

UPDATED GENERATION PLANNING FOR THE SAUDI ELECTRICITY SECTOR

EXECUTIVE SUMMARY AND RECOMMENDATIONS

Prepared for

Electricity & Cogeneration Regulatory Authority (ECRA)

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INTRODUCTION

This is the executive summary of the 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 being conducted by a project team from the King Fahd University of Petroleum & Minerals (KFUPM), Dhahran, Saudi Arabia.

The purpose of this study is 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 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 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.

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 Producer (IPP) and Electricity and Cogeneration Regulatory Authority (ECRA).

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.

Study Horizon Year

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

Planning Year

The planning year is 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 is used.

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 E1.

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 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.

Table E1. 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

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.

Forced Outage Rates

The (equivalent) forced outage rates (EFOR) used in the study is shown in Table E2 for various classes of generating units in different regions of the Kingdom.

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 E2 illustrates the maintenance schedule for various plant types for different regions of the Kingdom.

Table E2. 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 |

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 E3 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 E3. 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 |

Cash Flows for Generation Expansion

Table E4 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.

Service Life of Generating Unit

The service or economic operating lives of new generating units are as shown in Table E4. 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 E4. 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

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 $\pm 10\%$ and $\pm 20\%$ has also been studied.

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 E5 shows the interconnection year and the link capacity between different operating areas.

Table E5. Interconnecting link with capacity and year of interconnection.

| Interconnecting Link | Year | Link Capacity (MW) | Sub-Station | Remarks |
|----------------------|------|--------------------|--------------------------------------|-------------------------------|
| EOA - COA | 2013 | 4,500 | Not determined | 380 kV Double Circuit AC line |
| 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 SWCC and IWPP generating plants would be added. Table E6 illustrates the future generating capacities of SWCC and IWPP plants. Moreover, a number of IPP plants are also in construction phase. Table E7 shows the list of IPP and their capacities.

Table E6. SWCC/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 E7. 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 |

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.

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 E8 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 E8. 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 E9 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 E9. 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 E10 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 E10. 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 E11 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 E11. 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 E12 to E14 summarizes the peak load forecast for the isolated areas. Table E12 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 E13. Table E14 shows the peak load demand for the area under SOA.

Table E12. 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 E13. 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 E14. 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 E15 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 E15. 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 |

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.

Reference Generation Plan for Interconnected System

Table E16 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/SWCC 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 E16. 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 SWCC/IPP) | | | | | |

* indicates the committed SWCC/IPP/IWPP generations

For the COA (refer Table E17), 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 E17. 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 E18 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/SWCC 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 E19) 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 SWCC 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 E18. 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 SWCC/IPP/IWPP generations.

Table E19. Reference Generation Plan for the Southern Operating Area (SOA).

| Year | Load* (MW) | Addition (MW) | Gen. SOA (MW) | Gen. SWCC/IWP P (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 SWCC) | | | | | |

The load forecast shown is for the high growth case.

indicates the committed SWCC/IPP/IWPP generations.

Reference Generation Plan for Isolated Systems

The isolated load centers referred 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 E20 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 E20. 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 |

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.

Table E21 illustrates the unified generation plan for the EOA. The study has assumed that an additional interconnection line between EOA and COA in 2013. The generation plans for the years 2008 to 2012 are the same as that of the reference generation plan. The plan indicates that during the study horizon (2008 to 2023), a total of 13,000 MW are required to meet the demand adequately in EOA. Out of the total requirement 6,700 MW would be supplied by the IWPP/SWCC cogeneration plants. The remaining 6,300 MW are further required for addition. This will include 8 units of 600 MW steam turbine and 12 units of 125 MW gas turbines. During the same period 2,738 MW will be retired from the EOA system.

Table E21. Unified Generation Plan for Eastern Operating Area (EOA).

| Year | Load (MW) | Addition (MW) | Gen. EOA (MW) | Gen. SWCC/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 | 0 | 9,743 | 8,320 | 18,063 |
| 2014 | 13,372 | 1,100* | 9,569 | 9,420 | 18,989 |
| 2015 | 13,876 | 0 | 9,400 | 9,420 | 18,820 |
| 2016 | 14,380 | 600 | 9,816 | 9,420 | 19,236 |
| 2017 | 14,883 | 725 | 10,343 | 9,420 | 19,763 |
| 2018 | 15,387 | 600 | 10,746 | 9,420 | 20,166 |
| 2019 | 15,891 | 850 | 11,402 | 9,420 | 20,822 |
| 2020 | 16,346 | 725 | 11,912 | 9,420 | 21,332 |
| 2021 | 16,802 | 600 | 12,319 | 9,420 | 21,739 |
| 2022 | 17,257 | 725 | 12,808 | 9,420 | 22,228 |
| 2023 | 17,713 | 850 | 13,408 | 9,420 | 22,828 |
| Total Generation Additions = 13,000 MW (including 6,700 MW from SWCC/IPP) | | | | | |

