region, there are four autonomous systems that are not presently interconnected with each other. There is a plan to link these four autonomous systems resulting in a grid for the Southern region's major load centers. As far as the Northern region is concerned, there are a number of isolated systems.

The Kingdom of Saudi Arabia (KSA) has decided to restructure the electricity sector to operate on an independent and fully commercial basis. The Saudi Electricity Company (SEC), which incorporates all previous electrical energy companies in the Kingdom and the Saudi Electricity Corporation projects, was formed in April 2000 pursuant to the Council of Ministers Decision # 169 (CMD 169) dated 30 December 1998. Part of the apparatus, foreseen in CMD 169, is an independent authority or regulator, who will oversee the electricity industry, and ensure fair play for all stakeholders, such as new companies in the industry, as well as the SEC, and the consumer. The Saudi Electricity Regulatory Authority (SERA) was formed on 27/8/1422H (corresponding to 13/11/2001) as per CMD #236. In 2004, the Council of Ministers added the co-production of Electricity and Water to the responsibilities of the regulatory authority and its title was also changed correspondingly to Electricity and Co-Generation Regulatory Authority (ECRA). The Authority aims to ensure the provision of services at high levels of quality and reliability and at appropriate prices. In this respect, ECRA intends to carry out a study to assess the electricity needs of the country for the years 2008 to 2023.

The present installed generation capacity owned by the Saudi Electricity Company (SEC) is approximately 27,500 MW. In addition to this, there is over 5,500 MW operated by Saline Water Conversion Corporation (SWCC) and Power and Water Utilities Company for Jubail and Yanbu (Marafiq). Also, there are several Independent Power Producers (IPPs) being actively considered by Saudi Petrochemical Company (SADAF) and Saudi Aramco. The Eastern and the Central regions grids are interconnected by 230kV and 380kV overhead lines. Hail and Qassim are also interconnected by 380kV lines. Various studies have been done in the past for the interconnection between the Western and the Central regions and the Western and the Southern regions to have one national grid. This study would draw on the findings of the previous studies to develop the plans for the study horizon.

1.3 PROJECT OBJECTIVES AND TASKS

The primary objectives of this study may be stated as follows:

1. To develop a demand forecast for the Kingdom for the coming 15 years 2008 to 2023).

2. To develop a viable Electricity Generation Plan for the coming 15 years (2008 to 2023). The plan shall take into consideration a provision for co-generation of electricity and water from the saline water desalination plants.

3. To provide investment requirements in generation for the coming 15 years (2008 to 2023).

The purpose of this study is to develop an updated electricity generation plan. The plan shall cover the electricity need for the Kingdom of Saudi Arabia for the coming 15 years (2008 to 2023). This study consists of the following six (6) tasks:

- Data Collection
- Development of Planning Basis
- Development of Electricity Demand Forecast
- Development of Electricity Generation Plan
- Development of Generation Cost Estimates, and
- Reporting

1.4 REPORT OUTLINE

This report is made of seven (7) sections. The first section contains the introduction which provides the background of the study with reference to the main tasks in the scope of the study.

Section 2, Demand Forecast, describes the methodology for carrying out the demand forecast for the Kingdom. The developed energy and demand forecast is presented in this section.

Section 3, Generation Planning Methodology and Study Basis, provides an overview of the planning process used to develop the various generation expansion plans.

Section 4, Reference Generation Development Plan describes the developed generation plan for the interconnected areas of all the four operating areas and also the major isolated systems.

The plan for the unified system based on reserve sharing is discussed in Section 5. The Unified Generation Development Plan takes into account the potential interconnections.

The Capital Investment Expenditure required for the generation additions is presented in Section 6. Various sensitivity analyses are also presented here.

Finally, the Conclusions and Recommendations are discussed in Section 7.

SECTION 2 DEMAND FORECAST

2.1 INTRODUCTION

The electric utility planning process begins with the electricity load-demand forecast. The demand for electricity initiates actions by utilities to add generation, transmission, or distribution capacity. Because of the long lead time required to construct new facilities, decisions are often to be made 2 to 10 years in advance.

A load forecast was developed for the Kingdom and the results are presented in the following sections covering the study period 2008 to 2023. Load forecasts are developed for all SEC operating areas.

2.2 METHODOLOGY

The output from a load forecast generally includes a forecast for the annual energy sales (MWh) and the annual peak demand (MW). Most utilities forecast the annual energy requirements first. The energy forecast is then used to determine the annual peak demand forecast.

There are three widely used methods in load (energy) forecasting:

1. Econometric Regression Analysis,
2. Application Saturation Methods, and
3. End-use Energy Methods.

For the current study, the econometric multiple regression analysis method has been used. This method uses historical annual energy, population and gross domestic product (GDP) to determine customer elasticities. Based on customer elasticities, and assuming that these do not change through time, a forecast for the sold energy is made.

The methodology and the basis of development of demand forecast are highlighted below:

- Multiple regression analysis is used to forecast the Energy for the KSA.
- Independent variables are chosen to be the population and the Gross Domestic Product (GDP).
- The dependent variable is the Energy forecast for KSA.
- The data for the historical and the forecasted GDP has been obtained from the Ministry of Planning. Figure 2.1 shows the variations of the GDP for the Kingdom from the year 1986 to 2023.

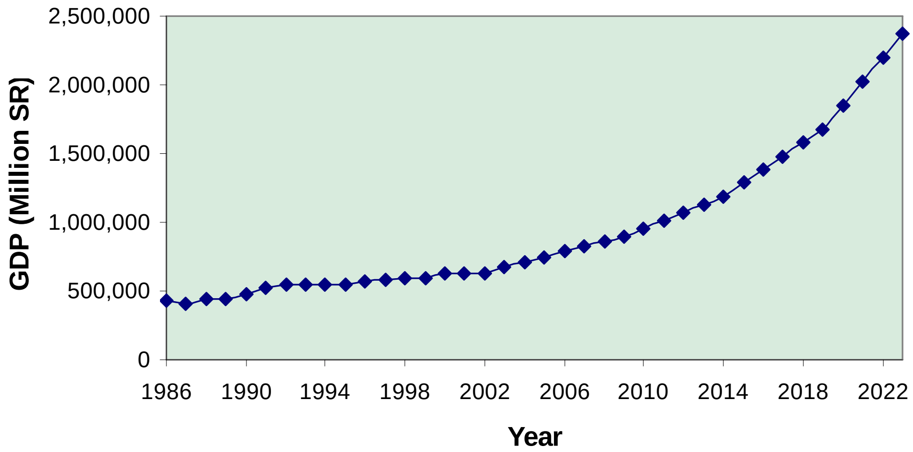

Figure 2.1. GDP (Saudi Arabia) for the period 1986-2023.

- It is observed that the increase in GDP beyond year 2005 is exponential in shape resulting in a very high growth rate that may be difficult to achieve. For the purpose of developing the energy forecast, the study team proposed to adopt three scenarios for the GDP, high, most likely, and low growth rate. The high growth estimate is the GDP as provided by the Ministry of Planning for the entire study duration. The most likely growth scenario forecast is based on maintaining the same slope of the GDP growth as up from the year 2004 and forward. The low growth estimate is obtained by reducing the slope of the GDP for each year by 20% as compared to the most likely case. Table 2.1 show the GDP growth rate for the three scenarios.

Table 2.1. Kingdom GDP Growth Rate.

Period	**High Growth Scenario**	**Most Likely Growth Scenario**	**Low Growth Scenario**
2008 to 2013	6.33	4.27	3.54
2013 to 2018	7.91	3.52	3.01
2018 to 2023	10.03	2.99	2.61

Figure 2.2 shows the variations of the GDP for the three scenarios from the year 2005 to 2023.

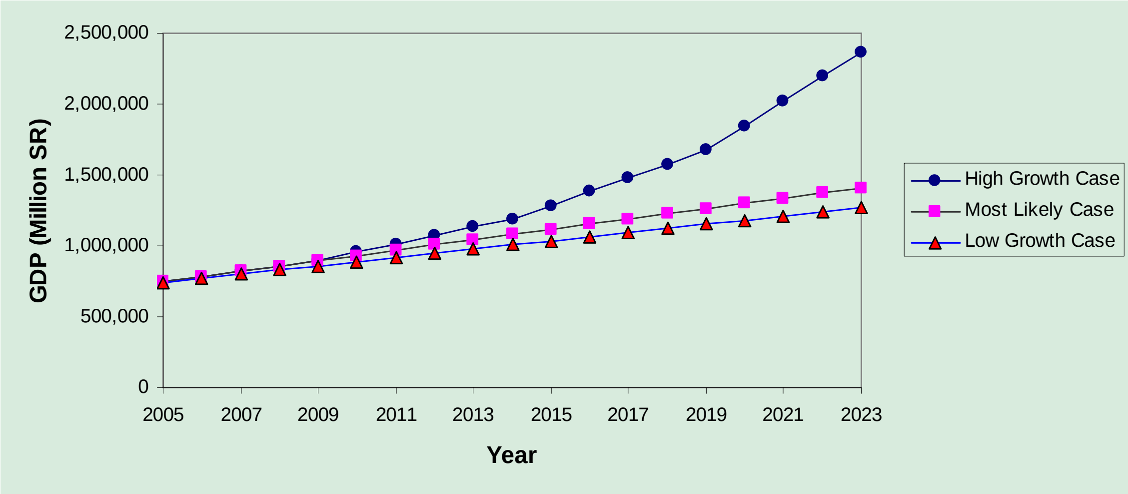

Figure 2.2. Saudi Arabia GDP for the three growth scenarios.

- The data for the historical and the forecasted population has been obtained from the Ministry of Planning. Figure 2.3 shows the population growth.
- The data for the historical energy values has been obtained from the Saudi Electricity Company.
- The forecast for the total sold energy for the Kingdom was obtained using the regression model. The total sold energy was then divided between the four operating areas using historical value of percentage energy sales for each operating areas. This gives the total sold energy forecast for each of the operating areas.

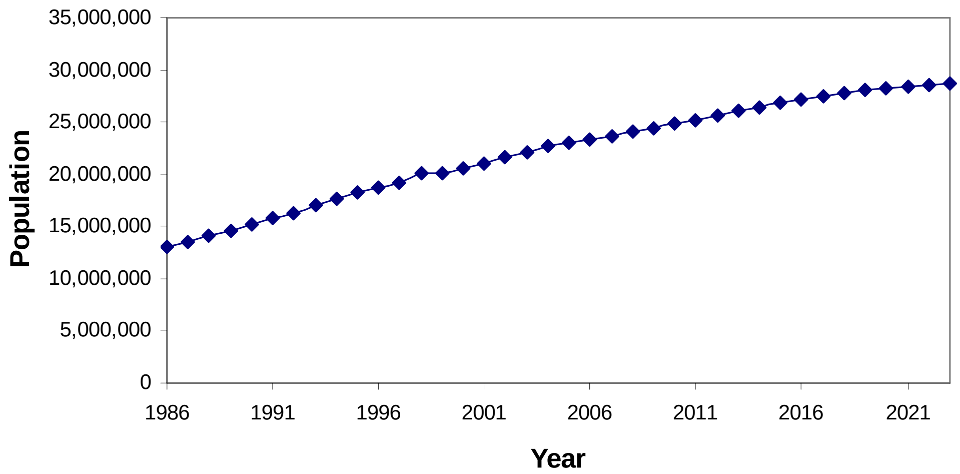

Figure 2.3. Saudi Arabia Population.

- Peak Demand is calculated using the equation,

$$\text{Forecasted Peak Demand in Region} = \frac{\text{Forecasted Energy in Region}}{8760 * \text{Load Factor}}$$

- Load factors provided by the Ministry of Water and Electricity for the period 2008 to 2014 are utilized to predict the value of the Peak Demand for different regions of the Kingdom. For the period 2015 to 2020, the load factors of 2014 are utilized.

- Using these load factors and the forecasted energy per region, the peak demand forecast for different regions for High, Most likely, and Low Growth scenarios are calculated.

2.3 DEMAND FORECAST - EASTERN OPERATING AREA (EOA)

2.3.1 Interconnected System

The Eastern Operating Area (EOA) is the largest producer of electricity in the Kingdom. EOA is connected to the Central Operating Area (COA) by a 230 k double circuit and two double circuit 380 kV lines. The transfer to the central operating area can go up to 2,500 MW.

Table 2.2 summarizes the energy and the load forecast for the territorial EOA interconnected system. The isolated areas such as Arar, Rafha, Qurayat and Al-Jawf that are now part of EOA are discussed separately.

As shown in Table 2.2 below the total sold energy would reach a figure of 117,769 GWh for the base case forecast. The peak load recorded for the year 2005 is 9,247 MW and it is forecast to increase to 17,713 MW in the year 2023.

The energy forecast for the high growth case is likely to reach a figure of 191,050 GWh in the year 2023. The peak load is expected to rise to a level of 28,734 MW in the year 2023.

For the low growth scenario the energy forecast is likely to reach a figure of 107,135 GWh in the year 2023. The peak load is expected to reach a level of 16,113 MW in the year 2023.

The average load factor used for the EOA is 75.9% for the years 2010 and onwards.

Table 2.2. Demand Forecast – EOA Interconnected System.

Year	Most Likely Case		High Growth Case		Low Growth Case		Load Factor (%)
	Peak Load (MW)	Energy (GWh)	Peak Load (MW)	Energy (GWh)	Peak Load (MW)	Energy (GWh)	
2008	10,440	68,225	10,440	68,225	10,097	65,986	74.6
2009	10,953	71,579	10,953	71,580	10,525	68,781	74.6
2010	11,287	75,045	11,541	76,732	10,782	71,687	75.9
2011	11,808	78,511	12,316	81,885	11,219	74,593	75.9
2012	12,330	81,977	13,091	87,038	11,656	77,499	75.9
2013	12,851	85,443	13,866	92,191	12,093	80,405	75.9
2014	13,372	88,909	14,641	97,343	12,530	83,312	75.9
2015	13,876	92,258	15,838	105,305	12,950	86,101	75.9
2016	14,380	95,607	17,036	113,267	13,369	88,891	75.9
2017	14,883	98,956	18,233	121,229	13,789	91,680	75.9
2018	15,387	102,306	19,431	129,191	14,208	94,470	75.9
2019	15,891	105,655	20,628	137,153	14,628	97,259	75.9
2020	16,346	108,684	22,655	150,627	14,999	99,728	75.9
2021	16,802	111,712	24,681	164,101	15,371	102,197	75.9
2022	17,257	114,741	26,708	177,576	15,742	104,666	75.9
2023	17,713	117,769	28,734	191,050	16,113	107,135	75.9

2.3.2 Isolated System

Isolated areas such as Arar, Rafha, Qurayat and Al-Jawf which were part of the northern region and earlier administered by the Electricity Corporation are now part of EOA.

The peak load and energy forecast for Arar for the three scenarios are presented in Table 2.3. The peak demand increases from a level of 92 MW to 156 MW for the most likely case (base case). The high growth scenario forecast reaches a value of 253 MW, whereas for the low growth case it reaches a value of 142 MW, both in the year 2023.

The peak load and energy forecast for Rafha for the three scenarios are presented in Table 2.4. The peak demand increases from a level of 55 MW to 94 MW for the most likely case (base case). The high growth scenario forecast reaches a value of 152 MW, whereas for the low growth case it reaches a value of 85, both in the year 2023.

Table 2.5 shows the forecast for Qurayat. The peak demand increases from a level of 133 MW to 226 MW for the most likely case (base case). The high growth scenario forecast reaches a value of 366 MW whereas for the low growth case it reaches a value of 205 MW, both in the year 2023.

Table 2.6 shows the forecast for Al-Jawf system. The peak demand increases from a level of 169 MW to 287 MW for the most likely case (base case). The high growth scenario forecast reaches a value of 465 MW, whereas for the low growth case it reaches a value of 261 MW, both in the year 2023.

The total peak load forecast for the isolated areas under the jurisdiction of the EOA is 449 MW in the year 2008 and increases to a level of 762 MW in the year 2023 for the most likely case.

Table 2.3. Demand Forecast – Arar.

Year	Most Likely Case		High Growth Case		Low Growth Case	
	Peak Load (MW)	**Energy (GWh)**	**Peak Load (MW)**	**Energy (GWh)**	**Peak Load (MW)**	**Energy (GWh)**
2008	92	612	92	612	89	592
2009	96	638	96	638	93	618
2010	99	658	102	678	95	632
2011	104	691	108	718	99	658
2012	109	725	115	765	103	685
2013	113	751	122	811	106	705
2014	118	785	129	858	110	731
2015	122	811	139	924	114	758
2016	127	844	150	997	118	785
2017	131	871	160	1,064	121	805
2018	135	898	171	1,137	125	831
2019	140	931	182	1,210	129	858
2020	144	957	199	1,323	132	878
2021	148	984	217	1,443	135	898
2022	152	1,011	235	1,562	139	924
2023	156	1,037	253	1,682	142	944

Table 2.4. Demand Forecast – Rafha.

Year	Most Likely Case		High Growth Case		Low Growth Case	
	Peak Load (MW)	**Energy (GWh)**	**Peak Load (MW)**	**Energy (GWh)**	**Peak Load (MW)**	**Energy (GWh)**
2008	55	366	55	366	53	352
2009	58	386	58	386	56	372
2010	60	399	61	406	57	379
2011	62	412	65	432	59	392
2012	65	432	69	459	62	412
2013	68	452	73	485	64	426
2014	71	472	77	512	66	439
2015	73	485	84	559	68	452
2016	76	505	90	598	71	472
2017	79	525	96	638	73	485
2018	81	539	103	685	75	499
2019	84	559	109	725	77	512
2020	86	572	120	798	79	525
2021	89	592	131	871	81	539
2022	91	605	141	937	83	552
2023	94	625	152	1,011	85	565

Table 2.5. Demand Forecast – Qurayat.

Year	Most Likely Case		High Growth Case		Low Growth Case	
	Peak Load (MW)	Energy (GWh)	Peak Load (MW)	Energy (GWh)	Peak Load (MW)	Energy (GWh)
2008	133	884	133	884	129	858
2009	139	924	139	924	134	891
2010	144	957	147	977	137	911
2011	150	997	157	1,044	143	951
2012	157	1,044	167	1,110	148	984
2013	164	1,090	177	1,177	154	1,024
2014	170	1,130	186	1,237	160	1,064
2015	177	1,177	202	1,343	165	1,097
2016	183	1,217	217	1,443	170	1,130
2017	190	1,263	232	1,543	176	1,170
2018	196	1,303	247	1,642	181	1,203
2019	202	1,343	263	1,749	186	1,237
2020	208	1,383	288	1,915	191	1,270
2021	214	1,423	314	2,088	196	1,303
2022	220	1,463	340	2,261	200	1,330
2023	226	1,503	366	2,433	205	1,363

Table 2.6. Demand Forecast – Al-Jawf.

Year	Most Likely Case		High Growth Case		Low Growth Case	
	Peak Load (MW)	Energy (GWh)	Peak Load (MW)	Energy (GWh)	Peak Load (MW)	Energy (GWh)
2008	169	1,124	169	1,124	163	1,084
2009	177	1,177	177	1,177	170	1,130
2010	183	1,217	187	1,243	174	1,157
2011	191	1,270	199	1,323	181	1,203
2012	199	1,323	212	1,410	189	1,257
2013	208	1,383	224	1,489	196	1,303
2014	216	1,436	237	1,576	203	1,350
2015	224	1,489	256	1,702	209	1,390
2016	233	1,549	276	1,835	216	1,436
2017	241	1,602	295	1,961	223	1,483
2018	249	1,656	314	2,088	230	1,529
2019	257	1,709	334	2,221	237	1,576
2020	264	1,755	366	2,433	243	1,616
2021	272	1,808	399	2,653	249	1,656
2022	279	1,855	432	2,872	255	1,695
2023	287	1,908	465	3,092	261	1,735

2.4 DEMAND FORECAST – CENTRAL OPERATING AREA (COA)

2.4.1 Interconnected System

The Central Operating Area is connected to the Eastern Operating Area by a 230 kV double circuit and two double circuit 380 kV lines. The transfer to the central from the eastern operating area can reach up to 2,500 MW.

Table 2.7 summarizes the energy and the load forecast for the territorial COA interconnected system.

As shown in Table 2.7 the total energy is expected to reach a figure of 94,860 GWh in the year 2023 for the most likely scenario. The peak load recorded for the year 2005 is 9,072 MW. The forecast varies from a value of 10,369 MW in the year 2008 to 17,494 MW in the year 2023.

The energy forecast for the high growth case is likely to reach a figure of 153,885 GWh in the year 2023. The peak load is expected to rise to a level of 28,379 MW. For the low growth scenario, the energy forecast is likely to reach a figure of 86,294 GWh in the year 2023. The peak load is expected to reach a level of 15,914 MW in the year 2023.

The average load factor used is 61.9% for the year 2010 and onwards.

Table 2.7. Demand Forecast – COA Interconnected System.

Year	Most Likely Case		High Growth Case		Low Growth Case		Load Factor (%)
	Peak Load (MW)	Energy (GWh)	Peak Load (MW)	Energy (GWh)	Peak Load (MW)	Energy (GWh)	
2008	10,369	54,953	10,369	54,953	10,029	53,150	60.5
2009	10,879	57,655	10,879	57,655	10,453	55,401	60.5
2010	11,148	60,447	11,398	61,806	10,649	57,742	61.9
2011	11,662	63,238	12,164	65,956	11,080	60,083	61.9
2012	12,177	66,030	12,929	70,106	11,512	62,423	61.9
2013	12,692	68,822	13,694	74,257	11,944	64,764	61.9
2014	13,207	71,613	14,460	78,407	12,375	67,105	61.9
2015	13,704	74,311	15,642	84,820	12,790	69,352	61.9
2016	14,202	77,009	16,825	91,233	13,204	71,599	61.9
2017	14,699	79,707	18,008	97,647	13,619	73,846	61.9
2018	15,197	82,404	19,191	104,060	14,033	76,093	61.9
2019	15,694	85,102	20,373	110,473	14,447	78,340	61.9
2020	16,144	87,542	22,375	121,326	14,814	80,328	61.9
2021	16,594	89,981	24,376	132,179	15,181	82,317	61.9
2022	17,044	92,420	26,378	143,032	15,547	84,305	61.9
2023	17,494	94,860	28,379	153,885	15,914	86,294	61.9

2.4.2 Isolated System

Juba, an area that was part of the northern region earlier is now under the Central Operating Area (COA). The peak load and the energy forecast for Juba for the three scenarios are presented in Table 2.8. The peak demand increases from a level of 207 MW in the year 2008 to 350 MW in the year 2023 for the most likely case (base case). The high growth scenario forecast reaches a value of 568 MW in the year 2023, whereas, for the low growth case it reaches a value of 318 MW in the year 2023.

Table 2.8. Demand Forecast – Juba.

Year	Most Likely Case		High Growth Case		Low Growth Case	
	Peak Load (MW)	Energy (GWh)	Peak Load (MW)	Energy (GWh)	Peak Load (MW)	Energy (GWh)
2008	207	1,122	207	1,122	201	1,090
2009	218	1,182	218	1,182	209	1,133
2010	223	1,209	228	1,236	213	1,155
2011	233	1,263	243	1,318	222	1,204
2012	244	1,323	259	1,404	230	1,247
2013	254	1,377	274	1,486	239	1,296
2014	264	1,432	289	1,567	248	1,345
2015	274	1,486	313	1,697	256	1,388
2016	284	1,540	337	1,827	264	1,432
2017	294	1,594	360	1,952	272	1,475
2018	304	1,648	384	2,082	281	1,524
2019	314	1,703	407	2,207	289	1,567
2020	323	1,751	447	2,424	296	1,605
2021	332	1,800	488	2,646	304	1,648
2022	341	1,849	528	2,863	311	1,686
2023	350	1,898	568	3,080	318	1,724

2.5 DEMAND FORECAST – WESTERN OPERATING AREA (WOA)

2.5.1 Interconnected System

Table 2.9 summarizes the energy and the load forecast for the WOA interconnected system. The isolated areas of Tabuk, Dhuba, Al-Oula and other small areas are not included in this forecast and are discussed separately.

As shown in Table 2.9 the total energy is expected to reach a figure of 93,014 GWh in the year 2023 for the most likely scenario. The peak load recorded for the year 2005 is 8,599 MW. The forecast varies from a value of 9,478 MW in the year 2008 to 16,335 MW in the year 2023.

The energy forecast for the high growth case is likely to reach a figure of 150,891 GWh in the year 2023. The peak load is expected to rise to a level of 26,500 MW. For the low growth scenario, the energy forecast is likely to reach a figure of 84,614 GWh in the year 2023. The peak load is expected to reach a level of 14,860 MW, also in the year 2023.

The average load factor used for the WOA is 65% for the year 2010 and onwards.

Table 2.9. Demand Forecast – WOA Interconnected System.

Year	Most Likely Case		High Growth Case		Low Growth Case		Load Factor (%)
	Peak Load (MW)	Energy (GWh)	Peak Load (MW)	Energy (GWh)	Peak Load (MW)	Energy (GWh)	
2008	9,478	53,884	9,478	53,884	9,167	52,115	64.9
2009	9,944	56,533	9,944	56,533	9,555	54,323	64.9
2010	10,409	59,270	10,643	60,603	9,943	56,618	65.0
2011	10,890	62,008	11,358	64,672	10,347	58,913	65.0
2012	11,371	64,745	12,073	68,742	10,750	61,209	65.0
2013	11,851	67,482	12,787	72,812	11,153	63,504	65.0
2014	12,332	70,220	13,502	76,881	11,556	65,799	65.0
2015	12,797	72,865	14,607	83,170	11,943	68,002	65.0
2016	13,261	75,510	15,711	89,458	12,330	70,205	65.0
2017	13,726	78,155	16,815	95,746	12,717	72,409	65.0
2018	14,190	80,801	17,920	102,034	13,104	74,612	65.0
2019	14,655	83,446	19,024	108,323	13,491	76,815	65.0
2020	15,075	85,838	20,893	118,965	13,833	78,765	65.0
2021	15,495	88,230	22,762	129,607	14,175	80,715	65.0
2022	15,915	90,622	24,631	140,249	14,518	82,665	65.0
2023	16,335	93,014	26,500	150,891	14,860	84,614	65.0

2.5.2 Isolated System

Isolated areas such as Tabuk, Dhuba, Al-Oula and other small areas referred to here as “others” are now part of WOA.

The peak load and the energy forecast for Tabuk for the three scenarios are presented in Table 2.10. The peak demand increases from a level of 338 MW in the year 2008 to 583 MW in the year 2023 for the most likely case. In the high growth scenario, the peak load forecast reaches a value of 945 MW, whereas for the low growth case it reaches a value of 530 MW, both in the year 2023.

The peak load and the energy forecast for Dhuba system for the three scenarios are presented in Table 2.11. The peak demand increases from a level of 50 MW in the year 2008 to 86 MW in the year 2023 for the most likely case. In the high growth scenario, the forecast reaches a value of 139 MW, whereas for the low growth case it reaches a value of 78 MW, both in the year 2023.

Table 2.12 shows the forecast for Al-Oula system. The peak demand increases from a level of 41 MW in the year 2008 to 71 MW in the year 2023 for the most likely case (base case). In the high growth scenario, the forecast reaches a value of 116 MW, whereas for the low growth case it reaches a value of 65 MW, both in the year 2023.

Table 2.13 shows the forecast for other small areas. The expected peak demand varies from a level of 92 MW in the year 2008 to 159 MW in the year 2023 for the most likely case. In the high growth scenario, the forecast reaches a value of 258 MW, whereas for the low growth case it reaches a value of 145 MW, both in the year 2023.

The total peak load forecast for the isolated area under the jurisdiction of the WOA is 521 MW in the year 2008 and increases to a level of 898 MW in the year 2023 for the most likely case (base case).

Table 2.10. Demand Forecast – Tabuk.

Year	Most Likely Case		High Growth Case		Low Growth Case	
	Peak Load (MW)	Energy (GWh)	Peak Load (MW)	Energy (GWh)	Peak Load (MW)	Energy (GWh)
2008	338	1,925	338	1,925	327	1,862
2009	355	2,021	355	2,021	341	1,942
2010	371	2,112	380	2,164	355	2,021
2011	388	2,209	405	2,306	369	2,101
2012	406	2,312	431	2,454	383	2,181
2013	423	2,409	456	2,596	398	2,266
2014	440	2,505	482	2,745	412	2,346
2015	456	2,596	521	2,967	426	2,426
2016	473	2,693	560	3,189	440	2,505
2017	490	2,790	600	3,416	454	2,585
2018	506	2,881	639	3,638	467	2,659
2019	523	2,978	679	3,866	481	2,739
2020	538	3,063	745	4,242	493	2,807
2021	553	3,149	812	4,624	506	2,881
2022	568	3,234	879	5,005	518	2,949
2023	583	3,320	945	5,381	530	3,018

Table 2.11. Demand Forecast – Dhuba.

