

ELECTRICITY DEMAND FORECAST AND OTHER SOURCES OF ENERGY IN SAUDI ARABIA

**A Thesis submitted in partial of fulfillment of the
requirements for the**

**DEGREE OF
MASTER OF BUSINESS ADMINISTRATION**

**University of Bahrain
College of Business Administration
Sakhir Campus
Bahrain**

**Submitted By
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JUNE 2000

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DECLARATION

I declare that this work is the result of my own investigation and that it has not been accepted in substance for any degree, nor is it currently being submitted for any degree.

SAAD A. AL-RASHID

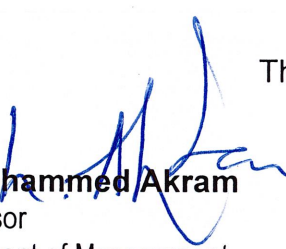
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ELECTRICITY DEMAND FORECAST AND OTHER SOURCES OF ENERGY IN SAUDI ARABIA

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ACKNOWLEDGEMENT

I would like to express my profound gratitude and respect to my
Project Director, Dr. Mohammad Akram, for his support,
encouragement and for his stimulating ideas and discussions.

Special appreciation to

Dr. Eggert Peterson and Dr. Zafar Kayani

For their efforts and valuable comments.

ABSTRACT

Electric power has become a vital factor in modern living. Without it, life would have been much different.

In spite of all the developments and the comforts mankind has derived from the use of electricity, today, the industry faces tremendous challenges.

In some countries, it is the challenge of load growth. In others, it is the challenge of de-regulation and competition. The market forces companies to reduce costs while maintaining a reliable and quality power supply.

In order to meet the rapid growth of population and the increasing demand by industrial sector, Saudi Arabia crossed the bridge to the new millennium by diversifying its economy through the development of non-oil based industries.

Our focus in this study is to deal with the challenge of rapid load growth and to highlight other alternative sources of energy. The study also covers Saudi Arabia's 20-year forecasts for electricity demands.

We will begin our study with a preview of the establishment of the Kingdom of Saudi Arabia and its unique geographical structure. Its population and climate differs from region to region. Economic development and the development of electric companies also differ, hence the necessity to provide comparative regional analysis about their respective generating capabilities, sales, and number of customers. Highlights in the form of literature information about energy in general. It underlines the importance of energy and the means to produce it. It is therefore essential for any decision maker to have not only historical data at hand for forecasting but also to understand alternatives for short and long term electricity generation.

Examines the methodology to be used to forecast electricity demand. I conducted similar study for post-graduation project where I used simple model for analyzing demand of electricity in Saudi Arabia and generating long-term forecasts. This study, which was based on univariate analysis, generated reasonable forecasts, but not optimum as were anticipated.

For this purpose, Multiple Regression model will be used to forecast the 20-year electricity demand requirement of Saudi Arabia.

For computation purpose, Microsoft Excel, statistics and other statistical software were used for correlation and regression analysis, and generating forecasts along with the residuals. From these residuals, Mean Square Error, Mean Absolute Error and other yardsticks to measure accuracy of forecasts are computed and validity of models is determined.

Finally presents data analysis of our forecast, and provides the conclusion and the recommendations of our electricity forecast in the Kingdom of Saudi Arabia.

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Chapter 1
**HISTORICAL BRIEF ABOUT THE DEVELOPMENT
OF SAUDI ARABIA**

1.0 HISTORICAL BACKGROUND

Before the establishment of Saudi Arabia, there were nomad tribes that travelled from one area to another in search for water and grasslands for their herds. Others were settlers in small cities like Makkah and Madinat Al-Monawarh, living in small houses built from clay.

Either in the desert or cities, life was harsh and difficult. There were times when the temperature was very hot in the daytime and extremely cold at night.

When Saudi Arabia became a united nation, King Abdulaziz recognized the necessity of electrification to advance and promote Saudi Arabia's social and industrial development.

1.1 LOCATION

The Kingdom of Saudi Arabia lies at the crossroads of three continents: Asia, Africa and Europe. It forms part of western Asia, opposite of East Africa, and is separated from the latter only by the Red Sea. It has close links with Europe, via the Mediterranean, and the Atlantic via Gibraltar. Its unique location has allowed it to play a major role in world affairs since ancient times. It was a transit point for peoples migrating Eastwards, Westwards or Northwards. The meeting of cultures, which resulted from Saudi Arabia's location, has

had a major impact on the regions surrounding the Arabian Peninsula, particularly in the dissemination of Islam.

Saudi Arabia covers 80% of the total area of the peninsula. Its northernmost point, Ras Al-Sheikh Humeid, is 34° east of Greenwich, and its Southeastern border is 56° East. It spans 16° of latitude from the point where it meets with Jordan in the north to its Southernmost point.

The location of Saudi Arabia, and its climate, has affected how its population is distributed, the diversity of its geography, and its agriculture. The Arabian Gulf to the east, and the Red Sea to the west, has influenced in the lives and movements of the people of Saudi Arabia throughout its history.

1.2 AREA

The Kingdom of Saudi Arabia occupies about four-fifths of the Arab Peninsula, with a total area of over 2,250,000 square kilometres.

1.3 GEOGRAPHICAL FEATURES

Because of its large area, the Kingdom has varied topographical structure. Along the Red Sea lies Tihama coastal plain. It is 1,100 kilometers long, 60 kilometers wide in the South, and gradually narrows to the North until it reaches the Aqaba Gulf. To the East of this plain lies a chain of mountains called Sarawat. These mountains rise to 9,000 feet in the South and gradually fall to 3,000 feet in the North. Several large valleys slope Eastward and Westward from Sarawat such as Najran Valley, Tathleeth Valley, Bisha Valley, Himdh Valley, Rumah Valley, Yanbu Valley and Fatima Valley. To the East

of the chain stands the Najd Plateau which extends Eastward to Samman Desert and Dahnaa Dunes and Southward to a region penetrated by Wadi Al-Dawaser and bordered by the Empty Quarter. The Plateau stretches Northward to Najd Plains, passing through Hael until combining with the Great Nefud Desert, then to the borders of Iraq and Jordan. There are also some mountains in this plateau such as Tawabek Mountains, Al-Aradh, Aja and Salmah. The Empty Quarter, the Southeastern part of the Kingdom, occupies an estimated area of 640,000 square kilometers composed of sandhills and lava fields. The Eastern coastal plain is 620 kilometers long and consists of large sand areas.

1.4 POPULATION

Preliminary results of the population census taken on 01/04/1413 showed a total population of 16,929,294. The current density of 24.8 people per square mile will increase to 29.7 people per square mile by year 2010.

The main cities have a population of one to two million people, whereas the smaller villages have populations of a few hundred.

The ministry of Municipal and Rural Affairs has begun a programme to reorganize the distribution of population by creating urban areas, which provide all the services people need. The intention is to attract increasing numbers of Bedouin and rural populations to towns and cities.

1.5 BOUNDARIES

The Kingdom of Saudi Arabia is bordered by the following countries or natural barriers:

- North-East : Kuwait
- North : Iraq and Jordan
- East : Arabian Gulf, Bahrain, Qatar & United Arab Emirates
- South : Sultanate of Oman and Yemen Republic
- West : The Red Sea

1.6 COASTS

The Red Sea coast of Saudi Arabia is 1,800 km, or 1,100 miles long. Its eastern coast on the Arabian Gulf is 610 km. or 380 miles in length. Saudi Arabian territorial waters extend to its continental shelf, in accordance with international laws giving every state the right to benefit from the economic resources of its territorial waters extending from its borders to the continental shelf.

1.7 CLIMATE

The climate of Saudi Arabia varies from one province to another. The Kingdom lies in the tropics, and the nationwide average temperature is 18°C (64°F). Local averages vary considerably, from 24°C (75°F) in the Western Province, rising as we descend towards the Southwest until it reaches 28°C (82°F) in Jeddah and 30°C (86°F) in Jizah. In the Northwest, the average temperature is only 19°C because of the high altitude. The Central Province, which is surrounded by desert, has an average of 25°C for Riyadh, 21°C in Hail and 23°C in Qassim. In Dhahran, in the Eastern Province, the temperature is an average of 26°C.

Apart from topographical factors, Saudi Arabia's climate is also affected by tropical winds, which cause monsoons in the West and Southwest. These occur during the summer months. In the South, tropical continental winds blow particularly in winter, often accompanied by sandstorms.

The climate of the North is affected by polar winds blowing from the sea, which cause rainfall in winter.

Torrential rain often occurs in parts of the Kingdom as a result of cold wind currents meeting warm ones. This rain is often accompanied by thunderstorms.

Most of Saudi Arabia has a desert climate, with very little rainfall. But its location between two rainy areas in the South, where the monsoon region lies, and the sea in the North, means that it rains throughout the year in some regions. The highest annual rainfall in the Kingdom occurs in Khamis Mishait (215.5 mm, or 9 in.), and the lowest is Al-Wajeh. (See map on page 21-22)

1.8 SAUDI ARABIAN ECONOMY

The following highlights the importance of electricity in the economy of Saudi Arabia and the necessity to select a system to help meet water and electricity supply shortages in the country.

1.8.1 The Economy of Saudi Arabia

Saudi Arabia is entering the millennium with an ambitious new economic development plan to meet the changing world economy.

As a result of the discovery of oil in the Kingdom of Saudi Arabia at the end of the fourth decade of the 20th Century and the increase in oil revenue, Saudi economy started to develop and grow remarkably beginning in 1947.

Other contributing factors to Saudi Arabia's continued progress and stability can be attributed to the following:

- (a) Political stability.
- (b) It holds one of the largest oil reserves in the world estimated to contain more than 260 billion barrels of oil and 200 trillion cubic feet of natural gas at different locations. (Table 1.1)
- (c) Saudi Arabia lies at the crossroads of three continents: Asia, Africa and Europe; and sea boundaries that are rich in various types of fishes and abundant sweet-water supply.
- (d) Complete infrastructure with large roads and communication networks.
- (e) Free economic system where the private sector own 40% of (GNP) and privatization of government controlled enterprises is ongoing.
- (f) Expected population growth rate of 3.8% per annum.
- (g) Availability of educated and experienced workforce.

- (h) Industries play a key role in future economic development of Saudi Arabia. This role is derived from strategic, long-term objectives of the Kingdom, which call for diversification of its economic base through development of non-oil producing sectors.

Table 1.1
Saudi Oil Exports
(in Million Saudi Riyals)

PARTICULAR	1997	1996	1995	1994
Crude Oil	157,339	163,282	132,990	117,200
Refinery Product	38,503	39,965	30,093	25,629
Visual fuel	(588)	(610)	(4,90)	(428)
TOTAL	195,842	203,247	163,083	142,829

Reference : Saudi Arabian Monetary Agency (SAMA)

Table 1.2
Saudi Non-Oil Exports
(in Million Saudi Riyals)

PARTICULAR	1997	1996	1995	1994
Chemical	9912	10435	10166	7878
Building Product	3593	2964	2706	1151
Agric, Food & Livestock	1194	1339	1589	1430
Others	12975	9443	9859	6302
TOTAL	27674	24181	24320	16761

Reference : Saudi Arabian Monetary Agency (SAMA)

1.8.2 Shortage of Water in Saudi Arabia

The scarcity of water in the world in general and Saudi Arabia in particular prompted the government to find ways to alleviate the problem. Although 70% of our planet is covered by water (1,357,506,250 cu. kilo meter), a large part of it still remains not suitable for consumption due the following reasons:

- 97.2%, or 1,320,000,000 cu. kilo-meter, is sea/ocean water with 35 gram/liter of salt.
- 2.15%, or 29,000,000 cu. kilo-meter, is frozen in the south and north poles.

Only 0.65%, or 8,506,250 cu. kilo-meter, is sweet water suitable for consumption.

(a) Climate and Level of Rain in Saudi Arabia

Saudi Arabia is a desert country where an estimate of 640,000 square kilometers considered desert lands with no rivers. Temperature ranges between zero to as high as 48°C during summer season with low level of rains at 95 mm/year all year round.

(b) Water Status in Saudi Arabia

The sources of water in Saudi Arabia are given in Tables 1.3 and 1.4.

(c) Surface Water

Available mainly in the Western and Southwestern regions where tropical rain is enough to supply requirements of dams, built to efficiently store rain water for future consumption, particularly in areas of Holy Mosques in Makkah, Bisha Village with capacity of 325 cu. million liters.

(d) Underground Water

This is a reservoir of rainwater and injected water.

(e) Saline Water Conversion

This composed of seawater made potable by desalination plants for consumption. Saudi Arabia is utilizing the latest technology in the field of saline water conversion. Its plants are located along the coast of Arabian Gulf and Red seas producing 512,247,829 American gallons of sweet water daily.

(f) Sewage Water Treatment Plants

Treatment of sewage water for agricultural use has been introduced.

Table 1.3
Water Consumption

YEAR	SECTOR'S CONSUMPTION	PERCENT	WATER CONSUMPTION (in million cu. meter annually)
1980G (1400H)	Residential/Industrial	21.6%	510
	Agricultural	78.4%	1,850
1985G (1405H)	Residential/Industrial	14.0%	1,200
	Agricultural	86.0%	7,400
1990G (1410H)	Residential/Industrial	10.2%	1,650
	Agricultural	89.8%	14,580
1995G (1415H)	Residential/Industrial	9.9%	1,800
	Agricultural	90.1%	16,400

Reference : Ministry of Agriculture & Water

Table 1.4
Sources of Water

YEAR	SOURCES	PERCENT	WATER SOURCES (in million cu. meter)
1400	Surface Water	48.3%	1,140
	Saline Water Conversion	21.1%	50
	Underground	49.6%	1,170
	Sewage Water Treatment	-	1,850
1405	Surface Water	21.5%	330
	Saline Water Conversion	3.8%	
	Underground	73.5%	6,320
	Sewage Water Treatment	1.2%	100
1410	Surface Water	1.3%	2,100
	Saline Water Conversion	3.3%	540
	Underground	83%	13,480
	Sewage Water Treatment	.07%	110
1415	Surface Water	13.7%	2,500
	Saline Water Conversion	3.9%	714
	Underground	81.5%	14,836
	Sewage Water Treatment	0.08%	150

Reference : Ministry of Agriculture & Water

1.9 DEVELOPMENT STAGES OF ELECTRICITY IN SAUDI ARABIA

The development of electricity in the Kingdom of Saudi Arabia (KSA) can be divided into two phases:

(a) Phase - 1

During the period, which preceded the development plans of KSA (before 1390H/1970G), electricity generation was limited to small national commercially operated companies. These existed in cities and villages. Electricity tariff during that period was different from one company to another due to the actual power generation cost, after taking into consideration the necessity for attaining satisfactory revenues.

In 1381H/1961G, the first Department of Electricity Affairs was established in the Ministry of Commerce to establish rules and regulations, to issue permits and licenses to electric companies and to encourage national investment in this utility.

(b) Phase - 2

During the period of development plans in KSA (after 1390H/1970G), the Department of Electricity Services was established in 1392H/1972G. Its functions were separated from the function of the Ministry of Commerce, with the additional responsibility for planning electrical services for the entire Kingdom.

In 1394H/1974G, the Ministry of Commerce and Industry was divided into two main sectors. One was the Commerce Agency and the other was the Industry & Electricity Agency. During the

same year, the Electricity tariff was fixed at standard prices for all such companies at levels below their actual costs.

In 1395H/1975G, Saudi Arabia laid down an ambitious program for economic development. Industry and electricity were key sectors. The Ministry of Industry & Electricity was established and included two Affairs Agencies: first, the Industrial Affairs Agency; second, the Electrical Affairs Agency. The Electricity Agency expanded planning and co-ordination roles and standards for providing electrical services for all regions of the Kingdom. The Electricity Corporation was established in 1396H/1976G to undertake the tasks of co-ordination and supervision of achievement of the ambitious electricity plans through the national development plans of KSA.

During the period from 1396H to 1401H (1976H to 1981G), all community electricity generation companies were gradually combined to form the four SCECO regional subsidiaries, the Saudi Consolidated Electric Companies in the Eastern Province, Central, Southern and Western regions.

Government, during this stage and through the development plans, was able to electrify and provide electricity to cities, villages and settlements and to establish electricity networks extending for thousands of kilometers.

