PN CER2272

REVISED FINAL REPORT

UPDATED GENERATION PLANNING FOR THE SAUDI ELECTRICITY SECTOR

EXECUTIVE SUMMARY & RECOMMENDATIONS

Prepared for

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Riyadh, Saudi Arabia

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March 2006 G

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SECTION 1 INTRODUCTION

This is the executive summary of 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 the 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 specific 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 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.

The present installed generation capacity owned by the Saudi Electricity Company (SEC) is approximately 27,500 MW. In addition to this, there are over 5,500 MW in plants operated by Saline Water Conversion Corporation (SWCC) and Power and Water Utilities Company for Jubail and Yanbu (Marafiq). Also, there are several plants to be owned and operated by Independent Power Producers (IPPs) being actively considered.

SECTION 2 STUDY BASIS AND ASSUMPTIONS

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 (IPPs) and Electricity and Cogeneration Regulatory Authority (ECRA).

The main tasks involved in the development of the generation plan were 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.

2.1 Study Horizon

The study horizon for this study was a 15 year simulation period starting from 2008 and ending in 2023G.

2.2 Planning Year

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

2.3 Power Supply Options

The principal generations options considered were 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 1.

2.4 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).

For this study it was assumed that the existing generating units will continue burning the same fuel type. However, for the future units it was assumed that natural gas would be available for the eastern and central operating areas. As for western and southern operating areas it was assumed that they would be using liquid fuel for the study period.

Table 1. 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
EOA: Eastern Operating Area, COA: Central Operating Area,
WOA: Western Operating Area, SOA: Southern Operating Area

2.5 Generation Planning Standard

The generation planning standard used in this study is based on the Loss-of-Load-Expectation (LOLE) risk index expressed in hours per year. 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.

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.

2.6 Forced Outage Rates

The (equivalent) forced outage rates (EFOR) used in the study are shown in Table 2 for various classes of generating units in different regions of the Kingdom.

2.7 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 2 illustrates the maintenance schedule for various plant types for different regions of the Kingdom.

Table 2. Forced outage rates for various types of generating units.

Operating Areas	Unit Type	Net Site Rating (MW)	Primary/Backup Fuel	Equivalent Forced Outage Rates (%)	Scheduled 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

2.8 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 provides the typical capital cost of different types of generating units used for the four interconnected operating areas of the Kingdom as well as the isolated system.

Table 3. Typical capital costs for various 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
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

2.9 Cash Flows for Generation Expansion

Table 4 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. For the units added in the isolated system which are generally smaller in size the money is spent in one year.

2.10 Service Life of Generating Unit

The service or economic operating lives of new generating units are as shown in Table 4. 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.

Table 4. 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

2.11 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 has been carried out for the discount rate of 3% and 10%. The case of annual escalation of the unit capital cost by 3% has been studied. The effect of changes in the unit capital cost by ±10% and ±20% has also been studied.

2.12 Other Assumptions

Contribution from Interconnections

There is an existing interconnection between EOA and COA. At present EOA is delivering about 2,500 MW to COA and the capacity will be enhanced to 3,500 MW in 2008.

Additional interconnections are assumed for the development of the unified generation plan. Table 5 shows the interconnection year and the additional link capacity between different operating areas.

Table 5. 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

Contribution from SWCC, 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. In future, a number of IWPP generating plants would be added. Table 6 illustrates the future generating capacities of Water & Electricity Company (WEC) and IWPP plants. Moreover, a number of IPP plants are also in construction phase. Table 7 shows the list of IPP and their capacities.

Table 6. 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 7. 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 (Ras Tanura)	140	2006	EOA	Captive
Saudi Aramco (Othmaniyah)	170	2006	EOA	Captive
Saudi Aramco (Juaymah)	190	2006	EOA	Captive
Saudi Aramco (Shedgum)	170	2006	EOA	Captive
Saudi Aramco (Rabigh)	350	2008	WOA	Captive

Retirement of Existing Generating Units

Based on the economic life of the generating units, a large number of the generating units have reached the end of their economic life. 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 3 DEMAND FORECAST

A load forecast was developed for the Kingdom covering the study period 2008 to 2023. The econometric multiple regression analysis method has been used in the development of demand forecast. 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.