Year	Most Likely Case		High Growth Case		Low Growth Case	
	Peak Load (MW)	Energy (GWh)	Peak Load (MW)	Energy (GWh)	Peak Load (MW)	Energy (GWh)
2008	50	285	50	285	48	273
2009	52	296	52	296	50	285
2010	55	313	56	319	52	296
2011	57	325	60	342	54	307
2012	60	342	63	359	56	319
2013	62	353	67	381	59	336
2014	65	370	71	404	61	347
2015	67	381	77	438	63	359
2016	70	399	82	467	65	370
2017	72	410	88	501	67	381
2018	74	421	94	535	69	393
2019	77	438	100	569	71	404
2020	79	450	110	626	73	416
2021	81	461	119	678	74	421
2022	84	478	129	735	76	433
2023	86	490	139	791	78	444

Table 2.12. Demand Forecast – Al-Oula.

Year	Most Likely Case		High Growth Case		Low Growth Case	
	Peak Load (MW)	Energy (GWh)	Peak Load (MW)	Energy (GWh)	Peak Load (MW)	Energy (GWh)
2008	41	233	41	233	40	228
2009	43	245	43	245	42	239
2010	45	256	46	262	43	245
2011	47	268	50	285	45	256
2012	50	285	53	302	47	268
2013	52	296	56	319	49	279
2014	54	307	59	336	50	285
2015	56	319	64	364	52	296
2016	58	330	68	387	54	307
2017	60	342	73	416	55	313
2018	62	353	78	444	57	325
2019	64	364	83	473	59	336
2020	66	376	91	518	60	342
2021	68	387	99	564	62	353
2022	69	393	107	609	63	359
2023	71	404	116	661	65	370

Table 2.13. Demand Forecast – Others.

Year	Most Likely Case		High Growth Case		Low Growth Case	
	Peak Load (MW)	**Energy (GWh)**	**Peak Load (MW)**	**Energy (GWh)**	**Peak Load (MW)**	**Energy (GWh)**
2008	92	524	92	524	89	507
2009	97	552	97	552	93	530
2010	101	575	103	586	97	552
2011	106	604	110	626	101	575
2012	111	632	117	666	105	598
2013	115	655	124	706	108	615
2014	120	683	131	746	112	638
2015	124	706	142	809	116	661
2016	129	735	153	871	120	683
2017	133	757	164	934	124	706
2018	138	786	174	991	127	723
2019	143	814	185	1,053	131	746
2020	147	837	203	1,156	135	769
2021	151	860	221	1,258	138	786
2022	155	883	240	1,367	141	803
2023	159	905	258	1,469	145	826

2.6 DEMAND FORECAST – SOUTHERN OPERATING AREA (SOA)

2.6.1 Interconnected System

The Southern Operating Area is presently not connected to any other operating area. Table 2.14 summarizes the energy and the load forecast for the Southern Operating Area interconnected system. The regional load forecast includes the forecast for the loads served by the interconnected system. The isolated areas of Sharourah, Farasan and Tathlith in the southern region are treated separately and are not included in this forecast and are discussed separately.

As shown in Table 2.14 the total energy is expected to reach a figure of 24,819 GWh in the year 2023 for the most likely scenario. The peak load recorded for the year 2005 is 2,270 MW. The forecast varies from a value of 2,410 MW in the year 2008 to 4,160 MW in the year 2023.

The energy forecast for the high growth case is likely to reach a figure of 40,263 GWh and the peak load is expected to rise to a level of 6,749 MW in the year 2023.

For the low growth scenario, the energy forecast is likely to reach a figure of 22,578 GWh and the peak load is expected to reach a level of 3,785 MW in the year 2023.

The average load factor used for the SOA is 68.1% for the entire study horizon.

Table 2.14. Demand Forecast – SOA Interconnected System.

Year	Most Likely Case		High Growth Case		Low Growth Case		Load Factor (%)
	Peak Load (MW)	Energy (GWh)	Peak Load (MW)	Energy (GWh)	Peak Load (MW)	Energy (GWh)	
2008	2,410	14,378	2,410	14,378	2,331	13,906	68.1
2009	2,529	15,085	2,529	15,085	2,430	14,495	68.1
2010	2,651	15,815	2,711	16,171	2,532	15,108	68.1
2011	2,774	16,546	2,893	17,257	2,635	15,720	68.1
2012	2,896	17,276	3,075	18,343	2,738	16,333	68.1
2013	3,018	18,007	3,257	19,429	2,840	16,945	68.1
2014	3,141	18,737	3,439	20,515	2,943	17,557	68.1
2015	3,259	19,443	3,720	22,193	3,042	18,145	68.1
2016	3,378	20,149	4,001	23,870	3,140	18,733	68.1
2017	3,496	20,855	4,283	25,548	3,239	19,321	68.1
2018	3,614	21,560	4,564	27,226	3,337	19,909	68.1
2019	3,732	22,266	4,845	28,904	3,436	20,497	68.1
2020	3,839	22,905	5,321	31,744	3,523	21,017	68.1
2021	3,946	23,543	5,797	34,584	3,610	21,537	68.1
2022	4,053	24,181	6,273	37,423	3,698	22,058	68.1
2023	4,160	24,819	6,749	40,263	3,785	22,578	68.1

2.6.2 *Isolated System*

The peak load and the energy forecast for Sharourah for the three scenarios are presented in Table 2.15. The peak demand increases from a level of 35.8 MW in the year 2008 to 61.7 MW in the year 2023 for the most likely case. In the high growth scenario, the peak load forecast reaches a value of 100 MW, whereas for the low growth case it reaches a value of 56 MW, both in the year 2023.

The peak load and the energy forecast for Farasan area for the three scenarios are presented in Table 2.16. The peak demand increases from a level of 11.1 MW in the year 2008 to 19.2 MW in the year 2023 for the most likely case. In the high growth scenario, the forecast reaches a value of 31.2 MW whereas for the low growth case it reaches a value of 17.5 MW in the year 2023.

Table 2.17 shows the forecast for the Tathlith area. The peak demand increases from a level of 8.5 MW in the year 2008 to 14.7 MW in the year 2023 for the most likely case. In the high growth scenario, the forecast reaches a value of 23.9 MW whereas for the low growth case it reaches a value of 13.4 MW, both in the year 2023.

The total peak load forecast for the isolated area under the jurisdiction of the SOA is 55 MW in the year 2008 and increases to a level of 96 MW in the year 2023 for the most likely case.

Table 2.15. Demand Forecast – Sharourah.

Year	**Most Likely Case**		**High Growth Case**		**Low Growth Case**	
	Peak Load (MW)	**Energy (GWh)**	**Peak Load (MW)**	**Energy (GWh)**	**Peak Load (MW)**	**Energy (GWh)**
2008	35.76	213	35.76	213	34.59	206
2009	37.52	224	37.52	224	36.05	215
2010	39.34	235	40.22	240	37.58	224
2011	41.15	245	42.92	256	39.1	233
2012	42.97	256	45.62	272	40.62	242
2013	44.79	267	48.32	288	42.15	251
2014	46.6	278	51.03	304	43.67	261
2015	48.36	288	55.2	329	45.13	269
2016	50.12	299	59.37	354	46.59	278
2017	51.87	309	63.55	379	48.06	287
2018	53.63	320	67.72	404	49.52	295
2019	55.38	330	71.89	429	50.98	304
2020	56.97	340	78.96	471	52.28	312
2021	58.56	349	86.02	513	53.57	320
2022	60.14	359	93.08	555	54.86	327
2023	61.73	368	100.14	597	56.16	335

Table 2.16. Demand Forecast – Farasan.

Year	Most Likely Case		High Growth Case		Low Growth Case	
	Peak Load (MW)	Energy (GWh)	Peak Load (MW)	Energy (GWh)	Peak Load (MW)	Energy (GWh)
2008	11.13	66	11.13	66	10.77	64
2009	11.68	70	11.68	70	11.22	67
2010	12.24	73	12.52	75	11.7	70
2011	12.81	76	13.36	80	12.17	73
2012	13.37	80	14.2	85	12.64	75
2013	13.94	83	15.04	90	13.12	78
2014	14.51	87	15.88	95	13.59	81
2015	15.05	90	17.18	102	14.05	84
2016	15.6	93	18.48	110	14.5	87
2017	16.14	96	19.78	118	14.96	89
2018	16.69	100	21.08	126	15.41	92
2019	17.24	103	22.38	134	15.87	95
2020	17.73	106	24.57	147	16.27	97
2021	18.23	109	26.77	160	16.67	99
2022	18.72	112	28.97	173	17.08	102
2023	19.21	115	31.17	186	17.48	104

Table 2.17. Demand Forecast – Tathlith.

Year	Most Likely Case		High Growth Case		Low Growth Case	
	Peak Load (MW)	Energy (GWh)	Peak Load (MW)	Energy (GWh)	Peak Load (MW)	Energy (GWh)
2008	8.54	51	8.54	51	8.26	49
2009	8.96	53	8.96	53	8.61	51
2010	9.4	56	9.61	57	8.97	54
2011	9.83	59	10.25	61	9.34	56
2012	10.26	61	10.9	65	9.7	58
2013	10.7	64	11.54	69	10.07	60
2014	11.13	66	12.19	73	10.43	62
2015	11.55	69	13.18	79	10.78	64
2016	11.97	71	14.18	85	11.13	66
2017	12.39	74	15.18	91	11.48	68
2018	12.81	76	16.17	96	11.83	71
2019	13.23	79	17.17	102	12.18	73
2020	13.61	81	18.86	113	12.49	75
2021	13.99	83	20.54	123	12.79	76
2022	14.36	86	22.23	133	13.1	78
2023	14.74	88	23.92	143	13.41	80

2.7 DEMAND FORECAST – SUMMARY FOR THE KINGDOM

Table 2.18 shows the summary of the demand forecast for the Kingdom. This includes the interconnected systems as well as the isolated systems. The detailed results are presented in the preceding sections. The results are presented for every five years. The peak load for the most likely case is expected to reach a level of 57,808 MW in the year 2023. The total energy is expected to reach a figure of 343,110 GWh in the year 2023.

For the scenario of high growth in GDP, the peak load is expected to reach a level of 93,779 MW. The total energy is expected to reach 556,607 GWh in the year 2023.

In case of the low growth scenario, the peak load is expected to reach a value of 52,588 MW in the year 2023. The total energy is expected to reach 312,127 GWh in the year 2023.

The results of the demand forecast will be used to develop generation plans that meet standard reliability indices. The generation plans will be based on a number of planning bases and assumptions which are discussed in Section 3.

Table 2.18. Kingdom Forecast Summary.

Year	**Most Likely Case**		**High Growth Case**		**Low Growth Case**	
	Peak Load (MW)	**Energy (GWh)**	**Peak Load (MW)**	**Energy (GWh)**	**Peak Load (MW)**	**Energy (GWh)**
2008	33,930	198,766	33,930	198,767	32,816	192,244
2013	41,940	248,930	45,253	268,589	39,468	234,254
2018	50,218	298,058	63,415	376,386	46,371	275,229
2023	57,808	343,110	93,779	556,607	52,588	312,127

SECTION 3 GENERATION PLANNING METHODOLOGY AND STUDY BASIS

3.1 GENERAL APPROACH

This section provides an overview of the generation planning process to cover the study period 2008 to 2023. The main objective of the study is to develop a generation plan based on the future demand forecast with adequate levels of reserves to ensure the continuity of power supply.

From the operations point of view the Saudi electricity sector is divided into four operating areas: East, Central, West, and South. The planning process is therefore structured to determine the system plans for each of the operating areas and then assess the adjustments that may be made into the plan from the Kingdom's point of view. Other than the Eastern and the Central Operating areas, the other areas are planned and operated independently. The remote areas in the north are divided between Eastern, Central and Western operating areas based on their geographical proximity.

This section addresses the following:

- Adequacy of Supply.
- Future generation requirements, their types and costs.
- Interconnection between Western-Central and Western-Southern operating areas.
- Additional interconnection between Eastern and Central operating areas.

The first step in the planning process is the development of a data base of the elements of the existing power system and the demand and the supply options. Data were collected from the Ministry of Water & Electricity, Ministry of Planning, Saudi Electricity Company, Saline Water Conversion Corporation (SWCC), Independent Power Producers (IPP) and Electricity and Cogeneration Regulatory Authority (ECRA).

The potential supply options for different operating areas were identified and the unit costs and other characteristics were determined. The basic supply options are steam turbine and single cycle gas turbines for the Eastern, Western and Southern operating areas and only single cycle gas turbines for the Central operating areas. This was presented and agreed in follow-up meetings with the client.

The load forecast was developed for the Kingdom based on econometric study and the results are presented in Section 2 of this report. The generation requirements are calculated based on most likely demand forecast (reference case or base case). In the case of the SOA, the generation plans are based on the high growth scenario. This is done to reflect the special growth rates and development status of the Southern region.

The generation study is carried out for the reference case with the existing interconnections between the EOA and COA. A generation plan is also developed to include the future interconnection of WOA and COA, WOA and SOA and the additional interaction of EOA and COA. Finally, the investment costs are calculated and are expressed in present worth value at January 2005.

3.2 ANALYSIS METHODOLOGY

The main tasks involved in the development of the generation plan are as follows:

- Develop the load forecast.
- Develop the planning basis.
- Define the generation supply options.
- Develop the generation plan for the interconnected system with the four operating areas.
- Develop the generation plan for the isolated load centers.
- Develop the generation plan with future regional interconnections.
- Determine the capital expenditure requirements.

3.2.1 Load Forecast

The methodology used to develop the demand forecast is discussed in Section 2. The demand forecasts were developed to cover the period 2008 to 2023 using an appropriate methodology. The results are described in Section 2.

In addition to the most likely scenario load forecast, high and low growth scenarios were also produced using high/low growth of GDP estimates.

3.2.2 Development of the Planning Basis

The first major task of the planning study was to collect the relevant and coherent data for carrying out the task from the electric utilities and appropriate government ministries/departments.

The generation data for the existing power systems were prepared by the study team and sent to the client for update/verification. The data required were as follows:

- Peak loads and energy recorded for the period 1995 to 2004 for all regions including the isolated systems of the Kingdom.
- Hourly load data for all regions including the isolated systems of the Kingdom for the year 2004.
- Actual generation from all the SWCC plants for the period 1995 to 2004.
- Hourly energy transfer data between EOA and COA.

- Updated Long Term Electrification Plan for the Kingdom of Saudi Arabia (ULTEP), Final Report, 1998.
- Committed generation projects for each regions of the Kingdom.
- Water & Electricity Company (WEC) electricity generation plans.
- Committed generation expansion plan for WEC.
- Short term and medium term demand forecast developed by SEC for all regions including the isolated systems up to the period available.
- Fuel availability.
- Committed Plans for different IPP/IWPP.

3.2.3 Generation Supply Options

The generation supply options are location specific as the options have to take into account the resources that are available in the region or the country. With regards to the fuel needs, there is adequate supply of liquid fuels to meet the present as well as the future needs of the Kingdom.

The basic generation supply options considered are conventional thermal plants, steam units, gas turbines and diesel units. The supply options such as unit type and size for the candidate unit of expansion for a given region is dictated by the characteristic of the existing systems into which they are to be integrated. The details of the unit sizes and types for different regions are described in the subsequent section. Presently, the fuels used for electricity generation are natural gas, crude oil, diesel and heavy fuel oil.

The Saline Water Conversion Corporation (SWCC) also represents an important and substantial source of energy supply. They use Multi Stage Flash (MSF) process for desalination of sea water. The electricity generated in the cogeneration mode that is surplus to the SWCC plant requirements is made available to the regional electricity network. The SWCC generation in the Eastern and the Western Regions are quite significant. There was also some generation contribution to the Southern Region.

The IPP/IWPP such as Marafiq, Maa'den and Saudi Aramco are expected to be significant contributors in the generation supply. Interconnections between different operating areas can also be considered as a generation supply option. They may be used for reducing the reserve margin in a given system.

3.2.4 Development of Reference Generation Expansion Plan for the Operating Areas

The generation expansion planning process would involve reliability criteria to determine the timing of the generation additions. The reliability criteria used in the development of the reference plan for the interconnected system within each of the four operating areas is the Loss-of-load expectation (LOLE). The criteria used was presented, discussed and agreed upon with the client.

The timing and amount of generation to be added would be dictated by the following:

- Results and analysis of the load forecast.
- Reliability/reserve criteria.
- Existing generation capacities.
- Committed generation additions, and
- Policies regarding the retirements of the existing generating units.

The development of the generation expansion plan is based on the use of the advanced computerized tool (Multi Area Reliability Program) MAREL. MAREL is a well known modeling program within the utility industry. This program assesses the reliability of an isolated or interconnected electric power system. It calculates standard reliability indices, which can be used to develop generation expansion plans. Standard indices such as the Loss-of-load expectation (LOLE), the Expected-energy-not-served (EENS), and area deficiencies are generated. MAREL may be used to compare the reliability indices of alternate generation expansion plans. Simulation of single area as well as interconnected power systems can be conducted.

The input required are the data defining the existing generation, the demand forecast, the planning criteria and the generation supply options. The study horizon was fixed as 15 years, i.e. 2008 to 2023G.

For the development of the generation expansion sequence, the adequacy of the supply is measured by the value of the reliability index.

3.2.5 Development of the Isolated Load Centers

The isolated load centers referred to here are the areas in the northern region that were earlier part of the Electricity Corporation. These areas are included in three operating areas.

- Arar, Rafha, Qurayat and Al-Jawf are under the Eastern Operating Area (EOA).
- Juba is under the Central Operating Area (COA).
- Tabuk, Dhuba, Al-Oula and other small areas are under the Western Operating Area (WOA).

The isolated areas of Sharourah, Farasan and Tathlith are also included in the isolated load centers and fall under the Southern Operating Area (SOA).

The development of the generation expansion plan for the above load centers is based on a deterministic approach. The unit additions are based on the separate load forecast for these isolated areas and the criteria for the reserve margin and contingencies.

3.2.6 Development of the Unified Generation Expansion Scenarios

At present the only regional interconnection is between the EOA and COA. The generation expansion scenarios considering new interconnections between the regions are referred here as the unified generation expansion scenarios. The incentive to consider the regional interconnections comes from the cost savings and the reliability of the system. Additional interconnections are studied in this project, namely, the West-Central and the West-South interconnections. The assumed years of interconnection and the link capacity have been discussed and agreed upon with the client.

The future interconnection is generally based on one or both of the following two concepts:

- Reserve Sharing Concepts.
- Firm Transfer or Purchase from another region.

In the present study the selected basis is reserve sharing.

The reserve sharing benefits can be realized by interconnecting two or more systems and thus reducing the overall installed capacity. Each system is planned to have adequate supply to meet its load. Assistance from other systems depends on the capacity of the transmission interconnecting link and reserve.

The firm transfer from one region to another would be of interest if there was a substantial difference in the cost of generation between the two systems or for strategic reasons. The other benefits that cannot be quantified are the multiple outages in one system or the unexpected load growth.

3.2.7 Capital Expenditure Analysis

The capital investment requirements for both the reference and the unified plans for each of the operating areas are calculated at 5% discount rate using cash flow and unit capital cost as given in this section. Sensitivity analyses are also carried out for 3 and 10 percent discount rates with and without escalation in the generating unit capital costs. Additional sensitivity scenarios were also studied. These are changes in the unit capital costs by ±10 and ±20%.

3.3 PLANNING BASIS

3.3.1 Introduction

The project team developed the system planning basis and assumption. The parameters which were discussed in the planning basis are: study horizon, demand forecast, power supply options, fuel availability and prices, generation planning standard, generating unit forced outage rate, its maintenance schedule, capital and O&M costs, service life of the generating unit, cash flow, and economic parameters.

Moreover, other assumptions, such as, contribution from regional interconnection, contribution from SWCC, IWPP, and IPP plants, and retirement policies of the existing generating units were also taken up in this task. The system planning basis and assumption developed are discussed below.

3.3.2 Study Horizon Year

The study horizon for this study is a 15 year simulation period starting from 2008 and ending in 2023G. The study horizon is long enough to assess the medium to long term development taking place in the Kingdom.

3.3.3 Planning Year

The planning year is based on the Gregorian calendar. The Kingdom's peak load is dictated by the summer months. For consistencies between the months of the year and the load, therefore, the Gregorian calendar is used.

3.3.4 Demand Forecasts

The demand forecast was developed based on the previous report, "Updated Long Term Electrification Plan (ULTEP)," the GDP and population data acquired from the Ministry of Planning, and the historical recorded actual peak loads and energy for the period 1995 to 2005 as provided by the Ministry Water and Electricity and SEC. Table 3.1 illustrates the summary of demand forecast for the four interconnected operating areas for the most likely case.

Table 3.1. Most likely peak load demand forecast.

Year	EOA (MW)	COA (MW)	WOA (MW)	SOA (MW)
2008	10,440	10,369	9,478	2,410
2013	12,851	12,692	11,851	3,018
2018	15,387	15,197	14,190	3,614
2023	17,713	17,494	16,335	4,160

The occurrence of Ramadan and Hajj during the summer months (May to September) will have an impact on the load characteristics and profile during those months. This will add a level of uncertainty that is addressed by having a stringent generation planning standard as explained in Section 3.3.8.

3.3.5 Power Supply Options

The principal generations options considered are conventional thermal steam turbine, gas turbine and diesel units (for isolated systems only). The unit type and size is dictated by the existing system and, as such, unit type and size is region specific. The generation types and sizes utilized for different operating areas in the study are illustrated in Table 3.2.

Table 3.2. Future generation types and sizes for each operating area.

Operating Areas	Unit Type	Site Rating (MW)	Primary Fuel
EOA	ST	600	NG
WOA	ST	400	HFO
WOA	ST	600	HFO
SOA	ST	250	HFO
EOA	GT	125	NG
COA	GT	116	NG
WOA	GT	123	DO
SOA	GT	123	DO
Isolated	GT	28	CR
Isolated	GT	15	CR
Isolated	GT	53	CR
Isolated	GT	30	CR
Isolated	DI	9.9	CR
Isolated	DI	5	CR
Isolated	DI	10	CR
Isolated	DI	4.9	CR
Isolated	DI	2	CR

ST: Steam Turbine, GT: Gas Turbine, DI: Diesel Engine
NG: Natural Gas, DO: Diesel Oil, HFO: Heavy Fuel Oil, CR: Crude Oil

3.3.6 Fuel Types and Availability

The fuel types used by present generating units in the Kingdom are Natural Gas (NG), Heavy Fuel Oil (HFO), Crude Oil (CO) and Diesel Oil (DO).

The general policy regarding the fuel is to use crude oil as the basic fuel for the gas turbines. However, in the eastern region natural gas is used for most of the power plants. Diesel oil is used for some small gas turbines. The steam turbine at Rabigh and Shaiba uses heavy fuel oil as the basic fuel. There are adequate reserves of crude oil to meet the growing demand of fuel for power generation.

For this study it will be assumed that the existing generating units will continue burning the same fuel type. However, for the future units it will be assumed that natural gas would be available for the eastern and central operating areas. As for western and southern operating areas it will be assumed that they would be using liquid fuel for the study period. The diesel units in the isolated system would use crude oil as a primary fuel.

3.3.7 Fuel Prices

Based on the current market prices for crude oil and information on domestic fuel prices the following international and domestic fuel prices are assumed and are illustrated in Tables 3.3 and 3.4. Fuel prices used in this study are based on higher heating value (HHV). The heat content of the fuel is acquired from the ULTEP generation planning report. Heavy fuel oil is assumed as 75 % and diesel oil as 132% of crude oil prices respectively for international fuel prices, as indicated in the ULTEP report. Natural gas is not trade-able in the world market; therefore, an opportunity cost inside the Kingdom will be used. The local utilities have provided the domestic price of natural gas as 2.813 SR/MBTU (0.75 $/MBTU).

The data shown are not used in this study and are given for the sake of completeness of the report.

Table 3.3. International fuel prices.

Fuel Type	Fuel Price ($/BBL)	Fuel Price (SR/m$^{3)}$	Heat Content (MBTU/m^3)	Fuel Price ($/MBTU)	Fuel Price (SR/MBTU)
Natural Gas	-	-	42.37	-	-
Crude Oil	50.00	1179.34	35.96	8.75	32.80
Diesel Oil	66.00	1556.73	36.16	11.48	43.05
Heavy Fuel Oil	37.50	884.51	40.61	5.81	21.78

Table 3.4. Domestic fuel prices.

Fuel Type	Fuel Price ($/BBL)	Fuel Price (SR/m$^{3)}$	Heat Content (MBTU/m^3)	Fuel Price ($/MBTU)	Fuel Price (SR/MBTU)
Natural Gas	-	-	42.37	0.75	2.81
Crude Oil	4.24	100.00	35.96	0.74	2.78
Diesel Oil	3.60	85.00	36.16	0.63	2.35
Heavy Fuel Oil	2.54	60.00	40.61	0.39	1.48

3.3.8 Generation Planning Standard

In any generating planning study it is essential that the generation addition (size and timing) is based on consistent and justifiable criteria.

The generation planning standard used in this study is based on the Loss-of-Load-Expectation (LOLE) risk index expressed in hours per year. The advantage of using a risk based criterion such as LOLE is that it provides an objective assessment of reserves, taking into account the forced outage rate (FOR) and different types and sizes of generating units.

In this study, an LOLE index of 4.8 hours/year (0.2 day/year or 1 day in 5 years) will be adopted for planning studies for all interconnected systems. However, to take into account the occurrence of Ramadan and Hajj during the summer months (May – September); the generation planning standard (LOLE) will be made more stringent to 4.5 hours/year. This would take care of the uncertainty in load characteristics and profile due to Ramadan and Hajj. This planning criterion will only be considered, for the years Ramadan and Hajj occur during the summer months and for those operating areas which are affected by the above events.

For the isolated system, a deterministic approach of maintaining a minimum reserve of 15% in addition to the loss of the two largest units (N-2) in that system is used.

3.3.9 Forced Outage Rates

The (equivalent) forced outage rates (EFOR) used in the study are shown in Table 3.5 for various classes of generating units in different regions of the Kingdom.

3.3.10 Maintenance Schedule

In addition to forced outages, generating units are unavailable due to planned maintenance. The duration of maintenance for a generating unit varies from year to year. However, for long term planning average maintenance duration for a given plant type is adopted for this study. Table 3.5 illustrates the maintenance schedule for various plant types for different regions of the Kingdom.

Table 3.5. Forced outage rate for various types of generating units.

Operating Areas	Unit Type	Net Site Rating (MW)	Primary/Backup Fuel	Equivalent Forced Outage Rates (%)	Schedule Maintenance (weeks)
East	ST	600	NG/HFO	6	6
West	ST	400	HFO/NG	6	6
West	ST	600	HFO/NG	6	6
South	ST	250	HFO/NG	6	6
East	GT	125	NG/DO	8	4
Central	GT	116	NG/DO	8	4
West	GT	123	DO/NG	9	4
South	GT	123	DO/NG	9	4

NG: Natural Gas, DO: Diesel Oil, HFO: Heavy Fuel Oil

3.3.11 Capital Cost of Plant

The capital cost estimates include the cost of all the necessary facilities, and control equipment. However, the cost estimates exclude interest during construction or other finance or development cost. Table 3.6 provides the typical capital cost of different types of generating units used for the four interconnected operating areas of the Kingdom. Typical capital cost estimates of different types of generating units used for the isolated system are however shown in Table 3.7.

3.3.12 Operation and Maintenance Costs

Operation and maintenance (O&M) cost includes the cost of manpower at the generating station as well as cost of materials for operating the station, however, this excludes the fuel cost. The O&M costs are further divided into fixed and variable operation and maintenance costs. Fixed O&M costs are the essential costs which are independent of energy production and are expressed in SR/kW-year. The variable O&M costs are the costs that are proportional to the energy produced and are expressed in SR/MWh. Table 3.6 shows the typical O&M costs of different type of generating units for the four regions of the Kingdom.

Even though the O&M costs are not used in this study, they are given for the sake of completeness of the report.

Table 3.6. Typical capital costs and O&M costs for various types of generating units.

Operating Areas	Unit Type	Net Site Rating (MW)	Primary Fuel	Capital Cost (SR/kW)	Fixed O&M Cost (SR/kW-year)	Variable O&M Cost (SR/MWh)
East	ST	600	NG	2,716	25.9	3.8
West	ST	400	HFO	3,117	35.3	5.3
West	ST	600	HFO	2,813	27.8	4.1
South	ST	250	HFO	3,711	46.1	7.1
East	GT	125	NG	1,500	16.8	26.4
Central	GT	116	NG	1,616	18.1	28.4
West	GT	123	DO	1,594	17.1	30.7
South	GT	123	DO	1,594	17.1	30.7

NG: Natural Gas, DO: Diesel Oil, HFO: Heavy Fuel Oil

Table 3.7. Typical capital costs for various types of generating units.