Currently, electricity is supplied to approximately 95% of inhabited area of Saudi Arabia and due to vast network of electricity generation and supply system, 82.92% of its residents enjoy the benefits of electricity.

1.10 GENERATING CAPACITY

Generating capacities in the Kingdom witnessed huge development both in quality and quantity within a few years. Concerning quantity, the actual generating capacities for all electric companies and projects in the Kingdom reached to the level of 20,266 MW by the end of the year 1418 H (1997G), seventeen times of what they were during the year 1395H (1975G). (Please refer to page 14)

Minimum available power capacities from some of the desalination plants in the Kingdom reached 2,192 MW (with a maximum monthly peak load of 3,141 MW during the year 1418H (1997G)) were utilized. The electricity sector in the Kingdom witnessed a qualitative growth that is reflected in the usage of high capacity steam power stations to meet the increased electric demand. The first steam power station in the Kingdom at Ghazlan in the Eastern region was commissioned in the year 1400H (1980G). It is comprised of four generating units with 400 MW generating capacity each.

In 1406H (1986G) Rabigh steam power station in the Western Region was completely commissioned. It contains four generating units of 260 MW capacity each.

**Nominal/Actual Generating Capacities & Peak Load
For the Years 1395 to 1418
Kingdom of Saudi Arabia**

GREGORIAN YEAR	HIJRA YEAR	NOMINAL GENERATING CAPACITY (MW)	ACTUAL GENERATING CAPACITY (MW)	PEAK LOAD (MW)
1974-1975	1395	1,315	1,141	8480
1975-1976	1396	2,050	1,749	1,140
1976-1977	1397	2,940	2,368	1,633
1977-1978	1398	4,073	3,213	2,161
1978-1979	1399	5,497	4,129	2,955
1979-1980	1400	7,038	5,913	3,986
1980-1981	1401	8,567	7,355	5,227
1981-1982	1402	11,510	8,953	6,309
1982-1983	1403	13,336	10,720	7,708
1983-1984	1404	14,599	11,857	8,503
1984-1985	1405	16,762	13,939	9,424
1985-1986	1406	17,777	14,763	10,252
1986-1987	1407	18,215	14,910	10,690
1987-1988	1408	18,527	15,212	11,202
1988-1989	1409	20,194	16,471	11,573
1989-1990	1410	20,214	16,459	12,173
1990-1991	1411	20,733	16,849	12,889
1991-1992	1412	20,888	17,051	14,389
1992-1993	1413	21,415	17,627	15,674
1993-1994	1414	21,917	17,544	17,387
1994-1995	1415	21,910	17,494	16,907
1995-1996	1416	23,130	18,805	17,706
1996-1997	1417	23,204	19,351	1,7995
1997-1998	1418	24,569	20,266	1,9326

Reference : Ministry of Industry & Electricity from years 1400 to 1418.

A new steam power station was commissioned at the end of 1409H (1989G) at Al-Qurarra in the Eastern Region.

It consists of four units of 600 MW capacities each. In 1413H (1993G), the electricity sector has begun using the combined cycle power generating units with capacity of 126 MW each in Rabigh steam plant in the Western Region.

1.11 GENERATED ENERGY

Generated energy by the electric companies and projects in the Kingdom during 1418H (1997-1998G) reached 86.6 million MWH, equal to approximately eighteen times generated energy in the year of 1396H (1975G).

Electric energy imported from some of the desalination plants in the Kingdom during the year 1418H (1997/1998G) exceeded 20.9 million MWH while the total energy production in the Kingdom registered 107.5 million MWH.

1.12 ENERGY SOLD

The total energy sold in the Kingdom during 1418H (1997-1998G) reached 97.1 million MWH.

Quantity sold energy this year equals to approximately twenty-five times of what it had been during the year 1395H (1975G).

Industrial consumption represents 25.41% of the total sold energy during this year. (Please refer to page 17)

Development of Energy Sold and Industrial Consumption
(In Million MWH)

DETAILS	YEAR					
	1395	1400	1405	1410	1415	1418
Energy Sold	3.83	17.45	40.32	58.97	85.91	97.05
Industrial Consumption	2.17	6.84	11.59	16.67	21.39	25.41

Reference : Ministry of Industry & Electricity

1.13 ELECTRICITY PRICES

Energy in the Kingdom is sold at prices that are much less than production cost to supply citizens with their requirements of energy at a suitable price. For this purpose, the government provided large amounts of financial subsidies and long term loans to support electric companies enabling them to continue development of this vital sector, consistent with the comprehensive advancement experienced by the Kingdom.

Electricity prices in the Kingdom are subjected to brackets system to rationalize consumption and to limit over usage of electric energy while maintaining a high standard.

Its type of consumption is divided in two divisions.

(a) The First Division

This includes residential, commercial and governmental consumption. The prices are graduated from 5 Halalas to 15 Halalas (per KWH) according to the amount of monthly energy consumption.

Energy Sold
For Years 1395 to 1418
Kingdom of Saudi Arabia

GREGORIAN YEAR	HIJRA YEAR	ENERGY SOLD (MWH)
1974-1975	1395	3,826,340
1975-1976	1396	5,298,330
1976-1977	1397	6,352,783
1977-1978	1398	8,464,629
1978-1979	1399	13,456,008
1979-1980	1400	17,451,867
1980-1981	1401	21,172,863
1981-1982	1402	27,143,782
1982-1983	1403	31,152,475
1983-1984	1404	36,111,124
1984-1985	1405	40,319,532
1985-1986	1406	45,795,932
1986-1987	1407	48,905,941
1987-1988	1408	51,530,686
1988-1989	1409	55,200,892
1989-1990	1410	58,972,475
1990-1991	1411	63,632,003
1991-1992	1412	67,436,756
1992-1993	1413	74,112,883
1993-1994	1414	82,198,157
1994-1995	1415	85,908,297
1995-1996	1416	89,641,328
1996-1997	1417	92,227,609
1997-1998	1418	97,050,250

Reference : Ministry of Industry & Electricity

(b) The Second Division

This includes Industrial, Agricultural, Hospitals and Charitable Associations. Here the price is fixed at 5 Halalas (per KWH) for any amount of consumption.

Note: Beginning from 1/8/1415H (2/1/1995G), 5 Halalas per KWH were added as an electricity fee per monthly consumed energy (over 2000 KWH).

1.14 CUSTOMERS

The number of new customers in the Kingdom during 1418H (1997-1998G) was 117,629 as indicated in the table below. The total number of customers by the end of 1418H (1997-1998G) reached to 3,256,643 (please refer to page 19), equal to approximately nine times what it was at the end of 1395H (1975G).

**Classification of New Customers
During the Year 1418H (1997-1998G)**

YEAR (H)	REGIONS					TOTAL
	EASTERN	CENTRAL	SOUTHERN	WESTERN	NORTHERN	
Residential	16,067	32,851	12,120	29,300	5,839	96,177
Commercial	4,274	6,598	814	4,536	922	17,144
Government	547	218	235	461	158	1,619
Streets	28	74	43	107	20	272
Mosques	136	293	203	239	86	957
Hospitals	10	1	8	37	1	57
Charitable Org.	5	9	14	11	18	57
Industrial	219	39	-	50	5	313
Agricultural	367	438	38	90	100	1,033
TOTAL	21,653	40,521	13,475	34,831	7,149	117,629

Reference : Ministry of Industry & Electricity

**Number of Customers, Industrial Consumption
and Average Energy Sold Per Customers
For Hijra Years 1395 to 1418
Kingdom of Saudi Arabia**

GREGORIAN YEAR	HIJRA YEAR	NUMBER OF CUSTOMERS	INDUSTRIAL CONSUMPTION (MWH)	AVERAGE ENERGY SOLD PER CUSTOMER (KWH)
1974-1975	1395	346,129	2,171,709	11,055
1975-1976	1396	399,665	3022051	13,257
1976-1977	1397	464,830	3,140,491	13,667
1977-1978	1398	582,632	4,063,751	14,528
1978-1979	1399	724,805	6,642,699	18,565
1979-1980	1400	872,054	6,839,646	20,012
1980-1981	1401	1,054,009	7,675,247	20,088
1981-1982	1402	1,212,420	8,037,692	22,388
1982-1983	1403	1,392,622	8,820,790	22,370
1983-1984	1404	1,585,720	9,279,877	22,773
1984-1985	1405	1,761,803	11,585,932	22,985
1985-1986	1406	1,902,445	12,037,234	24,672
1986-1987	1407	2,043,365	12,442,670	23,934
1987-1988	1408	2,153,541	12,576,075	23,928
1988-1989	1409	2,259,288	15,450,185	24,433
1989-1990	1410	2,366,878	16,665,886	24,916
1990-1991	1411	2,460,892	16,992,695	25,857
1991-1992	1412	2,587,747	18,316,181	26,060
1992-1993	1413	2,687,018	19,083,224	27,586
1993-1994	1414	2,815,471	20,908,158	29,195
1994-1995	1415	2,926,294	21,387,548	29,357
1995-1996	1416	3,036,429	22,509,303	29,523
1996-1997	1417	3,151,198	23,421,668	29,267
1997-1998	1418	3,256,643	25,412,560	29,801

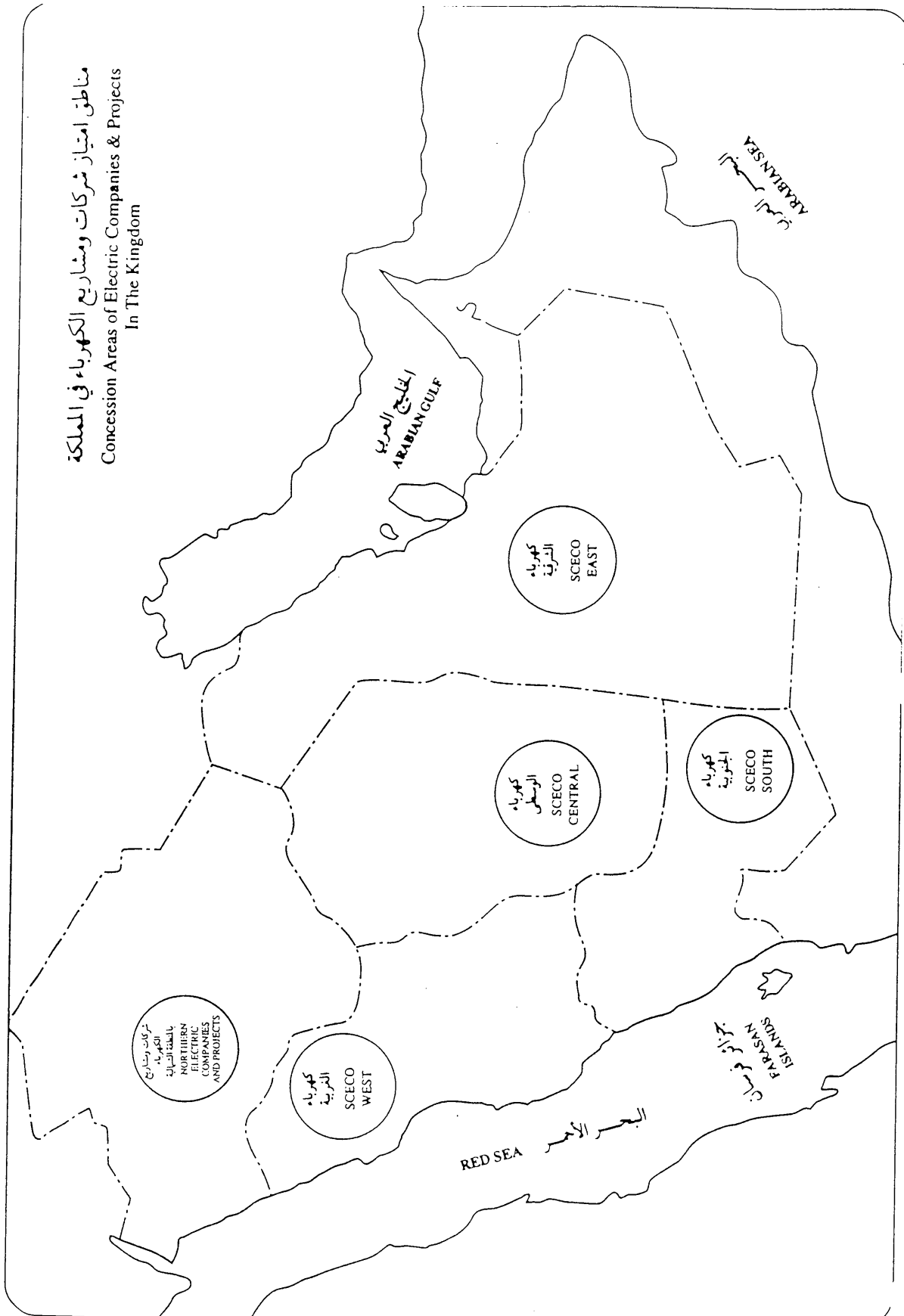
Reference : Ministry of Industry & Electricity from year 1400 to 1418

**Classification & Proportional Distribution
Of Total Number of Customers
Up To Year 1418H (1997-1998G)**

DETAILS		EASTERN	CENTRAL	SOUTHERN	WESTERN	NORTHERN	TOTAL
Residential	No.	398,282	798,510	336,394	1,018,892	148,375	2,700,453
	%	79.18	80.63	89.13	85.17	78.25	82.92
Commercial	No.	80,191	132,180	21,789	138,266	27,286	399,712
	%	15.94	13.35	5.77	11.56	14.39	12.27
Government	No.	10,754	26,174	9,801	22,471	5,035	74,235
	%	2.14	2.64	2.6	1.88	2.66	2.28
Streets	No.	2,490	4,039	1,045	4,620	1,098	13,301
	%	0.50	0.41	0.28	0.39	0.58	0.41
Mosques	No.	2,088	10,666	6,876	6,636	2,590	28,856
	%	0.42	1.08	1.82	0.55	1.37	0.89
Hospitals	No.	402	155	247	556	103	1,463
	%	0.08	0.02	0.07	0.05	0.05	0.04
Charitable Orgs.	No.	149	142	48	1,286	61	1,656
	%	0.03	0.01	0.01	0.11	0.03	0.05
Industrial	No.	1,481	1,089	136	1,499	51	4,256
	%	0.29	0.11	0.04	0.13	0.02	0.13
Agricultural	No.	7,159	17,444	1,061	2,032	5,015	32,711
	%	1.42	1.76	0.28	0.17	2.73	1.00
TOTAL	No.	502,996	990,369	377,406	1,196,258	189,614	3,256,643
	%	100	100	100	100	100	100

Reference : Ministry of Industry & Electricity from year 1400 to 1418

مناطق امتياز شركات ومشاريع الكهرباء في المملكة
Concession Areas of Electric Companies & Projects
In The Kingdom



1.15 DEVELOPMENT OF ELECTRIC COMPANIES IN THE IN KINGDOM OF SAUDI ARABIA

1.15.1 Saudi Consolidated Electric Company In The Eastern Region (SCECO-East)

The company was established under Royal Decree No. M/63 dated 27/8/1396H (1976G) with a capital of Five Thousand Million Saudi Riyals.

The twenty-six (26) electric companies that existed in the area in addition to the electric utilities of ARAMCO were consolidated. The effective date was 1/1/1398H (1978G) as per H.E. the Minister of Industry & Electricity Decision No. 2210 dated 26/6/1397 (1977G) concession area for this company is about 285,000 sq. km. (See Map on page 26)

By the end of the year 1418H (1997-1998G), Saudi Consolidated Electric Company in The Eastern Region provided services to 502,996 customers.

Fuel consumption as a result of the energy generated is provided in page 25.

