

**ELECTRIC ENERGY PRODUCTION COSTING FOR
THE SAUDI ELECTRICITY SECTOR (PHASE-I)**

EXECUTIVE SUMMARY AND RECOMMENDATIONS

Prepared for
**Electricity and Co-Generation Regulatory Authority
(ECRA)**
Riyadh, Saudi Arabia

**Shawwal 1425 H
November 2004 G**

EXECUTIVE SUMMARY

This is the final report of the study entitled *Electric Energy Production Costing for the Saudi Electricity Sector*, which started on September 1, 2003 for duration of 12 working months. It is carried out for the Electricity and Co-generation Regulatory Authority (ECRA), Riyadh, Saudi Arabia. The study was conducted by a project team from the Center for Engineering Research of the Research Institute and the Electrical Engineering Department of King Fahd University of Petroleum & Minerals, Dhahran, Saudi Arabia.

The main objective of this study was to determine and evaluate the electric energy production cost for each generating unit in the electric system of Saudi Arabia. These include the generating units in the power stations of Saudi Electricity Company (SEC), Saline Water Conversion Corporation (SWCC), Saudi Aramco and the Power and Water Utility Company known as MARAFIQ. The results of the study will show the realistic economic merit of each generating unit and plant in the national electric grid system of Saudi Arabia. Moreover, it will also provide a summary of the cost of producing electric energy for all generating units in the Kingdom's power system.

This is the final report of the study. It consists of eight sections which describe the data collection and analysis, the study methodology, the results, the conclusions, and recommendations. In addition, the report includes a number of technical appendices.

A questionnaire reflecting the required information for the generating units was designed and sent to the concerned organizations. The required information included the major production cost components, such as fuel type and cost, operation and maintenance (O & M) costs, commissioning date, lifetime, heat rate, capital cost, etc., of every generating unit. A thorough review of the data received from the relevant organizations was done. Issues pertaining to a number of critical missing data, and clarifications on some of the data provided were raised and resolved with the concerned organizations. Suitable assumptions were made for the data that were not available.

Generation studies are conducted over a number of years reflecting plant life time. The cost components include the capital, fixed O & M, variable O & M and the fuel intake. The generating units in the Kingdom use several types of fuel: natural gas, crude oil, heavy fuel oil (HFO), and diesel oil. The base fuel prices, considered in the study, were based on the data provided by SEC. Transportation costs were then added for the liquid fuel to reflect regional diversities. Calculations were carried out to determine the levelized cost of producing per kWh of electric energy at a number of assumed capacity factors. All calculations were levelized to the year 2004.

One of the main objectives of this study is to rank the generating units in the electric power stations based on cost of production in addition to unit operating conditions and in accordance with developed performance indicators. The purpose of this ranking is to provide ECRA with enough information and data that can be used for power plant evaluation and performance assessment. The generating units were grouped and presented by technology type. The Steam Turbines, operated by SEC, were grouped separately from the Combined Cycle and Gas Turbines. Also the Diesel

units were placed in a separate group. Moreover, the isolated power plants were assembled in a separate group. Generating units operated by SWCC, MARAFIQ, and Saudi Aramco were grouped and ranked separately.

Performance indicators were calculated for each generating unit. The indicators adopted in this study represent typical indicators used by some international utilities. These indicators are: Utilization index (UI), Equivalent forced outage rate (EFOR), Fuel cost per unit (Hal/kWh) (FC), Total production cost (TPC), and Ageing Factor (AF). A weighted score is then determined. The weights were determined by the study team based on their experience and expertise. They are on scale of 1 to 10 and reflect the relative importance of the performance indicators. Generating units of low performance indicators and highest weighted sum are ranked the highest. The units were ranked in descending merit order. The objective of the ranking is to enable the decision maker to group the various types of units and plants into groups of approximately similar performance levels. This grouping may later be used as the basis for forming competitive electric generation companies of equal capabilities.

A major task of the study was to provide an overview of some international experiences in restructuring and/or privatizing the electric sector. The aim of this overview is to provide an insight into the process of privatization and to highlight some of the criteria and factors considered in assessing and evaluating the existing infrastructures. The information cited in this section was collected by the project team through questionnaires, visits, meetings, and other means. The review process has ascertained that the restructuring format is country and system specific, and the generation unbundling appears the most common feature. There are different forms of competition in distribution. Transmission is usually operated as a national grid. Large customers in many cases can contract directly with producers, and those customers' tariff is regulated in different forms. Moreover, each of the countries surveyed has different set of indicators to measure and gauge the performance of the power plants. They range from forced outage rate, total cost/unit, fuel cost/unit, reduction of planned outage duration, employee satisfaction index, and variance in capital utilization.