Operating Areas	Unit Type	Net Site Rating (MW)	Primary Fuel	Capital Cost (SR/kW)
Isolated	GT	28	CR	3,562
Isolated	GT	15	CR	4,498
Isolated	GT	53	CR	2,960
Isolated	GT	30	CR	3,325
Isolated	DI	9.9	CR	5,986
Isolated	DI	5	CR	6,500
Isolated	DI	10	CR	5,986
Isolated	DI	4.9	CR	6,500
Isolated	DI	2	CR	7,500

DI: Diesel Engine, CR: Crude Oil

3.3.13 Cash Flows for Generation Expansion

Table 3.8 shows the cash flow for each unit considered for generation expansion. The cash flows are shown in percent of the total capital cost. The construction period ranges between 2 to 4 years depending on type and size of generating unit. The actual disbursements are project specific and are a result of contract negotiations. They cannot be considered in a long term study.

3.3.14 Service Life of Generating Unit

The service or economic operating lives of new generating units are as shown in Table 3.8. The economic service life for the steam turbine units using both natural gas as well as liquid fuel is taken as 35 years. In case of the simple cycle combustion gas turbine the economic life is taken as 25 years.

3.3.15 Economic Parameters

The reference year is January 1, 2005. All costs are expressed in constant money terms and in Saudi Riyals (SR) based on a fixed exchange rate of 3.75 SR to the US dollar. For the base case a discount rate of 5% is used for economic evaluation. Sensitivity analysis will be carried out for the discount rate of 3% and 10%. Also, the case of escalation of the capital cost by 3% will be studied.

Table 3.8. Cash flow and operating life for generation expansion.

Unit Type	Unit Size (MW)	Primary Fuel	Operating Life	Construction Period (Years)	Annual construction cash flow			
					Year 1 (%)	Year 2 (%)	Year 3 (%)	Year 4 (%)
ST	600	NG	35	4	9	32	32	27
ST	600	HFO	35	4	9	32	32	27
ST	400	HFO	35	4	9	32	32	27
ST	250	HFO	35	4	9	32	32	27
GT	125	NG	25	2	35	65	-	-
GT	116	NG	25	2	35	65	-	-
GT	123	DO	25	2	35	65	-	-

NG: Natural Gas, DO: Diesel Oil, HFO: Heavy Fuel Oil

3.4 OTHER ASSUMPTIONS

3.4.1 Contribution from Interconnections

There is an existing interconnection between EOA and COA. The interconnection consists of two (2) 380 kV double circuit lines and one (1) 230 kV double circuit line. Work is in progress on an additional double circuit 380 kV line. The line is expected to be operational by 2008. At present EOA is delivering about 2,500 MW to COA and the capacity will be enhanced to 3,500 MW in 2008.

The WOA and COA and the WOA and the SOA are not presently interconnected. The WOA and COA are assumed to be interconnected in the year 2011 with the firm transfer capability of 1,400 MW. The WOA and SOA are assumed to be interconnected in the year 2014 with the firm transfer capacity of 800 MW.

In the Western Operating Area, the SEC system is also interconnected with the Royal Commission for Jubail and Yanbu (RCJY) by a double circuit 380 kV line.

Table 3.9 indicates the firm capacity between the interconnected systems.

Table 3.9. Link capacity between operating areas.

Interconnecting Link	Year	Link Capacity (MW)
EOA - COA	2005	2,500
EOA - COA	2008	3500
WOA - COA	2011	1,400
WOA - SOA	2014	800

3.4.2 Contribution from SWCC, WEC, IWPP and IPP plants

The SWCC plants contribute substantially to both the EOA and WOA. Based on the information received the capacity contribution to EOA is around 1,800 MW and to WOA is around 1,050 MW as shown in Table 3.10. In future a number of WEC and IWPP generating plants would be added. Table 3.11 illustrates the future generating capacities of WEC and IWPP plants. Moreover, a number of IPP plants are also in construction phase. However, most of them would be supplying their own loads (captive). Table 3.12 shows the list of IPP and their capacities.

Table 3.10. SWCC capacity export to SEC network.

SEC Operating Area	Capacity Exports (MW)
Eastern Operating Area	1,800
Western Operating Area	1,050

Table 3.11. WEC/IWPP future generating plants and capacities.

IWPP	Capacity (MW)	Year	Operating Area
Shoaiba	800	2008	WOA
MARAFIQ	2,500	2009	EOA
Shuqaiq	750	2009	SOA
Ras Azzour	2,500	2009	EOA
Jubail 3	1,100	2013	EOA

Table 3.12. Contribution from IPP plants.

IPP	Capacity (MW)	Year	Operating Area	Remarks
SADAF	250	2005	EOA	Captive
Maa'den	1,800	2008	EOA	600 MW to Grid
Saudi Aramco (Rastannurah)	140	2006	EOA	Captive
Saudi Aramco (Othmaiyah)	170	2006	EOA	Captive
Saudi Aramco (Juymah)	190	2006	EOA	Captive
Saudi Aramco (Shedgum)	170	2006	EOA	Captive
Saudi Aramco (Rabigh)	350	2008	WOA	Captive

3.4.3 Retirement of Existing Generating Units

Based on the economic life of the generating units, a large number of the generating units would reach the end of their economic life. For example, in the year 2005 about 2,200 MW would be retiring in EOA, about 3,500 MW would be retiring in COA, about 2,500 MW would be retiring in WOA and about 190 MW would have reached the end of economic life in SOA. These retired units have to be replaced by new generating units in addition to the units required to meet the load. This would place severe financial requirements in order to meet the reliability criteria of 4.8 hours/year. Moreover, it is not practically feasible to retire a large number of units at a particular time. In order to meet this special requirement, it is proposed to delay the retirements of the existing units and to adopt the following policy:

- No units would be retired up to the year 2009.
- After 2009, units would be retired gradually. The capacity to be retired during a particular year should not exceed 2% of the installed capacity in that operating area for that year.

SECTION 4 DEVELOPMENT OF REFERENCE GENERATION PLAN

4.1 INTRODUCTION

This section provides the details of the generation plans developed for each SEC operating area. The plan is based on certain reliability criteria to meet the demand adequately.

4.2 REFERENCE GENERATION PLAN FOR THE EASTERN OPERATING AREA (EOA)

4.2.1 Introduction

The development of the reference generation expansion plan for the Eastern Operating Area is described in this section. The plan is based on the existing generation of EOA, the energy available from SWCC, the energy transfer commitments to COA, the existing and committed units of IPP/IWPP and the units committed by SEC for addition. The demand forecast for the most likely case has been utilized for the development of the reference generation plan. As indicated in Section 3 natural gas will be used as a primary fuel source for all the future generating units in EOA. Liquid fuel will be used as a backup fuel during emergencies.

4.2.2 Existing Generation for EOA Interconnected System

The existing generating system for EOA has a generating capacity of 9,846 MW supplied by 11 major generating stations as illustrated in Table 4.1.

Table 4.1. Generating Plants with their capacity for EOA.

S No.	Plant Name	Plant Type	Total Generating Capacity (MW)
1.	Ghazlan-I	Steam Turbine	1,600
2.	Ghazlan-II	Steam Turbine	2,528
3.	Qurayyah	Steam Turbine	2,500
4.	Shedgum	Gas Turbine	1,069
5.	Faras	Gas Turbine	803
6.	Dammam	Gas Turbine	615
7.	Berri	Gas Turbine	171
8.	Uthmaniyah	Gas Turbine	284
9.	Juaymah	Gas Turbine	91
10.	Qaisumah	Gas Turbine	123
11.	Safaniyah	Gas Turbine	63

The three steam turbine (ST) power plants (Ghazlan-I, Ghazlan-II, and Qurayyah) supply the bulk of the generating capacity of 6,628 MW, which is around 67% of the total generating capacity of the EOA. The remaining 3,218 MW is supplied using gas turbine (GT) by the other eight power plants; however, Shedgum, Faras, and Dammam are the three major GT plants. Natural gas is used as a primary fuel for all (except Qaisumah) plants. Liquid fuel is used as backup during emergency conditions.

The characteristics of the existing EOA generating units are illustrated in Table 4.2. The table indicates the unit installation retirement date, the equivalent forced outage rate, and the maintenance period as provided by SEC. It can be observed from the table, based on the economic life, most of the gas turbine would retire before the start of the study period. These retired units have to be replaced by new generating units in addition to the units required to meet the load growth. This would place severe financial requirements in order to meet the reliability criteria of 4.8 hours/year. Moreover, it's not practically feasible to retire a large number of units at a particular time.

In-order to meet this special requirement it is proposed to delay the retirement of the existing units and to pursue the following policy on retirement of these units, as indicated in Section 3.

- No units would be retired up to the year 2009.
- After 2009, units would be retired gradually. The annual retired capacity during that particular year would not exceed 2% of the installed capacity in that operating area for that year.

Based on the above retirement policy Table 4.2 indicates a proposed year of retirement for GT during the study period. It can be seen that most of the existing GT units would retire during the study period.

4.2.3 Saline Water Conversion Corporation (SWCC)

The EOA is also supplied by Saline Water Conversion Corporation (SWCC) plants in Al-Khobar and Jubail. In the year 2004 the energy imported by EOA was 13,168 GWh, about 19% of the total EOA energy. In terms of capacity, around 1,800 MW was available to the EOA grid.

The monthly distribution of energy supplied by SWCC was provided by SEC and is shown in Table 4.3. It can be seen that the monthly energy supplied by SWCC is fairly constant. As indicated in Section 3.4.2 the existing capacity and energy is kept the same for the entire study period. However, committed WEC plants are added as IWPP plants in the study.

Table 4.2. Characteristics of the Existing Generation Units for the EOA, with Proposed Extension of Operating Life.

Plant Name	**Unit No.**	**Capacity (MW)**	**Unit Type**	**Fuel Type**	**Installation Date**	**Retirement (Economic Life)**	**Proposed Retirement**	**EFOR (%)**	**Maintenance (Weeks/Year)**
Ghazlan-I	1	400	ST	NG	Mar-80	2015	-	4	6
Ghazlan-I	2	400	ST	NG	Mar-80	2015	-	4	6
Ghazlan-I	3	400	ST	NG	Nov-81	2016	-	4	6
Ghazlan-I	4	400	ST	NG	Nov-81	2016	-	4	6
Ghazlan-II	5	632	ST	NG	2001	2036	-	4	6
Ghazlan-II	6	632	ST	NG	2002	2037	-	4	6
Ghazlan-II	7	632	ST	NG	2002	2037	-	4	6
Ghazlan-II	8	632	ST	NG	2003	2038	-	4	6
Qurayyah	1	625	ST	NG	Oct-88	2023	-	4	6
Qurayyah	2	625	ST	NG	Oct-89	2024	-	4	6
Qurayyah	3-4	625	ST	NG	Oct-92	2027	-	4	6
Shedgum	1-3	65.98	GT	NG	Apr-79	2004	2017	6	4
Shedgum	4-5	65.98	GT	NG	Apr-79	2004	2018	6	4
Shedgum	6-7	67.05	GT	NG	Oct-80	2005	2020	6	4
Shedgum	8-9	67.05	GT	NG	Oct-80	2005	2021	6	4
Shedgum	10	58.83	GT	NG	Jun-82	2007	2021	6	4
Shedgum	11-14	58.83	GT	NG	Jun-82	2007	2022	6	4
Shedgum	15-17	58.83	GT	NG	Jun-82	2007	2023	6	4
Faras	1-8	59.975	GT	NG	1985	2010	-	6	4
Faras	9	64.7	GT	NG	Nov-79	2004	2018	6	4
Faras	10-12	64.7	GT	NG	Nov-79	2004	2019	6	4
Faras	13	64.7	GT	NG	Nov-79	2004	2020	6	4

Table 4.2 (cont'd). Characteristics of the Existing Generation Units for the EOA, with Proposed Extension of Operating Life.

Plant Name	Unit No.	Capacity (MW)	Unit Type	Fuel Type	Installation Date	Retirement (Economic Life)	Proposed Retirement	EFOR (%)	Maintenance (Weeks/Year)
Dammam	3-4	17.7	GT	NG	Sep-68	1993	2010	7	4
Dammam	5,6	17.7	GT	NG	Jul-72	1997	2010	7	4
Dammam	7,8	31.5	GT	NG	Sep-74	1999	2011	7	4
Dammam	9-10	31.5	GT	NG	Jun-75	2000	2011	7	4
Dammam	13-14	34.5	GT	NG	Sep-76	2001	2013	7	4
Dammam	15-16	34.5	GT	NG	May-77	2002	2013	7	4
Dammam	17-18	55.975	GT	NG	May-78	2003	2015	7	4
Dammam	19-21	55.975	GT	NG	May-78	2003	2016	7	4
Berri	1-2	56.96	GT	NG	Jan-77	2002	2014	9	4
Berri	3	56.96	GT	NG	Jan-77	2002	2015	9	4
Uthmaniyah	1-4	24.075	GT	NG	Mar-73	1998	2010	6	4
Uthmaniyah	5-8	46.9	GT	NG	Jan-75	2000	2012	6	4
Juaymah	1-2	22.6	GT	NG	Sep-74	1999	2011	6	4
Juaymah	3	45.4	GT	NG	Feb-76	2001	2013	6	4
Qaisumah	1	16.7	GT	DO	Jul-80	2005	2016	6	4
Qaisumah	2	16.7	GT	DO	Jul-80	2005	2020	6	4
Qaisumah	3	15.9	GT	DO	Nov-77	2002	2014	6	4
Qaisumah	4	16.1	GT	DO	Jan-83	2008	2023	6	4
Qaisumah	5-6	29	GT	DO	Apr-85	2010	2023	6	4
Safaniyah	1	19	GT	NG	Oct-74	1999	2010	6	4
Safaniyah	2	43.6	GT	NG	Apr-76	2001	2014	6	4

Table 4.3. Monthly energy supplied (2004) by SWCC to EOA network.

Month	Energy (MWh)	Monthly Distribution (%)
January	1,176,247	8.93
February	1,044,576	7.93
March	1,063,577	8.08
April	1,118,070	8.49
May	1,186,147	9.01
June	1,102,859	8.38
July	1,141,883	8.67
August	1,099,031	8.35
September	1,051,586	7.99
October	1,024,508	7.78
November	1,039,624	7.90
December	1,119,631	8.50
Total	13,167,739	100

4.2.4 Independent Power Producer /Independent Water and Power Producer (IPP/IWPP)/ Water & Electricity Company (WEC)

Following the restructuring of the Kingdom's electricity sector a number of Independent Power Producer's (IPP) and Independent Water and Power Producer's (IWPP) are connected to the EOA grid or will be connected to the EOA grid during the planning period. The plants' details are provided in Table 4.4. A total capacity of 9,420 MW is planned to be built during 2005 to 2013. Saudi Aramco and SADAF plants supply their own load. Of its total capacity of 1,800 MW, Maa'den will contribute 600 MW to the grid, and rest of the capacity would be used by the company. Marafiq, Ras-Azzour and Jubail-3 are cogeneration plants producing desalinated water and electricity. Their contribution to the grid would be 6,100 MW. It should be noted that the IPP/IWPP sources would be the major suppliers to the EOA grid.

4.2.5 Export to Central Operating Area (COA)

EOA is interconnected with COA through two (2) 380 kV double circuit lines and one (1) 230 kV double circuit line. Work is in progress on an additional one (1) double circuit 380 kV line and the line is expected to be operational by 2008. At present EOA is delivering a firm capacity of about 2,500 MW to COA and will increase to 3,500 MW in 2008.

During 2004 EOA exports to COA reached 2,087 MW during the month of June. The total energy export during that year was 12,404 GWh. The capacity transfer is around 2,000 MW during the months of May to October and is reduced to around 1,500 MW for the months of January and February.

Table 4.4. Contribution from IPP, IWPP and WEC plants.

IPP/IWPP	Capacity (MW)	Year of Commercial Start	Remarks
SADAF	250	2005	Captive
Saudi Aramco (Rastannurah)	140	2006	Captive
Saudi Aramco (Othmaiyah)	170	2006	Captive
Saudi Aramco (Juymah)	190	2006	Captive
Saudi Aramco (Shedgum)	170	2006	Captive
Maa'den	1,800	2008	Mostly captive, 600 MW to EOA grid
MARAFIQ	2,500	2009	IWPP
Ras Azzour	2,500	2009	IWPP
Jubail 3	1,100	2013	WEC

4.2.6 Committed Generation Additions for EOA

A list of SEC committed generation plans for the years 2005 to 2007 was provided by MOW&E. The plan indicates that there no committed additions in the interconnected system of the EOA for the above years.

4.2.7 Development of the Reference Generation Plan for the EOA Interconnected System

The generation planning procedure is described in Section 3. The EOA load forecast, the capabilities of the existing generating units, and an assessment on the adequacy of the supply based on the system LOLE defines the new generation requirements. As indicated in the planning basis, the occurrence of Ramadan during the summer months (May to September) will have an impact on the load characteristics and profile during those months. This will add a level of uncertainty that is addressed by having a stringent generation planning LOLE standard of 4.5 hours/year. This planning criterion will only be considered for the years Ramadan occurs during the summer months. In all other years a generation planning standard of 4.8 hours/year will be adopted.

The load forecast developed is used for development of the generation plan. Because EOA and COA are interconnected, a number of modeling assumptions were further made in order to develop the reference generation plan for each operating area. The reference plans of EOA and COA were developed by isolating the systems. In the case of EOA, the territorial load was increased by the amount exported to COA. Hourly load profile for the EOA territorial load as well as the transfer to COA was used to develop the plans.

The Multi-Area Reliability Analysis Program (MAREL) was used to develop the reference generation plan for the EOA system. The existing generation along with the committed units (including IPP/IWPP) and the load forecast were analyzed. If the generation planning standard “LOLE” is within the acceptable level, as defined in the planning basis, the program will proceed to the next year for evaluation. However, if the LOLE is outside the acceptable range, generating units are added based on the generating supply option till the LOLE is within the acceptable range.

Table 4.5 illustrates the generation plan developed for EOA system. The plan shows the year-by-year installation schedule for future generating units and the retirement schedule of existing units. The table also provides the total load demand, the plant reserves, transfer to COA, system LOLE and expected-unserved-energy (EUE) for each year. It can be seen from the table that the IPP/IWPP are added as committed plans. If the committed units are coming in the second half of the year they will be added in the following year. However, in case of MARAFIQ and Ras Azzour the generating capacities are added in stages from 2008 through 2010.

In case of Maa’den, only 600 MW of generation, which is available to the EOA grid, is included in the expansion plan assessment.

The LOLE for the year 2008 is very high (247.5 hours/year). This is due to the fact that there are not enough committed units. The lead time for a steam unit is around four years; therefore, no units are added in the year 2008 to bring down the generation planning standard. Due to the same reason the transfer to COA is limited to only 3,000 MW. The transfer is increased to full capacity of 3,500 MW in 2010, as there is sufficient generation in EOA. It can also be observed from Table 4.5, that the LOLE levels for the years 2010 through 2014 are well below 4.8 hours/year. This is due to the fact that several committed IWPP units are to be installed in those years.

During the study horizon 2008 to 2023 a total of 13,875 MW are required to meet the demand adequately. Out of the total requirement 6,700 MW would be supplied by the IWPP/WEC cogeneration plants. The remaining 7,175 MW are further required for addition. This will include 8 units of 600 MW steam turbine and 19 units of 125 MW gas turbines. During the same period 2738 MW will be retired from the EOA system. Almost all the existing gas turbine capacity in EOA, except 8 units (60 MW each) at Faras is retired.

Table 4.5. Reference Generation Plan for the Eastern Operating Area (EOA).

Year	Load (MW)	Transfer to COA (MW)	Addition (MW)	Addition (Comments)	Ret. (MW)	Ret. (Comments)	Gen. EOA (MW)	Gen. IWPP/IPP* (MW)	Total Gen. (MW)	Res. (%)	LOLE (hrs/Yr)	EUE (GWh)
2008	10,440	3,000	1,250	1250(Marafiq)	-		9,846	3,970	13,816	2.80	247.50	83.49
2009	10,953	3,000	2,100	1250(R Azzour)+600(Maaden)+2X125GT	-		10,096	5,820	15,916	14.07	2.77	0.28
2010	11,287	3,500	2,500	1250(Marafiq) + 1250(R Azzour)	186.1	4x17.7Dam +1x19Safn+4x24Uthm	9,910	8,320	18,230	23.28	0.00	0.00
2011	11,808	3,500	0	-	171.2	4x31.5Dam+2x22.6Juay	9,739	8,320	18,059	17.97	0.02	0.00
2012	12,330	3,500	375	3X125GT	187.6	4x46.9Uthm	9,926	8,320	18,246	15.27	0.32	0.04
2013	12,851	3,500	500	4X125GT	183.4	4x34.5Dam+1x45.4Juay	10,243	8,320	18,563	13.53	1.82	0.22
2014	13,372	3,500	1,100	1100(Jubail3)	173.4	2x57Beri+1x15.9Qais+1x43.6Safn	10,069	9,420	19,489	15.51	0.15	0.02
2015	13,876	3,500	250	2X125GT	168.9	2x56Dam+1x57Beri	10,150	9,420	19,570	12.63	3.52	0.60
2016	14,380	3,500	725	1X600ST+1X125GT	184.6	3x56Dam+1x16.7Qais	10,691	9,420	20,111	12.48	3.27	0.54
2017	14,883	3,500	725	1X600ST+1X125GT	197.9	3x66Shed	11,218	9,420	20,638	12.26	3.74	0.65
2018	15,387	3,500	725	1X600ST+1X125GT	196.7	3x66Shed+1x64.7Faras	11,746	9,420	21,166	12.07	4.08	0.71
2019	15,891	3,500	850	1X600ST+2X125GT	194.1	3x64.7Faras	12,402	9,420	21,822	12.54	2.73	0.64
2020	16,346	3,500	725	1X600ST+1X125GT	215.5	2x67Shed+1x16.7Qais=1x64.7Faras	12,912	9,420	22,332	12.52	2.77	0.65
2021	16,802	3,500	600	1X600ST	192.9	2x67+1x58.8Shed	13,319	9,420	22,739	12.00	3.83	0.89
2022	17,257	3,500	725	1X600ST+1X125GT	235.3	4x58.8Shed	13,808	9,420	23,228	11.90	3.65	0.86
2023	17,713	3,500	725	1X600ST+1X125GT	250.6	3x58.8Shed+1x16.1+2x29Qais	14,283	9,420	23,703	11.74	4.59	1.13

* Including Existing Transfer from SWCC 1800 MW and Saudi Aramco (670 MW) and SADAF (250 MW)

4.3 REFERENCE GENERATION PLAN FOR THE CENTRAL OPERATING AREA (COA)

4.3.1 Introduction

The development of the reference generation expansion plan for the COA is described in this section. The plan is based on the existing generation of COA, the energy import commitments from EOA, and the units committed by SEC for addition. The demand forecast for the most likely case has been utilized for the development of the reference generation plan. As indicated in Section 3, natural gas will be used as a primary fuel for all the future generating units in COA. Liquid fuel will be used as a backup fuel during emergencies.

4.3.2 Existing Generation for COA Interconnected System

The existing generating system for COA has a generating capacity of 6,829 MW supplied by 13 major generating stations as illustrated in Table 4.6.

Table 4.6. Generating Plants with their capacity for COA.

S No.	Plant Name	Plant Type	Total Generating Capacity (MW)
1.	Riyadh PP9X	Gas Turbine	480
2.	Riyadh PP9	Combined Cycle	1,417
3.	Riyadh PP8	Gas Turbine	1,588
4.	Riyadh PP7	Gas Turbine	1,113
5.	Riyadh PP5	Gas Turbine	538
6.	Riyadh PP4X	Gas Turbine	90
7.	Riyadh PP4	Gas Turbine	215
8.	Riyadh PP3	Gas Turbine	55
9.	Qassim PP3	Gas Turbine	816
10.	Buraydah	Gas Turbine	89
11.	Hail2	Gas Turbine	302
12.	Hail1	Gas Turbine	43
13.	Layla	Gas Turbine	81

The bulk of the COA supply is through 12 gas turbine (GT) plants with a total capacity of 5,412 MW, which is around 79% of the total generating capacity of COA. The remaining 1,417 MW is supplied using a single combined cycle (CC) plant. Natural gas is used as a primary fuel for PP9X, PP9, PP8, and PP7 plants at Riyadh, while the other nine plants use liquid fuel (crude and diesel) as primary fuel.

The characteristics of the existing COA generating plants are illustrated in Table 4.7. The table indicates the unit installation retirement date, the equivalent forced outage rate, and the maintenance period as provided by SEC. It can be observed from the table that most of the gas turbines would retire before the start of the study period. These units have to be replaced by new generating units in addition to the units required to meet the load growth. This would place severe financial requirements in order to meet the reliability criteria of 4.8 hours/year. Moreover, it is not practically feasible to retire a large number of units at a particular time.

In-order to meet this special requirement it is proposed to delay the retirement of the existing units and to pursue the adopted policy on retirement of these units, as indicated in Section 3.

Based on the retirement policy adopted, Table 4.7 indicates a proposed year of retirement for GT during the study period. It can be seen that a large number of GT units would retire during the study period.

4.3.3 Imports from Eastern Operating Area (EOA)

COA is interconnected with EOA through two (2) 380 kV double circuit lines and one (1) 230 kV double circuit line. Work is in progress on an additional one (1) double circuit 380 kV line and the line is expected to be operational by 2008. At present EOA is delivering a firm capacity of about 2,500 MW to COA and the capacity (firm) will be increased to 3,500 MW in 2008.

During 2004 EOA exports to COA reached 2,087 MW during the month of June. The total energy export during that year was 12,404 GWh. The capacity transfer is around 2,000 MW during the months of May to October and is reduced to around 1,500 MW for the months of January and February.

4.3.4 Committed Generation Additions for COA

A list of SEC committed generation plans for the years 2005 to 2007 was provided by MOW&E. The committed plan indicates that in the year 2005, two gas turbine units of 85 MW each are added to Riyadh PP7 Extension plant. Also in 2005, the capacity of 10 units in Riyadh PP8 is enhanced by 177 MW by installing air cooling to the generating system. Moreover in 2006, an air cooling system will be installed at the Hail plant; this will enhance the plant capacity by 70 MW.

Table 4.7. Characteristics of the Existing Generation Units for the COA, with Proposed Extension of Operating Life.

Plant Name	Unit No.	Capacity (MW)	Unit Type	Fuel Type	Installation Date	Retirement (Economic Life)	Proposed Retirement	EFO R (%)	Maintenance (Weeks/Year)
Riyadh PP9X	1-2	60	GT	NG	Sep-04	2024	-	5	4
Riyadh PP9X	3-4	60	GT	NG	Aug-04	2024	-	5	4
Riyadh PP9X	5-8	60	GT	NG	Jul-04	2024	-	5	4
Riyadh PP9	1	354.36	CC	NG	Dec-99	2024	-	4	6
Riyadh PP9	2	354.36	CC	NG	Dec-98	2023	-	4	6
Riyadh PP9	3	354.36	CC	NG	Aug-00	2025	-	4	6
Riyadh PP9	4	354.36	CC	NG	May-00	2025	-	4	6
Riyadh PP8	1-2	50.06	GT	NG	Jan-83	2003	2021	5.6	4
Riyadh PP8	3-4	50.06	GT	NG	Feb-83	2003	2021	5.6	4
Riyadh PP8	5-6	50.06	GT	NG	Mar-83	2003	2022	5.6	4
Riyadh PP8	7-8	50.06	GT	NG	Apr-83	2003	2022	5.6	4
Riyadh PP8	9-10	50.06	GT	NG	Jul-86	2003	-	5.6	4
Riyadh PP8	11	50.06	GT	NG	May-83	2003	2023	5.6	4
Riyadh PP8	12	50.06	GT	NG	Jul-83	2003	2023	5.6	4
Riyadh PP8	13	50.06	GT	NG	Sep-83	2003	2023	5.6	4
Riyadh PP8	14	50.06	GT	NG	Oct-83	2003	2023	5.6	4
Riyadh PP8	15	50.06	GT	NG	Dec-83	2003	2023	5.6	4
Riyadh PP8	16	50.06	GT	NG	Jan-84	2004	-	5.6	4
Riyadh PP8	17	50.06	GT	NG	Mar-84	2004	-	5.6	4
Riyadh PP8	18	50.06	GT	NG	Apr-84	2004	-	5.6	4
Riyadh PP8	19-20	50.06	GT	NG	Apr-85	2005	-	5.6	4
Riyadh PP8	21-22	58.71	GT	NG	Jun-96	2016	-	5.6	4
Riyadh PP8	23-24	58.71	GT	NG	May-96	2016	-	5.6	4
Riyadh PP8	25-26	58.71	GT	NG	Aug-95	2015	-	5.6	4
Riyadh PP8	27-28	58.71	GT	NG	Jul-95	2015	-	5.6	4
Riyadh PP8	29-30	58.71	GT	NG	Jun-95	2015	-	5.6	4

Table 4.7 (cont'd). Characteristics of the Existing Generation Units for the COA, with Proposed Extension of Operating Life.