**Classification of Generating Capacity & Energy Generated
For the Year 1418 (1997-1998G)
In SCECO-East**

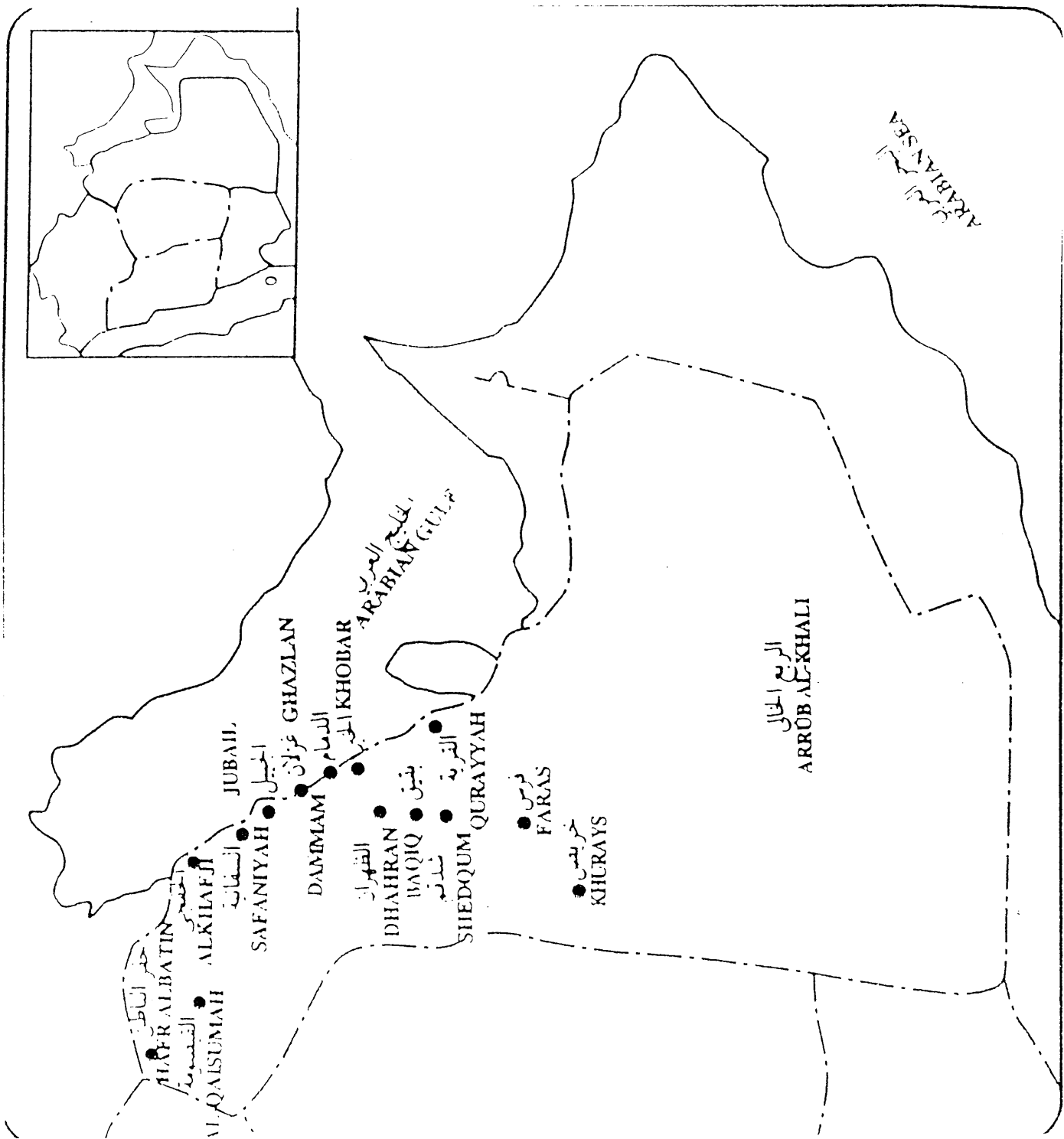
REGIONS	ACTUAL GENERATING CAPACITIES AS PER TYPE OF GENERATING UNITS									GRAND TOTAL
	DIESEL ENGINES		GAS TURBINES		STEAM TURBINES		TOTAL		IMPORTED FM. DESALINATION PLANTS	
	CONNECTED NETWORK	ISOLATED NETWORK	CONNECTED NETWORK	ISOLATED NETWORK	CONNECTED NETWORK	ISOLATED NETWORK	CONNECTED NETWORK	ISOLATED NETWORK		
Actual Capacity (MW)	-	28	3,153	-	4,000	-	7,153	28	1,576	8,757
							7,181			
Generated Energy (MW)	64,594		6,831,982		27,683,982		34,579,638		13,489,775	48,069,413

Reference : SCECO-East Annual Report

**Fuel Consumed in Power Stations
SCECO-East**

YEAR	DIESEL (In M. Tons)	CRUDE OIL (In M. Tons)	GAS (In Million Cu. Meter)
1397	90,877	-	473
1398	99,510	-	479
1399	74,026	-	637
1400	82,231	-	795
1401	74,673	41,118	4,948
1402	124,356	44,406	5,224
1403	70,789	71,654	4,755
1404	11,148	141,090	4,313
1405	27,979	243,968	4,145
1406	14,536	144,748	4,628
1407	17,815	136,128	4,478
1408	17,138	134,889	4,685
1409	19,374	209,076	5,669
1410	16,569	160,644	5,172
1411	20,659	180,254	6,041
1412	21,766	197,073	6,563
1413	86,387	125,556	6,876
1414	118,633	83,846	7,595
1415	16,749	17,358	7,976
1416	16,748	3,535	7,913
1417	21,477	122,306	8,674
1418	29,610	3,397	9,465

Reference : SCECO-East Annual Budget



**1.15.2 Saudi Consolidated Electric Company
 In The Central Region (SCECO-Central)**

The company was established according to Royal Decree No. M/8 dated 22/2/1399 (1979G), with a capital of Eight Thousand Million Saudi Riyals.

The thirty-six (36) electric companies that existed in the area in addition to the government projects of the Electricity Corporation in Riyadh and Al-Qassim were consolidated. The effective date was from 1/1/1401H (1981G) as per H.E. the Minister of Industry & Electricity Decision No. 346 dated 16/4/1400H (1980G). Concession area for this company is about 470,000 sq. km. (See Map on page 30)

By the end of the year 1418H (1997-1998G), Saudi Consolidated Electric Company in the Central Region provided services to 990,369 customers.

Fuel consumption as a result of the energy generated is provided in page 29.

Development of Generating Capacity, Energy & Number of Customers
Saudi Consolidated Electric Company
In the Central Region

YEAR	NOMINAL GENERATING CAPACITY (MW)	ACTUAL GENERATING CAPACITY (MW)	PEAK LOAD (MW)	NUMBER OF CUSTOMERS	ENERGY GENERATED (MWH)	ENERGY SOLD (MWH)	INDUSTRIAL CONSUMPTION (MWH)	AVE. ENERGY SOLD PER CUSTOMER (KWH)
1395	242	203	131	109,601	597,454	383,032	45,457	3,495
1396	292	244	179	121,096	834,803	668,214	79,131	5,518
1397	657	535	253	139,526	1,204,697	935,133	76,141	6,702
1398	787	634	387	171,318	1,718,351	1,300,270	76,272	7,590
1399	1,282	998	558	198,557	2,631,149	1,989,449	108,867	10,020
1400	1,527	1,300	789	248,237	3,724,194	3,339,272	157,749	13,452
1401	2,241	1,978	1,113	304,067	4,565,126	4,629,618	177,942	15,226
1402	2,639	2,238	1,518	353,448	6,487,306	5,088,424	201,953	14,397
1403	3,353	3,117	2,144	392,783	8,657,247	7,497,151	249,293	19,087
1404	3,819	3,693	2,176	443,559	9,102,804	8,926,317	273,756	20,124
1405	3,918	3,786	2,459	496,678	9,516,083	10,286,902	334,151	20,711
1406	4,026	3,888	2,716	539,658	10,229,924	11,148,004	410,571	20,658
1407	4,048	3,909	2,858	577,236	11,690,730	12,089,725	392,298	20,944
1408	4,287	4,142	3,218	613,988	11,950,884	12,996,074	566,019	21,167
1409	4,290	4,144	3,266	643,678	11,795,922	14,175,656	605,676	22,023
1410	4,297	4,138	3,438	676,167	11,655,793	15,051,369	812,206	22,260
1411	4,257	4,108	3,641	702,835	11,294,615	15,997,360	936,124	22,761
1412	3,725	3,677	3,966	756,948	12,282,372	17,736,868	990,515	23,432
1413	3,752	3,723	4,477	786,869	13,787,073	19,051,295	1,185,047	24,212
1414	4,165	3,645	5,062	829,807	15,333,025	20,764,681	1,166,140	25,024
1415	4,176	3,643	4,851	876,395	16,445,275	22,176,705	1,206,883	25,304
1416	4,637	4,049	5,126	911,532	17,251,612	22,898,115	1,286,072	25,120
1417	4,744	4,376	5,415	951,434	17,150,455	24,118,988	1,495,744	25,350
1418	4,974	4,546	5,977	990,369	20,146,899	25,664,806	1,609,595	25,914

References: SCECO-Central Annual Reports (Years 1400 to 1418)

**Classification of Generating Capacity & Energy Generated
For the Year 1418 (1997-1998G)
In SCECO-Central**

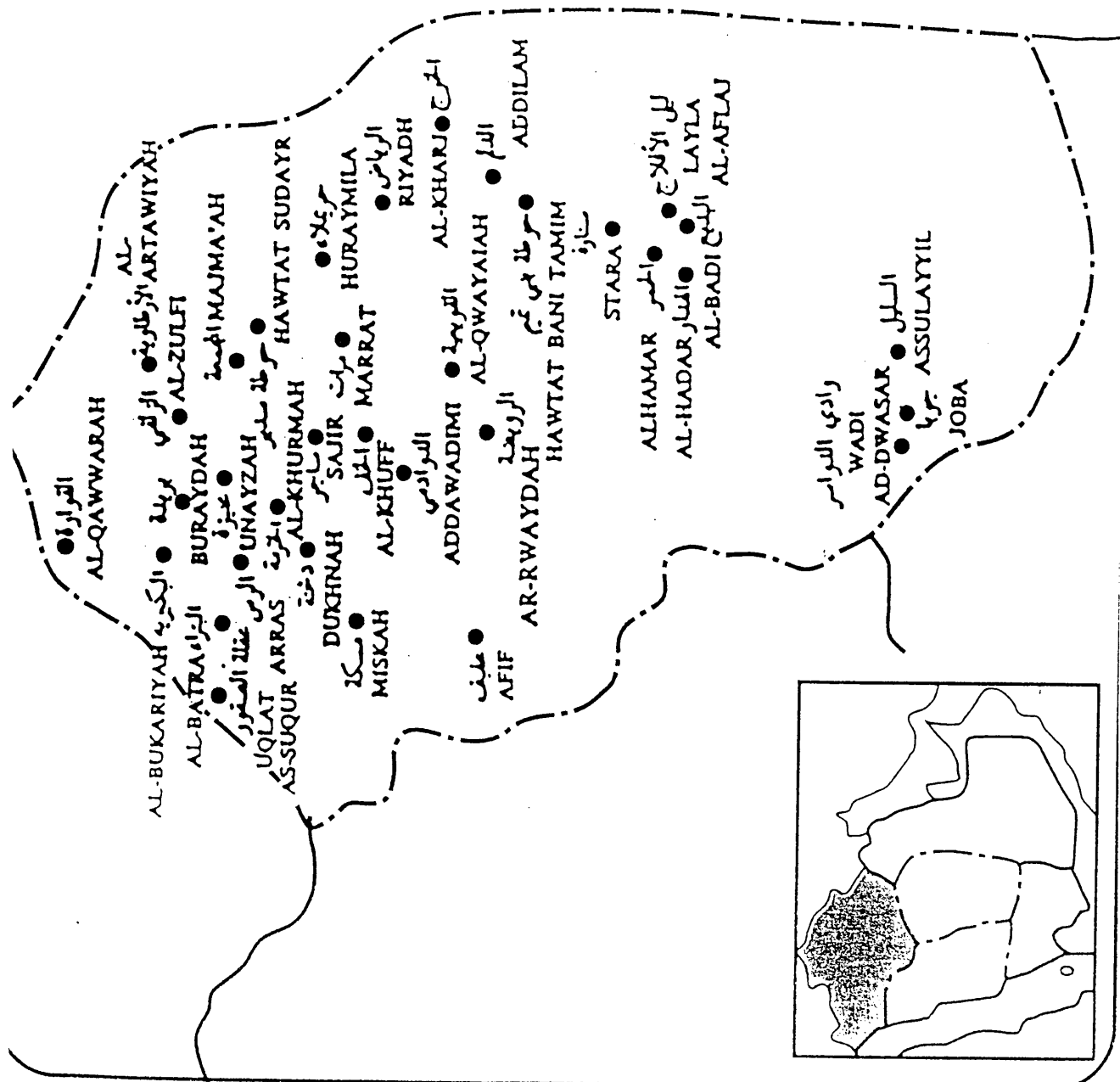
REGIONS	ACTUAL GENERATING CAPACITIES AS PER TYPE OF GENERATING UNITS									GRAND TOTAL
	DIESEL ENGINES		GAS TURBINES		STEAM TURBINES		TOTAL		IMPORTED ENERGY FROM SCECO-EAST	
	CONNECTED NETWORK	ISOLATED NETWORK	CONNECTED NETWORK	ISOLATED NETWORK	CONNECTED NETWORK	ISOLATED NETWORK	CONNECTED NETWORK	ISOLATED NETWORK		
Actual Capacity (MW)	-	29	4,348	169	-	-	4,348	198	1,200	5,746
							4,546			
Generated Energy (MW)	114,599		20,032,300		-		20,146,899		7,763,525	27,910,424

Reference : SCECO-Central Annual Report

**Fuel Consumed in Power Stations
SCECO-Central**

YEAR	DIESEL (In M. Tons)	CRUDE OIL (In M. Tons)	GAS (In Million Cu. Meter)
1397	141,270	416,965	-
1398	278,609	471,660	-
1399	253,164	755,485	-
1400	265,474	1,182,301	-
1401	311,934	1,542,252	-
1402	406,688	1,972,131	-
1403	491,608	2,684,139	-
1404	462,646	2,688,133	-
1405	579,678	2,577,594	-
1406	861,107	2,505,630	-
1407	736,520	3,080,167	-
1408	622,359	3,261,255	-
1409	682,135	3,084,014	-
1410	761,569	2,961,793	-
1411	710,129	2,881,102	-
1412	726,283	3,151,856	-
1413	688,537	3,725,532	-
1414	727,834	4,261,225	-
1415	775,166	4,557,528	-
1416	928,346	4,706,602	-
1417	861,853	4,692,703	-
1418	138,728	5,083,445	-

Reference : SCECO-Central Annual Report



**1.15.3 Saudi Consolidated Electric Company
In The Southern Region (SCECO-South)**

The company was established according to Royal Decree No. M/43 dated 22/8/1399 (1979G), with a capital of Four Thousand Million Saudi Riyals.

The twenty-one (21) electric companies that existed in the area in addition to the government projects of the Electricity Corporation in Baha, Asir, Najaran and Jizan areas were consolidated. The effective date was 1/1/1401H (1981G) as per H.E. the Minister of Industry & Electricity Decision No. 766 dated 12/9/1400H (1980G). Concession area for this company is about 270,000 sq. km. (See Map on page 34)

By the end of the year 1418H (1997-1998G), Saudi Consolidated Electric Company in the Southern Region provided services to 377,406 customers.

Fuel consumption as a result of the energy generated is provided in page 33.