Table E1 to E6 shows the ranking of SEC owned generation on a power plant basis. All the units of the same type (such as ST, CC, GT, DE) at one location are combined. The cost of production reflects the average for that power plant and also the average weighted score is the average for all the units within that power plant. Table E1 summarizes the results for all the Steam Turbines which are in the eastern and the western regions. Table E2 gives the results for the combined cycle units that are only at Riyadh PP9 and Rabigh. The production cost is calculated at a capacity factor of 70%. Similarly, the results for the Gas Turbines for the SEC interconnected system are shown in Table E3. The results for the diesel units in the interconnected system are shown in Table E4. They are all in the southern region branch of SEC. Results and the ranking for the Gas Turbines for the isolated system of SEC are shown in Table E5 while the diesel units at Tabuk I and Al-Wajh are shown in Table E6. The production cost is calculated at a capacity factor of 40% for all the GT and the DE

The detailed generating unit performance indicators are presented in the Main Report.

Table E1. Ranking of SEC steam turbine power plants.

Plant Name	No. of units	Total Plant Capacity (MW)	Fuel Type	Average Levelized Cost of Production (Hal/kWh)	Average Weighted Score	Rank
Ghazlan-II	4	2528	Natural Gas	5.59	257.26	1
Sha'iba	5	1965	Heavy Fuel Oil	6.90	209.82	2
Qurayyah	4	2500	Natural Gas	4.70	189.29	3
Rabigh A ST	6	1572	Heavy Fuel Oil	6.50	167.45	4
Ghazlan-I	4	1600	Natural Gas	5.73	161.44	5

Table E2. Ranking of SEC combine cycle power plants.

Plant Name	No. of units	Total Plant Capacity (MW)	Fuel Type	Average Levelized Cost of Production (Hal/kWh)	Average Weighted Score	Rank
PP 9	4	1417.4	Natural Gas	9.41	284.48	1
Rabigh A	3	1090.6	Crude	6.97	195.96	2

Table E3. Ranking of SEC gas turbine power plants.

Plant Name	No. of units	Total Plant Capacity (MW)	Fuel Type	Average Levelized Cost of Production (Hal/kWh)	Average Weighted Score	Rank
Madinah 2B	4	224.0	Diesel	7.03	183.28	1
Jizan CPS	19	677.0	Diesel	7.59	169.86	2
Faras	13	803.3	Natural Gas	7.59	161.16	3
Asir CPS	8	433.0	Diesel	8.59	158.07	4
PP 8	30	1588.3	Natural Gas	9.16	157.52	5
Tihama CPS	9	482.0	CR/DI	9.26	155.08	6
PP 7	22	1112.7	Natural Gas	9.05	149.60	7
Makkah C	11	555.1	Diesel	8.12	149.38	8
Qassim PP3	15	761.3	Diesel	9.72	148.96	9
Jeddah-PP3B	16	827.2	Crude	8.22	147.91	10
Shedgum	17	1068.7	Natural Gas	8.81	144.49	11
PP 4X	7	215.2	Diesel	9.51	143.67	12
Qaisumah	6	123.4	Diesel	10.58	140.06	13
Jeddah-PP3A	11	490.6	Diesel	8.92	139.00	14
Berri	3	170.9	Natural Gas	8.45	138.89	15
Uthmaniyah	8	283.9	Natural Gas	8.25	138.84	16
Hail 2	5	302.1	Diesel	10.96	138.24	17
Juaymah	3	90.6	Natural Gas	9.83	135.65	18
Makkah B	4	161.2	Diesel	9.47	134.85	19
Madinah 2A	3	60.0	Diesel	9.73	133.97	20
Hail 1	4	43.0	Diesel	10.21	131.74	21
PP 5	12	538.2	Crude	10.42	131.41	22
Najran CPS	8	267.0	Crude	9.69	131.21	23
Bisha CPS	4	144.0	Diesel	10.19	127.70	24
PP 4	4	90.3	Diesel	11.21	127.22	25
Buraydah	5	89.3	Diesel	14.15	126.34	26
Madinah1	2	34.0	Diesel	10.68	124.47	27
Biesh P/S	3	24.0	Diesel	11.75	120.38	28
Makkah A	3	62.0	Diesel	10.41	117.95	29
Yanbu	3	54.5	Diesel	12.32	116.98	30
Safaniyah	2	62.6	Natural Gas	11.34	112.78	31
Layla	6	81.1	Crude	14.95	112.31	32
Jeddah-PP2	5	116.0	Diesel	11.16	111.92	33
Taif	6	115.8	Diesel	12.40	108.42	34
Baha CPS	3	24.0	Diesel	14.44	107.28	35
Dammam	17	614.7	Natural Gas	14.69	106.95	36
PP 3	5	85.0	Diesel	11.41	106.64	37

Table E4. Ranking of SEC diesel engine power plants.