Plant Name	Unit No.	Capacity (MW)	Unit Type	Fuel Type	Installation Date	Retirement (Economic Life)	Proposed Retirement	EFO R (%)	Maintenance (Weeks/Year)
Riyadh PP7	1-2	48.32	GT	NG	Nov-81	2001	2019	8.1	4
Riyadh PP7	3-4	48.32	GT	NG	Jul-81	2001	2018	8.1	4
Riyadh PP7	5-6	48.32	GT	NG	Apr-81	2001	2018	8.1	4
Riyadh PP7	7	48.32	GT	NG	Jan-81	2001	2017	8.1	4
Riyadh PP7	8	48.32	GT	NG	Feb-81	2001	2017	8.1	4
Riyadh PP7	9-10	48.32	GT	NG	Jul-80	2000	2015	8.1	4
Riyadh PP7	11	48.32	GT	NG	Sep-80	2000	2016	8.1	4
Riyadh PP7	12-13	48.32	GT	NG	Oct-80	2000	2016	8.1	4
Riyadh PP7	14	48.32	GT	NG	Nov-80	2000	2016	8.1	4
Riyadh PP7	15-16	48.32	GT	NG	Nov-80	2000	2017	8.1	4
Riyadh PP7	17-18	56.6	GT	NG	Feb-94	2014	-	8.1	4
Riyadh PP7	19-20	56.6	GT	NG	Jan-94	2014	-	8.1	4
Riyadh PP7	21-22	56.6	GT	NG	May-94	2014	-	8.1	4
Riyadh PP5	1	44.85	GT	CR	Jan-79	1999	2013	7	4
Riyadh PP5	2	44.85	GT	CR	May-79	1999	2014	7	4
Riyadh PP5	3	44.85	GT	CR	Mar-79	1999	2013	7	4
Riyadh PP5	4-5	44.85	GT	CR	May-79	1999	2013	7	4
Riyadh PP5	6	44.85	GT	CR	Jun-79	1999	2014	7	4
Riyadh PP5	7	44.85	GT	CR	Oct-79	1999	2014	7	4
Riyadh PP5	8	44.85	GT	CR	Dec-79	1999	2014	7	4
Riyadh PP5	9	44.85	GT	CR	Mar-80	2000	2015	7	4
Riyadh PP5	10	44.85	GT	CR	Feb-80	2000	2015	7	4
Riyadh PP5	11	44.85	GT	CR	May-82	2002	2019	7	4
Riyadh PP5	12	44.85	GT	CR	Jun-82	2002	2019	7	4
Riyadh PP4	1	22.57	GT	DO	Jan-75	1995	2010	7	4
Riyadh PP4	2	22.57	GT	DO	Apr-75	1995	2010	7	4
Riyadh PP4	3	22.57	GT	DO	Aug-75	1995	2010	7	4

Table 4.7 (cont'd). Characteristics of the Existing Generation Units for the COA, with Proposed Extension of Operating Life.

Plant Name	Unit No.	Capacity (MW)	Unit Type	Fuel Type	Installation Date	Retirement (Economic Life)	Proposed Retirement	EFO R (%)	Maintenance (Weeks/Year)
Riyadh PP4	4	22.57	GT	DO	Dec-75	1995	2010	7	4
Riyadh PP4X	1-2	13.25	GT	DO	Jan-77	1997	2011	7	4
Riyadh PP4X	3	37.73	GT	DO	May-77	1997	2011	7	4
Riyadh PP4X	4	37.73	GT	DO	Jun-77	1997	2011	7	4
Riyadh PP4X	5	37.73	GT	DO	Sep-77	1997	2011	7	4
Riyadh PP4X	6	37.73	GT	DO	Nov-77	1997	2012	7	4
Riyadh PP4X	7	37.73	GT	DO	Jan-78	1998	2012	7	4
Riyadh PP3	1	10	GT	DO	1969	1989	2010	15	4
Riyadh PP3	2-3	10	GT	DO	1970	1990	2010	15	4
Riyadh PP3	4	10	GT	DO	1972	1992	2010	15	4
Riyadh PP3	5	15	GT	DO	1978	1998	2010	15	4
Qassim PP3	1	47.92	GT	CR	Dec-82	2002	2020	5.2	4
Qassim PP3	2	47.92	GT	CR	Jan-83	2003	2020	5.2	4
Qassim PP3	3	47.92	GT	CR	Dec-82	2002	2020	5.2	4
Qassim PP3	4	47.92	GT	CR	Dec-83	2003	-	5.2	4
Qassim PP3	5-6	47.92	GT	CR	Mar-83	2003	2020	5.2	4
Qassim PP3	7	47.92	GT	CR	Jul-83	2003	2022	5.2	4
Qassim PP3	8	47.92	GT	CR	Aug-83	2003	-	5.2	4
Qassim PP3	9	47.92	GT	CR	Dec-83	2003	-	5.2	4
Qassim PP3	10-11	55.01	GT	CR	May-99	2019	-	5.2	4
Qassim PP3	12-16	55.01	GT	CR	Jun-99	2019	-	5.2	4
Buraydah	1	17.86	GT	DO	May-77	1997	2012	4	4
Buraydah	2	17.86	GT	DO	Apr-77	1997	2012	4	4
Buraydah	3	17.86	GT	DO	Jun-77	1997	2012	4	4
Buraydah	4	17.86	GT	DO	Dec-81	2001	2012	4	4
Buraydah	5	17.86	GT	DO	Jan-82	2002	2012	4	4

Table 4.7 (cont'd). Characteristics of the Existing Generation Units for the COA, with Proposed Extension of Operating Life.

Plant Name	**Unit No.**	**Capacity (MW)**	**Unit Type**	**Fuel Type**	**Installation Date**	**Retirement (Economic Life)**	**Proposed Retirement**	**EFO R (%)**	**Maintenance (Weeks/Year)**
Hail 2	1-2	60.42	GT	CR	Jun-85	2005	-	12.4	4
Hail 2	3	60.42	GT	CR	Oct-85	2005	-	12.4	4
Hail 2	4-5	60.42	GT	CR	Jun-85	2005	-	12.4	4
Hail 1	1-2	14.5	GT	DO	Aug-83	2003	-	15	4
Hail 1	3	7	GT	DO	Feb-81	2001	2017	15	4
Hail 1	4	7	GT	DO	Jul-81	2001	2017	15	4
Layla	1-2	13.52	GT	CR	Apr-87	2007	-	6.5	4
Layla	3	13.52	GT	CR	Aug-87	2007	-	6.5	4
Layla	4-5	13.52	GT	CR	Oct-87	2007	-	6.5	4
Layla	6	13.52	GT	CR	Nov-87	2007	-	6.5	4

4.3.5 Development of the Reference Generation Plan for the COA Interconnected System

The generation planning procedure is described in Section 3. The COA load forecast, the capabilities of the existing generating units, and an assessment on the adequacy of the supply based on the system LOLE defines the new generation requirements. As indicated in the planning basis, the occurrence of Ramadan during the summer months (May to September) will have an impact on the load characteristics and profile during those months. This will add a level of uncertainty that is addressed by having a stringent generation planning standard of 4.5 hours/year. This planning criterion will only be considered for the years when Ramadan occurs during the summer months. In all other years a generation planning standard of 4.8 hours/year will be adopted.

The load forecast developed is used for development of the generation plan. Because EOA and COA are interconnected, a number of modeling assumptions were further made in order to develop the reference generation plan for each operating area. The reference plans of EOA and COA were developed by isolating the systems. In the case of COA, the territorial load was reduced by the amount of firm power imports from EOA. Hourly load profile for the COA territorial load as well as imports from EOA was used to develop the plan.

As indicated in Section 3, the Multi-Area Reliability Analysis Program (MAREL) was used to develop the reference generation plan for the COA system. The existing generation along with the committed units and the load forecast were analyzed. If the generation planning standard “LOLE” is within the acceptable level, as defined in the planning basis the program will proceed to the next year for evaluation. However, if the LOLE is outside the acceptable range, generating units are added based on the generating supply option till the LOLE is within the acceptable range.

Table 4.8 illustrates the generation plan developed for COA system. The plan shows the year-by-year installation schedules for future generating units and the retirement schedules of existing units. The table also provides the total load demand, the plant reserves, import to COA, system LOLE, and expected-unserved-energy (EUE) for each year.

The reserve margin is around 6% for all the planning years. It should be noted that the imports from EOA are 3,000 MW only during the years 2008 to 2009 due to deficiency in generation in EOA, as explained in Section 4.2. The imports from EOA are increased to its full capacity (3,500 MW) in the year 2010.

During the study horizon 2008 to 2023 a total of 10,556 MW are required to meet the demand adequately. The plan proposes the addition of 91 units of 116 MW gas turbines. During the same period 2,713 MW will be retired from the COA system, which is almost half of the gas turbine capacity in COA.

Table 4.8. Reference Generation Plan for the Central Operating Area (COA).

Year	Load (MW)	Imports to COA (MW)	Addition (MW)	Addition (Comments)	Ret. (MW)	Ret. (Comments)	Gen. COA (MW)	Res. (%)	LOLE (hrs/Yr)	EUE (GWh)
2008	10,369	3,000	812	7X116GT	-	-	8,058	6.65	2.63	0.30
2009	10,879	3,000	464	4X116GT	-	-	8,522	5.91	4.47	0.57
2010	11,148	3,500	0	-	145.3	4x10RydPP3+1x15RydPP3+4x23RydPP 4	8,377	6.54	2.33	0.26
2011	11,662	3,500	696	6X116GT	139.7	2x13RydPP4X+3x38RydPP4X	8,933	6.61	2.32	0.27
2012	12,177	3,500	696	6X116GT	164.8	2x38RydPP4X+5x18Burdah	9,464	6.46	2.77	0.35
2013	12,692	3,500	696	6X116GT	179.4	4x45RydPP5	9,981	6.21	3.56	0.48
2014	13,207	3,500	696	6X116GT	179.4	4x45RydPP5	10,497	5.99	4.32	0.62
2015	13,704	3,500	812	7X116GT	186.3	2x45RydPP5+2x48RydPP7	11,123	6.70	2.52	0.36
2016	14,202	3,500	696	6X116GT	193.3	4x48RydPP7	11,626	6.51	3.04	0.45
2017	14,699	3,500	696	6X116GT	207.3	4x48RydPP7+2x7Hail1	12,115	6.23	3.81	0.59
2018	15,197	3,500	696	6X116GT	193.3	4x48RydPP7	12,617	6.06	4.46	0.73
2019	15,694	3,500	812	7X116GT	186.3	2x45RydPP5+2x48RydPP7	13,243	6.68	2.68	0.43
2020	16,144	3,500	696	6X116GT	239.6	4x48QasmPP3	13,699	6.53	3.24	0.54
2021	16,594	3,500	696	6X116GT	200.2	4x50RydPP8	14,195	6.63	3.11	0.54
2022	17,044	3,500	696	6X116GT	248.2	4x50RydPP8+1x48QasmPP3	14,643	6.45	3.73	0.67
2023	17,494	3,500	696	6X116GT	250.3	5x50RydPP8	15,089	6.26	4.54	0.85

4.4 REFERENCE GENERATION PLAN FOR THE WESTERN OPERATING AREA (WOA)

4.4.1 Introduction

The development of the reference generation expansion plan for the WOA is described in this section. The plan is based on the existing generation of WOA and Marafiq (Yanbu), the energy available from SWCC, the existing and committed units of IPP/IWPP, and the units committed by SEC for addition. The demand forecast for the most likely case has been utilized for the development of the reference generation plan. Moreover, Marafiq, Yanbu load is also taken into account in the development of the generation plan. As indicated in Section 3, natural gas will not be available during the study period. Liquid fuel will be used for all the future generating units in WOA.

4.4.2 Existing Generation for the WOA Interconnected System

The existing generating system for the WOA has a generating capacity of 7,328 MW supplied by 9 major generating stations as illustrated in Table 4.9. The WOA is also interconnected to MARAFIQ network through 380 kV double circuit transmission lines. MARAFIQ provides electricity to the industrial city of Yanbu.

Table 4.9. Generating Plants with their capacity for WOA.

S No.	Plant Name	Plant Type	Total Generating Capacity (MW)
1.	Jeddah PP3	Gas Turbine	1,318
2.	Jeddah PP2	Gas Turbine	116
3.	Rabigh	Steam Turbine	1,572
4.	Rabigh	Combined Cycle	1,091
5.	Sha'iba	Steam Turbine	1,965
6.	Makkah	Gas Turbine	778
7.	Madinah	Gas Turbine	318
8.	Taif	Gas Turbine	116
9.	Yanbu	Gas Turbine	55

The two steam turbine (ST) power plants (Rabigh and Sha'iba) supply the bulk of the generating capacity of 3,537 MW, which is around 48% of the total generating capacity of the WOA. The only combined cycle plant is installed at Rabigh which accounts for about 15% (1,091 MW) of the generating capacity of WOA. The remaining 2,700 MW are supplied by the other six gas turbine (GT) power plants. Diesel and crude oil are used as primary fuel for all the GT plants, however, the steam plants utilizes heavy fuel oil for firing the boilers.

The characteristics of the existing WOA generating units are illustrated in Table 4.10. The table indicates the unit installation retirement date, the equivalent forced outage rate, and the maintenance period as provided by SEC. It can be observed from the table that all of the gas turbine capacity would retire before the start of the study period. Those units have to be replaced by new generating units in addition to the units required to meet the load growth. This would place severe financial requirements in order to meet the reliability criteria of 4.8 hours/year. Moreover, it is not practically feasible to retire a large number of units at a particular time.

In-order to meet this special requirement it is proposed to delay the retirement of the existing units and to pursue the adopted policy on retirement of these units, as indicated in Section 3.

Based on the adopted retirement policy, Table 4.10 indicates a proposed year of retirement for GT during the study period. It can be seen that all of the existing GT units would retire during the study period.

4.4.3 Saline Water Conversion Corporation (SWCC)

The Western Operating Area is also supplied by Saline Water Conversion Corporation (SWCC) plants in Jeddah, Shoaibah and Yanbu. In the year 2004 the energy imported by WOA was 8,182 GWh about 17.4% of the total WOA energy. In terms of capacity, around 1,050 MW was available to the WOA grid.

The monthly distribution of energy supplied by SWCC was provided by SEC and is shown in Table 4.11. It can be seen that the monthly energy supplied by SWCC varies between 7.7 to 9%. As indicated in Section 3, the existing capacity and energy are kept the same for the entire study period. Committed WEC plants are added as IWPP plants in the study.

Table 4.10. Characteristics of the Existing Generation Units for the WOA, with Proposed Extension of Operating Life.

Plant Name	Unit No.	Capacity (MW)	Unit Type	Fuel Type	Installation Date	Retirement (Economic Life)	Proposed Retirement	EFOR (%)	Maintenance (Weeks/Year)
Jeddah-PP3A	1-3	44.6	GT	DO	Aug-76	1996	2012	12	4
Jeddah-PP3A	4	44.6	GT	DO	Sep-77	1997	2012	12	4
Jeddah-PP3A	5-7	44.6	GT	DO	Nov-78	1998	2013	12	4
Jeddah-PP3A	8	44.6	GT	DO	Feb-79	1999	2013	12	4
Jeddah-PP3A	9-10	44.6	GT	DO	Feb-79	1999	2014	12	4
Jeddah-PP3A	11	44.6	GT	DO	Apr-80	2000	2015	12	4
Jeddah-PP3B	1-3	51.7	GT	CR	May-80	2000	2016	12	4
Jeddah-PP3B	4	51.7	GT	CR	Jun-81	2001	2016	12	4
Jeddah-PP3B	5-6	51.7	GT	CR	Jun-81	2001	2017	12	4
Jeddah-PP3B	7-10	51.7	GT	CR	Jul-82	2002	2019	12	4
Jeddah-PP3B	11-12	51.7	GT	CR	Jul-82	2002	2020	12	4
Jeddah-PP3B	13-14	51.7	GT	CR	May-83	2003	2020	12	4
Jeddah-PP3B	15-16	51.7	GT	CR	Jun-84	2004	2022	12	4
Jeddah-PP2	1	11.5	GT	DO	1965	1985	2010	10	4
Jeddah-PP2	2-4	26.5	GT	DO	1974	1994	2010	10	4
Jeddah-PP2	5	25	GT	DO	1978	1998	2010	10	4
Rabigh A ST	1-4	260	ST	HFO	May-85	2020	-	5	6
Rabigh A ST	5-6	266	ST	HFO	Nov-95	2030	-	5	6
Rabigh A CC	1	398.4	CC	CR	Jul-94	2019	-	10	6
Rabigh A CC	2-3	346.1	CC	CR	Aug-94	2019	-	10	6
Makkah A	1	18	GT	DO	Dec-75	1995	2010	9	4
Makkah A	2	22	GT	DO	Nov-76	1996	2010	9	4
Makkah A	3	22	GT	DO	Mar-77	1997	2010	9	4
Makkah B	1	40.3	GT	DO	Apr-78	1998	2011	9	4
Makkah B	2-3	40.3	GT	DO	Jun-79	1999	2014	9	4

Table 4.10 (cont'd). Characteristics of the Existing Generation Units for the WOA, with Proposed Extension of Operating Life.

Plant Name	Unit No.	Capacity (MW)	Unit Type	Fuel Type	Installation Date	Retirement (Economic Life)	Proposed Retirement	EFOR (%)	Maintenance (Weeks/Year)
Makkah B	4	40.3	GT	DO	Jun-79	1999	2015	9	4
Makkah C	1-2	46.3	GT	DO	Feb-80	2000	2015	9	4
Makkah C	3	46.3	GT	DO	Aug-81	2001	2017	9	4
Makkah C	4-5	48.5	GT	DO	Jul-82	2002	2018	9	4
Makkah C	6-9	53.2	GT	DO	Jun-83	2003	2021	9	4
Makkah C	10-11	53.2	GT	DO	Apr-84	2004	2022	9	4
Sha'iba	1	393	ST	HFO	Jun-01	2036	-	7	6
Sha'iba	2	393	ST	HFO	Feb-02	2037	-	7	6
Sha'iba	3	393	ST	HFO	Jun-02	2037	-	7	6
Sha'iba	4	393	ST	HFO	Jan-03	2038	-	7	6
Sha'iba	5	393	ST	HFO	Jun-03	2038	-	7	6
Sha'iba	9	393	ST	HFO	Dec-06	2041	-	7	6
Sha'iba	10	393	ST	HFO	Jul-06	2041	-	7	6
Sha'iba	11	393	ST	HFO	Jun-06	2041	-	7	6
Madinah1	1	18	GT	DO	1976	1996	2011	9	4
Madinah1	2	16	GT	DO	1978	1998	2011	9	4
Madinah 2A	1-2	20	GT	DO	1977	1997	2011	9	4
Madinah 2A	3	20	GT	DO	1980	2000	2014	9	4
Madinah 2B	1-2	50	GT	DO	1981	2001	2018	9	4
Madinah 2B	3-4	62	GT	DO	1998	2018	2023	9	4
Taif	1-2	19.5	GT	DO	Mar-76	1996	2011	9	4
Taif	3	15.9	GT	DO	May-77	1997	2011	9	4
Taif	4-6	20.3	GT	DO	Jun-81	2001	2017	9	4
Yanbu	1	18.1	GT	DO	Jul-82	2002	2018	9	4
Yanbu	2-3	18.2	GT	DO	May-83	2003	2020	9	4

Table 4.11. Monthly energy supplied (2004) by SWCC to WOA network.

Month	Energy (MWh)	Monthly Distribution (%)
January	695,672	8.50
February	630,244	7.70
March	662,734	8.10
April	740,476	9.05
May	705,281	8.62
June	648,879	7.93
July	737,956	9.02
August	714,012	8.73
September	636,091	7.77
October	674,677	8.25
November	683,278	8.35
December	652,781	7.98
Total	8,182,082	100.00

4.4.4 Independent Power Producer (IPP) and Water & Electricity Company (WEC)

Following the restructuring of the Kingdom's electricity sector, an Independent Power Producer (IPP) will be connected to the WOA grid during the planning period. WEC capacity will also be augmented during this period. The plant details are provided in Table 4.12. A total capacity of 1,150 MW is planned to be built in the year 2008. A 350 MW plant of Saudi Aramco will be in commercial operation in the second half of 2008. Also, Shoaibah-3 (WEC) plant supplying 800 MW capacity will be connected to the WOA grid in the year 2008.

Table 4.12. Contribution from IPP and WEC plants.

IPP/WEC	Capacity (MW)	Year	Remarks
Saudi Aramco (Rabigh)	350	2008	Captive
Shoaibah	800	2008	WEC

4.4.5 Committed Generation Additions for WOA

A list of SEC committed generation plans for the years 2005 to 2007 was provided by MOW&E. A total capacity of 1,659 MW is committed in WOA during the above period. Jeddah PP3 plant is to have 8 GT units of 60 MW each in commercial operation in year 2005. While there would be 3 new steam units at Sha'iba of 393 MW each in commercial operation by the year 2006.

4.4.6 Development of the Reference Generation Plan for the WOA Interconnected System

The generation planning procedure is described in Section 3. The WOA load forecast, the capabilities of the existing generating units, and an assessment on the adequacy of the supply based on the system LOLE defines the new generation requirements. As indicated in the planning basis, the occurrence of Ramadan and Hajj during the summer months (May to September) will have an impact on the load characteristics and profile during those months. This will add a level of uncertainty that is addressed by having a stringent generation planning standard of 4.5 hours/year. This planning criterion will only be considered for the years Ramadan and Hajj occurs during the summer months. In all other years, a generation planning standard of 4.8 hours/year will be adopted.

The load forecast developed for WOA is used for development of the generation plan. As indicated in Section 3, the Multi-Area Reliability Analysis Program (MAREL) was used to develop the reference generation plan for the WOA system. The existing generation along with the committed units (including IPP/WEC) and the load forecast were analyzed. If the generation planning standard “LOLE” is within the acceptable level, as defined in the planning basis the program will proceed to the next year for evaluation. However, if the LOLE is outside the acceptable range, generating units are added based on the generating supply option till the LOLE is within the acceptable range.

Table 4.13 illustrates the generation plan developed for WOA system. The plan shows the year-by-year installation schedules for future generating units and the retirement schedules of existing units. The table also provides the total load demand, the plant reserves, system LOLE, and expected-unserved-energy (EUE) for each year. It can be seen from the table the IPP/WEC are added as committed plans. If the committed units are coming in the second half of the year they will be added in the following year as indicated in Section 4.3.4. The table also indicates that the LOLE level for the years 2008 and 2009 are quite low, this is due to the committed IPP/WEC units.

During the study horizon 2008 to 2023, a total of 10,271 MW are required to meet the demand adequately. Out of the total requirements, 1,150 MW would be supplied by the IPP/WEC plants. The remaining 9,121 MW are further required for addition. This will include 7 units of 400 MW and 5 units of 600 MW of steam units and 27 units of 123 MW of gas turbines. During the same period, 2,700 MW will be retired from the WOA system. This represents almost all the existing gas turbine capacity in WOA.

Table 4.13. Reference Generation Plan for the Western Operating Area (WOA).

Year	Load (MW)	Addition (MW)	Addition (Comments)	Ret. (MW)	Ret. (Comments)	Gen. WOA (MW)	Gen. IWPP/IPP* (MW)	Total Gen. (MW)	Res (%)	LOLE (hrs/Yr)	EUE (GWh)
2008	10,248	800	800(Shoaibah)	-	-	8,987	2,766	11,753	14.69	0.48	0.07
2009	10,714	350	350(S. Aramco)	-	-	8,987	3,116	12,103	12.97	0.88	0.14
2010	11,179	369	3X123	178.0	(1x12+2x27+1x25)JedPP2+(1x18+2x22)MakA	9,178	3,116	12,294	9.97	3.38	0.66
2011	11,660	646	1X400ST+2X123GT	169.2	1x40MakB+(1x18+1x16)Mad1+2x20Mad2A+(2x20+1x16)Taif	9,655	3,116	12,771	9.53	3.86	0.79
2012	12,141	646	1X400ST+2X123GT	178.4	4x45JedPP3A	10,122	3,116	13,238	9.04	4.41	0.95
2013	12,621	769	1X400ST+3X123GT	178.4	4x45JedPP3A	10,713	3,116	13,829	9.57	3.08	0.66
2014	13,102	646	1X400ST+2X123GT	189.8	2x45JedPP3A+2x40MakB+1x20Mad2A	11,169	3,116	14,285	9.03	3.70	0.83
2015	13,567	646	1X400ST+2X123GT	177.5	1x45JedPP3A+1x40MakB+2x46MakC	11,638	3,116	14,754	8.75	3.89	0.91
2016	14,031	646	1X400ST+2X123GT	206.8	4x52JedPP3B	12,077	3,116	15,193	8.28	4.44	1.08
2017	14,496	769	1X400ST+3X123GT	210.6	2x52JedPP3B+1x46MakC+2x20Taif	12,635	3,116	15,751	8.66	3.48	0.83
2018	14,960	723	1X600ST+1X123GT	215.1	2x49MakC+2x50Mad2B+1x18Yanbu	13,143	3,116	16,259	8.68	3.57	0.88
2019	15,425	723	1X600ST+1X123GT	206.8	4x52JedPP3B	13,659	3,116	16,775	8.75	3.37	0.86
2020	15,845	615	5X123GT	243.2	4x52JedPP3B+2x18Yanbu	14,031	3,116	17,147	8.22	4.04	1.10
2021	16,265	723	1X600ST+1X123GT	212.8	4x53MakC	14,541	3,116	17,657	8.56	3.55	0.95
2022	16,685	600	1X600ST	209.8	2x52JedPP3B+2x53MakC	14,932	3,116	18,048	8.16	4.11	1.18
2023	17,105	600	1X600ST	124.0	2x62Mad2B	15,408	3,116	18,524	8.29	3.88	1.11

* Including Existing Transfer from SWCC 1,800 MW and Marafiq, Yanbu generation.
Load includes Marafiq, Yanbu load.

4.5 REFERENCE GENERATION PLAN FOR THE SOUTHERN OPERATING AREA (SOA)

4.5.1 Introduction

The development of the reference generation expansion plan for the SOA is described in this section. The plan is based on the existing generation of SOA, the energy available from SWCC, the existing and committed units of WEC, and the units committed by SEC for addition. The demand forecast for the high growth case has been utilized for the development of the reference generation plan for the SOA. This is due to the fact that there is a substantial suppressed demand in the SOA in the historical load data. As indicated in Section 3, natural gas will not be available during the study period. Liquid fuel will be used for all the future generating units in SOA.

4.5.2 Existing Generation for SOA Interconnected System

The existing generating system for SOA has a generating capacity of 2,179 MW supplied by 6 major generating stations as illustrated in Table 4.14. Out of the 6 plants 3 plants have both gas turbines and diesel generating units, while the other 3 are powered by gas turbines only.

Table 4.14. Generating Plants with their capacity for SOA.

S No.	Plant Name	Plant Type	Total Generating Capacity (MW)
1.	Asir CPS	Gas Turbine	433
2.	Asir CPS	Diesel Units	77
3.	Jizan CPS	Gas Turbine	677
4.	Jizan CPS	Diesel Units	24
5.	Bisha CPS	Gas Turbine	144
6.	Baha CPS	Gas Turbine	24
7.	Baha CPS	Diesel Units	51
8.	Tihama CPS	Gas Turbine	482
9.	Najran CPS	Gas Turbine	267

The bulk of the generating capacity of 2,027 MW is supplied by the gas turbines, while, the diesel generating units contribute only 152 MW (6.9%) to the SOA total supply. Diesel and crude oil are used as primary fuel for all the plants in SOA.

The characteristics of the existing SOA generating units are illustrated in Table 4.15. The table indicates the unit installation retirement date, the equivalent forced outage rate, and the maintenance period as provided by SEC. It can be observed from the table that a large number of the gas turbines would retire before the start of the study period. These retired units have to be replaced by new generating units in addition to the units required to meet the load growth. This would place severe financial requirements in order to meet the reliability criteria of 4.8 hours/year.

Moreover, it is not practically feasible to retire a large number of units at a particular time.

In-order to meet this special requirement it is proposed to delay the retirement of the existing units and to pursue the adopted policy on retirement of these units, as indicated in Section 3.

Based on the adopted retirement policy, Table 4.15 indicates a proposed year of retirement for GT during the study period. It can be seen that a number of existing GT would retire during the study period.