Development of Generating Capacity, Energy & Number of Customers
Saudi Consolidated Electric Company
In the Southern Region

YEAR	NOMINAL GENERATING CAPACITY (MW)	ACTUAL GENERATING CAPACITY (MW)	PEAK LOAD (MW)	NUMBER OF CUSTOMERS	ENERGY GENERATED (MWH)	ENERGY SOLD (MWH)	INDUSTRIAL CONSUMPTION (MWH)	AVE. ENERGY SOLD PER CUSTOMER (KWH)
1395	34	33	12	10,746	41,162	16,217	378	1,509
1396	39	37	13	12,308	41,162	26,583	392	2,159
1397	42	38	15	13,616	43,720	32,198	305	2,365
1398	79	75	25	23,576	88,543	52,826	530	2,241
1399	144	130	45	32,634	104,859	76,140	1,498	2,333
1400	174	127	61	46,073	223,222	175,633	1,820	3,812
1401	346	313	158	89,281	592,617	473,643	4,184	5,305
1402	488	425	233	101,237	916,155	675,280	9,117	6,670
1403	670	588	335	125,350	1,273,011	949,210	12,116	7,572
1404	906	813	404	143,803	1,609,643	1,369,406	15,145	9,523
1405	1,033	927	472	167,840	1,873,302	1,643,384	18,931	9,791
1406	1,323	1,229	476	186,716	2,134,620	1,907,531	23,664	10,216
1407	1,341	1,227	604	223,776	2,596,313	2,032,837	29,580	9,084
1408	1,435	1,317	676	241,228	2,984,726	2,562,499	36,975	10,623
1409	1,855	1,372	720	258,604	3,208,121	2,734,389	45,271	10,574
1410	1,857	1,392	810	272,645	3,441,449	3,144,412	60,499	11,533
1411	1,924	1,447	828	284,853	3,664,947	3,273,768	60,478	11,493
1412	2,001	1,508	972	305,833	4,020,009	3,642,656	64,683	11,911
1413	1,703	1,278	1,025	320,440	4,402,245	4,090,852	62,328	12,766
1414	1,706	1,275	1,106	334,420	5,259,571	4,813,119	75,117	14,392
1415	1,711	1,279	1,125	346,857	5,513,117	5,008,947	71,833	14,440
1416	1,779	1,337	1,199	355,176	5,855,942	5,353,196	71,395	15,072
1417	1,779	1,337	1,228	366,157	6,098,709	5,646,671	76,969	15,421
1418	2,366	1,741	1,312	377,406	6,694,012	5,794,584	75,227	15,354

References: SCECO-South Annual Reports (Years 1400 to 1418)

**Classification of Generating Capacity & Energy Generated
For the Year 1418 (1997-1998G)
In SCECO-South**

REGIONS	ACTUAL GENERATING CAPACITIES AS PER TYPE OF GENERATING UNITS									GRAND TOTAL
	DIESEL ENGINES		GAS TURBINES		STEAM TURBINES		TOTAL		IMPORTED ENERGY FROM SCECO-EAST	
	CONNECTED NETWORK	ISOLATED NETWORK	CONNECTED NETWORK	ISOLATED NETWORK	CONNECTED NETWORK	ISOLATED NETWORK	CONNECTED NETWORK	ISOLATED NETWORK		
Actual Capacity (MW)	51	179	403	1,108	-	-	454	1,287	28	1,769
							1,741			
Generated Energy (MW)	570,597		6,123,415		-		6,694,012		400,216	7,094,228

Reference : SCECO-South Annual Report

**Fuel Consumed in Power Stations
SCECO-South**

YEAR	DIESEL (In M. Tons)	CRUDE OIL (In M. Tons)	GAS (In Million Cu. Meter)
1397	5,435	-	-
1398	7,873	-	-
1399	11,701	-	-
1400	14,586	266	-
1401	139,770	171	-
1402	258,566	-	-
1403	335,942	-	-
1404	506,889	-	-
1405	550,735	45,698	-
1406	617,631	101,662	-
1407	694,243	201,431	-
1408	774,480	257,465	-
1409	819,753	281,405	-
1410	848,074	295,818	-
1411	890,731	326,151	-
1412	986,317	324,564	-
1413	1,079,151	376,535	-
1414	1,338,013	410,691	-
1415	1,342,685	467,379	-
1416	1,450,863	469,581	-
1417	1,483,139	544,123	-
1418	1,598,477	629,588	-

Reference : SCECO-South Annual Report

**1.15.4 Saudi Consolidated Electric Company
In The Western Region (SCECO-West)**

The company was established according to Royal Decree No. M/6 dated 26/3/1401 (1981G), with a capital of Eight Thousand Million Saudi Riyals.

The twelve (12) electric companies that existed in the area in addition to government projects of the Electricity Corporation were consolidated. The effective date was 1/1/1402 (1982G) as per H.E. the Minister of Industry & Electricity Decision No. 887 dated 18/8/1401 (1981G). Concession area for this company is about 320,000 sq. km. (See Map on page 39)

By the end of the year 1418H (1997-1998G), Saudi Consolidated Electric Company in the Western Region provided services to 1,196,258 customers.

Fuel consumption as a result of the energy generated is provided in page 38.

Development of Generating Capacity, Energy & Number of Customers
Saudi Consolidated Electric Company
In the Western Region

YEAR	NOMINAL GENERATING CAPACITY (MW)	ACTUAL GENERATING CAPACITY (MW)	PEAK LOAD (MW)	NUMBER OF CUSTOMERS	ENERGY GENERATED (MWH)	ENERGY SOLD (MWH)	INDUSTRIAL CONSUMPTION (MWH)	AVE. ENERGY SOLD PER CUSTOMER (KWH)
1395	236	235	224	155,236	950,408	786,104	22,641	5,064
1396	650	575	279	174,130	1,251,294	1,042,571	25,641	5,987
1397	756	659	383	203,966	1,694,535	1,424,214	28,670	6,983
1398	979	874	532	251,121	2,396,112	1,999,124	71,631	7,961
1399	1,399	1,135	768	307,146	3,461,110	2,956,599	90,599	9,626
1400	1,717	1,414	1,041	361,552	4,837,941	4,148,511	129,768	11,474
1401	2,113	1,780	1,379	415,189	6,169,083	5,149,935	136,521	12,404
1402	2,833	2,133	1,738	491,533	7,716,561	6,458,410	141,241	13,139
1403	3,134	2,439	2,177	570,161	5,702,261	8,514,698	311,654	14,930
1404	3,376	2,580	2,558	667,202	6,704,375	9,994,175	388,572	14,979
1405	4,158	3,381	2,694	732,333	7,753,000	11,577,061	418,256	15,809
1406	4,590	3,653	2,846	779,863	8,593,168	12,268,347	459,409	15,731
1407	5,010	3,800	3,137	820,024	9,624,902	12,821,428	527,257	15,635
1408	5,015	3,802	3,257	855,004	9,711,762	14,297,501	652,002	16,722
1409	5,015	3,811	3,412	893,605	10,604,040	14,373,567	630,514	16,085
1410	5,007	3,800	3,314	933,149	9,523,664	15,580,852	649,001	16,697
1411	5,528	4,193	3,487	970,636	11,299,712	18,023,289	731,900	18,569
1412	5,526	4,186	4,033	1,003,695	11,635,663	17,273,335	780,556	17,210
1413	5,748	4,344	4,260	1,035,520	14,522,080	20,391,074	883,043	19,692
1414	5,786	4,393	4,896	1,080,844	17,744,780	22,635,381	1,038,879	20,942
1415	5,789	4,358	4,590	1,099,710	17,354,162	23,367,948	1,068,832	21,249
1416	6,314	5,084	4,835	1,130,983	19,700,241	24,859,586	1,221,795	21,981
1417	6,254	5,291	4,883	1,175,942	21,155,274	24,290,898	1,442,253	20,834
1418	6,792	5,616	5,088	1,196,258	21,746,297	25,120,307	1,398,232	20,999

References: SCECO-West Annual Reports (Years 1400 to 1418)

**Imported Energy from the Desalination Plants
in the Western Region (MWH)**

YEAR	DESALINATION PLANTS			TOTAL
	JEDDAH	YANBU	AL-SHUAIBAH	
1403	3,133,600	435,700	-	3,569,300
1404	3,852,115	686,693	-	4,538,808
1405	3,843,530	991,809	-	4,835,339
1406	3,696,371	1,104,655	-	4,801,026
1407	4,321,486	449,273	-	4,770,759
1408	4,264,897	2,015,709	-	6,280,606
1409	4,086,650	1,646,303	156,536	5,889,489
1410	4,960,223	2,000,528	563,487	7,524,238
1411	4,850,360	1,978,117	737,708	7,566,185
1412	4,496,859	1,869,427	808,101	7,174,387
1413	4,333,237	2,040,659	964,311	7,338,207
1414	4,496,796	2,074,820	962,947	7,534,563
1415	4,847,663	2,098,616	968,870	7,915,149
1416	5,136,535	1,756,692	887,737	7,780,964

Reference : SCECO-West Annual Report

**Classification of Generating Capacity & Energy Generated
For the Year 1418 (1997-1998G)
In SCECO-West**

REGIONS	ACTUAL GENERATING CAPACITIES AS PER TYPE OF GENERATING UNITS									GRAND TOTAL
	DIESEL ENGINES		GAS TURBINES		STEAM TURBINES		TOTAL		IMPORTED ENERGY FROM SCECO-EAST	
	CONNECTED NETWORK	ISOLATED NETWORK	CONNECTED NETWORK	ISOLATED NETWORK	CONNECTED NETWORK	ISOLATED NETWORK	CONNECTED NETWORK	ISOLATED NETWORK		
Actual Capacity (MW)	62	225	3,725*	32	1,572	-	5,359	257	588	6,034
							5,616			
Generated Energy (MW)	634,519		12,180,728		8,931,050		21,746,297		7,061,262	28,807,559

Reference : SCECO-West Annual Report

**Fuel Consumed in Power Stations
SCECO-West**

YEAR	DIESEL (In M. Tons)	CRUDE OIL (In M. Tons)	GAS (In Million Cu. Meter)
1397	650,617	4,441	-
1398	992,273	6,477	-
1399	1,374,308	-	-
1400	1,629,213	62,474	-
1401	1,716,479	361,352	-
1402	2,068,048	178,594	-
1403	1,855,550	543,040	-
1404	2,121,986	560,574	-
1405	1,946,430	961,494	-
1406	1,670,631	1,162,677	-
1407	1,530,704	1,377,393	-
1408	1,582,891	1,322,802	-
1409	1,619,508	1,488,678	-
1410	1,544,913	1,270,184	-
1411	1,839,027	1,507,829	-
1412	1,883,443	1,549,804	-
1413	1,956,796	2,294,371	-
1414	2,329,017	2,838,322	-
1415	2,007,405	2,970,495	-
1416	2,278,002	3,302,919	-
1417	2,206,693	3,691,121	-
1418	2,124,575	3,829,762	-

Reference : SCECO-West Annual Report

**1.15.5 Saudi Consolidated Electric Company
In The Northern Region (SCECO-North)**

There are six (6) companies involved in electric power generation and distribution in Tabuk, Arar, Rafha, Dawmat Al-Jandal, Tayma and Haqi, and eight (8) government projects of the Electricity Corporation in Hail, Al-Jouf, Qurayyat, Duba (Tabuk Central Project) Turayf, Tubarjal, Al-Qulaybah and Bir Bin Hirnas. (See Map on page 43)

By the end of the year 1418H (1997-1998G), those electric companies and projects provided services to 189,614 customers.

Fuel consumption as a result of the energy generated is provided in page 42.

**Development of Generating Capacity, Energy & Number of Customers
In Electric Companies and Projects in the Northern Region**

YEAR	NOMINAL GENERATING CAPACITY (MW)	ACTUAL GENERATING CAPACITY (MW)	PEAK LOAD (MW)	NUMBER OF CUSTOMERS	ENERGY GENERATED (MWH)	ENERGY SOLD (MWH)	INDUSTRIAL CONSUMPTION (MWH)	AVE. ENERGY SOLD PER CUSTOMER (KWH)
1395	18	17	14	10,711	29,944	22,572	200	2,107
1396	19	18	15	12,843	45,598	37,809	422	2,944
1397	62	53	22	17,346	75,531	57,809	725	3,333
1398	101	92	34	25,871	116,623	94,392	886	3,649
1399	117	102	62	39,177	219,826	168,710	1,050	4,306
1400	157	129	75	46,952	342,041	279,605	1,497	5,955
1401	260	197	102	54,490	438,508	348,416	1,873	6,394
1402	272	205	140	60,106	576,650	413,500	2,034	6,880
1403	446	347	179	67,922	778,191	602,079	2,122	8,864
1404	475	362	200	74,238	811,246	687,779	2,285	9,265
1405	1,017	854	233	82,909	962,814	832,571	2,926	10,042
1406	1,096	926	255	93,945	1,105,180	952,805	3,206	10,142
1407	1,106	931	298	104,507	1,410,887	1,128,920	3,507	10,802
1408	1,080	908	328	112,562	1,489,157	1,239,940	6,397	11,016
1409	1,074	901	361	119,594	1,676,517	1,387,188	7,833	11,599
1410	1,180	981	368	129,416	1,760,853	1,446,568	7,261	11,178
1411	1,511	953	392	136,003	1,829,583	1,501,672	8,928	11,041
1412	1,137	931	470	142,765	2,152,788	1,811,786	11,275	12,691
1413	1,201	986	536	151,128	2,424,928	1,998,446	12,257	13,224
1414	1,257	1,034	531	160,282	2,634,449	2,193,727	15,932	13,687
1415	1,234	1,018	562	168,326	2,862,959	2,404,514	17,792	14,285
1416	1,396	1,126	605	176,026	3,036,553	2,575,801	18,777	14,633
1417	1,441	1,165	643	183,099	3,260,479	2,841,113	17,856	15,517
1418	1,451	1,182	700	189,614	3,428,023	2,877,688	25,738	15,177

References: SCECO-North Annual Reports (Years 1400 to 1418)

**Fuel Consumed in Power Stations
Electric Companies & Projects in the Northern Region**

YEAR	DIESEL (In M. Tons)	CRUDE OIL (In M. Tons)	GAS (In Million Cu. Meter)
1397	21,660	-	-
1398	29,297	-	-
1399	55,323	-	-
1400	88,684	-	-
1401	154,371	307	-
1402	192,140	-	-
1403	286,366	-	-
1404	295,646	-	-
1405	297,050	98,181	-
1406	290,887	233,714	-
1407	294,200	290,409	-
1408	320,977	281,961	-
1409	385,137	264,201	-
1410	407,326	274,328	-
1411	410,829	288,216	-
1412	456,548	329,602	-
1413	543,876	353,645	-
1414	630,085	352,289	-
1415	720,069	325,579	-
1416	773,847	323,332	-
1417	789,316	364,333	-
1418	874,628	348,591	-

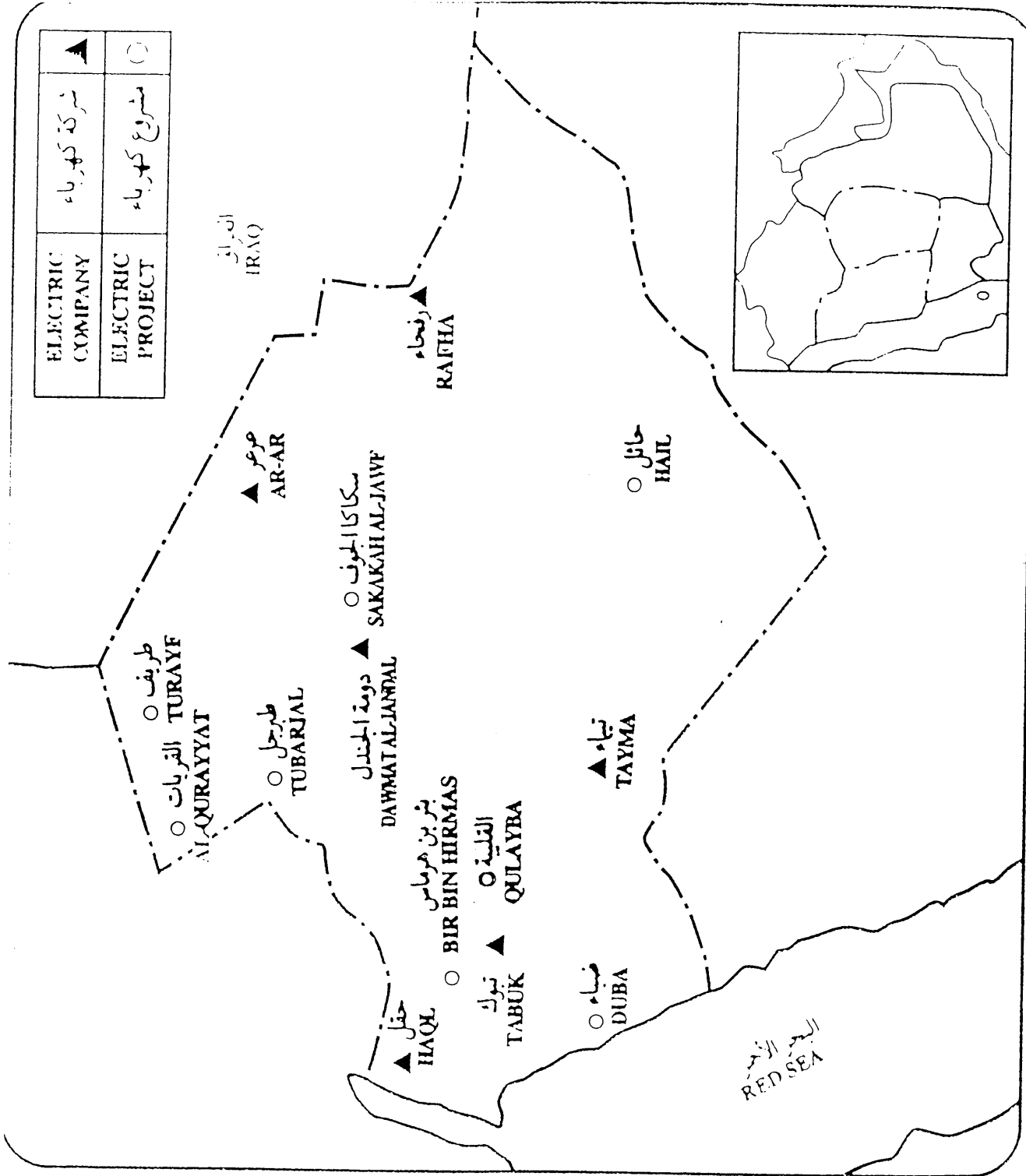
Reference : SCECO-North Annual Report

**Classification of Generating Capacity & Energy Generated
For the Year 1418 (1997-1998G)
In SCECO-North**

REGIONS	ACTUAL GENERATING CAPACITIES AS PER TYPE OF GENERATING UNITS								
	DIESEL ENGINES		GAS TURBINES		TOTAL				
	CONNECTED NETWORK	ISOLATED NETWORK	CONNECTED NETWORK	CONNECTED NETWORK	CONNECTED NETWORK	ISOLATED NETWORK			
Actual Capacity (MW)	-	169	-	1,013	-	1,182			
	169		1,013		1,182				
Generated Energy (MW)	289,412		3,138,611		3,428,023				

Reference : SCECO-North Annual Report

ELECTRIC COMPANY	شركة كهرباء	▲
ELECTRIC PROJECT	مشروع كهرباء	○



1.16 ENERGY SOURCES

1.16.1 Energy

Man first made use of energy from a source outside his own body when he discovered how to use fire, greatly enhancing his ability to survive.