Based on the data received for the GDP, it is observed that the increase in GDP beyond year 2005 is exponential resulting in very high growth rate that may be difficult to sustain. 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. Accordingly, three scenarios of load forecast were developed.

Table 8 summarizes the energy and the load forecast for the territorial Eastern Operating Area (EOA) interconnected system for the most likely growth case, high growth case and low growth case.

Table 8. Demand forecast – EOA interconnected system.

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	10,440	68,225	10,440	68,225	10,097	65,986
2013	12,851	85,443	13,866	92,191	12,093	80,405
2018	15,387	102,306	19,431	129,191	14,208	94,470
2023	17,713	117,769	28,734	191,050	16,113	107,135

Table 9 summarizes the energy and the load forecast for the territorial Central Operating Area (COA) interconnected system for the most likely growth case, high growth case and low growth case.

Table 9. Demand forecast – COA interconnected system.

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	10,369	54,953	10,369	54,953	10,029	53,150
2013	12,692	68,822	13,694	74,257	11,944	64,764
2018	15,197	82,404	19,191	104,060	14,033	76,093
2023	17,494	94,860	28,379	153,885	15,914	86,294

Table 10 summarizes the energy and the load forecast for the territorial Western Operating Area (WOA) interconnected system for the most likely growth case, high growth case and low growth case.

Table 10. Demand forecast – WOA interconnected system.

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	9,478	53,884	9,478	53,884	9,167	52,115
2013	11,851	67,482	12,787	72,812	11,153	63,504
2018	14,190	80,801	17,920	102,034	13,104	74,612
2023	16,335	93,014	26,500	150,891	14,860	84,614

Table 11 summarizes the energy and the load forecast for the territorial Southern Operating Area (SOA) interconnected system for the most likely growth case, high growth case and low growth case.

Table 11. Demand forecast – SOA interconnected system.

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	2,410	14,378	2,410	14,378	2,331	13,906
2013	3,018	18,007	3,257	19,429	2,840	16,945
2018	3,614	21,560	4,564	27,226	3,337	19,909
2023	4,160	24,819	6,749	40,263	3,785	22,578

Tables 12 to 14 summarize the peak load forecast for the isolated areas. Table 12 shows the peak load every five years for Arar, Rafha, Qurayat, Al-Jawf and Juba. Juba falls under the COA while Arar, Rafha, Qurayat and Al-Jawf are under the EOA. The forecasted peak load demand for areas falling under the WOA is shown in Table 13. Table 14 shows the peak load demand for the area under SOA.

Table 12. Demand forecast – EOA and COA isolated system (most likely case).

Year	Arar (MW)	Rafha (MW)	Qurayat (MW)	Al-Jawf (MW)	Juba (MW)
2008	92	55	133	169	207
2013	113	68	164	208	254
2018	135	81	196	249	304
2023	156	94	226	287	350

Table 13. Demand forecast – WOA isolated system (most likely case).

Year	Tabuk (MW)	Dhuba (MW)	Al-Oula (MW)	Others (MW)
2008	338	50	41	92
2013	423	62	52	115
2018	506	74	62	138
2023	583	86	71	159

Table 14. Demand forecast – SOA isolated system (most likely case).

Year	Sharourah (MW)	Farasan (MW)	Tathlith (MW)
2008	36	11	9
2013	45	14	11
2018	54	17	13
2023	62	19	15

Table 15 shows the summary of the demand forecast for the Kingdom. This includes the interconnected systems as well as the isolated systems. The peak load for the most likely case would 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 would reach a level of 93,779 MW and the total energy is expected to reach 556,607 GWh in the year 2023. In case of the low growth scenario, the peak load would 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.

Table 15. Kingdom demand 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 4 GENERATION PLAN

The generation requirements are calculated based on the 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.

4.1 Reference Generation Plan for Interconnected System

Table 16 shows the developed generation plan for the EOA during the study horizon 2008 to 2023. During this period, a total of 13,875 MW are required to be added 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 2,738 MW will be retired from the EOA system.

Table 16. Reference generation plan for eastern operating area (EOA).