4.5.3 Saline Water Conversion Corporation (SWCC)

The Southern Operating Area is also supplied by Saline Water Conversion Corporation (SWCC) plants in Ash Shuqaiq. In the year 2004 the energy imported by SOA was 482 GWh about 3.9 % of the total SOA energy. In terms of average capacity, around 55 MW was available to the SOA grid. Since the level of import is relatively small, SOA does not consider the source of the existing power or energy in their development plan. However, WEC will be augmenting 750 MW in the year 2009 and this capacity will be considered in the planning study.

Table 4.15. Characteristics of the Existing Generation Units for the SOA, with Proposed Extension of Operating Life.

Plant Name	Unit No.	Capacity (MW)	Unit Type	Fuel Type	Installation Date	Retirement (Economic Life)	Proposed Retirement	EFOR (%)	Maintenance (Weeks/Year)
Asir CPS	1	47	GT	DO	Oct-85	2010	2020	9	4
Asir CPS	2	47	GT	DO	Oct-85	2010	2021	9	4
Asir CPS	3	47	GT	DO	Jan-86	2011	2022	9	4
Asir CPS	4	50	GT	DO	Mar-96	2021		9	4
Asir CPS	5	66	GT	DO	Sep-97	2022		9	4
Asir CPS	6	66	GT	DO	Feb-98	2023		9	4
Asir CPS	7	55	GT	DO	Dec-02	2027		9	4
Asir CPS	8	55	GT	DO	Nov-03	2028		9	4
Asir CPS-DE	1-6	8.5	DE	DO	Dec-78	life extended	2010	15	4
Asir CPS-DE	7-9	8.5	DE	DO	Dec-78	life extended	2011	15	4
Jizan CPS	1	18	GT	DO	May-80	2005	2013	9	4
Jizan CPS	2	18	GT	DO	May-80	2006	2013	9	4
Jizan CPS	3	18	GT	DO	Feb-82	2007	2013	9	4
Jizan CPS	4	18	GT	DO	Feb-82	2008	2014	9	4
Jizan CPS	5	18	GT	DO	Nov-82	2009	2014	9	4
Jizan CPS	6	18	GT	DO	Nov-82	2010	2014	9	4
Jizan CPS	7	24	GT	DO	May-83	2007	2015	9	4
Jizan CPS	8	24	GT	DO	May-86	2007	2020	9	4
Jizan CPS	9	24	GT	DO	Dec-86	2008	2021	9	4
Jizan CPS	10-11	56	GT	DO	Feb-89	2014		9	4
Jizan CPS	12-13	15	GT	DO	Dec-90	2015	2022	9	4
Jizan CPS	14	15	GT	DO	Dec-90	2015	2023	9	4
Jizan CPS	15	62	GT	DO	Feb-98	2023		9	4
Jizan CPS	17	79	GT	DO	Dec-97	2022		9	4
Jizan CPS	18	79	GT	DO	Feb-98	2023		9	4
Jizan CPS	19	60	GT	DO	Jan-03	2028		9	4
Jizan CPS	20	60	GT	DO	Nov-03	2028		9	4

Table 4.15 (cont'd). Characteristics of the Existing Generation Units for the SOA, with Proposed Extension of Operating Life.

Plant Name	**Unit No.**	**Capacity (MW)**	**Unit Type**	**Fuel Type**	**Installation Date**	**Retirement (Economic Life)**	**Proposed Retirement**	**EFOR (%)**	**Maintenance (Weeks/Year)**
Jizan CPS-DE	1-4	4	DE	DO	Feb-80	2000	2011	9	4
Jizan CPS-DE	5	4	DE	DO	Mar-80	2000	2011	9	4
Jizan CPS-DE	6	4	DE	DO	May-80	2000	2011	9	4
Bisha CPS	1-2	22.5	GT	DO	Mar-84	2009	2017	9	4
Bisha CPS	3	49.5	GT	DO	Jun-84	2009	2016	9	4
Bisha CPS	4	49.5	GT	DO	Jun-84	2009	2018	9	4
Baha CPS	1-3	8	GT	DO	Jun-83	2008	2015	9	4
Baha CPS-DE	1	8.5	DE	DO	Jun-80	2000	2012	15	4
Baha CPS-DE	2	8.5	DE	DO	Apr-80	2000	2012	15	4
Baha CPS-DE	3	8.5	DE	DO	May-80	2000	2012	15	4
Baha CPS-DE	4	8.5	DE	DO	Aug-80	2000	2012	15	4
Baha CPS-DE	5	8.5	DE	DO	Jun-80	2000	2012	15	4
Baha CPS-DE	6-7	4.25	DE	DO	Feb-80	2000	2012	15	4
Tihama CPS	1	20	GT	CR	Feb-86	2011	2017	12	4
Tihama CPS	2	20	GT	CR	Jul-86	2011	2018	12	4
Tihama CPS	3	53	GT	CR	May-86	2011	2019	12	4
Tihama CPS	4	53	GT	CR	Jul-86	2011	2023	12	4
Tihama CPS	5	56	GT	CR	Dec-91	2016		12	4
Tihama CPS	6	80	GT	DO	Jul-99	2024		12	4
Tihama CPS	7	80	GT	DO	Sep-99	2024		12	4
Tihama CPS	8	60	GT	CR	Feb-03	2028		12	4
Tihama CPS	9	60	GT	CR	Dec-03	2028		12	4
Najran CPS	1-5	22.5	GT	CR	Mar-85	2010		12	4
Najran CPS	6	51.5	GT	CR	Jun-98	2023		12	4
Najran CPS	7	51.5	GT	CR	Dec-01	2025		12	4
Najran CPS	8	51.5	GT	CR	Apr-02	2027		12	4

4.5.4 *Committed Generation Additions for SOA*

A list of SEC committed generation plans for the years 2005 to 2007 was provided by MOW&E. A total of 10 units with a capacity of 603 MW are committed in four locations of SOA during the above period. Table 4.16 shows the committed units with their location and capacities. All the units are gas turbine. Only one unit of 55 MW is committed in the year 2005. The remaining 9 units are committed in the year 2006.

Table 4.16. Committed units with their capacities for SOA.

Plant	Year	Unit Type	No. of Units	Capacity of each Unit (MW)
Asir CPS	2005	Gas Turbine	1	55
Asir CPS	2006	Gas Turbine	1	70
Jizan CPS	2006	Gas Turbine	3	55
Jizan CPS	2006	Gas Turbine	1	70
Bisha CPS	2006	Gas Turbine	2	55
Bisha CPS	2006	Gas Turbine	1	73
Najran CPS	2006	Gas Turbine	1	60

4.5.5 *Development of the Reference Generation Plan for the SOA Interconnected System*

The generation planning procedure is described in Section 3. The SOA load forecast, the capabilities of the existing generating units, and an assessment on the adequacy of the supply based on the system LOLE defines the new generation requirements. As indicated in the planning basis, the occurrence of Ramadan during the summer months (May to September) will have an impact on the load characteristics and profile during those months. This will add a level of uncertainty that is addressed by having a stringent generation planning standard of 4.5 hours/year. This planning criterion will only be considered for the years Ramadan occurs during the summer months. In all other years a generation planning standard of 4.8 hours/year will be adopted.

The load forecast developed for SOA for the high growth case is used for development of the generation plan. As indicated in Section 3, the Multi-Area Reliability Analysis Program (MAREL) was used to develop the reference generation plan for the SOA system. The existing generation along with the committed units (including IWPP/WEC) and the load forecast were analyzed. If the generation planning standard "LOLE" is within the acceptable level, as defined in the planning basis, the program will proceed to the next year for evaluation. However, if the LOLE is outside the acceptable range generating units are added based on the generating supply option till the LOLE is within the acceptable range.

Table 4.17 illustrates the generation plan developed for SOA system. The plan shows the year-by-year installation schedules for future generating units and the retirement schedules of existing units. The table also provides the total load demand, the plant reserves, system LOLE, and expected-unserved-energy (EUE) for each year. The table also indicates that the LOLE levels for the initial year are quite low; this is due to the committed plant at Ash Shuqaiq. This is also reflected in the reserve margin indicated in the table.

During the study horizon 2008 to 2023 a total of 6,063 MW are required to meet the demand adequately. Out of the total requirement 750 MW would be supplied by the WEC plant at Ash Shuqaiq. The remaining 5,313 MW are further required for addition. This will include 6 units of 250 MW of steam turbine and 31 units of 123 MW of gas turbines. During the same period 832 MW will be retired form the SOA system. This is about 38% of the existing generating capacity.

Table 4.17. Reference Generation Plan for the Southern Operating Area (SOA).

Year	Load* (MW)	Addition (MW)	Addition (Comments)	Ret. (MW)	Ret. (Comments)	Gen. SOA (MW)	Gen. WEC/IWPP (MW)	Total Gen. (MW)	Res (%)	LOLE (hrs/Yr)	EUE (GWh)
2008	2,410	369	3X123GT	-	-	3,151	0	3,151	30.72	1.07	0.06
2009	2,529	750	750 (Shuqaiq)	-	-	3,151	750	3,901	54.25	0.00	0.00
2010	2,711	0	-	51.0	6x9AsirDE	3,100	750	3,850	42.01	0.00	0.00
2011	2,893	0	-	49.5	3x9AsirDE+6x4JizanDE	3,050	750	3,800	31.36	0.31	0.01
2012	3,075	123	1X123GT	51.0	5x9BahaDE+2x4BahaDE	3,122	750	3,872	25.93	1.91	0.11
2013	3,257	246	2X123GT	54.0	3x18Jizan	3,314	750	4,064	24.78	2.11	0.13
2014	3,439	246	2X123GT	54.0	3x18Jizan	3,506	750	4,256	23.76	2.65	0.17
2015	3,720	492	4X123GT	48.0	1x24Jizan+3x8Baha	3,950	750	4,700	26.34	1.94	0.14
2016	4,001	369	3X123GT	49.5	1x50Bisha	4,270	750	5,020	25.44	2.65	0.21
2017	4,283	369	3X123GT	65.0	2x25Bisha+1x20Tihama	4,574	750	5,324	24.30	3.35	0.29
2018	4,564	373	1X250ST+1X123GT	69.5	1x50Bisha+1x20Tihama	4,877	750	5,627	23.29	4.47	0.42
2019	4,845	373	1X250ST+1X123GT	53.0	1x53Tihama	5,197	750	5,947	22.74	3.46	0.33
2020	5,321	619	1X250ST+3X123GT	71.0	1x47Asir+1x24Jizan	5,745	750	6,495	22.06	1.91	0.16
2021	5,797	619	1X250ST+3X123GT	71.0	1x47Asir+1x24Jizan	6,293	750	7,043	21.49	2.37	0.23
2022	6,273	619	1X250ST+3X123GT	77.0	1x47Asir+2x15Jizan	6,835	750	7,585	20.91	2.84	0.31
2023	6,749	496	1X250ST+2X123GT	68.0	1x15Jizan+1x53Tihama	7,263	750	8,013	18.72	4.12	0.47

* The load forecast shown is for the high growth case.

4.6 REFERENCE GENERATION PLAN FOR THE ISOLATED SYSTEMS

4.6.1 Introduction

The development of generation expansion plans for the major isolated systems are described in this section. These isolated systems are in the northern region and were earlier under the Electricity Corporation and also some major load centers in the south and central operating areas. The locations are given in the Table 4.18 below. The plans are based on the existing generation capacity and the units committed by SEC for addition. Liquid fuel is assumed to be used for the units that are added in the plans.

4.6.2 Existing Generation for the Isolated Systems

The existing generating capacity for the eleven (11) isolated systems combined is 1,164 MW supplied by 11 major generating stations as illustrated in Table 4.18. This excludes the committed plan as provided by SEC.

Table 4.18. Generating Plants with their capacity for Isolated System.

S. No.	Plant Name	Operating Area	Unit Type	Total Generating Capacity (MW)
1.	Arar	EOA	Gas Turbine	100.2
2.	Rafha	EOA	Diesel Engine	44.9
3.	Qurayat	EOA	Gas Turbine	48.0
4.	Al-Jawf	EOA	Gas Turbine	157.5
5.	Juba	COA	Gas Turbine	202.7
6.	Tabuk	WOA	Gas Turbine	328.5
7.	Tabuk	WOA	Diesel Engine	34.2
8.	Dhuba	WOA	Gas Turbine	111.0
9.	Al-Oula	WOA	Diesel Engine	35.5
10.	Sharourah	SOA	Diesel Engine	60.9
11.	Farasan	SOA	Diesel Engine	19.8
12.	Tathlith	SOA	Diesel Engine	20.6

Based on the economic life, most of the above units would retire before the start of the study period. These retired units have to be replaced by new generating units in addition to the units required to meet the load. This would place severe financial requirements in order to meet the reserve margin criteria and to cover the load under (N-2) criteria. Moreover, it is not practically feasible to retire a large number of units at a particular time.

In-order to meet this requirement it is proposed to delay the retirement of the existing units and to pursue the following policy on retirement of these units is assumed.

- No units would be retired up to the year 2009.
- After 2009, units would be retired gradually. Starting with the oldest unit, only one (1) unit is made to retire in a year. The criteria of retirement, i.e. not to exceed 2% of the installed capacity in that location cannot be applied here as the system size is small and the size of one unit is more than 2% of installed capacity at that location.

4.6.3 Committed Generation Additions for Isolated System

The details of the unit additions in the isolated system as per the committed plan provided by the MOW&E for the year 2005 to 2007 are shown in Table 4.19. While developing the generation plan covering the period 2008 to 2023 for each of these locations, these units are added to the existing capacity and are shown as existing generation in the plan. However, the plan indicates there are no committed additions for the other locations.

Table 4.19. Committed Plan for Isolated System.

Region	Location	Commissioning Year	Unit Type	No. of units	Capacity of each unit (MW)
EOA	Qurayat	2007	Gas Turbine	2	25
EOA	Al-Jawf	2007	Gas Turbine	1	60
COA	Juba	2005	Gas Turbine	2	25
WOA	Tabuk	2005	Gas Turbine	2	60

4.6.4 Development of the Isolated System Plans

The generation planning procedure is based on a deterministic approach. The load forecast, the capabilities of the existing generating units, and the criteria to maintain a minimum reserve margin of 15% and meeting the load following the loss of the two largest units in that system (N-2) define the new generation requirements. The load forecast developed in Section 2 is used for development of the generation plan.

Tables 4.20 to 4.30 show the developed reference plan for each of the isolated locations considered. This includes the existing capacity for each location (including the committed units), peak load, capacity additions, retirements, total generation taking into account the proposed additions and retirements, capacity available after the loss of the two largest units (N-2) in the system, net generation under (N-2) and the calculated reserve margin on the basis of total generation.

Tables 4.20 to 4.23 show the developed generation plans for Arar, Rafha, Qurayat and Al-Jawf which are under the jurisdiction of EOA.

During the study period (2008 to 2023), it is foreseen that in order to adequately meet the load demand of Arar, a total of 224 MW (8x28 MW GT) of generation will be required to be added. These generation additions would allow for the retirement of the existing generation as given in Table 4.20.

For the case of Rafha, it is foreseen that in order to adequately meet the load demand a total of 125.6 MW of generation will be required to be added. This comprises of 2x15 MW, 2x28 MW of GT and 4x9.9 MW of Low Speed Diesel Units (LSD). The details are given in Table 4.21.

For the case of Qurayat, it is foreseen that in order to adequately meet the load demand, a total of 252 MW (equivalent to 9x28 MW GT) of generation will be required to be added. These generation additions would allow for the retirement of the existing generation as given in Table 4.22.

The Al-Jawf interconnected system is one of the large systems in the north of the country. It is foreseen that, during the study period (2008 to 2023), in order to adequately meet the load demand a total of 371 MW (7x53 MW GT) of generation will be required to be added. The details are given in Table 4.23. The existing generation of 7x22.5 MW GT is to be retired starting from 2010.

Table 4.24 shows the developed plan for Juba. There is a committed plan to add 2x25 MW of GT in the year 2005 in the Juba isolated network. In order to adequately meet the load demand, a total of 360 MW of generation (24x15 MW GT) will be required to be added.

Tables 4.25 to 4.27 show the developed generation plan for Tabuk, Dhuba, and Al-Oula. During the study period (2008 to 2023), it is foreseen that in order to adequately meet the load demand of the Tabuk interconnected system, a total of 583 MW (equivalent to 11x53 MW GT) of generation will be required to be added. These generation additions would allow for the retirement of the existing generation as given in Table 4.25.

In case of Dhuba system, during the study period (2008 to 2023) it is foreseen that in order to adequately meet the load demand, a total of 150 MW (equivalent to 5x30 MW GT) of generation will be required to be added. The details are given in Table 4.26.

Al-Oula is a small isolated load center of the WOA. It is fed by diesel units only of 1.5 MW and 2.5 MW capacity. It is foreseen that in order to adequately meet the load demand a total of 85 MW of generation will be required to be added. This comprises 17x5 MW Diesel Units. These generation additions would allow for the retirement of the existing diesel units as given in Table 4.27.

For the isolated load centers of Sharourah, Farasan and Tathlith in the SOA during the study horizon (2008 to 2023) a total of 138.5 MW are required to be added to meet the load demand adequately. The existing generating types are all diesel units.

For the case of Sharourah, it is foreseen that a total of 90 MW (equivalent to 9x10 MW diesel units) of generation will be required to be added. The details are given in Table 4.28.

For the case of Farasan, it is foreseen that a total of 24.5 MW (equivalent to 5x4.9 MW of diesel units) of generation will be required to be added. The details are given in Table 4.29.

For the case of Tathlith, it is foreseen that a total of 24 MW of generation will be required to be added. This comprises of 12x2 MW diesel units. The details are given in Table 4.30.

These generation additions would allow for the retirement of the existing diesel units as given in the above Tables.

Table 4.20. Reference Generation Plan for Arar.

Calendar Year	Peak Load (MW)	Existing Generation (MW)	Additions		Retirements		Total (MW)	(N-2) (MW)	Net Gen after (N-2) (MW)	Reserve Margin (%)
			Description	(MW)	Description	(MW)				
2008	92	100.20	2x28 MW GT	56.0			156.20	56.00	100.20	70.00
2009	96						156.20	56.00	100.20	62.04
2010	99						156.20	56.00	100.20	57.25
2011	104		1x28 MW GT	28.00			184.20	56.00	128.20	77.25
2012	109				1x14.2 MW GT	14.20	170.00	56.00	114.00	56.67
2013	113		1x28 MW GT	28.00	1x14.2 MW GT	14.20	183.80	56.00	127.80	62.51
2014	118		1x28 MW GT	28.00	1x14.2 MW GT	14.20	197.60	56.00	141.60	67.91
2015	122						197.60	56.00	141.60	61.81
2016	127		1x28 MW GT	28.00	1x19.2 MW GT	19.20	206.40	56.00	150.40	63.10
2017	131				1x19.2 MW GT	19.20	187.20	56.00	131.20	42.92
2018	135		1x28 MW GT	28.00	1x19.2 MW GT	19.20	196.00	56.00	140.00	44.74
2019	140						196.00	56.00	140.00	40.15
2020	144		1x28 MW GT	28.00			224.00	56.00	168.00	55.71
2021	148						224.00	56.00	168.00	51.49
2022	152						224.00	56.00	168.00	47.49
2023	156						224.00	56.00	168.00	43.69

Table 4.21. Reference Generation Plan for Rafha.

Calendar Year	Peak Load (MW)	Existing Generation (MW)	Additions		Retirements		Total (MW)	(N-2) (MW)	Net Gen after (N-2) (MW)	Reserve Margin (%)
			Description	(MW)	Description	(MW)				
2008	55	44.90	4x9.9 MW LSD	39.6			84.50	19.80	64.70	53.08
2009	58						84.50	24.90	59.60	45.90
2010	60		1x15 MW GT	15.00	2x0.4 MW DI	0.80	98.70	24.90	73.80	65.38
2011	62				3x0.4 MW DI	1.20	97.50	30.00	67.50	56.16
2012	65				1x2 MW DI	2.00	95.50	30.00	65.50	46.49
2013	68		1x15 MW GT	15.00	1x2 MW DI	2.00	108.50	30.00	78.50	59.68
2014	71				1x2 MW DI	2.00	106.50	30.00	76.50	50.63
2015	73				1x2 MW DI	2.00	104.50	30.00	74.50	42.43
2016	76		1x28 MW GT	28.00	1x4 MW DI	4.00	128.50	43.00	85.50	69.01
2017	79				1x4 MW DI	4.00	124.50	43.00	81.50	58.21
2018	81				1x2.3MW DI	2.30	122.20	43.00	79.20	50.20
2019	84		1x28 MW GT	28.00	1x2.3MW DI	2.30	147.90	56.00	91.90	76.03
2020	86				1x2.3MW DI	2.30	145.60	56.00	89.60	68.46
2021	89						145.60	56.00	89.60	63.89
2022	91						145.60	56.00	89.60	59.57
2023	94						145.60	56.00	89.60	55.46

Table 4.22. Reference Generation Plan for Qurayat.

Calendar Year	Peak Load (MW)	Existing Generation (MW)	Additions		Retirements		Total (MW)	(N-2) (MW)	Net Gen after (N-2) (MW)	Reserve Margin (%)
			Description	(MW)	Description	(MW)				
2008	133	148.00	2x28 MW GT	56.0			204.00	56.00	148.00	53.44
2009	139						204.00	56.00	148.00	46.25
2010	144						204.00	56.00	148.00	41.93
2011	150		1x28 MW GT	28.00			232.00	56.00	176.00	54.29
2012	157						232.00	56.00	176.00	47.76
2013	164		1x28 MW GT	28.00	1x21 MW GT	21.00	239.00	56.00	183.00	46.05
2014	170		1x28 MW GT	28.00	1x21 MW GT	21.00	246.00	56.00	190.00	44.46
2015	177				1x5 MW GT	5.00	241.00	56.00	185.00	36.39
2016	183						241.00	56.00	185.00	31.61
2017	190		1x28 MW GT	28.00			269.00	56.00	213.00	41.93
2018	196				1x17 MW GT	17.00	252.00	56.00	196.00	28.61
2019	202		1x28 MW GT	28.00	1x17 MW GT	17.00	263.00	56.00	207.00	29.97
2020	208		1x28 MW GT	28.00	1x17 MW GT	17.00	274.00	56.00	218.00	31.63
2021	214						274.00	56.00	218.00	28.06
2022	220		1x28 MW GT	28.00			302.00	56.00	246.00	37.42
2023	226						302.00	56.00	246.00	33.89

Table 4.23. Reference Generation Plan for Al-Jawf.

Calendar Year	Peak Load (MW)	Existing Generation (MW)	Additions		Retirements		Total (MW)	(N-2) (MW)	Net Gen after (N-2) (MW)	Reserve Margin (%)
			Description	(MW)	Description	(MW)				
2008	169	217.50	1x53 MW GT	53.0			270.50	75.50	195.00	60.16
2009	177		1x53 MW GT	53.00			323.50	106.00	217.50	82.57
2010	183				1x22.5MW GT	22.50	301.00	106.00	195.00	64.85
2011	191		1x53 MW GT	53.00	1x22.5MW GT	22.50	331.50	106.00	225.50	73.54
2012	199				1x22.5MW GT	22.50	309.00	106.00	203.00	54.92
2013	208		1x53 MW GT	53.00	1x22.5MW GT	22.50	339.50	106.00	233.50	63.31
2014	216		1x53 MW GT	53.00	1x22.5MW GT	22.50	370.00	106.00	264.00	71.04
2015	224				1x22.5MW GT	22.50	347.50	106.00	241.50	54.81
2016	233		1x53 MW GT	53.00	1x22.5MW GT	22.50	378.00	106.00	272.00	62.50
2017	241						378.00	106.00	272.00	57.00
2018	249						378.00	106.00	272.00	51.86
2019	257						378.00	106.00	272.00	47.04
2020	264						378.00	106.00	272.00	42.94
2021	272						378.00	106.00	272.00	39.07
2022	279		1x53 MW GT	53.00			431.00	106.00	325.00	54.38
2023	287						431.00	106.00	325.00	50.41

Table 4.24. Reference Generation Plan for Juba.

Calendar Year	Peak Load (MW)	Existing Generation (MW)	Additions		Retirements		Total (MW)	(N-2) (MW)	Net Gen after (N-2) (MW)	Reserve Margin (%)
			Description	(MW)	Description	(MW)				
2008	207	252.70	1x15MW GT	15.0			267.70	48.20	219.50	29.09
2009	218						267.70	48.20	219.50	23.04
2010	223		2x15MW GT	30.00	1x24.1 MW GT	24.10	273.60	48.20	225.40	22.72
2011	233		3x15MW GT	45.00	1x24.1 MW GT	24.10	294.50	48.20	246.30	26.26
2012	244		2x15MW GT	30.00	1x24.1 MW GT	24.10	300.40	48.20	252.20	23.35
2013	254		2x15MW GT	30.00	1x24.1 MW GT	24.10	306.30	48.20	258.10	20.67
2014	264		2x15MW GT	30.00	1x24.1 MW GT	24.10	312.20	48.20	264.00	18.20
2015	274		2x15MW GT	30.00	1x24.1 MW GT	24.10	318.10	41.10	277.00	16.06
2016	284		3x15MW GT	45.00	1x24.1 MW GT	24.10	339.00	34.00	305.00	19.35
2017	294						339.00	34.00	305.00	15.31
2018	304		1x15MW GT	15.00			354.00	34.00	320.00	16.47
2019	314		1x15MW GT	15.00			369.00	34.00	335.00	17.56
2020	323		1x15MW GT	15.00			384.00	34.00	350.00	18.93
2021	332						384.00	34.00	350.00	15.70
2022	341		2x15MW GT	30.00	1x17 MW GT	17.00	397.00	32.00	365.00	16.46
2023	350		2x15MW GT	30.00	1x17 MW GT	17.00	410.00	30.00	380.00	17.18

Table 4.25. Reference Generation Plan for Tabuk.

Calendar Year	Peak Load (MW)	Existing Generation (MW)	Additions		Retirements		Total (MW)	(N-2) (MW)	Net Gen after (N-2) (MW)	Reserve Margin (%)
			Description	(MW)	Description	(MW)				
2008	338	482.70					482.70	117.80	364.90	42.79
2009	355						482.70	117.80	364.90	36.10
2010	371		1x53 MW GT	53.00	2x5.7 MW DI	11.40	524.30	117.80	406.50	41.21
2011	388				2x5.7 MW DI	11.40	512.90	117.80	395.10	32.05
2012	406		1x53 MW GT	53.00	2x5.7 MW DI	11.40	554.50	117.80	436.70	36.72
2013	423		1x53 MW GT	53.00	1x17.1 MW GT	17.10	590.40	117.80	472.60	39.67
2014	440				1x17.1 MW GT	17.10	573.30	117.80	455.50	30.34
2015	456		1x53 MW GT	53.00	1x16.8 MW GT	16.80	609.50	117.80	491.70	33.53
2016	473				1x16.8 MW GT	16.80	592.70	117.80	474.90	25.30
2017	490		1x53 MW GT	53.00	1x27 MW GT	27.00	618.70	117.80	500.90	26.37
2018	506		1x53 MW GT	53.00	1x27 MW GT	27.00	644.70	117.80	526.90	27.37
2019	523		1x53 MW GT	53.00	1x31.2 MW GT	31.20	666.50	117.80	548.70	27.51
2020	538		1x53 MW GT	53.00	1x57.7 MW GT	57.70	661.80	117.80	544.00	23.08
2021	553		2x53 MW GT	106.00	1x57.7 MW GT	57.70	710.10	113.10	597.00	28.48
2022	568		1x53 MW GT	53.00	1x60.1 MW GT	60.10	703.00	106.00	597.00	23.84
2023	583						703.00	106.00	597.00	20.66

Table 4.26. Reference Generation Plan for Dhuba.

Calendar Year	Peak Load (MW)	Existing Generation (MW)	Additions		Retirements		Total (MW)	(N-2) (MW)	Net Gen after (N-2) (MW)	Reserve Margin (%)
			Description	(MW)	Description	(MW)				
2008	50	111.00					111.00	38.00	73.00	123.14
2009	52						111.00	38.00	73.00	112.69
2010	55				1x18 MW GT	18.00	93.00	38.00	55.00	70.23
2011	57		2x30 MW GT	60.00	1x18 MW GT	18.00	135.00	60.00	75.00	136.20
2012	60		1x30 MW GT	30.00	1x18 MW GT	18.00	147.00	60.00	87.00	146.32
2013	62						147.00	60.00	87.00	136.33
2014	65						147.00	60.00	87.00	127.12
2015	67						147.00	60.00	87.00	118.87
2016	70						147.00	60.00	87.00	111.20
2017	72						147.00	60.00	87.00	104.06
2018	74						147.00	60.00	87.00	97.37
2019	77						147.00	60.00	87.00	91.12
2020	79		1x30 MW GT	30.00	1x19 MW GT	19.00	158.00	60.00	98.00	99.70
2021	81		1x30 MW GT	30.00	1x19 MW GT	19.00	169.00	60.00	109.00	107.81
2022	84				1x19 MW GT	19.00	150.00	60.00	90.00	79.58
2023	86						150.00	60.00	90.00	74.96

Table 4.27. Reference Generation Plan for Al-Oula.