This makes energy one of the most fundamental parts of our universe. We use it to do work. Energy lights our cities. It powers our vehicles, trains, planes, and rockets. Energy warms our homes, cooks our food, plays our music, and gives us pictures on television sets. It powers factory machineries.

There are many sources of energy. In this chapter, we will be looking at the energy that makes our world work, which is an important part of our daily lives.

1.16.2 Energy Definition

Energy is defined as “the ability to do work”. When we eat, our bodies transform the food into energy to do work. When we run or walk, we “burn” food energy in our bodies. When we think, read, or write, we are also doing work.

1.16.3 Types of Energy

Any particle or system of particles subject to conservative forces has two kinds of energy:

- **Potential** energy is the energy due to position or configuration.
- **Kinetic** energy is the energy due to motion.

All forms of energy are associated with motion. For instance, a body has kinetic energy if it is in motion. A raised object, such as a trip hammer, and a tensioned device such as a spring or bow, though at rest has the potential for creating motion. They contain potential energy as a result of their position or configuration. Thermal energy is a manifestation of motion of and within the molecules of a substance. For example, the temperature of a gas such as helium is related directly to the velocity of its molecules as they move in random motion. An electric current is the flow of electrons through a conductor. Chemical energy and nuclear energy are potential energies resulting from the configuration of atoms in a molecule or of subatomic particles in the nucleus of an atom.

(a) Mass Energy

In 1905, A. Einstein showed that at high velocities near the speed of light important modifications must be made in physical concepts. One particularly radical idea, which he advanced, was that space and time are not independent, but rather are two aspects of the

same object, a space-time manifold. This necessitated a re-examination of the concept of energy and led to the conclusion that the inertia, or mass m , depends upon its energy through the mass energy relation where c is the speed of light in vacuum. Furthermore, energy and momentum conservation became joined in a single four-momentum conservation law in special relativity.

(b) Field Energy

Whereas the particles and rigid body of mechanics are localized objects, which have positions and velocities, there are quantities called fields that are defined throughout a region, such as fluids, the electromagnetic field, and sound and water waves. Fields are recognizable disturbances. Each field satisfies some field equation that determines what sort of disturbance is created under various conditions. A fluid or water wave is a disturbance in the fluid or water medium. A sound wave is a pressure wave in a solid, liquid, or gas. The electromagnetic wave consists of an electric vector and a magnetic vector and can propagate through a vacuum; that is, no medium is needed.

(c) Atomic Energy

An atomic or subatomic particle subject to the potential energy is described by a function whose behaviour is governed by Schrodinger's equation.

There are certain technical aspects that must be

considered in order that energy users can make intelligent decisions regarding energy sources. Following topic provides the different kinds of energy available.

(d) **Capital Energy**

Scientists refer to the stored over time energy collectively as capital energy, and this is subdivided into six categories: primary energy, secondary energy, renewable energy, non-renewable energy, combustion process, and non-combustion process.

(i) **Primary**

This classification includes all forms of potential energy created mainly by the sun in the earth's crust that need no processing or treatment to transform them into usable energy.

(ii) **Secondary**

This classification includes the forms of potential energy manufactured from primary energy forms generally by mechanical, chemical, thermal, or nuclear reaction means to transform them into usable energy.

(iii) **Combustion Process**

Many of the forms of potential energy must be utilized in a combustion process before they will release their stored energy into a work process. This is part of the process of conversion.

(iv) Non-Combustion Process

There are also ways to release energy without a combustion process, such as river water turning a waterwheel. This was an important source of energy for nineteenth century factories.

(v) Renewable

This term refers to forms of potential energy that constantly and rapidly renews them for steady, reliable use. Coal, crude petroleum, and natural gas are listed as non-renewable but this is not totally accurate. These forms of potential energy are, in fact, constantly being created. However, modern industrialized societies are utilizing these energy sources so rapidly compared to the geological time period required for the formation of additional sources as to render the concept of renewable useless within any reasonable time frame. On the other hand, such energy forms as solar and wind power is clearly renewed on a timely basis and is labelled as renewable energy.

(vi) Non-Renewable

Any form of potential energy that does not fall within the definition accepted for renewable energy is considered non-renewable. For example, the fossil fuels may be defined in specific considerations as non-renewable energy sources.

1.17 RECURRING ENERGY SOURCES

Energies continuously being created from primary sources are said to be recurring. These include solar energy, the energy in wind and flowing streams, geothermal energy, the energy in tides, fuel from trees and other plants, and a possible source of energy in thermal gradients in the ocean (oceanothermic energy).

Solar radiation striking the earth's atmosphere in one year is being absorbed over land and the remainder over water.

Many attempts have been made to use solar energy to operate power plants, to cook, and to heat. Solar concentrators such as large parabolic mirrors, accurately oriented toward the sun, are necessary to produce the required high temperatures for generating power and cooking. Their cost makes power generation uneconomical if other energy sources are available. The practicability of heating homes with solar radiation depends upon their location and the cost of other fuels.

1.18 EXPENDABLE ENERGY SOURCES

The fossil fuels (coal, lignite, peat, petroleum, and natural gas) are natural resources that are being consumed at an appreciable rate. Although deposits continue to be discovered, the reserves of these fuels remaining in the earth are finite. The amounts that can be recovered economically are difficult to estimate, depending as they do upon the future value of the fuels and their mining cost. Although the amount of recoverable fuel will increase as more efficient mining methods are developed, certainly at some time in the future uranium and thorium will supply a significant part of world energy requirements. Ultimately, if the technical problems of controlling

nuclear fusion are solved, man will have an essentially unlimited source of energy.

1.19 ENERGY NEEDS

Human use of energy, particularly capital energy, has accelerated over time due to an increase in the human population and the discovery of new technologies for utilizing energy. This acceleration took on exponential proportions during the industrial revolution of the nineteenth and twentieth centuries. As the utilization of, and therefore the demand for, energy rose, scientists, and engineers discovered ways to utilize new forms of energy. The availability and technical feasibility of many energy forms yielded a proliferation of energy choices, so that decisions had to be reached on the selection of energy sources. The need to make energy decisions has resulted in the development of an energy choice system. This system involves an economic analysis, which compares the cost of input versus the benefit of output for two specific energy sources. Among the factors included in this analysis are depletion cost, the cost of using non-renewable energy; social cost, the health and environmental issues; availability cost, the cost of utilizing energy sources subject to interruptions of supply; and switching or conversion cost, converting plant and equipment to other energy uses.

1.20 PRIMARY ENERGY SOURCE

The primary sources of energy include nuclear fusion, nuclear fission, radioactivity, and the motion of the earth and the moon. All forms of energy can be traced from these origins.

1.20.1 Nuclear Fusion

Energy is released in the sun by thermonuclear reactions that fuse hydrogen and other light elements into heavier elements, releasing very large amounts of energy. This is the source of the radiant energy that illuminates the earth and provides a practically inexhaustible supply of energy on earth and in space. The thermal effects of solar energy create winds in the earth's atmosphere, and even the energy in flowing streams is produced indirectly from solar radiation.

1.20.2 Nuclear Fission

Fissionable nuclear fuels are remarkable sources of energy. The energy released by the fissioning of one atom of uranium, for example, is several million times greater than that produced by the combustion of one molecule of gasoline. The knowledge of means for releasing atomic energy came about through a series of discoveries with the final development being motivated by the effort to create superior bombs for military use.

1.20.3 Radioactivity

The energy released in nuclear fission is in the form of radiations and kinetic energy of the fission products, which are released at high velocity. Most of these become thermal energy in the fuel elements as the fission products come to rest and as some of the radiations are absorbed. The thermal energy can be converted in part into mechanical energy, which can then be converted into

electrical energy by a steam turbine driving a generator.

Radioisotopes can produce electrical energy in small amounts for special purposes. Demonstrated as early as 1913 was a type of nuclear battery for generating electricity directly from radiations released in radioactive decay.

1.21 ENERGY CONVERSION

Energy conversion is the process of changing energy from one form to another. The technological progress has been marked by the invention and refinement of devices for converting energy from the forms provided by nature into other forms that can perform such tasks as lifting heavy objects, imparting motion to machinery, or transferring goods or information over distances. Several of these are quite simple: a windmill or a waterwheel redirects the energy of the wind or of flowing water into the rotation of a millstone or the reciprocating action of a pump. At the other extreme, a coal fired electric generating station can be regarded as a single device for the conversion of the chemical energy present in a combustible fuel and the oxygen of the air into electrical energy; along the way, the energy undergoes a sequence of transformations through various intermediate forms.

Useful mechanical or electrical energy is produced by fuel burning heat engines, by electric generators, batteries, photoelectric cells, and by many other devices, most of which have important applications.

Direct Energy Conversion Devices

Requirements for energy for space vehicles led to an exhaustive investigation, starting in 1955, of all possible energy sources (much of the literature on this subject has come from these programs). Direct energy conversion devices are of interest for providing electrical energy in space vehicles because of their reliability and their lack of moving parts. Sometimes called static energy conversion devices, they can be considered to use electrons as the working fluid in place of vapor or gas in a dynamic heat engine.

Another static energy conversion device that has been investigated extensively for the space program is the thermionic generator. Electrons are driven in a vacuum by thermal energy from a high temperature electrode, across a potential difference, to a cooler electrode. Thomas Alva Edison was the first to observe an electric current between an incandescent filament and a cold electrode in an evacuated tube, but not until 1958 did active development of thermionic generators begun. Although their performance has since been improved greatly, the lack of suitable materials for use at very high temperatures and problems in construction has limited their reliability. When these problems are solved, thermionic generators will be properly suited for use with nuclear reactors or radioisotope heat sources.

Chemical energy can be converted directly into electrical energy by electrochemical reactions in a battery or fuel cell. The efficiency of the process is not limited by the maximum theoretical efficiency of energy conversion when chemical energy is converted to thermal energy for operation of a heat engine. Batteries and fuel cells with efficiencies of over 80 percent (at very low current) have been

demonstrated, whereas the best efficiencies obtained in heat engines are about half this value.

The processes by which muscles convert chemical energy into mechanical energy are the subject of intensive research and are now partly understood. Blood carries food material and oxygen to the muscle where they react through the radiation of a system of proteinaceous substances called enzymes, producing heat as well as mechanical energy. A muscle at rest produces very little heat; but very soon after stimulation, resistance to stretch develops rapidly and heat production increases. Additional heat is produced as the muscle shortens. The amount is proportional to the distance of shortening and independent of load. A rapidly shortening muscle exerts less tension than when shortening slowly, and less thermal energy is released per unit distance. Perhaps some day these remarkable processes can be applied to inanimate energy conversion.

1.22 ENERGY STORAGE

Energy storage refers to general method and specific techniques of energy storage derived from some primary source in a form convenient for use at a later time when a specific energy demand is to be met, often in a different location.

In the past, energy storage on a large scale had been limited to storage of fuels. For example, large amounts of natural gas may be stored under pressure in underground reservoirs during the summer and used to meet increased demands for heating fuel in the colder season. Petroleum and its products are stored at several points in the energy system.

Energy storage in electric power systems has excellent potential for reducing the use of oil and gas for power generation, especially if pumped hydro storage can be supplemented by more broadly applicable techniques such as underground pumped hydro, compressed air storage, and batteries. These techniques also could provide utilities with special operating advantages not found in conventional generating plants. Storage technologies that could find application in one or more of the major energy use sectors are discussed below.

1.22.1 Pumped Hydro Storage

Electric utilities pumped hydro goes back to 1929 in the United States. The largest such facility in the world with a capacity of 15×10^6 kWh is the Ludington pumped storage plant on Lake Michigan. The construction of such facilities is limited by a variety of geographic, geologic, and environmental constraints, all of which may be considerably reduced if the power generation equipment and discharge reservoir are placed deep underground.

1.22.2 Compressed Air Storage

Off peak electric energy can also be converted into mechanical energy by pumping air into a suitable cavern where it is stored under pressure.

1.22.3 Batteries

The development of advanced batteries with characteristics superior to those of the familiar lead acid battery could

result in use of battery energy storage on large scale. For example, batteries lasting 2000 or more cycles could be used in installations of several hundred thousand kilowatt hour capacities in various locations on the electric power grid, as an almost universally applicable method of utility energy storage.

1.22.4 Thermal Storage

Ceramic brick "storage heaters" that store off peak electricity in the form of heat is used for heating buildings in Europe; the barriers to their use in the United States are more institutional and economical than technological.

Testing has been done on prototype "coolness" storage systems, which use electric refrigeration to chill water or produce ice at night. Experimental installations indicate that daytime electric power demand for air conditioning could be reduced up to 75% by using such systems, but these systems are still relatively bulky and expensive.

Solar hot water storage is technically simple and commercially available. However, the use of solar energy for space heating requires relatively large storage systems, with water or rock beds as storage media, and difficulties can arise in integrating this storage with existing buildings while keeping costs within acceptable limits.

1.22.5 Chemical Reaction Systems

Heat or electricity may be stored by using these energy forms to force certain chemical reactions to occur. Such reactions are chosen so that they can be reversed readily with release of energy; in some cases the products can be transported from the point of generation to that of consumption, adding flexibility to the ways stored energy can be used.

1.22.6 Super Conducting Magnets

Electrical energy can be stored directly in the form of large direct currents used to create fields surrounding the super conducting windings of electromagnets. In principle, such devices appear attractive because their storage efficiency is high, plant life could be long, and utilities would have few difficulties establishing the necessary conversion equipment. However, the need for maintenance system at temperatures approaching absolute zero and, particularly, the need to physically restrain the coils of the magnet when energized require auxiliary equipment, which will represent large expenditure.

1.22.7 Flywheels

Storage of kinetic energy in rotating mechanical systems such as flywheels is attractive where very rapid absorption and release of the stored energy is critical. However, even advanced designs and materials are likely to be too expensive for utility energy storage on a significant scale, and applications will probable remain limited to systems

where high power capacity and short charging cycles are the prime consideration. Such applications do exist in pulse power supplies and in electric transportation for recovery of braking energy.