* indicates the committed SWCC/IPP/IWPP generations

Table E22 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 E22. 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 | 464 | 9,285 |
| 2014 | 13,207 | 696 | 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 E23 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 9,533 MW are required to meet the demand adequately in WOA. Out of the total requirement 1,150 MW would be supplied by the IPP/SWCC plants. The remaining 8,383 MW are further required for addition. This will include 7 units of 400 MW and 5 units of 600 MW of steam units and 21 units of 123 MW gas turbines. During the same period 2,700 MW will be retired from the WOA system.

Table E23. 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 | 246 | 9,944 | 3,116 | 13,060 |
| 2014 | 13,102 | 646 | 10,400 | 3,116 | 13,516 |
| 2015 | 13,567 | 646 | 10,869 | 3,116 | 13,985 |
| 2016 | 14,031 | 646 | 11,308 | 3,116 | 14,424 |
| 2017 | 14,496 | 800 | 11,897 | 3,116 | 15,013 |
| 2018 | 14,960 | 846 | 12,528 | 3,116 | 15,644 |
| 2019 | 15,425 | 600 | 12,921 | 3,116 | 16,037 |
| 2020 | 15,845 | 738 | 13,416 | 3,116 | 16,532 |
| 2021 | 16,265 | 600 | 13,803 | 3,116 | 16,919 |
| 2022 | 16,685 | 600 | 14,194 | 3,116 | 17,310 |
| 2023 | 17,105 | 600 | 14,194 | 3,116 | 17,310 |

* Including Existing Transfer from SWCC 1,800 MW and Marafiq, Yanbu generation.
 Load includes Marafiq, Yanbu load.
 # indicates the committed SWCC/IPP/IWPP generations.

Table E24 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 5,325 MW are required to meet the demand adequately in the SOA. Out of the total requirement, 750 MW would be supplied by the SWCC plants. The remaining 4,575 MW are further required for addition. This will include 6 units of 250 MW of steam units and 25 units of 123 MW gas turbines. During the same period 832 MW will be retired from the SOA system.

Table E24. Unified Generation Plan for the Southern Operating Area (SOA).

| Year | Load* (MW) | Addition (MW) | Gen. SOA (MW) | Gen. SWCC/IWP P (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 | 0 | 3,212 | 750 | 3,962 |
| 2016 | 4,001 | 369 | 3,532 | 750 | 4,282 |
| 2017 | 4,283 | 369 | 3,836 | 750 | 4,586 |
| 2018 | 4,564 | 373 | 4,139 | 750 | 4,889 |
| 2019 | 4,845 | 373 | 4,459 | 750 | 5,209 |
| 2020 | 5,321 | 496 | 4,884 | 750 | 5,634 |
| 2021 | 5,797 | 619 | 5,432 | 750 | 6,182 |
| 2022 | 6,273 | 619 | 5,974 | 750 | 6,724 |
| 2023 | 6,749 | 619 | 6,525 | 750 | 7,275 |
| Total Generation Additions =5,325 MW (including 750 MW from SWCC) | | | | | |

The load forecast shown is for the high growth case.

indicates the committed SWCC/IPP/IWPP generations.

Table E25 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 875 MW or 7 GT units of 125 MW capacity, the COA will save 928 MW or 8 GT units of 116 MW capacity, the WOA will save 738 MW or 6 GT units of 123 MW capacity, and the SOA will also save 738 MW or 6 GT units of 123 MW capacity. The overall saving for the four operating areas is 3,279 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 E25. Capacity requirements and savings.

| Area | Reference Plan (MW) | Unified Plan (MW) | Savings (MW) | Remarks |
|----------|---------------------|-------------------|--------------|---------|
| EOA | 7,175 | 6,300 | 875 | 7x125GT |
| COA | 10,556 | 9,628 | 928 | 8X116GT |
| WOA | 9,121 | 8,383 | 738 | 6X123GT |
| SOA | 5,313 | 4,575 | 738 | 6X123GT |
| Isolated | 2,289 | 2,289 | - | - |
| Total | 34,454 | 31,175 | 3,279 | - |

CAPITAL INVESTMENT REQUIREMENTS

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 $\pm 20\%$.