Year	Load (MW)	Addition (MW)	Gen. EOA (MW)	Gen. IWPP/IPP (MW)	Total Gen. (MW)
2008	10,440	1,250*	9,846	3,970	13,816
2009	10,953	1,850*+250	10,096	5,820	15,916
2010	11,287	2,500*	9,910	8,320	18,230
2011	11,808	0	9,739	8,320	18,059
2012	12,330	375	9,926	8,320	18,246
2013	12,851	500	10,243	8,320	18,563
2014	13,372	1,100*	10,069	9,420	19,489
2015	13,876	250	10,150	9,420	19,570
2016	14,380	725	10,691	9,420	20,111
2017	14,883	725	11,218	9,420	20,638
2018	15,387	725	11,746	9,420	21,166
2019	15,891	850	12,402	9,420	21,822
2020	16,346	725	12,912	9,420	22,332
2021	16,802	600	13,319	9,420	22,739
2022	17,257	725	13,808	9,420	23,228
2023	17,713	725	14,283	9,420	23,703
Total Generation Additions = 13,875 MW (including 6,700 MW from WEC/IPP)					

* indicates the committed WEC/IPP/IWPP generations

For the COA (refer Table 17), 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.

Table 17. Reference generation plan for central operating area (COA).

Year	Load (MW)	Addition (MW)	Gen. COA (MW)
2008	10,369	812	8,058
2009	10,879	464	8,522
2010	11,148	0	8,377
2011	11,662	696	8,933
2012	12,177	696	9,464
2013	12,692	696	9,981
2014	13,207	696	10,497
2015	13,704	812	11,123
2016	14,202	696	11,626
2017	14,699	696	12,115
2018	15,197	696	12,617
2019	15,694	812	13,243
2020	16,144	696	13,699
2021	16,594	696	14,195
2022	17,044	696	14,643
2023	17,494	696	15,089
Total Generation Additions = 10,556 MW			

Table 18 shows the developed generation plan for the WOA during the study horizon 2008 to 2023. During this period 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.

For the SOA (refer Table 19) 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 from the SOA system.

Table 18. Reference generation plan for the western operating area (WOA).

Year	Load (MW)	Addition (MW)	Gen. WOA (MW)	Gen. IWPP/IPP* (MW)	Total Gen. (MW)
2008	10,248	800#	8,987	2,766	11,753
2009	10,714	350#	8,987	3,116	12,103
2010	11,179	369	9,178	3,116	12,294
2011	11,660	646	9,655	3,116	12,771
2012	12,141	646	10,122	3,116	13,238
2013	12,621	769	10,713	3,116	13,829
2014	13,102	646	11,169	3,116	14,285
2015	13,567	646	11,638	3,116	14,754
2016	14,031	646	12,077	3,116	15,193
2017	14,496	769	12,635	3,116	15,751
2018	14,960	723	13,143	3,116	16,259
2019	15,425	723	13,659	3,116	16,775
2020	15,845	615	14,031	3,116	17,147
2021	16,265	723	14,541	3,116	17,657
2022	16,685	600	14,932	3,116	18,048
2023	17,105	600	15,408	3,116	18,524
Total Generation Additions = 10,271 MW (including 1,150 MW from SWCC/IPP)					

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

# indicates the committed WEC/IPP/IWPP generations.

Table 19. Reference generation plan for the southern operating area (SOA).

Year	Load* (MW)	Addition (MW)	Gen. SOA (MW)	Gen. WEC/IWPP (MW)	Total Gen. (MW)
2008	2,410	369	3,151	0	3,151
2009	2,529	750#	3,151	750	3,901
2010	2,711	0	3,100	750	3,850
2011	2,893	0	3,050	750	3,800
2012	3,075	123	3,122	750	3,872
2013	3,257	246	3,314	750	4,064
2014	3,439	246	3,506	750	4,256
2015	3,720	492	3,950	750	4,700
2016	4,001	369	4,270	750	5,020
2017	4,283	369	4,574	750	5,324
2018	4,564	373	4,877	750	5,627
2019	4,845	373	5,197	750	5,947
2020	5,321	619	5,745	750	6,495
2021	5,797	619	6,293	750	7,043
2022	6,273	619	6,835	750	7,585
2023	6,749	496	7,263	750	8,013
Total Generation Additions = 6,023 MW (including 750 MW from WEC)					

*The load forecast shown is for the high growth case.
# indicates the committed WEC/IPP/IWPP generations.