Plant Name	No. of units	Total Plant Capacity (MW)	Fuel Type	Average Levelized Cost of Production (Hal/kWh)	Average Weighted Score	Rank
Jizan CPS-DE	6	24.0	Diesel	15.24	206.62	1
Smatah P/S	6	18.0	Diesel	9.15	187.60	2
Sharourah P/S	19	72.1	Diesel	12.00	184.86	3
Asir CPS-DE	9	76.5	Diesel	10.60	165.74	4
Baha CPS	7	55.3	Diesel	12.26	152.45	5

Table E5. Ranking of SEC-isolated system power plants (GT only).

Plant Name	No. of units	Total Plant Capacity (MW)	Fuel Type	Average Levelized Cost of Production (Hal/kWh)	Average Weighted Score	Rank
Al Wajh	2	36.0	Diesel	13.89	164.50	1
Tabuk II	6	260.7	Diesel	11.59	157.20	2
Qurayat	5	81.0	Diesel	11.16	146.27	3
Juba	9	202.7	Crude/DI	12.27	145.52	4
Tabuk I	4	67.8	Diesel	11.69	144.38	5
Tabarjal	4	67.0	Diesel	18.49	143.04	6
Arar	8	110.2	Diesel	11.21	142.95	7
Dhuba	6	111.0	Diesel	14.82	128.49	8
Jawf	7	157.5	Crude	12.89	122.46	9

Table E6. Ranking of SEC-isolated system power plants (DE only).

Plant Name	No. of units	Total Plant Capacity (MW)	Fuel Type	Average Levelized Cost of Production (Hal/kWh)	Average Weighted Score	Rank
Al Wajh DE	10	30.0	Diesel	14.11	146.89	1
Tabuk I DE	6	34.2	Diesel	16.01	141.65	2

Tables E7 to E12 shows the ranking of SEC owned generation on a power plant basis excluding the capital cost of the generating units. This will allow a fair comparison without being influenced by the capital cost components. It will provide a good comparison on the operation of the units.

Table E7. Ranking of SEC steam turbine power plants, excluding capital cost.

Plant Name	No. of units	Total Plant Capacity (MW)	Fuel Type	Average Levelized Cost of Production (Hal/kWh)	Average Weighted Score	Rank
Ghazlan-II	4	2528	Natural Gas	4.11	271.28	1
Sha'iba	5	1965	Heavy Fuel Oil	5.74	212.96	2
Qurayyah	4	2500	Natural Gas	4.28	186.40	3
Rabigh A ST	6	1572	Heavy Fuel Oil	4.97	176.63	4
Ghazlan-I	4	1600	Natural Gas	4.84	164.17	5

Table E8. Ranking of SEC combine cycle power plants, excluding capital cost.

Plant Name	No. of units	Total Plant Capacity (MW)	Fuel Type	Average Levelized Cost of Production (Hal/kWh)	Average Weighted Score	Rank
PP 9	4	1417.4	Natural Gas	4.76	307.31	1
Rabigh A	3	1090.6	Crude	4.90	194.33	2

Table E9. Ranking of SEC gas turbine power plants, excluding capital cost.