1.22.8 Combined Systems

The rising importance of energy storage comes from its potential for shifting demand from scarce to plentiful primary energy sources. As such, the most successful storage devices are likely to be those that are adopted as components of larger systems designed specifically for resource conservation. In electric power generation, for example, system wide storage may be combined with solar electric systems to flatten load curves and reduce oil consumption. If such complex systems are eventually to be developed and commercially introduced, financial incentives and more coherent national energy policy planning must be adopted. Thus, while advanced energy storage systems could have a major impact on United States energy consumption patterns before the end of the century with continued, successful research, non-technical factors such as regulatory strategies and pricing policies are likely to become decisive to their large scale use.

1.23 ENERGY FORMS

Energy takes on one of following forms.

1.23.1 Chemical Energy

Chemical energy results from changes in the chemical structure of substances, such as during combustion of fuel.

1.23.2 Chemical Energy from Fossil Fuels

Crude petroleum, natural gas, and coal were formed in the earth's crust over the course of millions years and exist today in subsurface locations. Crude petroleum is found trapped in the pores of rock (sandstone, limestone, or dolomite) or sand overlain with some kind of impervious cap rock that prevents the liquid from dispersing. Natural gas is normally found trapped in the earth alongside or with crude petroleum.

1.23.3 Wood

Wood was long the principal in some regions the only fuel. In addition to its use for heating and cooking, it became a source of charcoal for reducing ores to metals.

1.23.4 Coal

This complex mineral substance is found worldwide where economically mined in commercial quantities.

Many parts of the world contain extensive coal deposits, but coal was difficult to mine with primitive tools and only the

Chinese are known to have mined it to supplement natural gas and their dwindling supply of wood.

Coal is used in the United States for generating electric power, metallurgical production, general industrial processes, residential commercial uses and synthetic fuels. For most part, coal is burned in fire tube or water tube boilers for raising steam that is used to generate electricity, provide heat for factories and buildings, and steam for production processes.

1.23.5 Crude Petroleum

Oil is also a complex substance derived from the carbonised remains of trees, ferns, mosses, and other types of vegetable matter. Like coal, there is doubt about the exact nature of its origin. The principal chemical constituents of oil are carbon, hydrogen, and sulphur. Crude petroleum extracted from the earth will burn and produce thermal energy, but virtually all crude oil is processed in refineries, where it is converted into several useful fuels and special products (for example, feedstock for chemicals, plastics, food products, medicines, and tires, plus tar, asphalts, and lubricating oils). The various fuels made from crude oil are jet fuel, gasoline, kerosene, diesel fuel, and heavy fuel oils.

Major oil consumption in most of the world is in the following areas: transportation, residential commercial, industry boilers and other industrial uses and generating electric power.

1.24 NATURAL GAS

This energy source is 83-93% methane, so that its principal chemical constituents are carbon and hydrogen. Natural gas is usually found in the immediate vicinity of crude petroleum, although some natural gas wells do not yield oil.

Of all the chemical or mineral sources of energy, natural gas may well be the most desirable because it can be pipelined directly to the customer, requires no storage vessels, is clean burning, requires no air pollution control equipment, produces no ash for disposal, and mixes with air easily to provide complete combustion at low excess air.

The principal uses for natural gas are residential, commercial buildings, industrial, transportation, and generating electric power.

1.25 SOLAR ENERGY

The ultimate source of energy on earth is the sun, solar power, which produces energy on a daily basis and stored over time. By far the most attractive energy source because it is free, is clean and nonpolluting, and does not involve the use of dwindling, finite reserves of capital energy.

The sun provides radiant heat on a daily basis to the earth, which drives many reactions. For example, solar heat evaporates water from the sea and the lakes, providing the moisture for cloud formations, which break into rain in mountainous regions. The rain falls off into constructed reservoir lakes which feed water through hydroelectric dams, thus rotating electric generators that produce the

kinetic electrical energy supplied through power lines to industrial plants, commercial buildings, and residential homes. Tidal power, wave power, solar power, and wind power are additional examples of daily energy sources.

The problem with solar energy is its cost, particularly for large industrial uses. Roughly 50% of the sunlight approaching earth is reflected or absorbed by the atmosphere and the other 50% strikes earth's surface. In the tropical and temperate zones, the sun provides the equivalent of, on average, about 622 MW of energy per square mile (250 MW/km²). Unfortunately, technology is able to convert only about 15% of the sun's radiant heat to usable work, so that a typical large electric generating station capable of producing 1000 MW would require an array of solar head collector converters covering an area of at least 11 mi² (28 km²).

The collector converters are made of silicon, which produces electricity when it is exposed to light. The high cost of these devices derives from the cost of growing and cutting large crystals into thin slices of silicon. The more this process becomes automated, the lower the price and the more the process is likely to be employed.

Another idea is the solar power tower. An Italian scientist, G. Francia, demonstrated this type of technology in 1976. A 10 MW electric generating station is in operation in Daggett, California; it utilizes 72 acre (29 hectare) field of mirrors to concentrate sunlight at the top of a central tower. The thermal energy from the sunlight superheats steam that is used to power electricity generating turbines.

Finally, the concept of solar ponds has received attention in many parts of the world. These are artificial, salt gradient ponds. They are

derived from the work of a Russian Scientist, A. Von Karaczinsky, who in 1902 found that the temperature of the water in Lake Medve in Transylvania a few feet below the surface was 185°F (85°C) due to the variation in salinity of the water. Experiments have been conducted with ponds in which layers of different salinity allow the water to trap and hold solar heat. The hot brine can be used for space heating or for producing electricity with a thermoelectric device or organic Rankine cycle engine.

1.26 NUCLEAR ENERGY

The two ways to utilize radioactive fuel as an energy source are fission and fusion. In both cases, large quantities of energy are released. More conventionally, nuclear power is interpreted as the utilization of the fission reactions in a nuclear power reactor to produce steam for electric power production, for ship propulsion, or for process heat.

1.26.1 Nuclear Fission

In nuclear fission heavy atoms are split into two principal elements that form the nucleus of two new, smaller atoms.

1.26.2 Nuclear Fusion

The fusion process is the opposite of fission. Instead of splitting atoms into two or more pieces, the fusion process causes two atoms to collide with such force that their natural electronic repulsion is overcome and their nuclei fuse into one.

At any rate, fusion power is still an important potential source of continuous low cost energy, provided that the technical problems can be solved.

1.26.3 Nuclear Energy from a Reactor

A nuclear reactor is a device designed to permit self-sustaining and controlled nuclear fissions, with the object of generating heat, producing radioactive isotopes or plutonium, developing an intense field of nuclear radiation, or serving some other useful purpose.

1.27 ELECTRICAL ENERGY

Electrical energy results from electrons and protons in motion in a stream called an electric current, or in temporary storage as in a battery or fuel cell.

What is Electricity? The word “electricity” comes from the Greek word electron, which means “amber”. Amber is a translucent yellowish mineral made of fossilized resin. The ancient Greeks used the words “electric force” in referring to the mysterious forces of attraction and repulsion exhibited by amber when it was rubbed with a cloth. They did not understand the nature of this force and could not answer the question, “What is electricity?” Today, we still cannot answer the question, although the success with which we have used electricity is obvious everywhere.

Electric power, which is basic to modern life, is largely responsible for the high standard of living and advanced level of industrialization of much of the world. The consumption of electric power has expanded

steadily in the 20th century, doubling roughly every 10 years.

The modern electric power industry was founded on a series of inventions and developments for converting the mechanical energy of falling water and the heat energy of fossil fuels into electrical energy.

1.28 SOURCES OF ELECTRICAL ENERGY

1.28.1 Tidal Electrical Energy

Power from tidal movement that uses barrage type of dam across estuary of a river. Turbines located in this barrage pump water into the estuary when the tide is rising. When a sufficient head of water is built up in the estuary, the water is permitted to flow back through the turbines to produce electricity.

1.28.2 Wind Electrical Energy

This is also a form of energy that can be used to generate electrical or mechanical energy. Rotating devices known as windmills can convert the mechanical energy of wind to useful work.

Windmills, probably invented in China, spread slowly into the Middle East. They were used in Persia (now Iran) before the 10th century and reached Europe, via the Arabs, by the 12th century. These early windmills were an important inanimate source of mechanical energy, especially for drainage and milling grain.

1.28.3 Ocean Electrical Energy

Ocean power may become an energy source in the future, either as wave power or as ocean temperature differential. Both forms are highly experimental and may require many years to become significant energy sources.

(a) Wave Power

Many different devices have been proposed and tested for exploiting the wave motion of the sea. In Scandinavia, one device is designed so that ocean waves cause massive quantities of water to flow into the confines of the device, which then generates electricity as the water tries to escape back to the sea. In England, S. Salter demonstrated his so called nodding duck device, which is floating device that rotates due to the motion of waves rolling over it. The float is capable of driving a hydraulic pump that, in turn, can drive an electrical generating device.

(b) Ocean Temperature

An energy producing system known as ocean thermal energy conversion (OTEC) is based on the temperature differential in the oceans near the equator where the surface water is about 40°F (20°C) warmer than the water a few thousand feet down. This temperature difference can be utilized to vaporize a working fluid (such as ammonia) that can be run through an electricity-producing turbine.

1.28.4 Geothermal Electrical Energy

As with ocean power, the geothermal energy source may be exploited in either or both of two ways: hot rocks and hydrothermal.

(a) Hard Rocks

It is known that hot granite rock (up to 400°F or 200°C) exists almost everywhere on earth. A slow radioactive decay process deep within the earth generates the heat, for the most part.

The technique, (still experimental) for tapping this energy source involves conventional oil or gas drilling expertise.

(b) Hydrothermal

The earth emits steam in many locations, such as Iceland, the United States, the Philippines, and New Zealand, where it is captured and employed for space heating, generating electricity, or industrial process steam applications. Hydrothermal steam now provides the equivalent of about 1200 MW of electric power.

1.28.5 Biomass Electrical Energy

As applied to the field of energy, the term biomass energy encompasses a broad selection of energy sources: Any and all types of living matter that can be converted to a form of energy can be said to be biomass. Hence, scientists tend to think of such items as wood, wood waste,

coffee grounds, corn husks, peanut shells, rice hulls, garbage, animal and human waste, sugarcane waste (bagasse), or organic effluent from streams and ponds as biomass.

The biomass considered to be most significant in terms of energy sources is wood and wood waste. Up until the end of the nineteenth century, when coal took over as the leading energy source, wood was a pre-eminent provider of energy to the world. Wood is again being used on a limited scale at the residential level. The lumber, furniture, plywood, and pulp and paper industries all utilize wood waste items for raising steam that, in turn, is employed for space heating and industrial processes.

1.28.6 Hydro Electrical Energy

One of the oldest energy producing mechanisms uses water flowing in a river or falling from a height to rotate work devices, ranging from the watersheds of the past to the massive modern hydroelectric dams that employ gigantic electricity generating turbines. Internationally, only 7% of the total potential hydroelectric power. Much of that potential, unfortunately, is located in remote places from which lengthy transmission lines would be prohibitively expensive. Furthermore, environmental protectionists are resisting new projects that might threaten natural resources.

1.29 ELECTRICITY SUPPLY TO CUSTOMERS

Three distinct functions are involved in supplying electricity to the consumer, generation, transmission, and distribution. These functions correspond to the manufacture, transportation to market, and retail distribution of many other products, the chief differences being that electricity moves from the point of generation to the point of ultimate use in a continuous flow at a speed approaching that of light and that it cannot be stored in its original form.

1.29.1 Power Generation

Power generation, the production of electrical energy from mechanical energy, takes place at central stations that may be either thermal power plants, in which the energy source is steam driven turbines, or hydroelectric plants, in which the energy source is water driven turbines. Transmission is the moving of this electrical energy from generating plants to bulk delivery points called substations, whence distribution delivers it to the consumer.

(a) Electric Generators

Generators in thermal power stations are 2-pole and 4-pole machines (3,600 or 1,800 revolutions per minute at 60 hertz), directly connected to the steam turbines. In cross compound units, two or more generators constitute one unit and are treated electrically as a single machine. Generators are rated in kilowatts and kilovolt amperes at a certain power factor.

(b) Turbine Generators

A steam turbine, designed for converting thermal energy stored as steam into work.

(c) Gas Turbines

A gas turbine is, as noted above, a form of heat engine for producing work with the aid of heated gases. It differs from the conventional internal combustion engine in the manner in which the heated gases are employed.

1.29.2 Power Transmission

The transmission system carries electric power efficiently in large amounts from generating stations to consumers. Such transmission is also used to interconnect adjacent power systems for mutual assistance in cases of emergency and to gain on the interconnected power systems the economies possible in regional operations.

Generation and transmission facilities are usually economically interdependent in that the choice of location, design, and scale of generating capacity must take into account the associated cost of transmission and vice versa. Responsibilities for generation and transmission customarily go together. Distribution can be and frequently is, conducted efficiently as a separate operation.

For many technical and economic reasons, the most appropriate arrangement for electric service to all customers in a given area is provided by a strongly

integrated complex of generation and transmission facilities with sole responsibility for meeting all of the power requirements.

1.29.3 Power Distribution

The part of the electric power system that takes power from a bulk power substation to customers' switches, commonly about 35% of the total plant investment, is called distribution. This category includes distribution substations, sub transmission circuits that feed them, primary circuits that extend from distribution substations to every street and alley, distribution transformers, secondary lines, house service drops or loops, metering equipment, street and highway lighting, and a wide variety of associated devices.

At conveniently located distribution transformers in residential and commercial areas, the line voltage is stepped down to supply low voltage secondary lines, from which service drops extend to supply the customers' premises. Most such service is at 120/240 V, but other common voltages are 120/208 V and 125/216 V, and for larger commercial and industrial buildings, 240/480, 265/460 or 277/480 V. These are classified as utilization voltages.

1.30 ELECTRIC POWER SYSTEMS – ELECTRIC UTILITY

The electric utility is unique in that it sells a product that must be generated at the instant it is to be used. With existing technology, it is impossible to build up an appreciable stockpile of electric power, so that the utility must be ready to generate enough electricity to satisfy the demand at any time. If the utility has excess generating capacity, it can usually cover any anticipated demand; but an overabundance of excess capacity means that too much of the plant is idle too much of the time, thus increasing costs. At the same time, few products have a greater need for quality and reliability.

Private electric utilities can operate only by the grant of a special privilege or franchise from the national or local government that permits use of streets, sub surfaces, and other public property. The franchise is usually granted only to a single concern in any given area creating a monopoly. In the past, duplication of service to one area was sometimes permitted to increase competition. In such cases, the streets were cluttered with facilities and equipment were duplicated, leading to an over investment. A franchise, therefore, gives the utility certain rights and imposes corresponding duties.

A utility has legal rights that allows it:

- (a) To invoke under certain circumstances the law of eminent domain to obtain property; that is invoke condemnation proceedings to acquire it;
- (b) To charge and obtain a reasonable rate for the service; and
- (c) To establish and enforce reasonable rules and regulations under which it provides service.

The principal duties are that the utility must:

- (a) Serve all who apply for the service;
- (b) Provide power up to maximum capacity and be prepared to meet future increase in demand;
- (c) Provide service that is adequate and safe;
- (d) Not discriminate unfairly among customers (though it may serve different categories of customers at different rates); and
- (e) Not obtain more than a reasonable price for its service.

The physical property of an electric utility usually comprises the following:

- (a) One or more power stations, which may be thermal stations using coal, oil, gas, or nuclear fuel, a combination of some or all of these, hydroelectric stations, or a combination of both types. Each power station has a switchyard containing transformers, circuit breakers, and control equipment.
- (b) A transmission line, usually constructed on private right of ways.
- (c) Transmission substations with transformers to reduce the voltage to several sub transmission circuits, the attendant circuit breakers and control equipment.
- (d) Distribution substations in which the sub transmission voltage is again reduced to supply transformers mounted on poles for general distribution in suburban and rural areas or to supply transformers in vaults for underground distribution. For industrial customers, electricity is delivered at transmission voltage, at sub transmission voltage, or at distribution voltage, depending on the size and location of the factory and the most economical supply in the circumstances.

Chapter 2

PURPOSE OF THIS RESEARCH

2.0 PURPOSE

The intention of Saudi Arabia in its development plans is to improve the economy by increasing the participation of non-oil based industries. As an integral part of this plan, progress in electricity generation and distribution has become essential to meet growing demands.