Table E26 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 E26. 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 E27 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 E27. 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 E28. 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 E28. 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.

Unified Plan

Table E29 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 6,300 MW and this would require a total cumulative investment of MSR 8,226 at 5% discount rate. For the COA, the total generation addition is 9,628 MW and the total cumulative investment required is MSR 9,377 at 5% discount rate. For the WOA, the total generation addition is 8,383 MW and the total cumulative investment required is MSR 12,603 at 5% discount rate. Similarly, for the SOA, the total generation addition is 4,575 MW and the total cumulative investment required is MSR 5,582 at 5% discount rate.

The total plant additions for the Kingdom's power systems are 31,175 MW. The cumulative present worth of capital investment to January, 2005 at the base discount rate of 5 percent is MSR 41,210. When the discount rate is changed to 3 percent, the investments change to MSR 50,874. The corresponding figures for a 10 percent discount rate are MSR 25,451.

Table E29. 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 | 6,300 | 10,472 | 8,226 | 4,667 |
| Central Operating Area | 9,628 | 11,379 | 9,377 | 6,066 |
| Western Operating Area | 8,383 | 15,432 | 12,603 | 7,891 |
| Southern Operating Area | 4,575 | 7,120 | 5,582 | 3,184 |
| Isolated Systems | 2,289 | 6,471 | 5,423 | 3,644 |
| TOTAL | 31,175 | 50,874 | 41,210 | 25,451 |

Table E30 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 57,120. When the discount rate is changed to 3 percent, the investments change to MSR 71,213. The corresponding figures for a 10 percent discount rate are MSR 34,411.

Table E30. 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 | 6,300 | 15,287 | 11,939 | 6,671 |
| Central Operating Area | 9,628 | 15,559 | 12,667 | 7,957 |
| Western Operating Area | 8,383 | 21,284 | 17,242 | 10,587 |
| Southern Operating Area | 4,575 | 10,468 | 8,135 | 4,527 |
| Isolated Systems | 2,289 | 8,615 | 7,137 | 4,669 |
| TOTAL | 31,175 | 71,213 | 57,120 | 34,411 |

The capital investment requirements for additional sensitivity scenarios for the unified plan are shown in Table E31. 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 45,331 and MSR 49,452 respectively at 5% discount rate. In case of decrease of the unit capital cost by 10% and 20% the requirement is MSR 37,089 and MSR 32,968 respectively. The table also gives the figures at 3 and 10% discount rates.

Table E31. 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 | 6,300 | 11,519 | 9,049 | 5,133 | 12,566 | 9,872 | 5,600 | 9,424 | 7,404 | 4,200 | 8,377 | 6,581 | 3,733 |
| COA | 9,628 | 12,517 | 10,314 | 6,672 | 13,655 | 11,252 | 7,279 | 10,242 | 8,439 | 5,459 | 9,104 | 7,501 | 4,853 |
| WOA | 8,383 | 16,975 | 13,863 | 8,680 | 18,518 | 15,123 | 9,469 | 13,889 | 11,342 | 7,102 | 12,346 | 10,082 | 6,312 |
| SOA | 4,575 | 7,832 | 6,140 | 3,502 | 8,544 | 6,698 | 3,820 | 6,408 | 5,024 | 2,865 | 5,696 | 4,465 | 2,547 |
| 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 | 31,175 | 55,961 | 45,331 | 27,996 | 61,049 | 49,452 | 30,541 | 45,787 | 37,089 | 22,906 | 40,699 | 32,968 | 20,361 |

Transmission Investment Requirements

The PW cumulative capital investments for all the interconnection links are shown in Table E32 for a discount rate of 5 percent. The table shows that the cumulative present worth total investments is Million Saudi Riyals (MSR) 3,019. The cost includes the line cost, converter station costs for the HVDC line and the modification cost for the interconnecting sub-stations.

Table E32. Interconnection Cost Estimates (Unified Plan).

| Link | Year | Link Capacity (MW) | PW Cost Estimate (MSR) |
|--------------------|-------------|---------------------------|-------------------------------|
| EOA – COA | 2013 | 1,000 | 646 |
| WOA – COA | 2011 | 1,400 | 1,940 |
| WOA - SOA | 2014 | 800 | 433 |
| Total (MSR) | | | 3,019 |

RECOMMENDATIONS

The following recommendations are observed:

- There is a need to perform a 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 the availability and type of fuel throughout the Kingdom regions.

- The generation locations are dictated by transmission studies. A detailed transmission study should be undertaken.
- The impact of the GCC interconnection on the Saudi Electric Sector should also be evaluated.
- There is a need for economic energy interchange study.