Plant Name	No. of units	Total Plant Capacity (MW)	Fuel Type	Average Levelized Cost of Production (Hal/kWh)	Average Weighted Score	Rank
Madinah 2B	4	224.0	DI	6.26	177.80	1
PP 8	30	1588.3	NG	5.87	176.19	2
Jizan CPS	19	677.0	DI	5.85	175.67	3
Asir CPS	8	433.0	DI	6.16	168.78	4
PP 7	22	1112.7	NG	5.86	167.73	5
Faras	13	803.3	NG	5.92	165.77	6
Qassim PP3	15	761.3	Crude	6.49	163.71	7
Tihama CPS	9	482.0	CR/DI	6.88	162.41	8
PP 4X	7	215.2	Diesel	6.50	157.13	9
Qaisumah	6	123.4	Diesel	6.77	155.61	10
Makkah C	11	555.1	DI	6.31	154.55	11
PP 5	12	538.2	Crude	6.49	150.17	12
Jeddah-PP3B	16	827.2	CR	6.75	148.77	13
Shedgum	17	1068.7	NG	7.01	147.42	14
Hail 2	5	302.1	Diesel	7.80	147.29	15
Makkah B	4	161.2	DI	6.60	146.84	16
Berri	3	170.9	NG	6.47	144.86	17
Biesh P/S	3	24.0	DI	6.56	144.73	18
PP 4	4	90.3	Diesel	7.01	144.48	19
Jeddah-PP3A	11	490.6	DI	6.90	144.01	20
Juaymah	3	90.6	NG	7.39	141.74	21
Uthmaniyah	8	283.9	NG	6.68	140.83	22
Madinah 2A	3	60.0	DI	7.46	139.09	23
Hail 1	4	43.0	Diesel	7.67	138.04	24
Najran CPS	8	267.0	CR	7.45	136.11	25
Bisha CPS	4	144.0	DI	7.66	134.00	26
Buraydah	5	89.3	Diesel	10.50	131.40	27
Madinah1	2	34.0	DI	7.93	131.20	28
Layla	6	81.1	Crude	8.85	128.14	29
Baha CPS	3	24.0	DI	9.31	119.03	30
Makkah A	3	62.0	DI	8.52	118.94	31
Yanbu	3	54.5	DI	10.19	117.34	32
PP 3	5	85.0	Diesel	8.43	113.10	33
Safaniyah	2	62.6	NG	9.40	112.98	34
Jeddah-PP2	5	116.0	DI	9.69	109.70	35
Taif	6	115.8	DI	10.49	107.61	36
Dammam	17	614.7	NG	12.73	105.44	37

Table E10. Ranking of SEC diesel engine power plants, excluding capital cost.

Plant Name	No. of units	Total Plant Capacity (MW)	Fuel Type	Average Levelized Cost of Production (Hal/kWh)	Average Weighted Score	Rank
Jizan CPS-DE	6	24.0	DI	4.60	257.22	1
Asir CPS-DE	9	76.5	DI	4.65	199.98	2
Smatah P/S	6	18.0	DI	5.20	194.30	3
Sharourah P/S	19	72.1	DI	7.32	192.59	4
Baha CPS	7	55.3	DI	7.38	161.29	5

Table E11. Ranking of SEC-isolated system power plants (GT only), excluding capital cost.

Plant Name	No. of units	Total Plant Capacity (MW)	Fuel Type	Average Levelized Cost of Production (Hal/kWh)	Average Weighted Score	Rank
Al Wajh	2	36.0	Diesel	11.64	153.48	1
Tabuk II	6	260.7	Diesel	8.59	150.14	2
Arar	8	110.2	Diesel	7.15	143.59	3
Juba	9	202.7	Crude/DI	8.91	140.94	4
Qurayat	5	81.0	Diesel	8.33	138.00	5
Tabuk I	4	67.8	Diesel	8.87	136.17	6
Tabarjal	4	67.0	Diesel	14.79	135.92	7
Dhuba	6	111.0	Diesel	12.00	119.45	8
Jawf	7	157.5	Crude	10.64	111.24	9

Table E12. Ranking of SEC-isolated system power plants (DE only), excluding capital cost.

Plant Name	No. of units	Total Plant Capacity (MW)	Fuel Type	Average Levelized Cost of Production (Hal/kWh)	Average Weighted Score	Rank
Al Wajh DE	10	30.0	Diesel	7.77	156.90	1
Tabuk I DE	6	34.2	Diesel	9.67	145.36	2

RECOMMENDATIONS

- The generating units in the SEC system may be grouped into at least three groups of similar performance based on the ranking system adopted in this study. The type of technology, fuel, and geographical location shall be taken into consideration.
- The SWCC system shall be treated separately. Its major objective, performance, and location shall be considered and its impact on other generation entities shall be taken into account.
- The power plants owned by other utilities such as Saudi Aramco, MARAFIQ etc. may remain under the jurisdiction of the present owners for the foreseeable future.
- The fuel cost is a major portion of the electric energy total production cost. Its cost shall be considered as a pass-through in any future pricing of electricity and the tariff structure.
- There is a definite need for preparing a new master plan for electricity and desalinated water covering the needs of the Kingdom of Saudi Arabia over the coming 25 years. The plan shall also take into account the restructuring process that has been taking place in the Kingdom since 1998 in both sectors: water desalination and electricity generation and transmission. It shall also take into account the recent major developments in the Natural Gas production and its impact on fuel supply.