The rapid growth and development of Saudi Arabia including the expected 3.8% annual population increase necessitated the expansion and modernization of electrical generation, transmission and distribution to cope with modern times and industrial development.

A forecast is important since it is used to make investment decisions concerning future developments. The uncertainties associated with the future make this process a difficult task, especially over the long-term. In addition to being useful for short term assessment, the analysis of the various forecast elements help to define the range within which the future values are likely to be found.

Because electrical energy cannot be stored efficiently in large quantities, it must be generated at the same time as the demand to maintain the equilibrium between generation and consumption.. Since the construction of a major power plant takes 4 to 5 years to complete, within the scope of the long-term electrification plan of the

kingdom, it was necessary to establish the electricity demand forecast covering the entire Saudi Arabia.

The purpose of this demand forecast is to provide a basis for long-term expansion of the generation and transmission facilities required in the kingdom over the study period. There are a number of alternative ways in which the Kingdom's demand could be met over this period, based on the expected economic and demographic evolution.

In view of the increasing demand for electrical energy, the government was compelled to expand its electricity generation capacities to meet the growing demands by its constituents. Cost to build new generating plants entails huge amounts of investments. Therefore the use of other alternative sources of energy was considered.

It is for this reason that a feasibility study, based on 20 years demand forecasts, was made to:

- Determine the growth in electricity demand in Saudi Arabia, and
- To draw attention to other alternative sources of energy.

2.1 RESEARCH METHODOLOGY

Business research is defined as the systematic and objective process of gathering, recording and analysing data in aid of making business decisions. The prime managerial value of business research is that it reduces uncertainty by providing information that improves decision-making process.

Business research is a sequence of highly interrelated activities. It follows a neat and orderly sequence of activities, which are explained as follows:

2.1.1 Definition of the Problem

It is essential to determine the organizational environmental condition in order to gain an awareness of the extent of the problem. The common mission of electrical companies in the Kingdom of Saudi Arabia is "*to serve customers by providing safe and reliable electric energy with optimum utilization of available resources*". Management must continuously review the demand and generating capacities of electrical companies in Saudi Arabia by analysing and forecasting its future requirements.

2.1.2 Collection of Data

The emphasis of my study focuses on the following:

(a) Economic Data

The economic data on for the last 24 years are gathered from various economical and financial publication of Saudi Arabia.

This data are displayed in appendices 1.1 to 1.4.

- Gross Domestic product (GDP)
- Average Oil Price
- Income per capita
- Population

(b) Electricity Data

Data on electricity Sold by the government and Electric Organizations, as displayed earlier in chapter 1# are gathered from the publications of electricity generating organizations, such as

- ♦ Ministry of Industry and Electricity
- ♦ Saudi Consolidated Electric Company - Eastern Region
- ♦ Saudi Consolidated Electric Company - Western Region
- ♦ Saudi Consolidated Electric Company - Southern Region
- ♦ Saudi Consolidated Electric Company - Central Region
- ♦ Electric Companies in the Northern Region

2.1.3 Analysis of Data

Data on energy sold are analysed using multiple correlation and regression models.

Data Test was used to verify the accuracy of our data.

2.1.4 Models & Forecast Accuracy

The Multiple Regression Model, which allows us to interact between more than one variable is explained as follows:

(a) Multiple Linear Regression Model

For n , the number of observations, the multiple linear regression models is:

$$Y_j = \beta_0 + \beta_1 \chi_{1j} + \beta_2 \chi_{2j} + \dots + \beta_n \chi_{nj} + E_j \text{ for } j=1, \dots, n$$

Where:

β_0 = Y intercept (constant)

$\beta_1, \beta_2, \dots, \beta_n$ = unknown regression coefficient parameters

$\chi_1, \chi_2, \dots, \chi_n$ = independent variable

E = White noise assumed Normally distributed with mean zero and a Constant variance (v)

The estimate of this model is:

$$\hat{Y}_i = b_0 + b_1 X_{1j} + \dots + b_n X_{nj}$$

Where $\beta_0, \beta_1, \beta_2, \dots, \beta_n$ respectively.

The parameters of this model are estimated by employing least squared estimation techniques, which minimizes the sum of square of residuals.

$$S^2 = \sum (Y_j - \hat{Y}_j)^2$$

(b) Coefficient of Multiple Determination

The coefficient of multiple determinations denoted by (R^2) is defined as:

$$\begin{aligned} R^2 &= \frac{\text{Sum of Squares Regression}}{\text{Total Sum of Squares}} = \frac{SSR}{TSS} \\ &= 1 - \frac{\text{Sum of Squares Error}}{\text{Total Sum of Squares}} = \frac{SSE}{TSS} \\ R^2 &= \frac{\sum (\hat{Y}_j - \bar{Y})^2}{\sum (Y_j - \bar{Y})^2} = 1 - \frac{\sum (Y_j - \hat{Y}_j)^2}{\sum (Y_j - \bar{Y})^2} \end{aligned}$$

The value of this coefficient that measures the proportionate reduction in TSS associated with the use of the independent variables $X_1, X_2, \dots, X_{p-1}$ in the multiple regression model ranges from 0 to 1.

In other word its Measures the percentage of variation in the dependent variable that can be accounted for by the independent variables.

(c) Test Significance of Regression Coefficients

To test the significance of the regression coefficients of α , the level of significance

Analysis of Variance technique (ANOVA) is used. It is explained as follows:

Sources of variation	SS	df	MS	F
Regression	$SSR = \sum(\hat{Y}_j - \bar{Y})^2$	p-1	$MSR = \frac{SSR}{p-1}$	$\frac{MSR}{MSE}$
Error	$SSE = \sum(Y_j - \hat{Y}_j)^2$	n-p	$MSE = \frac{SSE}{n-p}$	
Total	$TSS = \sum(Y_j - \bar{Y})^2$	n-1		

Where:

- P = no of model parameter (or regression)
- Df = Degrees of Freedom
- SSR = Sum of Square of Regression
- SSE = Sum of Square of Error
- TSS = Total Sum of Square
- MSR = Mean Square Regression
- MSE = Mean Square Error
- F = Fisher's F-Statistic

(d) Standard Error of the Estimate (S_e)

To measure the dispersion of observed dependent variable (Y), around the predicted values of the regression model, Standard Error of the estimate (S_e) is computed as follows

$$S_e = \sqrt{\frac{SSE}{n - k - 1}}$$

Where:

SSE = Sum of Square Error

n = no of observations

k = Number of independent variable

(e) Student t – Value

The student t – Value that indicates which of the independent variables explain a significant proportion of the variation of dependent variable is computed as follows

$$t = \frac{r\sqrt{n - 2}}{\sqrt{1 - r^2}}$$

Where:

r = sample correlation coefficient

n = sample size

(f) **Softwares**

For analysis of data the software used is :

- Explore Statistics, (Book Reference, p.104)
- Microsoft Excel 2000, 2.0.2720, USA (Book Reference, p.112)

Chapter 3

DATA ANALYSIS

3.1 REGRESSION ANALYSIS

The data consisting of 24 observations (1974-1997) are analysed using the Multiple Linear Regression (MLR) model (2.1.4.a) with four independent variables

That is:

$$Y_j = \beta_0 + \beta_1\chi_{1j} + \beta_2\chi_{2j} + \beta_3\chi_{3j} + \beta_4\chi_{4j} + E_j$$

Where:

Y_j = Demand of Electricity *(Chapter 1,p. 20)*

χ_1 = K.S.A Gross Domestic Product (GDP) *(Appendix #1.1)*

χ_2 = Average Oil prices *(Appendix #1.2)*

χ_3 = Income per capita *(Appendix #1.3)*

χ_4 = Population of K.S.A *(Appendix #1.4)*

E = Random Error as defined earlier

This model along with the multiple correlation formula (2.1.4.b) yielded the following result:

Table # 3.1
Mean and Standard Deviation

Variable	Mean	Standard Deviation
Energy Sold	4.680679E+07	3.021691E+07
GDP of S. A	52575.38	12435.55
Average oil prices	19.125	7.066839
Per Capita Income	8927.917	1928.998
Population	1.102621E+07	3106945

Note: The standard Deviation uses (n – 1) as adviser.
(page 106)

See Appendix

3.2 CORRELATION COEFFICIENT ANALYSIS

To study the relationship between various variables, the correlation coefficient matrix is generated and described as follows.

Table # 3.2
Matrix of Correlation Coefficient

Particulars	Energy Sold Y	GDP X1	Average Oil Prices X2	Income Per Capita X3	Population X4
Energy Sold (y)	1.000	0.763	0.026	-0.464	0.976
GDP of K.S.A. (x1)	0.763	1.000	0.144	-0.304	0.735
Average oil prices (x2)	0.026	0.144	1.000	-0.180	-0.101
Per Capita Income (x3)	-0.464	-0.304	-0.180	1.000	-0.306
Population (x4)	0.976	0.735	-0.101	-0.306	1.000

See Appendix (page107)

It is clear from the matrix that coefficients that are significantly different from zero display high relationship between various variables and energy sold.

This matrix further reveals that Income per Capita (χ_3) has strong negative relationship with the energy Sold. It means that when Income per Capita increases, the demand for electricity decreases, (not logical under the normal circumstances). Owing to this I have excluded the variable (χ_3) for my study.

The variable (χ_2) average oil price is also excluded from the study as it has insignificant relationship with the energy sold.

Excluding these two variables I am left with two independent variables (χ_1 and χ_4) for analysis of data and projection of forecast as these variables have strong relationship with Y_j as follows.

- Energy Sold and Gross Domestic product (GDP) =
(0.76)
- Energy Sold and Population in K.S.A =
(0.98)

3.3 MULTIPLE REGRESSION

Based on these independent variables the model becomes

$$Y_j = \beta_0 + \beta_1\chi_1 + \beta_4\chi_4 + E_j$$

The result yielded by this model is as follows:

Table # 3.3
Mean and Standard Deviation

Variable	Mean	Standard Deviation
Energy Sold (Y_j)	4.680679E+07	3.021691E+07
GDP of S. A (χ_1)	52575.38	12435.55
Population in S. A (χ_4)	1.102621E+07	3106945

See Appendix (page 108)

Table # 3.4
ANOVA TABLE
Analysis of Variance Technique

Sources of variation	Sum of Square	D. F	Mean Square
Regression	2.011622E+16	2	1.005811E+16
Error	8.805767E+14	21	4.193222E+13
Total	2.09968E+16	23	

See Appendix (page 109)

The measured the standard deviation and analysis of variance of Y_j , χ_1 and χ_4 are noted as follows:

F for analysis of variance = 239.87

Degree of Freedom (dF) = 2 and 21

The estimate of the model is:

$$\hat{Y}_i = \hat{\beta}_0 + \hat{\beta}_1 (\text{GDP}) + \hat{\beta}_4 ((\text{POPULATION}))$$

Table #3.5
Estimated Coefficient

Variable	Estimated Coefficient β	Estimated Standard Deviation	Computed Student t-Value
GDP of S. A (χ_1)	240.9454	160.0867	1.505
Population in S. A (χ_4)	8.787499	0.640744	13.714
Intercept	-6.277048E+07		

See Appendix (page 110)

The parameters of this model were estimated using Least Square Estimated Technique. These are as follows:

$$\hat{\beta}_0 = -6.277048\text{E}+07$$

$$\hat{\beta}_1 = 240.9454$$

$$\hat{\beta}_4 = 8.787499$$

As result of the above, I have concluded that two independent variables in the model are significant. And Student t - value indicated that population (χ_2) explained a significant proportion of the variation.

For forecasting Y_j , based on $(\chi_1 \text{ and } \chi_4)$ using (MLR) model.

The forecast values of $(\chi_1 \text{ and } \chi_4)$ are obtained using Simple Linear Regression Model as follows

$$\text{GDP} = a + bx + E$$

The estimated model is

$$\hat{\text{GDP}} = \hat{a} + \hat{b}x$$

$$\hat{\text{GDP}} = -2,648,405.00 + 1,360.35 (x)$$

See Appendix (page 111 - 112)

Similarly for projecting Population, the SLR model is as follows

$$\text{Pop} = \alpha + bx + E$$

The estimated of this model is

$$\hat{\text{Pop}} = \hat{\alpha} + \hat{b}x$$

$$\text{Population} = -8.321061\text{E}+08 + 424644.8 (x)$$

See Appendix (page 113 - 114)

Using these two models the following forecast are obtained:

Years	GPD	POPULATION
1998	69,580.29	16,334,210.40
1999	70,940.65	16,758,855.20
2000	72,301.00	17,183,500.00
2005	79,102.77	19,306,724.00
2010	85,904.53	21,429,948.00
2015	92,706.29	23,553,172.00
2020	99,508.06	25,676,396.00

For more details, please refer to Table at appendix (page 115)

3.4 COEFFICIENT OF MULTIPLE DETERINATION (R^2):

Using the formula (2.1.4.b) shows that percent of variation explained variance in Energy Sold can be explained by two independent variables in the regression model:

$$R^2 = 0.96$$

Percentage of Variation explained = 96 %

Multiple Correlation Coefficient = 0.98

Standard Error of Estimate = 6475510

The above figure shows the calculated F and degree of Freedom, which will be used to compare it with the F table in next stage.

3.5 TESTING OF SIGNIFICANCE OF REGRESSIONS

Hypothesis Testing Process:

To test whether or not Regression Model explains significant portion of variation in the dependent variable.

Hypothesis on the regression parameter are formulated and tested through f-test statistics.

This process is stated as follows:

Step #1 : Hypothesis on Energy Generated

H_0 : The Regression Model does not explain the significant portion of total variation in the dependent variable.

H_1 : The Regression Model does explain the significant portion of total variation in the dependent variable.

Step #2 : Test Statistic (F)

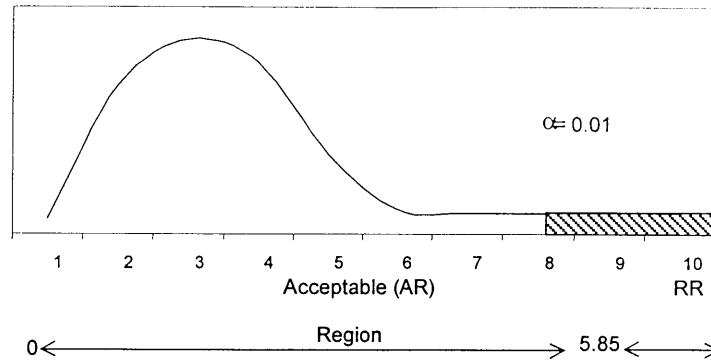
The F-test statistic is as mentioned under methodology.

$$F = 239.87$$

Step #3 : Decision Regions

Using $\alpha = 1\%$ the levels of significance. The acceptance and the rejection regions are defined as follows:

For Degree of freedom (df) 2, 21, the critical value of F is 5.85, as noted from the F-table (copy given in Appendix page 116).



$$AR = F \leq 5.85$$

$$RR = F \geq 5.85$$

Step #4 : Decision

H_0 is rejected as $F = 239.87$ lie in the rejection region.

Therefore, I am 99% confident that the regression coefficient is significantly different from zero, and explain the variation of the dependent variable.

It means that Regression Model used to forecast the electricity in the Kingdom of Saudi Arabia is valid.