4.2 Reference Generation Plan for Isolated Systems

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 and Al-Oula 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).

Table 20 summarizes the addition required in generation for each of the above locations between the period 2008 to 2013, 2014 to 2018, and 2019 to 2023.

Table 20. Reference generation plan for the isolated systems.

Location	Operating Area	Generation Additions (MW)		
		2008-2013	2014-2018	2019-2023
Arar	EOA	112	84	28
Rafha	EOA	70	28	28
Qurayat	EOA	112	56	84
Al-Jawf	EOA	212	106	53
Juba	COA	150	120	90
Tabuk	WOA	159	159	265
Dhuba	WOA	90	0	60
Al-Oula	WOA	40	20	25
Sharourah	SOA	30	20	40
Farasan	SOA	0	20	5
Tathlith	SOA	6	8	10

4.3 Unified System Generation Plan for the Interconnected System

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. Additional interconnections are proposed in this project, namely, the West-Central and the West-South interconnections. The effect of GCC interconnection 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.

Table 21 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 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 21. Unified generation plan for eastern operating area (EOA).

Year	Load (MW)	Addition (MW)	Gen. EOA (MW)	Gen. IWPP/IPP* (MW)	Total Gen. (MW)
2008	10,440	1,250*	9,846	3,970	13,816
2009	10,953	1,850*	9,846	5,820	15,666
2010	11,287	2,500*	9,660	8,320	17,980
2011	11,808	0	9,489	8,320	17,809
2012	12,330	0	9,301	8,320	17,621
2013	12,851	0	9,118	8,320	17,438
2014	13,372	1,100*	8,944	9,420	18,364
2015	13,876	375	9,150	9,420	18,570
2016	14,380	600	9,566	9,420	18,986
2017	14,883	850	10,218	9,420	19,638
2018	15,387	725	10,746	9,420	20,166
2019	15,891	725	11,277	9,420	20,697
2020	16,346	600	11,662	9,420	21,082
2021	16,802	725	12,194	9,420	21,614
2022	17,257	725	12,683	9,420	22,103
2023	17,713	850	13,283	9,420	22,703
Total Generation Additions = 12,875 MW (including 6,700 MW from WEC/IPP)					

* indicates the committed WEC/IPP/IWPP generations

Table 22 illustrates the unified generation plan for the COA. The study has assumed that the interconnection between WOA and COA will come in operation in 2011. The generation plans for the years 2008 to 2010 are 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 22. Unified generation plan for central operating area (COA).

Year	Load (MW)	Addition (MW)	Gen. COA (MW)
2008	10,369	812	8,058
2009	10,879	464	8,522
2010	11,148	0	8,377
2011	11,662	232	8,469
2012	12,177	696	9,000
2013	12,692	696	9,517
2014	13,207	464	9,801
2015	13,704	696	10,311
2016	14,202	696	10,814
2017	14,699	696	11,303
2018	15,197	696	11,805
2019	15,694	696	12,315
2020	16,144	696	12,771
2021	16,594	696	13,267
2022	17,044	696	13,715
2023	17,494	696	14,161
Total Generation Additions = 9,628 MW			

Table 23 illustrates the unified generation plan for the western operating area. The study has assumed that the interconnection between WOA and COA will come in operation in 2011. The generation plans for the years 2008 to 2010 are 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 from the WOA system.

Table 23. Unified generation plan for the western operating area (WOA).

Year	Load (MW)	Addition (MW)	Gen. WOA (MW)	Gen. IWPP/IPP* (MW)	Total Gen. (MW)
2008	10,248	800#	8,987	2,766	11,753
2009	10,714	350#	8,987	3,116	12,103
2010	11,179	369	9,178	3,116	12,294
2011	11,660	400	9,409	3,116	12,525
2012	12,141	646	9,876	3,116	12,992
2013	12,621	646	10,344	3,116	13,460
2014	13,102	400	10,554	3,116	13,670
2015	13,567	646	11,023	3,116	14,139
2016	14,031	646	11,462	3,116	14,578
2017	14,496	769	12,020	3,116	15,136
2018	14,960	723	12,528	3,116	15,644
2019	15,425	723	13,044	3,116	16,160
2020	15,845	615	13,416	3,116	16,532
2021	16,265	723	13,926	3,116	17,042
2022	16,685	600	14,317	3,116	17,433
2023	17,105	600	14,793	3,116	17,909
Total Generation Additions = 9,656 MW (including 1,150 MW from WEC/IPP)					

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

# indicates the committed WEC/IPP/IWPP generations.

Table 24 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 24. Unified generation plan for the southern operating area (SOA).