Calendar Year	Peak Load (MW)	Existing Generation (MW)	Additions		Retirements		Total (MW)	(N-2) (MW)	Net Gen after (N-2) (MW)	Reserve Margin (%)
			Description	(MW)	Description	(MW)				
2008	41	35.50	3x5 MW DI	15.0			50.50	10.00	40.50	22.22
2009	43		1x5 MW DI	5.00			55.50	10.00	45.50	28.03
2010	45		1x5 MW DI	5.00	1x2.5 MW DI	2.50	58.00	10.00	48.00	27.81
2011	47		1x5 MW DI	5.00	1x2.5 MW DI	2.50	60.50	10.00	50.50	27.44
2012	50		1x5 MW DI	5.00	1x2.5 MW DI	2.50	63.00	10.00	53.00	27.09
2013	52		1x5 MW DI	5.00	1x2.5 MW DI	2.50	65.50	10.00	55.50	26.77
2014	54		1x5 MW DI	5.00	1x2.5 MW DI	2.50	68.00	10.00	58.00	26.48
2015	56		1x5 MW DI	5.00	1x2.5 MW DI	2.50	70.50	10.00	60.50	26.37
2016	58				1x2.5 MW DI	2.50	68.00	10.00	58.00	17.62
2017	60		1x5 MW DI	5.00	1x1.5 MW DI	1.50	71.50	10.00	61.50	19.49
2018	62		1x5 MW DI	5.00	1x1.5 MW DI	1.50	75.00	10.00	65.00	21.23
2019	64		1x5 MW DI	5.00	1x5 MW DI	5.00	75.00	10.00	65.00	17.39
2020	66		2x5 MW DI	10.00	1x5 MW DI	5.00	80.00	10.00	70.00	21.73
2021	68		1x5 MW DI	5.00	1x5 MW DI	5.00	80.00	10.00	70.00	18.43
2022	69						80.00	10.00	70.00	15.30
2023	71		1x5 MW DI	5.00			85.00	10.00	75.00	19.36

Table 4.28. Reference Generation Plan for Sharourah.

Calendar Year	Peak Load (MW)	Existing Generation (MW)	Additions		Retirements		Total (MW)	(N-2) (MW)	Net Gen after (N-2) (MW)	Reserve Margin (%)
			Description	(MW)	Description	(MW)				
2008	35.76	60.90					60.90	20.00	40.90	70.29
2009	37.52						60.90	20.00	40.90	62.31
2010	39.34		1x10 MW DI	10.00	1x5.15 MW LSD	5.15	65.75	20.00	45.75	67.15
2011	41.15		1x10 MW DI	10.00	1x5.15 MW LSD	5.15	70.60	20.00	50.60	71.55
2012	42.97				1x5.15 MW LSD	5.15	65.45	20.00	45.45	52.31
2013	44.79		1x10 MW DI	10.00	1x5.15 MW LSD	5.15	70.30	20.00	50.30	56.96
2014	46.60		1x10 MW DI	10.00	1x5.15 MW LSD	5.15	75.15	20.00	55.15	61.25
2015	48.36				1x5.15 MW LSD	5.15	70.00	20.00	50.00	44.75
2016	50.12						70.00	20.00	50.00	39.68
2017	51.87		1x10 MW DI	10.00			80.00	20.00	60.00	54.23
2018	53.63						80.00	20.00	60.00	49.18
2019	55.38		1x10 MW DI	10.00	1x10 MW DI	10.00	80.00	20.00	60.00	44.45
2020	56.97		1x10 MW DI	10.00	1x10 MW DI	10.00	80.00	20.00	60.00	40.43
2021	58.56		1x10 MW DI	10.00	1x10 MW DI	10.00	80.00	20.00	60.00	36.62
2022	60.14						80.00	20.00	60.00	33.01
2023	61.73		1x10 MW DI	10.00			90.00	20.00	70.00	45.79

Table 4.29. Reference Generation Plan for Farasan.

Calendar Year	Peak Load (MW)	Existing Generation (MW)	Additions		Retirements		Total (MW)	(N-2) (MW)	Net Gen after (N-2) (MW)	Reserve Margin (%)
			Description	(MW)	Description	(MW)				
2008	8.54	19.80					19.80	4.00	15.80	131.82
2009	8.96						19.80	4.00	15.80	120.95
2010	9.40				1x0.6 MW DI	0.60	19.20	4.00	15.20	104.36
2011	9.83				1x0.6 MW DI	0.60	18.60	4.00	14.60	89.24
2012	10.26				1x0.6 MW DI	0.60	18.00	4.00	14.00	75.39
2013	10.70				1x2 MW DI	2.00	16.00	4.00	12.00	49.58
2014	11.13		1x4.9 MW DI	4.90	1x2 MW DI	2.00	18.90	6.90	12.00	69.80
2015	11.55		1x4.9 MW DI	4.90	1x2 MW DI	2.00	21.80	9.80	12.00	88.74
2016	11.97		1x4.9 MW DI	4.90	1x2 MW DI	2.00	24.70	9.80	14.90	106.36
2017	12.39				1x2 MW DI	2.00	22.70	9.80	12.90	83.23
2018	12.81		1x4.9 MW DI	4.90	1x2 MW DI	2.00	25.60	9.80	15.80	99.88
2019	13.23				1x2 MW DI	2.00	23.60	9.80	13.80	78.42
2020	13.61		1x4.9 MW DI	4.90	1x2 MW DI	2.00	26.50	9.80	16.70	94.76
2021	13.99				1x2 MW DI	2.00	24.50	9.80	14.70	75.18
2022	14.36						24.50	9.80	14.70	70.56
2023	14.74						24.50	9.80	14.70	66.17

Table 4.30. Reference Generation Plan for Tathlith.

Calendar Year	Peak Load (MW)	Existing Generation (MW)	Additions		Retirements		Total (MW)	(N-2) (MW)	Net Gen after (N-2) (MW)	Reserve Margin (%)
			Description	(MW)	Description	(MW)				
2008	11.13	20.60					20.60	4.00	16.60	85.07
2009	11.68						20.60	4.00	16.60	76.40
2010	12.24				1x1.8 MW DI	1.80	18.80	4.00	14.80	53.55
2011	12.81				1x1.8 MW DI	1.80	17.00	4.00	13.00	32.72
2012	13.37		2x2 MW DI	4.00	1x1.8 MW DI	1.80	19.20	4.00	15.20	43.56
2013	13.94		1x2 MW DI	2.00	1x1.8 MW DI	1.80	19.40	4.00	15.40	39.17
2014	14.51		1x2 MW DI	2.00	1x1.8 MW DI	1.80	19.60	4.00	15.60	35.12
2015	15.05		1x2 MW DI	2.00	1x1.8 MW DI	1.80	19.80	4.00	15.80	31.55
2016	15.60		1x2 MW DI	2.00	1x1.8 MW DI	1.80	20.00	4.00	16.00	28.22
2017	16.14		1x2 MW DI	2.00			22.00	4.00	18.00	36.27
2018	16.69						22.00	4.00	18.00	31.81
2019	17.24		1x2 MW DI	2.00	1x2 MW DI	2.00	22.00	4.00	18.00	27.63
2020	17.73		1x2 MW DI	2.00	1x2 MW DI	2.00	22.00	4.00	18.00	24.07
2021	18.23		1x2 MW DI	2.00	1x2 MW DI	2.00	22.00	4.00	18.00	20.71
2022	18.72		1x2 MW DI	2.00	1x2 MW DI	2.00	22.00	4.00	18.00	17.52
2023	19.21		1x2 MW DI	2.00			24.00	4.00	20.00	24.91

SECTION 5 DEVELOPMENT OF UNIFIED GENERATION PLAN

5.1 INTRODUCTION

One of the principal benefits of interconnecting power systems is the reduction in the amount of generation capacity needed to achieve a given level of reliability. The savings in the generating capacity are translated in cost savings. This cost savings are due to the capacity savings as well as savings in the operating cost.

Power systems are interconnected for the following two main reasons:

- Reserve sharing, and
- Power purchases between systems.

Benefits due to reserve sharing can be achieved by interconnecting two or more power systems, which will reduce the overall installed capacity with one system providing assistance to the other in case of emergencies. The only constraint is the capability of the interconnecting line and the available reserves. The benefit realized due to reserve sharing is because of the following two reasons. First, the percentage reserve requirement is reduced with the increased system size, and second, there is load diversity between the two systems.

The power purchase between systems can be further divided in two groups:

- Economy energy trading, and
- Firm power agreements.

The economy energy trading consists of transactions (purchase/sales) made to replace the high cost of energy production in one system with the lower cost energy from the other system, which is un-utilized in that system. An economy energy transaction would take place if the selling system/utility has a lower incremental cost of generation than the buying utility.

The firm power agreement would be of interest to the two systems/utilities if there exists a considerable difference between investment and production cost between the systems. That can justify building a plant in one area to meet the demand in the other. This would be the case if the power plants in one area using cheap fuel can be located in that area, supplying energy to the other area. For this type of arrangement to be viable the benefit of locating the generating plant in one area should exceed the costs of the transmission facilities required to deliver the power to the second area.

This section reports on the development of unified generation plans for the Kingdom and with the EOA of the Saudi Arabia's electrical system interconnected to the GCC grid. The objective is to quantify the capacity savings and to determine the reduction in capital expenditure.

Interconnecting the operating areas would result in savings to each area as a consequence of reserve sharing. The firm power agreement will be of interest to

COA if cheap energy is generated and delivered by EOA and WOA using large steam units. However, in this approach generation will be displaced from one operating system to the other which will not result in capacity savings. In this study the reserve sharing/capacity savings approach will be used to develop the unified generation plan.

5.2 GCC INTERCONNECTION

The six GCC countries, Bahrain, Kuwait, Qatar, Oman, Saudi Arabia and UAE are to be electrically interconnected. The major objectives of this grid are:

- Supply electrical power from one member state to another in case of emergency conditions.
- Reduce the electrical generation reserve of each of the member states.
- Improve the economic efficiency of the electricity power systems in the member states.
- Provide the basis for the exchange of electrical power among the member states in such a way as to serve the economic aspects and strengthen the reliability of the electrical supplies.

The GCC Interconnection Authority (GCCIA) has been formed in July 2001. The work on the phase I of the interconnection project have been awarded and the phase I interconnections would be commissioned in the year 2008. In the phase I, interconnection of the power systems of Saudi Arabia, Kuwait, Bahrain and Qatar (Figure 5.1) would be carried out. The GCC grid allows Saudi (EOA) system to import or export a maximum of 1800 MW under emergency conditions.

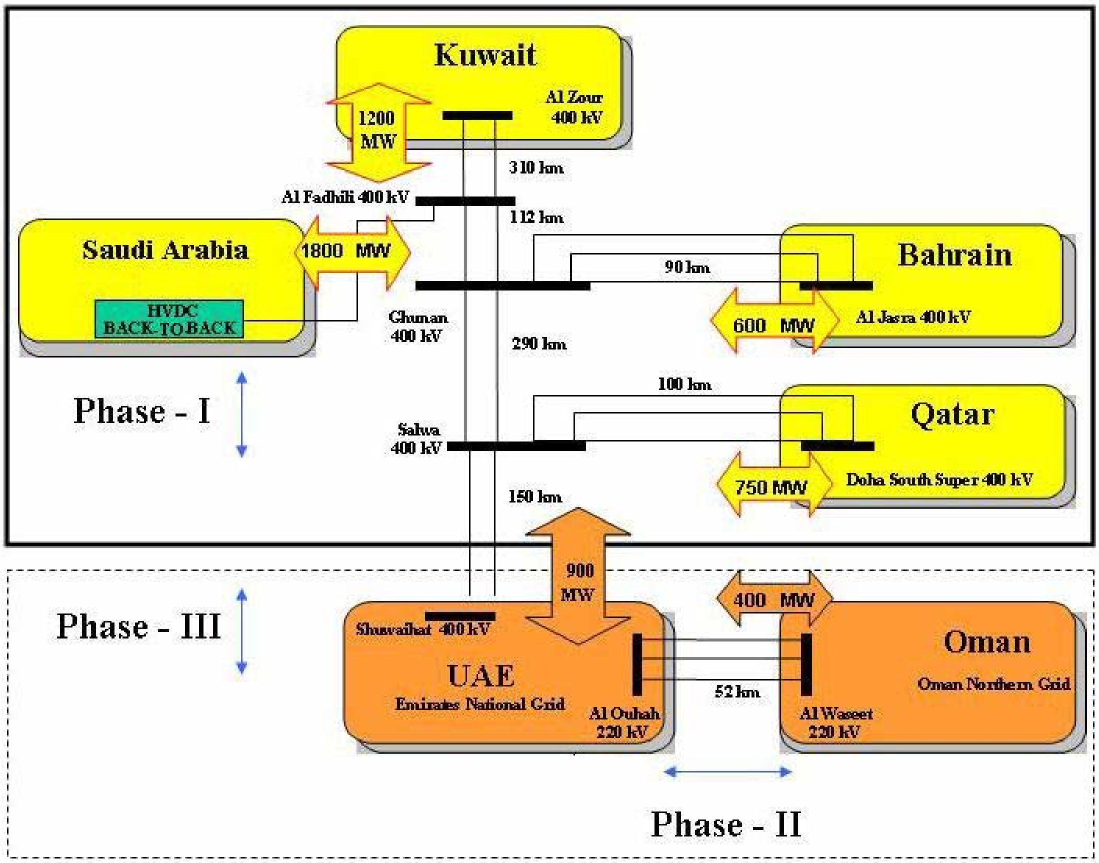

Figure 5.1. Single-Line Block Diagram of GCC Interconnection.

5.3 DEVELOPMENT OF THE UNIFIED GENERATION PLAN

The project team discussed possible future interconnections of the Saudi system with the representatives of MOW&E, ECRA, and SEC. In order to quantify the savings in generation to the Saudi (EOA) system due to GCC interconnection results of previous study would be taken into consideration. The previous study at KFUPM indicates the saving to the Saudi (EOA) system due to the GCC interconnection is 1600 MW. Taking into consideration the following aspects, the unified generation plan will be developed:

- Interconnection between the COA and WOA, the interconnecting capacity to be based on findings of a previous study conducted by KFUPM, and
- Interconnection between WOA and SOA, the interconnecting capacity to be based on findings of a previous study conducted by KFUPM.
- The effect of the GCC grid on the EOA is taken as a generation of 1600 MW capacity with a high level of availability. The high level of availability reflects the large number of generating units contributing to the Saudi system. This

value is based on a previous study conducted at KFUPM. The year of the GCC interconnection with Saudi system is taken as 2008.

- The link between WOA and COA is assumed to be ±500 kV bipolar DC line with the firm capacity transfer of 1,400 MW. The corridor of interconnection suggested in the previous studies is Riyadh-Jeddah. The nodes of interconnection are Bahra in the WOA and Muzahimiyah in the COA.

- The link between WOA and SOA is by a 380 kV double circuit line between Shaiba in WOA and Ash Shuqaiq in the SOA with the firm capacity transfer of 800 MW.

The additional link capacities along with the year of interconnection are illustrated in the Table 5.1.

Table 5.1. Interconnecting link with capacity and year of interconnection.

Interconnecting Link	Year	Link Capacity (MW)	Sub-Station	Remarks
WOA - COA	2011	1,400	Muzahimiyah in COA and Bahra in WOA	±500 kV Bipolar DC line
WOA - SOA	2014	800	Shaiba in WOA and Ash Shuqaiq in SOA	380 kV Double Circuit AC line

5.3.1 Methodology

The procedure adopted in developing the unified generation expansion plan based on generation capacity savings are as follows:

- Development of demand forecast for each isolated electric operating area or system. This has been described and conducted in Section 2 of the study.

- Development of reference generation expansion plans for each operating area separately to meet specified reliability criteria. This has been described and developed in Section 4 of the study.

- Development of a generation plan for systems with the interconnection in place to meet the specified reliability criteria. This plan would be referred to as the unified generation plan.

In development of the plan first the generation plan for EOA is developed using the effect of GCC grid as generating capacity to meet the specified reliability criteria. Modifications were made to the EOA reference generation plan in order to meet the required LOLE level. The modified plant requirements resulted in capacity savings due to the GCC interconnection.

Then the plans for the remaining three areas COA, WOA and SOA are developed by placing the links of specified capacity between the systems in the years indicated in the Table 5.1. The multi-area reliability program MAREL was used to analyze the system to meet the specified reliability criteria (LOLE). Year-by-year modifications of the reference generation plans were conducted to determine the actual plants that must be removed or shifted to satisfy the reliability standards. The plant requirements results in the capacity savings due to interconnection.

Certain rules were applied for evaluating the potential capacity sharing benefit among the systems; these are as follows:

- Firm generation installation plans were not removed. In the early years many of the utilities have firm plans for new power plants. These plans were not altered.

- Plants were removed from the systems in relation to their sizes (peak load). Because of the discrete nature of the generation units, and the fact that in some years some systems may not have sufficient capacity to be removed, the above rule was not strictly followed. The rule was applied as a general guide.

- Where plants were available for removal, priority was given to gas turbines (GT) since they have higher per kW owning cost than steam (ST) units. Whenever a steam unit was removed because of the unavailability of a sufficient number of gas turbines, this unit was brought back in service whenever the opportunity arose. For example, if in a later year GTs were available, then the ST unit removed earlier would be brought back into the installation plan. This amounts to a changing of the installation schedule of the ST unit.

- In finding the capacity benefits to each system, a constraint was recognized on the extent of saving that each system can realize. Each utility has to maintain a minimum reserve equal to the largest unit; although, because of its dependence on EOA, this constraint was relaxed for COA.

5.3.2 Unified Generation Plan

Using the methodology indicated in the previous section, the unified generation plans with the GCC interconnection for the four operating areas were developed. First the year by year plant requirements for EOA are quantified with the GCC grid in place in the year 2008. Then the transmission links with the specified capacity were put in place as per their year of interconnection and the reference generation plan modified to meet the specified generating standard. In the year 2011, COA will be interconnected to WOA, hence it would be a two area interconnected system with reserve sharing. Finally, in the year 2014, SOA would be integrated with the interconnected system of COA – WOA to evolve into a three-area interconnected system with reserve sharing.

Table 5.2 shows the saving in installed capacity in EOA due to the GCC interconnection. The reserve margin and the interconnected LOLE are also indicated in the table. The table indicates the savings start from the year 2009. The cumulative savings in the year 2023 for EOA is 1000 MW. Moreover, installation of a gas turbine was also delayed by 8 years with relation to the reference generation plan.

Table 5.2. Savings in installed capacity in the EOA.

Year	Savings (MW)	Cumulative Savings (MW)	Reserve (MW)	Reserve (%)	I/C LOLE (hrs/yr)
2008			376	2.80	14.97
2009	2X125	250	1713	12.28	0.00
2010		250	3193	21.59	0.00
2011		250	2501	16.33	0.00
2012	3X125	625	1792	11.32	0.12
2013	4X125	1125	1087	6.65	4.08
2014	-	1125	1492	8.84	0.35
2015	-1X125	1000	1195	6.88	2.85
2016	1X125	1125	1106	6.19	4.40
2017	-1X125	1000	1255	6.82	2.10
2018	-	1000	1279	6.77	2.67
2019	1X125	1125	1306	6.74	2.40
2020	1X125	1250	1235	6.22	4.14
2021	-1X125	1125	1312	6.46	3.12
2022	-	1125	1346	6.49	3.90
2023	-1X125	1000	1490	7.02	3.24

Table 5.3 illustrates the unified generation plan for the EOA. The plan indicates that during the study horizon (2008 to 2023), a total of 12,875 MW are required to meet the demand adequately in EOA. Out of the total requirement 6,700 MW would be supplied by the IWPP/WEC cogeneration plants. The remaining 6,175 MW are further required for addition. This will include 8 units of 600 MW steam turbine and 11 units of 125 MW gas turbines. During the same period 2,738 MW will be retired from the EOA system.

Table 5.3. Unified Generation Plan for the Eastern Operating Area (EOA).

Year	Load (MW)	Transfer to COA (MW)	Addition (MW)	Addition (Comments)	Ret. (MW)	Ret. (Comments)	Gen. EOA (MW)	Gen. IWPP/IPP * (MW)	Total Gen. (MW)	Res (%)	I/C LOLE (hrs/Yr)	EUE (GWh)
2008	10,440	3,000	1,250	1250(Marafiq)	-	-	9,846	3,970	13,816	2.80	14.97	4.19
2009	10,953	3,000	1,850	1250(R Azzour)+600(Maaden)	-	-	9,846	5,820	15,666	12.28	0.00	0.00
2010	11,287	3,500	2,500	1250(Marafiq) + 1250(R Azzour)	186.1	4x17.7Dam +1x19Safn+4x24Uthm	9,660	8,320	17,980	21.59	0.00	0.00
2011	11,808	3,500	0	-	171.2	4x31.5Dam+2x22.6Juay	9,489	8,320	17,809	16.33	0.00	0.00
2012	12,330	3,500	0	-	187.6	4x46.9Uthm	9,301	8,320	17,621	11.32	0.12	0.02
2013	12,851	3,500	0	-	183.4	4x34.5Dam+1x45.4Juay	9,118	8,320	17,438	6.65	4.08	0.61
2014	13,372	3,500	1,100	1100(Jubail3)	173.4	2x57Beri+1x15.9Qais+1x43.6Safn	8,944	9,420	18,364	8.84	0.35	0.05
2015	13,876	3,500	375	3X125GT	168.9	2x56Dam+1x57Beri	9,150	9,420	18,570	6.88	2.85	0.45
2016	14,380	3,500	600	1X600ST	184.6	3x56Dam+1x16.7Qais	9,566	9,420	18,986	6.19	4.40	0.78
2017	14,883	3,500	850	1X600ST+2X125GT	197.9	3x66Shed	10,218	9,420	19,638	6.82	2.10	0.46
2018	15,387	3,500	725	1X600ST+1X125GT	196.7	3x66Shed+1x64.7Faras	10,746	9,420	20,166	6.77	2.67	0.62
2019	15,891	3,500	725	1X600ST+1X125GT	194.1	3x64.7Faras	11,277	9,420	20,697	6.74	2.40	0.57
2020	16,346	3,500	600	1X600ST	215.5	2x67Shed+1x16.7Qais=1x64.7Faras	11,662	9,420	21,082	6.22	4.14	0.90
2021	16,802	3,500	725	1X600ST+1X125GT	192.9	2x67+1x58.8Shed	12,194	9,420	21,614	6.46	3.12	0.77
2022	17,257	3,500	725	1X600ST+1X125GT	235.3	4x58.8Shed	12,683	9,420	22,103	6.49	3.90	1.02
2023	17,713	3,500	850	1X600ST+2X125GT	250.6	3x58.8Shed+1x16.1+2x29Qais	13,283	9,420	22,703	7.02	3.24	0.89

Table 5.4 shows the saving in installed capacity in the COA due to the regional interconnection and GCC grid connected to EOA. The reserve margin and the interconnected LOLE are also indicated in the table. The table indicates the savings start from the year 2011 as COA is interconnected in that year. The cumulative savings in the year 2023 for COA are 928 MW. This is equivalent to saving 8 gas turbines of 116 MW capacity each with relation to the reference generation plan.

Table 5.4. Savings in installed capacity in the COA.

Year	Savings (MW)	Cumulative Savings (MW)	Reserve (MW)	Reserve (%)	I/C LOLE (hrs/yr)
2008					
2009					
2010					
2011	4X116	464	307	2.63	3.43
2012	-	464	323	2.65	3.84
2013	-	464	325	2.56	4.35
2014	2X116	696	95	0.72	3.81
2015	1X116	812	107	0.78	3.60
2016	-	812	112	0.79	3.79
2017	-	812	103	0.70	4.08
2018	-	812	108	0.71	3.88
2019	1X116	928	120	0.77	4.40
2020	-	928	127	0.79	4.44
2021	-	928	173	1.04	4.26
2022	-	928	171	1.00	4.42
2023	-	928	167	0.95	4.01

Table 5.5 illustrates the unified generation plan for the COA. Since the COA is interconnected with the WOA in the year 2011, the plan for the years 2008 to 2010 is the same as that of the reference generation plan. The plan indicates that during the study horizon (2008 to 2023), a total of 9,628 MW or 83 gas turbine of 116 MW capacity each are required to meet the demand adequately in COA. The firm transfer (3,500 MW) from EOA will remain the same as that in the reference generation plan. During the same period 2,713 MW will be retired from the COA system.

Table 5.5. Unified Generation Plan for the Central Operating Area (COA).

Year	Load (MW)	Transfer to COA (MW)	Addition (MW)	Addition (Comments)	Ret. (MW)	Ret. (Comments)	Gen. COA (MW)	Res. (%)	I/C LOLE (hrs/Yr)	EUE (GWh)
2008	10,369	3,000	812	7X116GT	-	-	8,058			
2009	10,879	3,000	464	4X116GT	-	-	8,522			
2010	11,148	3,500	0	-	145.3	4x10RydPP3+1x15RydPP3+4x23RydPP4	8,377			
2011	11,662	3,500	232	2X116GT	139.7	2x13RydPP4X+3x38RydPP4X	8,469	2.63	3.43	0.46
2012	12,177	3,500	696	6X116GT	164.8	2x38RydPP4X+5x18Burdah	9,000	2.65	3.86	0.55
2013	12,692	3,500	696	6X116GT	179.4	4x45RydPP5	9,517	2.56	4.35	0.65
2014	13,207	3,500	464	4X116GT	179.4	4x45RydPP5	9,801	0.72	3.81	0.52
2015	13,704	3,500	696	6X116GT	186.3	2x45RydPP5+2x48RydPP7	10,311	0.78	3.60	0.52
2016	14,202	3,500	696	6X116GT	193.3	4x48RydPP7	10,814	0.79	3.79	0.57
2017	14,699	3,500	696	6X116GT	207.3	4x48RydPP7+2x7Hail1	11,303	0.70	4.08	0.62
2018	15,197	3,500	696	6X116GT	193.3	4x48RydPP7	11,805	0.71	3.88	0.62
2019	15,694	3,500	696	6X116GT	186.3	2x45RydPP5+2x48RydPP7	12,315	0.77	4.40	0.70
2020	16,144	3,500	696	6X116GT	239.6	4x48QasmPP3	12,771	0.79	4.44	0.77
2021	16,594	3,500	696	6X116GT	200.2	4x50RydPP8	13,267	1.04	4.26	0.70
2022	17,044	3,500	696	6X116GT	248.2	4x50RydPP8+1x48QasmPP3	13,715	1.00	4.42	0.78
2023	17,494	3,500	696	6X116GT	250.3	5x50RydPP8	14,161	0.95	4.01	0.74

Table 5.6 shows the saving in installed capacity in the WOA due to the regional interconnection and GCC grid connected to EOA. The reserve margin and the interconnected LOLE are also indicated in the table. The table indicates the savings start from the year 2011 as the WOA is interconnected in that year. The cumulative savings in the year 2023 for the WOA are 615 MW. This is equivalent to saving of 5 gas turbines of 123 MW capacity each with relation to the reference generation plan.

Table 5.6. Savings in installed capacity in the WOA.

Year	Savings (MW)	Cumulative Savings (MW)	Reserve (MW)	Reserve (%)	I/C LOLE (hrs/yr)
2008					
2009					
2010					
2011	2X123	246	865	7.42	3.43
2012	-	246	852	7.01	3.86
2013	1X123	369	839	6.64	4.35
2014	2X123	615	568	4.33	3.81
2015	-	615	572	4.22	3.60
2016	-	615	547	3.90	3.79
2017	-	615	640	4.42	4.08
2018	-	615	684	4.57	3.88
2019	-	615	735	4.77	4.40
2020	-	615	687	4.34	4.44
2021	-	615	777	4.78	4.26
2022	-	615	747	4.48	4.42
2023	-	615	803	4.70	4.01

Table 5.7 illustrates the unified generation plan for the western operating area. Since the WOA is interconnected with the COA in the year 2011 the plan for the years 2008 to 2010 is the same as that of the reference generation plan. The plan indicates that during the study horizon (2008 to 2023) a total of 9,656 MW are required to meet the demand adequately in WOA. Out of the total requirement 1,150 MW would be supplied by the IPP/WEC plants. The remaining 8,506 MW are further required for addition. This will include 7 units of 400 MW and 5 units of 600 MW of steam units and 22 units of 123 MW gas turbines. During the same period 2,700 MW will be retired form the WOA system.

Table 5.7. Unified Generation Plan for the Western Operating Area (WOA).