Year	Load* (MW)	Addition (MW)	Gen. SOA (MW)	Gen. SWCC/IWPP (MW)	Total Gen. (MW)
2008	2,410	369	3,151	0	3,151
2009	2,529	750#	3,151	750	3,901
2010	2,711	0	3,100	750	3,850
2011	2,893	0	3,050	750	3,800
2012	3,075	123	3,122	750	3,872
2013	3,257	246	3,314	750	4,064
2014	3,439	0	3,260	750	4,010
2015	3,720	369	3,581	750	4,331
2016	4,001	369	3,901	750	4,651
2017	4,283	246	4,082	750	4,832
2018	4,564	373	4,385	750	5,135
2019	4,845	250	4,582	750	5,332
2020	5,321	619	5,130	750	5,880
2021	5,797	496	5,555	750	6,305
2022	6,273	619	6,097	750	6,847
2023	6,749	619	6,648	750	7,398
Total Generation Additions =5,448 MW (including 750 MW from WEC)					

The load forecast shown is for the high growth case.
# indicates the committed WEC/IPP/IWPP generations.

Table 25 shows the summary of the capacity requirements for the reference generation plan and the unified generation plan for the four operating areas. The capacity savings by adopting the unified generation plan are also indicated in the table. Thus, the EOA will save 1,000 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 is 3,158 MW. Moreover, there are a few delays in installation of generating units in the unified plan with relation to the reference plan. These delays will further augment the savings.

Table 25. Capacity requirements and savings.

Area	Reference Plan (MW)	Unified Plan (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
Isolated	2,289	2,289	-	-
Total	34,454	31,296	3,158	-

SECTION 5 CAPITAL INVESTMENT REQUIREMENTS

5.1 Reference Plan

The capital investment requirement for both the reference and the unified plans for each of the operating areas are calculated at 5% discount rate. Sensitivity analyses are also carried out for 3 and 10 percent discount rates with and without annual 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%.

Table 26 shows the cumulative capital investment requirements for the reference plan for each of the operating areas at different rates. The EOA requires an addition of 7,175 MW and this would require a total cumulative investment of MSR 9,111 at 5% discount rate. For the COA, the total generation addition is 10,556 MW and the total cumulative investment required is MSR 10,418 at 5% discount rate. For the WOA, the total generation addition is 9,121 MW and the total cumulative investment required is MSR 13,518 at 5% discount rate. Similarly, for the SOA, the total generation addition is 5,313 MW and the total cumulative investment required is MSR 6,342 at 5% discount rate. In case of the isolated areas, the total generation additions required is 2,289 MW. This would require a total capital investment of MSR 5,423 at 5% discount rate.

The total plant additions for the Kingdom's power systems are 34,454 MW. The cumulative present worth of capital investment for the Kingdom 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 26. 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 27 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 27. 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**

Table 28. Effect of unit capital costs 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**

The capital investment requirements for additional sensitivity scenarios for the reference plan are shown in Table 28. 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%. 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.

5.2 Unified Plan

Table 29 shows the cumulative capital investment requirements for the reference plan for each of the operating areas at different rates. The EOA requires an addition of 6,175 MW and this would require a total cumulative investment of MSR 7,964 at 5% discount rate. For the COA, the total generation addition is 9,628 MW and the total cumulative investment required is MSR 9,389 at 5% discount rate. For the WOA, the total generation addition is 8,506 MW and the total cumulative investment required is MSR 12,828 at 5% discount rate. Similarly, for the SOA, the total generation addition is 4,698 MW and the total cumulative investment required is MSR 5,742 at 5% discount rate.

The total plant additions for the Kingdom's 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 29. 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 30 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 30. 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**

The capital investment requirements for additional sensitivity scenarios for the unified plan are shown in Table 31. 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%. 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 31. 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**

5.3 Transmission Investment Requirements

The PW cumulative capital investments for all the interconnection links are shown in Table 32 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 32. 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**

SECTION 6 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.