Year	Load (MW)	Addition (MW)	Addition (Comments)	Ret. (MW)	Ret. (Comments)	Gen. WOA (MW)	Gen. IWPP/IPP * (MW)	Total Gen. (MW)	Res (%)	I/C LOLE (hrs/Yr)	EUE (GWh)
2008	10,248	800	800(Shoaibah)	-	-	8,987	2,766	11,753			
2009	10,714	350	350(S. Aramco)	-	-	8,987	3,116	12,103			
2010	11,179	369	3X123	178.0	(1x12+2x27+1x25)JedPP2+(1x18+2x22)MakA	9,178	3,116	12,294			
2011	11,660	400	1X400ST	169.2	1x40 MakB+(1x18+1x16)Mad1+2x20Mad2A+(2x20+1x16)Taif	9,409	3,116	12,525	7.42	3.43	0.56
2012	12,141	646	1X400ST+2X123GT	178.4	4x45JedPP3A	9,876	3,116	12,992	7.01	3.86	0.66
2013	12,621	646	1X400ST+2X123GT	178.4	4x45JedPP3A	10,344	3,116	13,460	6.64	4.35	0.78
2014	13,102	400	1X400ST	189.8	2x45JedPP3A+2x40MakB+1x20Mad2A	10,554	3,116	13,670	4.33	3.81	0.59
2015	13,567	646	1X400ST+2X123GT	177.5	1x45JedPP3A+1x40MakB+2x46MakC	11,023	3,116	14,139	4.22	3.60	0.58
2016	14,031	646	1X400ST+2X123GT	206.8	4x52JedPP3B	11,462	3,116	14,578	3.90	3.79	0.64
2017	14,496	769	1X400ST+3X123GT	210.6	2x52JedPP3B+1x46MakC+2x20Taif	12,020	3,116	15,136	4.42	4.08	0.69
2018	14,960	723	1X600ST+1X123GT	215.1	2x49MakC+2x50Mad2B+1x18Yanbu	12,528	3,116	15,644	4.57	3.88	0.68
2019	15,425	723	1X600ST+1X123GT	206.8	4x52JedPP3B	13,044	3,116	16,160	4.77	4.40	0.76
2020	15,845	615	5X123GT	243.2	4x52JedPP3B+2x18Yanbu	13,416	3,116	16,532	4.34	4.44	0.83
2021	16,265	723	1X600ST+1X123GT	212.8	4x53MakC	13,926	3,116	17,042	4.78	4.26	0.76
2022	16,685	600	1X600ST	209.8	2x52JedPP3B+2x53MakC	14,317	3,116	17,433	4.48	4.42	0.83
2023	17,105	600	1X600ST	124.0	2x62Mad2B	14,793	3,116	17,909	4.70	4.01	0.77

* Including Existing Transfer from SWCC 1,800 MW and Marafiq, Yanbu generation.
Load includes Marafiq, Yanbu load.

Table 5.8 shows the savings in installed capacity in the SOA due to the regional interconnection and GCC grid connected to EOA. The reserve margin and the interconnected LOLE are also indicated in the table. The table indicates the savings start from the year 2014 as SOA is interconnected in that year. The cumulative savings in the year 2023 for SOA is 615 MW. This is equivalent to saving 5 gas turbines of 123 MW capacity each with relation to the reference generation plan. Moreover, installation of a gas turbine of 123 MW capacity is delayed by 2 years with relation to the reference generation plan.

Table 5.8. Savings in installed capacity in the SOA.

Year	Savings (MW)	Cumulative Savings (MW)	Reserve (MW)	Reserve (%)	I/C LOLE (hrs/Yr)
2008					
2009					
2010					
2011					
2012					
2013					
2014	2X123	246	571	16.61	3.81
2015	1X123	369	611	16.42	3.60
2016	-	369	649	16.22	3.79
2017	1X123	492	549	12.82	4.08
2018	-	492	571	12.51	3.88
2019	1X123	615	487	10.05	4.40
2020	-	615	559	10.50	4.44
2021	1X123	738	508	8.76	4.26
2022	-	738	574	9.15	4.42
2023	-1X123	615	649	9.61	4.01

Table 5.9 illustrates the unified generation plan for the southern operating area. Since the SOA is interconnected in the year 2014 the plan for the years 2008 to 2013 is the same as that of the reference generation plan. The plan indicates that during the study horizon (2008 to 2023) a total of 5,448 MW are required to meet the demand adequately in the SOA. Out of the total requirement, 750 MW would be supplied by the WEC plants. The remaining 4,698 MW are further required for addition. This will include 6 units of 250 MW of steam units and 26 units of 123 MW gas turbines. During the same period 832 MW will be retired from the SOA system.

Table 5.9. Unified Generation Plan for the Southern Operating Area (SOA).

Year	Load (MW)	Addition (MW)	Addition (Comments)	Ret. (MW)	Ret. (Comments)	Gen. SOA (MW)	Gen. WEC/IWPP (MW)	Total Gen. (MW)	Res (%)	I/C LOLE (hrs/Yr)	EUE (GWh)
2008	2,410	369	3X123GT	-	-	3,151	0	3,151			
2009	2,529	750	750 (Shuqaiq)	-	-	3,151	750	3,901			
2010	2,711	0	-	51.0	6x9AsirDE	3,100	750	3,850			
2011	2,893	0	-	49.5	3x9AsirDE+6x4JizanDE	3,050	750	3,800			
2012	3,075	123	1X123GT	51.0	5x9BahaDE+2x4BahaDE	3,122	750	3,872			
2013	3,257	246	2X123GT	54.0	3x18Jizan	3,314	750	4,064			
2014	3,439	0	-	54.0	3x18Jizan	3,260	750	4,010	16.61	3.81	0.13
2015	3,720	369	3X123GT	48.0	1x24Jizan+3x8Baha	3,581	750	4,331	16.42	3.60	0.12
2016	4,001	369	3X123GT	49.5	1x50Bisha	3,901	750	4,651	16.22	3.79	0.13
2017	4,283	246	2X123GT	65.0	2x25Bisha+1x20Tihama	4,082	750	4,832	12.82	4.08	0.17
2018	4,564	373	1X250ST+1X123GT	69.5	1x50Bisha+1x20Tihama	4,385	750	5,135	12.51	3.88	0.16
2019	4,845	250	1X250ST	53.0	1x53Tihama	4,582	750	5,332	10.05	4.40	0.21
2020	5,321	619	1X250ST+3X123GT	71.0	1x47Asir+1x24Jizan	5,130	750	5,880	10.50	4.44	0.20
2021	5,797	496	1X250ST+2X123GT	71.0	1x47Asir+1x24Jizan	5,555	750	6,305	8.76	4.26	0.22
2022	6,273	619	1X250ST+3X123GT	77.0	1x47Asir+2x15Jizan	6,097	750	6,847	9.15	4.42	0.22
2023	6,749	619	1X250ST+3X123GT	68.0	1x15Jizan+1x53Tihama	6,648	750	7,398	9.61	4.01	0.17

* The load forecast shown is for the high growth case.

5.4 SUMMARY OF CAPACITY SAVINGS

Table 5.10 shows the capacity requirements for the reference generation plan and the unified generation plan with GCC interconnection for the four operating areas. The capacity savings by adopting the unified generation plan with GCC interconnection are also indicated in the table. Thus, the EOA will save 1000 MW or 8 GT units of 125 MW capacity, the COA will save 928 MW or 8 GT units of 116 MW capacity, the WOA will save 615 MW or 5 GT units of 123 MW capacity, and the SOA will also save 615 MW or 5 GT units of 123 MW capacity. The overall savings for the four operating areas are 3,158 MW. Moreover, there are a few delays in installation of generating units in the unified plan with GCC interconnection in relation to the reference plan. These delays will further augment the savings.

Table 5.10. Capacity requirements and savings for Unified Generation Plan

Area	**Reference Plan (MW)**	**Unified Plan with GCC Interconnection (MW)**	**Savings (MW)**	**Remarks**
EOA	7,175	6,175	1000	8x125GT
COA	10,556	9,628	928	8X116GT
WOA	9,121	8,506	615	5X123GT
SOA	5,313	4,698	615	5X123GT
Total	32,165	29,007	3,158	-

SECTION 6 CAPITAL INVESTMENT REQUIREMENTS

6.1 GENERAL APPROACH

This section reports on the estimation of the capital expenditure to cover generation requirements during the study period of 2008 to 2023. Generation plans were developed for each region and operating area. Sections 4 and 5 of this report provided details of the generation expansion, their type, size, and years of installation. This section will provide estimates of the capital investment required. The capital investments are estimated for each region and the Kingdom's total requirements are then found. These estimates do not include the committed IWPP projects and only future proposed plants are evaluated. The generation plans as reported in Sections 4 and 5 shows the year of installation of units of varying size. However, each unit requires a certain number of years for construction and commissioning. During this period funds are spent according to certain cash flow policy. The cash flow policy as provided by SEC is used in this report. The annual fund requirements thus reflect the size of the unit and the percentage of capital expenditure according to the cash flow policy. The gross annual investments are expressed in their equivalent present worth value of 2005. The cumulative investments are then evaluated by adding up the annual expenditures of all units required during the study period.

Capital expenditures are carried out for two generation plans. The first plan reflects the current status of SEC and its operating regions. This is referred to as the reference plan and is presented in Section 4. The second plan is developed to study the effects of the interconnection between SEC operating regions. Interconnections between COA & WOA and WOA & SOA are assumed at certain years. Also, an additional interconnection between COA & EOA is assumed. The results of this study are presented in Section 5.

In addition, generation plans were also developed for the isolated power systems within the Kingdom. The development and the results of these plans were presented in Section 4 of this report.

Many data items are required for the calculations of the capital investments. These are items such as capital cost of units, cash flow policy, economic parameters, and economic life of the units. These data were described in Section 3. They are included here for completeness and consistency.

6.2 CAPITAL EXPENDITURE ESTIMATES

6.2.1 Capital Cost of Plants

The capital cost estimates include cost of all the necessary facilities, and control equipment. However, the cost estimates exclude interest during construction or other financing or development costs. Table 6.1 provides the typical capital cost of different types of generating units for the four operating areas of the Kingdom. The base case does not include capital price escalation. Sensitivity analysis will be carried out to reflect capital escalation.

Table 6.1. Typical capital costs of different types of generating units.

Operating Areas	Unit Type	Net Site Rating (MW)	Primary Fuel	Capital Cost (SR/kW)
East	ST	600	NG	2,716
West	ST	400	HFO	3,117
West	ST	600	HFO	2,813
South	ST	250	HFO	3,711
East	GT	125	NG	1,500
Central	GT	116	NG	1,616
West	GT	123	DO	1,594
South	GT	123	DO	1,594

NG: Natural Gas, DO: Diesel Oil, HFO: Heavy Fuel Oil

6.2.2 *Cash Flows for Generation Expansion*

Table 6.2 shows the cash flow for each unit considered for generation expansion. The cash flows are shown in percent of the total capital cost. The construction period ranges between 2 to 4 years depending on type and size of generating unit. The actual disbursements are project specific and are a result of contract negotiations. They cannot be considered in a long term study.

Table 6.2. Cash flow and operating life for generation expansion.

Unit Type	Unit Size (MW)	Primary Fuel	Operating Life	Construction Period (Years)	Annual construction cash flow			
					Year 1 (%)	Year 2 (%)	Year 3 (%)	Year 4 (%)
ST	600	NG	35	4	9	32	32	27
ST	600	HFO	35	4	9	32	32	27
ST	400	HFO	35	4	9	32	32	27
ST	250	HFO	35	4	9	32	32	27
GT	125	NG	25	2	35	65	-	-
GT	116	NG	25	2	35	65	-	-
GT	123	DO	25	2	35	65	-	-

6.2.3 *Economic Life of Generating Unit*

The economic service life for the steam turbine units using natural gas as well as liquid fuel is taken as 35 years. In the case of the simple cycle combustion gas turbine using natural gas as well as liquid fuel the economic life is taken as 25 years.

6.2.4 *Economic Parameters*

The reference year for all costs is January 1, 2005. All costs are expressed in constant money and in Saudi Riyals (SR) based on a fixed exchange rate of 3.75 SR to the US dollar. For the base case a discount rate of 5% is used for economic evaluation. Sensitivity analysis will be carried out for the discount rates of 3% and 10%.

6.3 CAPITAL EXPENDITURE FOR THE REFERENCE GENERATION PLAN

6.3.1 EOA Investment Requirements

The capital investments required for generation expansion in the EOA system are shown in Table 6.3. Columns 1 and 2 show plant additions as discussed in Section 4. The plan adopts the addition of 125 MW GT and 600 MW ST units. The first plant additions of 2x125 MW GT is in 2009. The cash flow for a GT unit is assumed to be spread over two years. According to Table 6.2 above, 35 percent of the capital is needed in the first year and the remaining 65 percent in the second year. The entries in columns 3 reflect the cumulative cost components for the GT units.

The cash flow for a 600 MW ST unit is assumed to be spread over four years. According to Table 6.2 above, 9 percent of the capital is needed in the first year and the remaining 91 percent are divided according to Table 6.2. The first addition of a 600 MW ST is in the year 2016. The capital investment for this unit is divided into percentages as per Table 6.2 starting from 2013 to 2016. The entries in columns 4 reflect the gross cost components for the 600 MW ST units. The total gross capital requirements are shown in column 5. The entries in column 5 are obtained by adding up entries from column 3 & 4. The PW cumulative capital investments are shown in column 6 for a discount rate of 5 percent. The table shows that the cumulative plant additions are 7,175 MW, in addition to the committed IWPP projects. These plant additions will require total investments of **Million Saudi Riyals (MSR) 9,111.**

Table 6.3. EOA Generation & Investment Plan (Reference Plan).

Calendar Year	**Amount of Net Capacity in MW**		**Capital Cost (MSR)**		**Gross Capital Cost**	**PW Cumulative Capital Investment (5%)**
	125 MW GT	**600 MW ST**	**125 MW GT**	**600 MW ST**	**(MSR)**	**(MSR)**
Column	1	2	3	4	5	6
2005	0	0	0.00	0.00	0.00	0.00
2006	0	0	0.00	0.00	0.00	0.00
2007	0	0	0.00	0.00	0.00	0.00
2008	0	0	131.25	0.00	131.25	113.38
2009	250	0	243.75	0.00	243.75	313.91
2010	0	0	0.00	0.00	0.00	313.91
2011	0	0	196.88	0.00	196.88	460.82
2012	375	0	628.13	0.00	628.13	907.22
2013	500	0	487.50	146.66	634.16	1,336.45
2014	0	0	131.25	668.14	799.39	1,851.74
2015	250	0	309.38	1,189.61	1,498.98	2,771.98
2016	125	600	187.50	1,629.60	1,817.10	3,834.41
2017	125	600	187.50	1,629.60	1,817.10	4,846.23
2018	125	600	253.13	1,629.60	1,882.73	5,844.68
2019	250	600	309.38	1,629.60	1,938.98	6,824.00
2020	125	600	121.88	1,629.60	1,751.48	7,666.49
2021	0	600	65.63	1,482.94	1,548.56	8,375.90
2022	125	600	187.50	961.46	1,148.96	8,877.19
2023	125	600	121.88	439.99	561.87	**9,110.66**

6.3.2 COA Investment Requirements

The capital investments required for generation expansion in the COA system are shown in Table 6.4. Column 1 shows plant additions as discussed in Section 4. The first plant additions of 7x116 MW GT occur in 2008. The cash flow for a GT unit is assumed to be spread over two years. According to Table 6.2, 35 percent of the capital is needed in the first year and the remaining 65 percent in the second year. The entries in column 2 reflect the gross cost components for the 116 MW GT units.

The PW cumulative capital investments are shown in column 3 for a discount rate of 5 percent. The table shows that the cumulative plant additions are 10,556 MW, and in addition will require total investments of **MSR 10,418.**

Table 6.4. COA Generation & Investment Plan (Reference Plan).

Calendar Year	**Amount of Net Capacity in MW**	**Gross Capital Cost (MSR)**	**PW Cumulative Capital Investment (5%)**
	116 MW GT	**116 MW GT**	**(MSR)**
Column	1	2	3
2005	0	0.00	0.00
2006	0	0.00	0.00
2007	0	459.27	416.57
2008	812	1,115.36	1,380.06
2009	464	487.39	1,781.03
2010	0	393.66	2,089.48
2011	696	1,124.74	2,928.77
2012	696	1,124.74	3,728.10
2013	696	1,124.74	4,489.37
2014	696	1,190.35	5,256.67
2015	812	1,246.58	6,021.97
2016	696	1,124.74	6,679.58
2017	696	1,124.74	7,305.87
2018	696	1,190.35	7,937.14
2019	812	1,246.58	8,566.75
2020	696	1,124.74	9,107.76
2021	696	1,124.74	9,623.02
2022	696	1,124.74	10,113.74
2023	696	731.08	**10,417.51**

6.3.3 WOA Investment Requirements

The capital investments required for generation expansion in the WOA system are shown in Table 6.5. Columns 1, 2 and 3 show plant additions as discussed in Section 4. The plan adopts the addition of 123 MW GT, 400 MW ST and 600 MW ST units. The first plant additions of 3x123 MW GT occurs in 2010. The cash flow for a GT unit is assumed to be spread over two years. The entries in columns 4 reflect the gross cost components for the 123 MW GT units.

The cash flow for a 400 MW ST unit is assumed to be spread over four years. According to Table 6.2, 9 percent of the capital is needed in the first year and the remaining 91 percent are divided according to Table 6.2. The first addition of a 400 MW ST is in the year 2011. The capital investments for this unit are during the years 2008 to 2011 as per the percentages specified in Table 6.2. The entries in column 5 reflect the gross cost components for the 400 MW ST units.

The cash flow for a 600 MW ST unit is assumed to be spread over four years. The first addition of a 600 MW ST is in the year 2018. The capital investments for this unit are during the years 2015 to 2018 as per the percentages specified in Table 6.2. The entries in column 6 reflect the gross cost components for the 600 MW ST units. The gross capital requirements are shown in column 7. The entries in column 7 are obtained by adding up entries from columns 4, 5 & 6. The PW cumulative capital investments are shown in column 8 for a discount rate of 5 percent. The table shows that the cumulative plant additions are 9,121 MW in addition to the committed IWPP projects. These plant additions will require a total investment of **MSR 13,518.**

Table 6.5. WOA Generation & Investment Plan (Reference Plan).

Calendar Year	**Amount of Net Capacity in MW**			**Capital Cost (MSR)**			**Gross Capital Cost**	**PW Cumulative Capital Investment (5%)**
	123 MW GT	**400 MW ST**	**600 MW ST**	**123 MW GT**	**400 MW ST**	**600 MW ST**	**(MSR)**	**(MSR)**
Column	1	2	3	4	5	6	7	8
2005	0	0	0	0.00	0.00	0.00	0.00	0.00
2006	0	0	0	0.00	0.00	0.00	0.00	0.00
2007	0	0	0	0.00	0.00	0.00	0.00	0.00
2008	0	0	0	0.00	112.21	0.00	112.21	96.93
2009	0	0	0	205.87	511.19	0.00	717.05	686.85
2010	369	0	0	519.56	910.16	0.00	1,429.73	1,807.08
2011	246	400	0	392.12	1,246.80	0.00	1,638.92	3,030.07
2012	246	400	0	460.75	1,246.80	0.00	1,707.55	4,243.60
2013	369	400	0	519.56	1,246.80	0.00	1,766.36	5,439.14
2014	246	400	0	392.12	1,246.80	0.00	1,638.92	6,495.60
2015	246	400	0	392.12	1,134.59	151.90	1,678.61	7,526.13
2016	246	400	0	460.75	735.61	692.00	1,888.36	8,630.21
2017	369	400	0	450.94	336.64	1,080.19	1,867.77	9,670.26
2018	123	0	600	196.06	0.00	1,147.70	1,343.77	10,382.88
2019	123	0	600	470.55	0.00	1,147.70	1,618.25	11,200.21
2020	615	0	0	705.82	0.00	1,232.09	1,937.92	12,132.38
2021	123	0	600	127.44	0.00	1,535.90	1,663.34	12,894.38
2022	0	0	600	0.00	0.00	995.80	995.80	13,328.84
2023	0	0	600	0.00	0.00	455.71	455.71	**13,518.20**

6.3.4 SOA Investment Requirements

The capital investments required for generation expansion in the SOA system are shown in Table 6.6. Columns 1 and 2 show plant additions as discussed in Section 4. The plan adopts the addition of 123 MW GT and 250 MW ST units. The first plant additions of 3x123 MW GT occurs in 2008. The cash flow for a GT unit is assumed to be spread over two years. The entries in column 3 reflect the gross cost components for the 123 MW GT units.

The cash flow for a 250 MW ST unit is assumed to be spread over four years. According to Table 6.2, 9 percent of the capital is needed in the first year and the remaining 91 percent are divided according to Table 6.2. The first addition of a 250 MW ST occurs in the year 2018. The capital investments for this unit are during the years 2015 to 2018 as per the percentages specified in Table 6.2. The entries in column 4 reflect the gross cost components for the 250 MW ST units. The total gross capital requirements are shown in column 5. The entries in column 5 are obtained by adding up entries from column 3 & 4. The PW cumulative capital investments are shown in column 6 for a discount rate of 5 percent. The table shows that the cumulative plant additions are 5,313 MW. These plant additions will require total investments of **MSR 6,342.**

Table 6.6. SOA Generation & Investment Plan (Reference Plan).

Calendar Year	**Amount of Net Capacity in MW**		**Capital Cost (MSR)**		**Gross Capital Cost**	**PW Cumulative Capital Investment (5%)**
	123 MW GT	**250 MW ST**	**123 MW GT**	**250 MW ST**	**(MSR)**	**(MSR)**
Column	1	2	3	4	5	6
2005	0	0	0.00	0.00	0.00	0.00
2006	0	0	0.00	0.00	0.00	0.00
2007	0	0	205.87	0.00	205.87	186.73
2008	369	0	382.32	0.00	382.32	516.99
2009	0	0	0.00	0.00	0.00	516.99
2010	0	0	0.00	0.00	0.00	516.99
2011	0	0	68.62	0.00	68.62	568.20
2012	123	0	264.68	0.00	264.68	756.30
2013	246	0	392.12	0.00	392.12	1,021.71
2014	246	0	529.37	0.00	529.37	1,362.94
2015	492	0	715.63	83.50	799.12	1,853.53
2016	369	0	588.19	380.38	968.56	2,419.83
2017	369	0	450.94	677.26	1,128.20	3,048.06
2018	123	250	196.06	927.75	1,123.81	3,644.04
2019	123	250	333.31	927.75	1,261.06	4,280.96
2020	369	250	588.19	927.75	1,515.94	5,010.15
2021	369	250	588.19	844.25	1,432.44	5,666.36
2022	369	250	519.56	547.37	1,066.94	6,131.87
2023	246	250	254.88	250.49	505.37	**6,341.86**

6.3.5 Isolated Power Systems Investment Requirements

Tables 6.8 to 6.18 show the generation and capital requirements for the isolated power systems of Arar, Rafha, Qurayat , Al-Jawf , Juba, Tabuk, Dhuba, Al-Oula, Sharourah, Farasan, and Tathlith respectively. The generation plans vary in size and unit type. Diesel units, as small as 2 MW are installed in Tathlith while 53 MW GT is proposed for Tabuk and Al-Jawf. The details of these plans are described in Section 4. The capital costs of the units are shown in Table 6.7. The cash flow is assumed to be 100 percent in the year of the installation.

The estimation of the capital expenditure followed the same procedure as described for the interconnected systems. It reflects the year of installation, unit cost and the cumulative present value at 5 % discount rate. The net capacity addition for all the system is 2,289 MW. This corresponds to cumulative capital investments of **MSR 5,423.**

Table 6.7. Unit data for Isolated Power Systems.

Unit Type	Net Site Rating (MW)	Fuel	Unit Capital Cost (SR/kW)
GT	28	CR	3,562
GT	15	CR	4,498
GT	53	CR	2,960
GT	30	CR	3,325
DI	9.9	CR	5,986
DI	5	CR	6,500
DI	10	CR	5,986
DI	4.9	CR	6,500
DI	2	CR	7,500

Table 6.8. Arar Generation & Investment Plan.

Calendar Year	Amount of Net Capacity in MW	Gross Capital Cost (MSR)	PW Cumulative Capital Investment (5%)
	28 MW GT	28 MW GT	(MSR)
2005	0	0.00	0.00
2006	0	0.00	0.00
2007	0	0.00	0.00
2008	56	199.47	172.31
2009	0	0.00	172.31
2010	0	0.00	172.31
2011	28	99.74	246.74
2012	0	0.00	246.74
2013	28	99.74	314.24
2014	28	99.74	378.53
2015	0	0.00	378.53
2016	28	99.74	436.85
2017	0	0.00	436.85
2018	28	99.74	489.74
2019	0	0.00	489.74
2020	28	99.74	537.71
2021	0	0.00	537.71
2022	0	0.00	537.71
2023	0	0.00	537.71

Table 6.9. Rafha Generation & Investment Plan.

Calendar Year	Amount of Net Capacity in MW			Gross Capital Cost	PW Cumulative Capital Investment (5%)
	9.9 MW DI	15 MW GT	28 MW GT	(MSR)	(MSR)
2005	0	0	0	0.00	0.00
2006	0	0	0	0.00	0.00
2007	0	0	0	0.00	0.00
2008	39.6	0	0	237.05	204.77
2009	0	0	0	0.00	204.77
2010	0	15	0	67.47	257.63
2011	0	0	0	0.00	257.63
2012	0	0	0	0.00	257.63
2013	0	15	0	67.47	303.30
2014	0	0	0	0.00	303.30
2015	0	0	0	0.00	303.30
2016	0	0	28	99.74	361.61
2017	0	0	0	0.00	361.61
2018	0	0	0	0.00	361.61
2019	0	0	28	99.74	411.99
2020	0	0	0	0.00	411.99
2021	0	0	0	0.00	411.99
2022	0	0	0	0.00	411.99
2023	0	0	0	0.00	411.99

Table 6.10. Qurayat Generation & Investment Plan.

Calendar Year	Amount of Net Capacity in MW	Gross Capital Cost (MSR)	PW Cumulative Capital Investment (5%)
	28 MW GT	28 MW GT	(MSR)
2005	0	0.00	0.00
2006	0	0.00	0.00
2007	0	0.00	0.00
2008	56	199.47	172.31
2009	0	0.00	172.31
2010	0	0.00	172.31
2011	28	99.74	246.74
2012	0	0.00	246.74
2013	28	99.74	314.24
2014	28	99.74	378.53
2015	0	0.00	378.53
2016	0	0.00	378.53
2017	28	99.74	434.07
2018	0	0.00	434.07
2019	28	99.74	484.44
2020	28	99.74	532.42
2021	0	0.00	532.42
2022	28	99.74	575.93
2023	0	0.00	575.93

Table 6.11. Al-Jawf Generation & Investment Plan.

Calendar Year	Amount of Net Capacity in MW	Gross Capital Cost (MSR)	PW Cumulative Capital Investment (5%)
	53 MW GT	53 MW GT	(MSR)
2005	0	0.00	0.00
2006	0	0.00	0.00
2007	0	0.00	0.00
2008	53	156.88	135.52
2009	53	156.88	264.58
2010	0	0.00	264.58
2011	53	156.88	381.65
2012	0	0.00	381.65
2013	53	156.88	487.83
2014	53	156.88	588.96
2015	0	0.00	588.96
2016	53	156.88	680.68
2017	0	0.00	680.68
2018	0	0.00	680.68
2019	0	0.00	680.68
2020	0	0.00	680.68
2021	0	0.00	680.68
2022	53	156.88	749.13
2023	0	0.00	749.13

Table 6.12. Juba Generation & Investment Plan.

Calendar Year	Amount of Net Capacity in MW	Gross Capital Cost (MSR)	PW Cumulative Capital Investment (5%)
	15 MW GT	15 MW GT	(MSR)
2005	0	0.00	0.00
2006	0	0.00	0.00
2007	0	0.00	0.00
2008	15	67.47	58.28
2009	0	0.00	58.28
2010	30	134.94	164.01
2011	45	202.41	315.05
2012	30	134.94	410.95
2013	30	134.94	502.29
2014	30	134.94	589.27
2015	30	134.94	672.11
2016	45	202.41	790.46
2017	0	0.00	790.46
2018	15	67.47	826.24
2019	15	67.47	860.31
2020	15	67.47	892.77
2021	0	0.00	892.77
2022	30	134.94	951.64
2023	30	134.94	1,007.71

Table 6.13. Tabuk Generation & Investment Plan.

Calendar Year	Amount of Net Capacity in MW	Gross Capital Cost (MSR)	PW Cumulative Capital Investment (5%)
	53 MW GT	53 MW GT	(MSR)
2005	0	0.00	0.00
2006	0	0.00	0.00
2007	0	0.00	0.00
2008	0	0.00	0.00
2009	0	0.00	0.00
2010	53	156.88	122.92
2011	0	0.00	122.92
2012	53	156.88	234.41
2013	53	156.88	340.59
2014	0	0.00	340.59
2015	53	156.88	436.90
2016	0	0.00	436.90
2017	53	156.88	524.26
2018	53	156.88	607.46
2019	53	156.88	686.69
2020	53	156.88	762.16
2021	106	313.76	905.89
2022	53	156.88	974.34
2023	0	0.00	974.34

Table 6.14. Dhuba Generation & Investment Plan.

Calendar Year	Amount of Net Capacity in MW	Gross Capital Cost (MSR)	PW Cumulative Capital Investment (5%)
	30 MW GT	30 MW GT	(MSR)
2005	0	0.00	0.00
2006	0	0.00	0.00
2007	0	0.00	0.00
2008	0	0.00	0.00
2009	0	0.00	0.00
2010	0	0.00	0.00
2011	60	199.50	148.87
2012	30	99.75	219.76
2013	0	0.00	219.76
2014	0	0.00	219.76
2015	0	0.00	219.76
2016	0	0.00	219.76
2017	0	0.00	219.76
2018	0	0.00	219.76
2019	0	0.00	219.76
2020	30	99.75	267.74
2021	30	99.75	313.44
2022	0	0.00	313.44
2023	0	0.00	313.44

Table 6.15. Al-Oula Generation & Investment Plan.

Calendar Year	Amount of Net Capacity in MW	Gross Capital Cost (MSR)	PW Cumulative Capital Investment (5%)
	5 MW DI	5 MW DI	(MSR)
2005	0	0.00	0.00
2006	0	0.00	0.00
2007	0	0.00	0.00
2008	15	97.50	84.22
2009	5	32.50	110.96
2010	5	32.50	136.43
2011	5	32.50	160.68
2012	5	32.50	183.78
2013	5	32.50	205.77
2014	5	32.50	226.72
2015	5	32.50	246.67
2016	0	0.00	246.67
2017	5	32.50	264.77
2018	5	32.50	282.01
2019	5	32.50	298.42
2020	10	65.00	329.69
2021	5	32.50	344.58
2022	0	0.00	344.58
2023	5	32.50	358.08

Table 6.16. Sharourah Generation & Investment Plan.

Calendar Year	Amount of Net Capacity in MW	Gross Capital Cost (MSR)	PW Cumulative Capital Investment (5%)
	10 MW DI	10 MW DI	(MSR)
2005	0	0.00	0.00
2006	0	0.00	0.00
2007	0	0.00	0.00
2008	0	0.00	0.00
2009	0	0.00	0.00
2010	10	59.86	46.90
2011	10	59.86	91.57
2012	0	0.00	91.57
2013	10	59.86	132.09
2014	10	59.86	170.67
2015	0	0.00	170.67
2016	0	0.00	170.67
2017	10	59.86	204.00
2018	0	0.00	204.00
2019	10	59.86	234.24
2020	10	59.86	263.03
2021	10	59.86	290.45
2022	0	0.00	290.45
2023	10	59.86	315.33

Table 6.17. Farasan Generation & Investment Plan.

Calendar Year	Amount of Net Capacity in MW	Gross Capital Cost (MSR)	PW Cumulative Capital Investment (5%)
	4.9 MW DI	4.9 MW DI	(MSR)
2005	0	0.00	0.00
2006	0	0.00	0.00
2007	0	0.00	0.00
2008	0	0.00	0.00
2009	0	0.00	0.00
2010	0	0.00	0.00
2011	0	0.00	0.00
2012	0	0.00	0.00
2013	0	0.00	0.00
2014	4.9	31.85	20.53
2015	4.9	31.85	40.08
2016	4.9	31.85	58.71
2017	0	0.00	58.71
2018	4.9	31.85	75.60
2019	0	0.00	75.60
2020	4.9	31.85	90.92
2021	0	0.00	90.92
2022	0	0.00	90.92
2023	0	0.00	90.92

Table 6.18. Tathlith Generation & Investment Plan.

Calendar Year	Amount of Net Capacity in MW	Gross Capital Cost (MSR)	PW Cumulative Capital Investment (5%)
	2 MW DI	2 MW DI	(MSR)
2005	0	0.00	0.00
2006	0	0.00	0.00
2007	0	0.00	0.00
2008	0	0.00	0.00
2009	0	0.00	0.00
2010	0	0.00	0.00
2011	0	0.00	0.00
2012	4	26.00	18.48
2013	2	13.00	27.28
2014	2	13.00	35.66
2015	2	13.00	43.64
2016	2	13.00	51.24
2017	2	13.00	58.48
2018	0	0.00	58.48
2019	2	13.00	65.04
2020	2	13.00	71.30
2021	2	13.00	77.25
2022	2	13.00	82.92
2023	2	13.00	88.33

6.4 CAPITAL EXPENDITURE FOR THE UNIFIED GENERATION PLAN

Generation plans were developed to take into account the impact of interconnections between COA-WOA, WOA-SOA of the Kingdom and the GCC interconnection. The details of these plans are given in Section 5. The results show reduction in installed generation as compared to the reference plans of each operating area. Also, the installation of some of the units may be delayed. Both the capacity reductions and delayed installations will cause reductions in capital expenditure.

6.4.1 EOA Investment Requirements

The capital investments required for the generation expansion in the EOA system, with the existing and the committed interconnections to the COA system are shown in Table 6.19. The table shows that the cumulative plant additions are 6,300 MW in addition to the committed IWPP projects. The corresponding present worth of the capital investments is **MSR 7,964** at a discount rate of 5%. This is a reduction of MSR 1,147 from the reference plan of Table 6.3.

Table 6.19. EOA Generation & Investment Plan (Unified Plan).

Calendar Year	Amount of Net Capacity in MW		Capital Cost (MSR)		Gross Capital Cost	PW Cumulative Capital Investment (5%)
	125 MW GT	600 MW ST	125 MW GT	600 MW ST	(MSR)	(MSR)
2005	0	0	0.00	0.00	0.00	0.00
2006	0	0	0.00	0.00	0.00	0.00
2007	0	0	0.00	0.00	0.00	0.00
2008	0	0	0.00	0.00	0.00	0.00
2009	0	0	0.00	0.00	0.00	0.00
2010	0	0	0.00	0.00	0.00	0.00
2011	0	0	0.00	0.00	0.00	0.00
2012	0	0	0.00	0.00	0.00	0.00
2013	0	0	0.00	146.66	146.66	99.27
2014	0	0	196.88	668.14	865.01	656.86
2015	375	0	365.63	1189.61	1555.23	1,611.64
2016	0	600	131.25	1629.60	1760.85	2,641.17
2017	250	600	309.38	1629.60	1938.98	3,720.87
2018	125	600	187.50	1629.60	1817.10	4,684.51
2019	125	600	121.88	1629.60	1751.48	5,569.13
2020	0	600	65.63	1629.60	1695.23	6,384.56
2021	125	600	187.50	1482.94	1670.44	7,149.81
2022	125	600	253.13	961.46	1214.59	7,679.73
2023	250	600	243.75	439.99	683.74	**7,963.84**

6.4.2 COA Investment Requirements

The capital investments required for the generation expansion in the COA system, following the interconnection to the WOA in 2011 and the introduction of an additional link to SOA system in the year 2013, are shown in Table 6.20. The table shows that the cumulative plant additions are 9,628 MW. The corresponding present worth of the capital investments are **MSR 9,389.** This is a reduction of Million SR 1,029 from the reference plan of Table 6.4.

Table 6.20. COA Generation & Investment Plan (Unified Plan).

Calendar Year	Amount of Net Capacity in MW	Gross Capital Cost (MSR)	PW Cumulative Capital Investment (5%)
	116 MW GT	116 MW GT	(MSR)
2005	0	0.00	0.00
2006	0	0.00	0.00
2007	0	459.27	416.57
2008	812	1,115.36	1,380.06
2009	464	487.39	1,781.03
2010	0	131.22	1,883.85
2011	232	637.35	2,359.45
2012	696	1,124.74	3,158.78
2013	696	993.52	3,831.23
2014	464	881.04	4,399.16
2015	696	1,124.74	5,089.65
2016	696	1,124.74	5,747.26
2017	696	1,124.74	6,373.55
2018	696	1,124.74	6,970.02
2019	696	1,124.74	7,538.09
2020	696	1,124.74	8,079.11
2021	696	1,124.74	8,594.36
2022	696	1,124.74	9,085.08
2023	696	731.08	**9,388.86**

6.4.3 WOA Investment Requirements

The capital investments required for the generation expansion in the WOA system, following the interconnections to the COA in 2011 and to the SOA in 2014 are shown in Table 6.21.The table shows that the cumulative plant additions are 8,506 MW. The corresponding present worth of the capital investments are **MSR 12,828.** This is a reduction of MSR 690 from the reference plan of Table 6.5.

Table 6.21. WOA Generation & Investment Plan (Unified Plan).

Calendar Year	Amount of Net Capacity in MW			Capital Cost (MSR)			Gross Capital Cost (MSR)	PW Cumulative Capital Investment (5%) (MSR)
	123 MW GT	400 MW ST	600 MW ST	123 MW GT	400 MW ST	600 MW ST		
2005	0	0	0	0.00	0.00	0.00	0.00	0.00
2006	0	0	0	0.00	0.00	0.00	0.00	0.00
2007	0	0	0	0.00	0.00	0.00	0.00	0.00
2008	0	0	0	0.00	112.21	0.00	112.21	96.93
2009	0	0	0	205.87	511.19	0.00	717.05	686.85
2010	369	0	0	382.32	910.16	0.00	1,292.48	1,699.55
2011	0	400	0	137.24	1,246.80	0.00	1,384.04	2,732.34
2012	246	400	0	392.12	1,246.80	0.00	1,638.92	3,897.10
2013	246	400	0	254.88	1,246.80	0.00	1,501.68	4,913.49
2014	0	400	0	137.24	1,246.80	0.00	1,384.04	5,805.66
2015	246	400	0	392.12	1,134.59	151.90	1,678.61	6,836.18
2016	246	400	0	460.75	735.61	692.00	1,888.36	7,940.27
2017	369	400	0	450.94	336.64	1,080.19	1,867.77	8,980.31
2018	123	0	600	196.06	0.00	1,147.70	1,343.77	9,692.94
2019	123	0	600	470.55	0.00	1,147.70	1,618.25	10,510.27
2020	615	0	0	705.82	0.00	1,232.09	1,937.92	11,442.44
2021	123	0	600	127.44	0.00	1,535.90	1,663.34	12,204.43
2022	0	0	600	0.00	0.00	995.80	995.80	12,638.90
2023	0	0	600	0.00	0.00	455.71	455.71	**12,828.25**

6.4.4 SOA Investment Requirements

The capital investments required for the generation expansion in the SOA system, following the interconnection to the WOA in 2014 are shown in Table 6.22. The table shows that the cumulative plant additions are 4,698 MW. The corresponding present worth of the capital investments are **MSR 5,742.** This is a reduction of Million SR 600 from the reference plan of Table 6.6.

Table 6.22. SOA Generation & Investment Plan (Unified Plan).

Calendar Year	Amount of Net Capacity in MW		Capital Cost (MSR)		Gross Capital Cost	PW Cumulative Capital Investment (5%)
	123 MW GT	250 MW ST	123 MW GT	250 MW ST	(MSR)	(MSR)
2005	0	0	0.00	0.00	0.00	0.00
2006	0	0	0.00	0.00	0.00	0.00
2007	0	0	205.87	0.00	205.87	186.73
2008	369	0	382.32	0.00	382.32	516.99
2009	0	0	0.00	0.00	0.00	516.99
2010	0	0	0.00	0.00	0.00	516.99
2011	0	0	68.62	0.00	68.62	568.20
2012	123	0	264.68	0.00	264.68	756.30
2013	246	0	254.88	0.00	254.88	928.81
2014	0	0	205.87	0.00	205.87	1,061.52
2015	369	0	588.19	83.50	671.68	1,473.87
2016	369	0	519.56	380.38	899.94	2,000.05
2017	246	0	323.50	677.26	1,000.76	2,557.31
2018	123	250	127.44	927.75	1,055.19	3,116.90
2019	0	250	205.87	927.75	1,133.62	3,689.45
2020	369	250	519.56	927.75	1,447.31	4,385.64
2021	246	250	460.75	844.25	1,305.00	4,983.47
2022	369	250	588.19	547.37	1,135.56	5,478.91
2023	369	250	382.32	250.49	632.81	**5,741.86**

6.4.5 Transmission Investment Requirements

The interconnection between operating areas considered for the unified plan are discussed in Section 5.2.

The cash flow for the transmission interconnection is assumed to be spread over three years. Forty percent of the capital is taken in the first and the second year and the remaining 20 percent is in the third year which is the year of operation for the link. The link between WOA and COA is assumed to be operational in the year 2011. The capital investment for this link is divided into percentages of 40, 40 and 20 starting from 2009 to 2011. The other link considered is the 380 kV double circuit line between the WOA and the SOA. It may be noted that the transmission cost associated with the GCC interconnection is not shown here.

The PW cumulative capital investments for all the interconnection links are shown in Table 6.23 for a discount rate of 5 percent. The table shows that the cumulative present worth total investments is **Million Saudi Riyals (MSR) 2,373.** The cost includes the line cost, converter station costs for the HVDC line and the modification cost for the interconnecting sub-stations.

Table 6.23. Interconnection Cost Estimates (Unified Plan).

Link	**Year**	**Link Capacity (MW)**	**PW Cost Estimate (MSR)**
WOA – COA	2011	1,400	1,940
WOA - SOA	2014	800	433
Total (MSR)			**2,373**

6.5 SENSITIVITY ANALYSIS

A number of sensitivity analyses were carried out to study the impact of changing the discount rates. Discount rates of 3 percent and 10 percent were considered. Also calculations were undertaken to study the effects of capital escalation on the estimates of the investments. The studies were carried out for both the reference and interconnected generation plans as described in Sections 4 and 5 respectively.

6.5.1 Sensitivity Studies for the Reference Plan

Table 6.24 shows the effects of the discount rate on the investment requirements of the reference generation plan. The total plant additions for the Kingdom's power systems are 34,454 MW. The cumulative present worth of capital investment to January 2005 at the base discount rate of 5 percent is **MSR 44,811**. When the discount rate is changed to 3 percent, the investments change to **MSR 55,024.** The corresponding figures for a 10 percent discount rate are **MSR 28,010**.

Table 6.25 shows the effects of the annual capital escalation by 3% on the investment requirements of the reference generation plan. The cumulative present worth of capital investment to January 2005 at the base discount rate of 5 percent is **MSR 61,600**. When the discount rate is changed to 3 percent, the investments change to **MSR 76,378.** The corresponding figures for a 10 percent discount rate are **MSR 37,590**.

Table 6.24. Reference Plan - Investment Requirement, No Capital Escalation.

Region	**Net Capacity Additions**	**Cumulative Present Worth of Capital Investment to January 2005 (MSR)**		
		Discount Rate (%)		
	(MW)	**3**	**5**	**10**
Eastern Operating Area	7,175	11,506	9,111	5,268
Central Operating Area	10,556	12,579	10,418	6,811
Western Operating Area	9,121	16,443	13,518	8,607
Southern Operating Area	5,313	8,025	6,342	3,681
Isolated Systems	2,289	6,471	5,423	3,644
TOTAL	**34,454**	**55,024**	**44,811**	**28,010**

Table 6.25. Reference Plan - Investment Requirement, with 3% Capital Escalation.

Region	**Net Capacity Additions**	**Cumulative Present Worth of Capital Investment to January 2005 (MSR)**		
		Discount Rate (%)		
	(MW)	**3**	**5**	**10**
Eastern Operating Area	7,175	16,599	13,065	7,440
Central Operating Area	10,556	17,058	13,963	8,877
Western Operating Area	9,121	22,460	18,309	11,425
Southern Operating Area	5,313	11,644	9,126	5,178
Isolated Systems	2,289	8,615	7,137	4,669
TOTAL	**34,454**	**76,378**	**61,600**	**37,590**

6.5.2 Effect of Changes in Unit Capital Costs - Reference Plan

The capital investment requirements for additional sensitivity scenarios for the reference plan are shown in Table 6.26. The cases considered are the increase and decrease in the unit capital costs by 10% and 20%. The investment requirements are given for three discount rates 3, 5 and 10%. All the costs are present worth to January 1, 2005 values. When the unit capital cost is increased by 10% and 20%, the total investment requirement is MSR 49,292 and MSR 53,773 respectively at 5% discount rate. In case of decrease of the unit capital cost by 10% and 20% the requirement is MSR 40,330 and MSR 35,849 respectively. The table also gives the figures at 3 and 10% discount rates.

Table 6.26. Effect of unit capital cost changes- Reference Plan.

Region	Net Capacity Additions	10% Increase in Unit Capital Cost (MSR)			20% Increase in Unit Capital Cost (MSR)			10% Decrease in Unit Capital Cost (MSR)			20% Decrease in Unit Capital Cost (MSR)		
		Discount Rate (%)			Discount Rate (%)			Discount Rate (%)			Discount Rate (%)		
	(MW)	3	5	10	3	5	10	3	5	10	3	5	10
EOA	7,175	12,657	10,022	5,795	13,808	10,933	6,321	10,356	8,200	4,741	9,205	7,289	4,214
COA	10,556	13,837	11,459	7,492	15,095	12,501	8,173	11,321	9,376	6,130	10,063	8,334	5,449
WOA	9,121	18,088	14,870	9,467	19,732	16,222	10,328	14,799	12,166	7,746	13,155	10,815	6,885
SOA	5,313	8,827	6,976	4,049	9,629	7,610	4,417	7,222	5,708	3,313	6,420	5,073	2,945
Isolated	2,289	7,118	5,965	4,009	7,765	6,507	4,373	5,824	4,881	3,280	5,177	4,338	2,915
TOTAL	**34,454**	**60,527**	**49,292**	**30,811**	**66,029**	**53,773**	**33,612**	**49,522**	**40,330**	**25,209**	**44,019**	**35,849**	**22,408**

6.5.3 Sensitivity Studies for the Unified Plan

Table 6.27 shows the effects of the discount rate on the investment requirements of the unified generation plan. The total plant additions for the kingdom power systems are 31,296 MW. The cumulative present worth of capital investment to January 2005 at the base discount rate of 5 percent is **MSR 41,346**. When the discount rate is changed to 3 percent, the investments change to **MSR 51,035.** The corresponding figures for a 10 percent discount rate are **MSR 25,532.**

Table 6.27. Unified Plan - Investment Requirement, No Capital Escalation.

Region	Net Capacity Additions	Cumulative Present Worth of Capital Investment to January,2005 (MSR)		
		Discount Rate (%)		
	(MW)	3	5	10
Eastern Operating Area	6,175	10,229	7,964	4,390
Central Operating Area	9,628	11,388	9,389	6,082
Western Operating Area	8,506	15,651	12,828	8,111
Southern Operating Area	4,698	7,296	5,742	3,305
Isolated Systems	2,289	6,471	5,423	3,644
TOTAL	**31,296**	**51,035**	**41,346**	**25,532**

Table 6.28 shows the effects of the annual capital escalation by 3% on the investment requirements of the unified generation plan. The cumulative present worth of capital investment to January, 2005 at the base discount rate of 5 percent is **MSR 57,297**. When the discount rate is changed to 3 percent, the investments change to **MSR 71,417.** The corresponding figures for a 10 percent discount rate are **MSR 34,526**.

Table 6.28. Unified Plan - Investment Requirement, with 3% Capital Escalation.

Region	Net Capacity Additions	Cumulative Present Worth of Capital Investment to January 2005 (MSR)		
		Discount Rate (%)		
	(MW)	3	5	10
Eastern Operating Area	6,175	15,099	11,712	6,399
Central Operating Area	9,628	15,559	12,673	7,971
Western Operating Area	8,506	21,480	17,456	10,814
Southern Operating Area	4,698	10,664	8,319	4,673
Isolated Systems	2,289	8,615	7,137	4,669
TOTAL	**31,296**	**71,417**	**57,297**	**34,526**

6.5.4 Effect of Changes in Unit Capital Costs - Unified Plan

The capital investment requirements for additional sensitivity scenarios for the unified plan are shown in Table 6.29. The cases considered are the increase and decrease in the unit capital costs by 10% and 20%. The investment requirements are given for three discount rates 3, 5 and 10%. All the costs are present worth to January 1, 2005 values. When the unit capital cost is increased by 10% and 20% the total investment requirement is MSR 45,480 and MSR 49,615 respectively at 5% discount rate. In case of decrease of the unit capital cost by 10% and 20% the requirement is MSR 37,211 and MSR 33,077 respectively. The table also gives the figures at 3 and 10% discount rates.

Table 6.29. Effect of unit capital cost changes-Unified Plan.

Region	Net Capacity Additions	10% Increase in Unit Capital Cost (MSR)			20% Increase in Unit Capital Cost (MSR)			10% Decrease in Unit Capital Cost (MSR)			20% Decrease in Unit Capital Cost (MSR)		
		Discount Rate (%)			Discount Rate (%)			Discount Rate (%)			Discount Rate (%)		
	(MW)	3	5	10	3	5	10	3	5	10	3	5	10
EOA	6,175	11,252	8,760	4,829	12,275	9,557	5,268	9,206	7,168	3,951	8,183	6,371	3,512
COA	9,628	12,527	10,328	6,690	13,666	11,267	7,298	10,249	8,450	5,474	9,110	7,511	4,866
WOA	8,506	17,216	14,111	8,922	18,781	15,394	9,733	14,086	11,545	7,300	12,521	10,262	6,489
SOA	4,698	8,026	6,316	3,636	8,755	6,890	3,966	6,566	5,168	2,975	5,837	4,594	2,644
Isolated	2,289	7,118	5,965	4,009	7,765	6,507	4,373	5,824	4,881	3,280	5,177	4,338	2,915
TOTAL	**31,296**	**56,138**	**45,480**	**28,086**	**61,242**	**49,615**	**30,639**	**45,931**	**37,211**	**22,979**	**40,828**	**33,077**	**20,426**

SECTION 7 CONCLUSIONS & RECOMMENDATIONS

7.1 CONCLUSIONS

This study presented a plan for the expansion of Electricity Generation in the Kingdom of Saudi Arabia. A demand forecast for the coming 15 years (2008 to 2023) is developed to determine the generation requirements in the Kingdom. The demand forecast is based on the multiple regression analysis method. The historical annual energy and economic data, namely, population and gross domestic product (GDP) are used to determine customer elasticity. The peak demand forecast for the four operating areas: EOA, COA, COA, and SOA, as well as the different isolated areas were calculated for high, most likely, and low growth scenarios.

The demand forecast for the most likely scenario for the Kingdom is expected to reach a level of 57,808 MW in the year 2023. The energy requirement is expected to reach a figure of 343,110 GWh in the year 2023. The high growth in GDP scenario will result in demand of 93,779 MW in 2023. The corresponding energy requirement is expected to reach 556,607 GWh. The demand forecast for the low growth scenario is 52,588 MW in the year 2023. The corresponding energy requirement is expected to reach 312,127 GWh.

The demand scenarios indicated that there was a clear need to develop generation plans that will meet the expected load. The plan developed provides additional generation requirements with adequate supply reliability and within reasonable costs. It also takes into consideration the economic life of the existing generating units. The generation planning process was developed based on the information of the existing power system, the committed plans, the developed load forecast, and the available supply options. Data were collected for the Kingdom from the Ministry of Water & Electricity, Ministry of Planning, Electricity and Cogeneration Regulatory Authority (ECRA), Saudi Electricity Company, Saline Water Conversion Corporation (SWCC), and Independent Water & Power Producers (IWPP).

The basic generation supply options considered were conventional thermal plants-steam units, gas turbines and diesel units. The supply options such as unit type and size for the candidate unit of expansion for a given region was dictated by the characteristic of the existing system of that particular region into which they would be integrated. The fuels considered in electricity generation are natural gas, crude oil, diesel, and heavy fuel oil. The contribution of SWCC towards the total generation in the Eastern and the Western Regions were quite significant. There was also some generation contribution by SWCC to the Southern Region. The IPP/IWPP, such as WEC, Marafiq, Maa'den and Saudi Aramco were expected to be major contributors in the near future. Existing or planned interconnections between different operating areas were also considered as a generation supply option. The generation expansion plans for each interconnected system and the isolated systems were prepared.

A Multi-Area Reliability Analysis Program (MAREL) was used to develop the generation plan. This plan is referred to as the Reference Plan. The total generation additions, excluding the IWPP & IPP, are 34,454 MW. The figure includes 2,289 MW needed by the isolated power systems within the Kingdom. The cumulative present worth of capital investment to January 2005 at the base discount rate of 5 percent is MSR 44,811. A number of sensitivity analyses were carried out to study the impact of changing the discount rates on the reference generation plan. When the discount rate is changed to 3 percent, the investments change to MSR 55,024. The corresponding figure for a 10 percent discount rate is MSR 28,010. The effects of the capital escalation of 3% on the investment requirements of the reference generation plan are also considered. The cumulative present worth of capital investment to January 2005 at the base discount rate of 5 percent is MSR 61,600. When the discount rate is changed to 3 percent, the investments change to MSR 76,378. The corresponding figures for a 10 percent discount rate are MSR 37,590. The investment requirements for the changes in unit capital costs by ± 10% and ± 20% were also estimated. For the case of increase of 10% in unit capital cost, the total investment required is MSR 60,527, MSR 49,292 and MSR 30,811 for the discount rate of 3, 5 and 10% respectively. For the case of increase of 20% in unit capital cost, the total investment required is MSR 66,029, MSR 53,773 and MSR 33,612 for the discount rate of 3, 5 and 10% respectively. In the case of decrease of 10% in unit capital cost, the total investment required is MSR 49,522, MSR 40,330 and MSR 25,209 for the discount rate of 3, 5 and 10% respectively. For the case of decrease of 20% in unit capital cost, the total investment required is MSR 44,019, MSR 35,849 and MSR 22,408 for the discount rate of 3, 5 and 10% respectively.

The study then developed generation plans when further transmission interconnections between SEC operating areas were proposed. Interconnection links between the COA & WOA and WOA & SOA were considered. The effect of the GCC grid on the Saudi system (EOA) is taken as a generation of 1600 MW capacity with a high level of availability. The commissioning year for the GCC grid is taken as 2008. This is referred to as the unified generation plan. The total plant additions under this plan are 31,296 MW. This is a reduction of 3,158 MW in comparison to the reference plan. The cumulative present worth of capital investment to January 2005 at the base discount rate of 5 percent is MSR 41,346. When the discount rate is changed to 3 percent, the investments change to MSR 51,035. The corresponding figures for a 10 percent discount rate are MSR 25,532. The effects of the capital escalation 3% on the investment requirements of the interconnected generation plan are also considered. The cumulative present worth of capital investment to January 2005 at the base discount rate of 5 percent is MSR 57,297. When the discount rate is changed to 3 percent, the investments change to MSR 71,417. The corresponding figures for a 10 percent discount rate are MSR 34,526. The investment requirements for additional sensitivity scenarios such as increase and decrease in the unit capital cost by 10 and 20 percent were also developed. For the case of increase of 10% in unit capital cost, the total investment required is MSR 56,138, MSR 45,480 and MSR 28,086 for the discount rate of 3, 5 and 10% respectively. For the case of increase of 20% in unit capital cost, the total investment required is MSR 61,242, MSR 49,615 and MSR 30,639 for the discount rate of 3, 5 and 10% respectively. In the case of decrease of 10% in unit capital cost, the total investment required is MSR 45,931, MSR 37,211 and MSR 22,979 for the discount rate of 3, 5 and 10% respectively. For the case of decrease of 20% in unit capital cost, the total investment required is MSR 40,828, MSR 33,077 and MSR 20,426 for the discount rate of 3, 5 and 10% respectively.

The plan does not consider the costs associated with the transmission links and related equipment.

7.2 RECOMMENDATIONS

The following recommendations are observed:

- There is a need to perform detailed demand forecasts by sector, end-use and administrative-region wise. This would require substantial collection of data and analytical efforts.

- The study indicates that there is a need to add a large number of GT units in the Central Operating Area. This can be reduced through firm interconnection links to the West and East coasts. Thus, a detailed techno-economic interconnection study is recommended.

- The selection of candidate units for future expansion should be based on a much detailed study involving screening of the units of different sizes and types.

- A detailed study for the development of the generation plans taking into account the interconnection between the isolated systems and with the main grid should be undertaken.

- A careful generation retirement policy should be developed for the existing units.

- A detailed study is warranted regarding fuel availability and the types of fuel available throughout the Kingdom's regions.

- The generation locations are dictated by transmission studies. A detailed transmission study should be undertaken.

- There is a need for an economic energy interchange study.

APPENDIX A
REQUEST FOR CHANGE ORDER