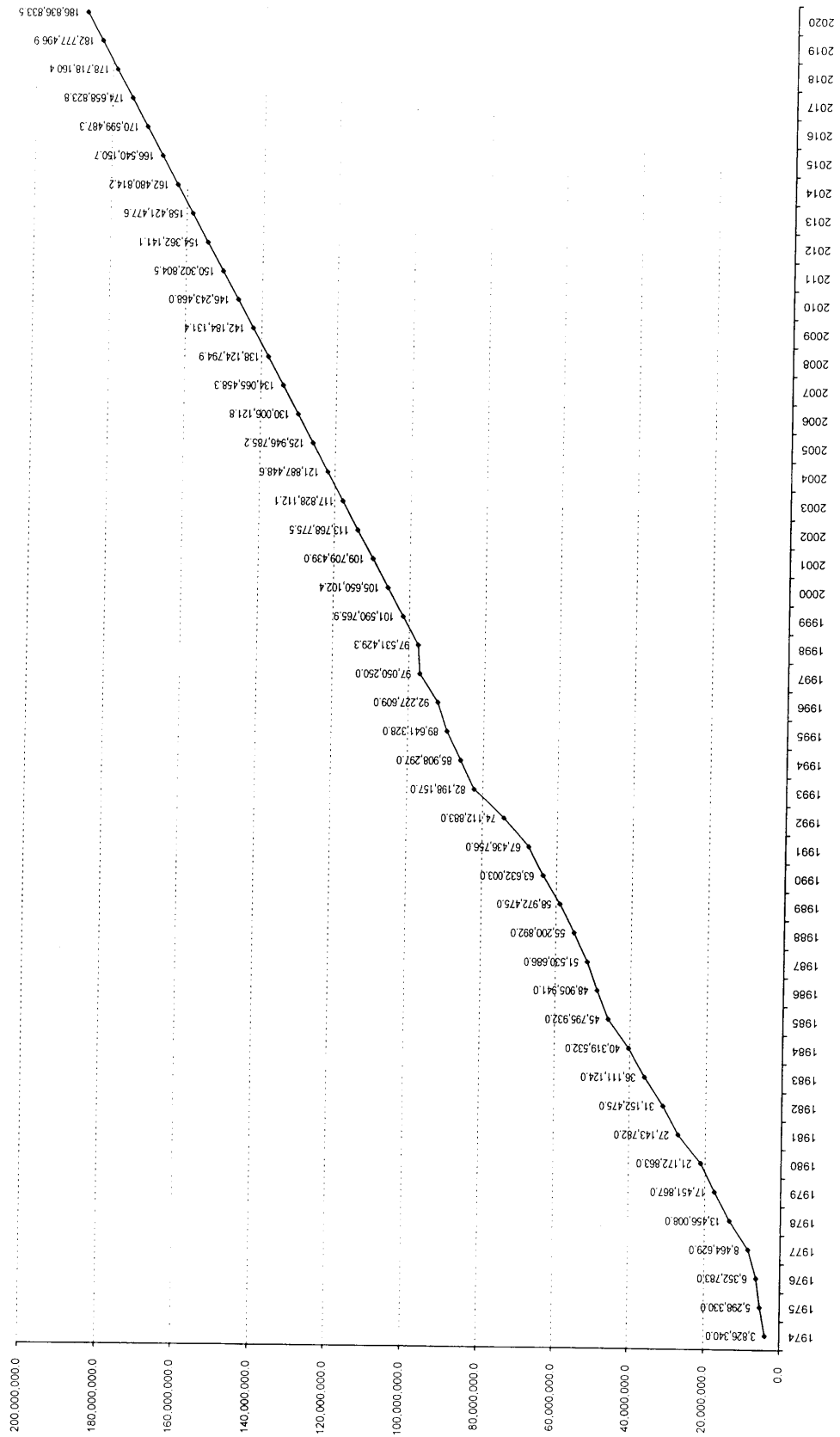
This model generated the following forecast for Energy demand:

**Kingdom of Saudi Arabia
Electricity Forecast**

Years	Forecast
1998	97,531,429.33
1999	101,590,765.88
2000	105,650,102.43
2001	109,709,438.98
2002	113,768,775.54
2003	117,828,112.09
2004	121,887,448.64
2005	125,946,785.20
2006	130,006,121.75
2007	134,065,458.30
2008	138,124,794.86
2009	142,184,131.41
2010	146,243,467.96
2011	150,302,804.52
2012	154,362,141.07
2013	158,421,477.62
2014	162,480,814.18
2015	166,540,150.73
2016	170,599,487.28
2017	174,658,823.83
2018	178,718,160.39
2019	182,777,496.94
2020	186,836,833.49

For visual inspection the graph of the original and forecasted data is displayed on page 93.

Energy Sold & Demand Forecast In the Kingdom of Saudi Arabia Year 1974 to 2020



Chapter 4

CONCLUSION & RECOMMENDATIONS

As a result of the analysis, my conclusion is that regression model:

$$\hat{Y}_i = \hat{b}_0 + \hat{b}_1 (\text{GDP}) + \hat{b}_2 ((\text{POPULATION}))$$

Where the population explained large proportion of the model.

As result of my review of energy sources, there is an indication that increasing demand and water shortages can be met and addressed with the use of steam turbines. Additionally, savings can be gained with maximum use of natural gas that is abundant in Saudi Arabia. Both energy sources can help reduce pollution in the environment.

The actual electricity demand in the Kingdom of Saudi Arabia of 97.1 million MW in 1997, the demand forecast was envisaged to reach by 187 million MW within the next twenty years.

It was noted that in the light of this conclusion, our recommendation covers short and long plan to meet the demand of electricity in the Kingdom of Saudi Arabia, as follows:

- (a) Further study to identify optimal generating power to meet the forecasted demand considering the water shortages and unique geographical structure of Saudi Arabia.
- (b) Concentrate and minimize the difference (lose power) between energy generated and energy sold by improving the efficiency.

- (c) Continue forecasting to monitor customer behavior and determine the change in energy demand.
- (d) The Kingdom of Saudi Arabia occupies large geographical area with environment and climate distinct from one area to another. Reserved electrical capacities during colder season in one area are utilized by other areas experiencing hot weather condition
- (e) Promote energy conservation by educating the customer to use heat insulators and design their building and factories benefiting from renewable energy, like solar energy, to reduce high demand on electricity.
- (f) Control of environmental pollution should be considered as one of the important factors in our future decisions.
- (g) Find ways to cool-off the environment within cities to reduce usage of electricity.
- (h) Committee from the electric companies and other Government agencies set rules and procedures to insure compliance by the customers.
- (i) Further study to utilize available energy sources such energy forms as solar and wind power considering the unique geographical structure and solar in the Kingdom of Saudi Arabia.
- (j) In long term consider the Electricity connection between Gulf countries, benefiting of available sources.
- (k) Further gradual connection with the entire Arab world in the Middle East, which will help reduce the cost of investing heavily on new project benefit from electricity surplus and changes of the weather between countries.

Other areas experiencing hot weather condition utilize reserved electrical capacities during colder season in one area. And vice-versa during the winter.

Appendices

APPENDIX 1 **REFERENCES TO RESEARCH PROJECT 550**

Appendix 1.1 **Kingdom of Saudi Arabia** **Total Gross Domestic Product (GDP)** (In Million Saudi Riyals)

Hijra	Year	Amount
1394-1395	1974	31,724
1395-1396	1975	34,462
1396-1397	1976	39,669
1397-1398	1977	42,028
1398-1399	1978	44,838
1399-1400	1979	49,371
1400-1401	1980	53,282
1401-1402	1981	54,163
1402-1403	1982	48,342
1403-1404	1983	48,247
1404-1405	1984	47,517
1405-1406	1985	45,304
1406-1407	1986	47,824
1407-1408	1987	47,165
1408-1409	1988	50,733
1409-1410	1989	50,825
1410-1411	1990	56,243
1411-1412	1991	60,962
1412-1413	1992	62,663
1413-1414	1993	62,264
1414-1415	1994	62,584
1415-1416	1995	62,877
1416-1417	1996	63,753
1417-1418	1997	64,969
TOTAL		1,231,809

Reference: Ministry of Planning
Current Rate: US\$1.00: SR3.76

MS EXPLORE

L I S T O F D A T A
File = GDP1

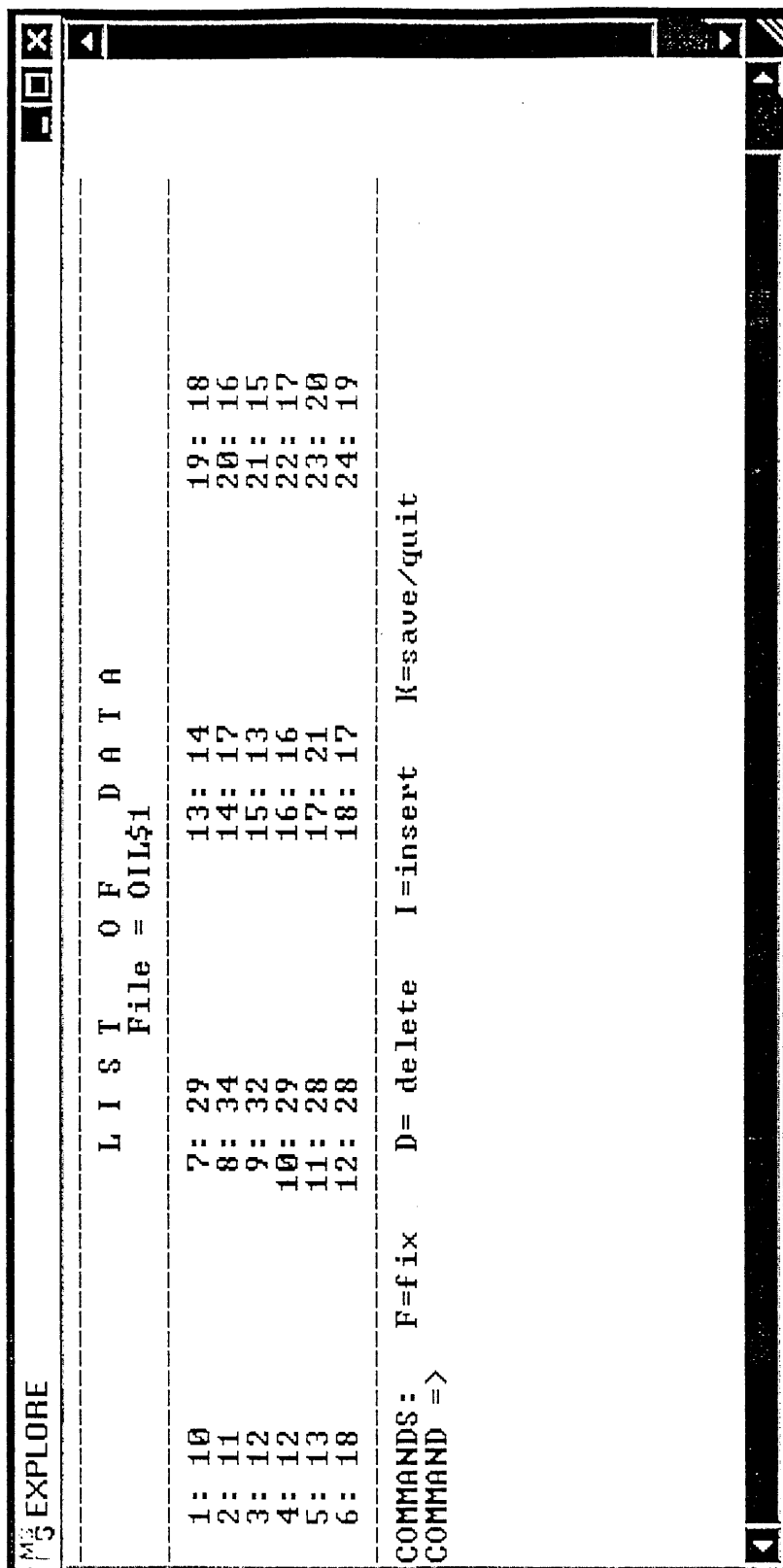
1: 31724	7: 53282	13: 47824	19: 92663
2: 34462	8: 54163	14: 47165	20: 62264
3: 39669	9: 48342	15: 50733	21: 62584
4: 42028	10: 48247	16: 50825	22: 62877
5: 44838	11: 47517	17: 56243	23: 63753
6: 49371	12: 45304	18: 60962	24: 64969

COMMANDS: F=fix D= delete I=insert K=save/quit
COMMAND =>

Appendix 1.2
Average Oil Prices
(In Million U.S. Dollars)

Hijra	Year	Amount
1394-1395	1974	10
1395-1396	1975	11
1396-1397	1976	12
1397-1398	1977	12
1398-1399	1978	13
1399-1400	1979	18
1400-1401	1980	29
1401-1402	1981	34
1402-1403	1982	32
1403-1404	1983	29
1404-1405	1984	28
1405-1406	1985	28
1406-1407	1986	14
1407-1408	1987	17
1408-1409	1988	13
1409-1410	1989	16
1410-1411	1990	21
1411-1412	1991	17
1412-1413	1992	18
1413-1414	1993	16
1414-1415	1994	15
1415-1416	1995	17
1416-1417	1996	20
1417-1418	1997	19

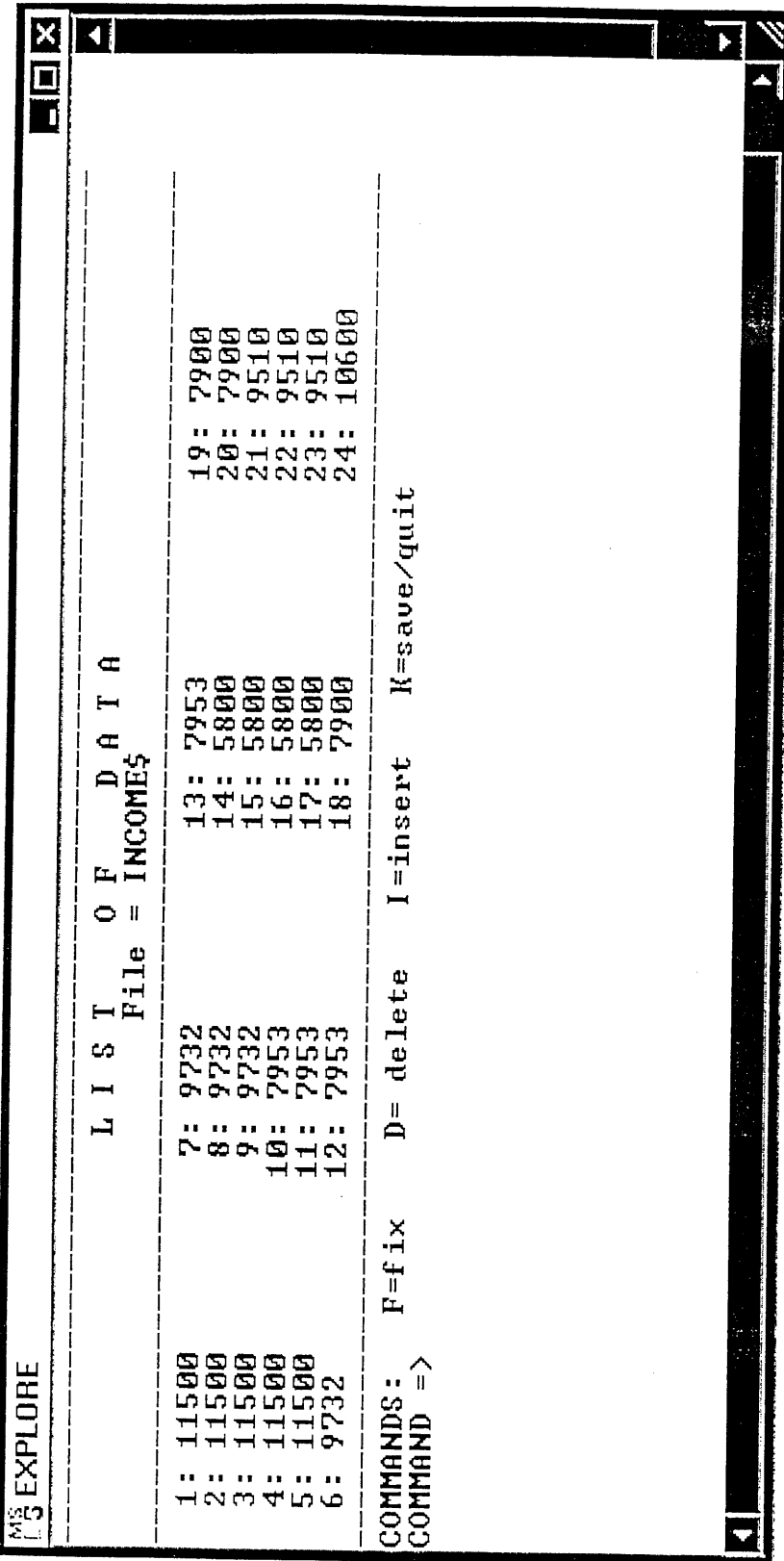
Reference Ministry of Petroleum and Mineral



Appendix 1.3
Saudi Arabia's Income Per Capita
(In U.S. Dollars)

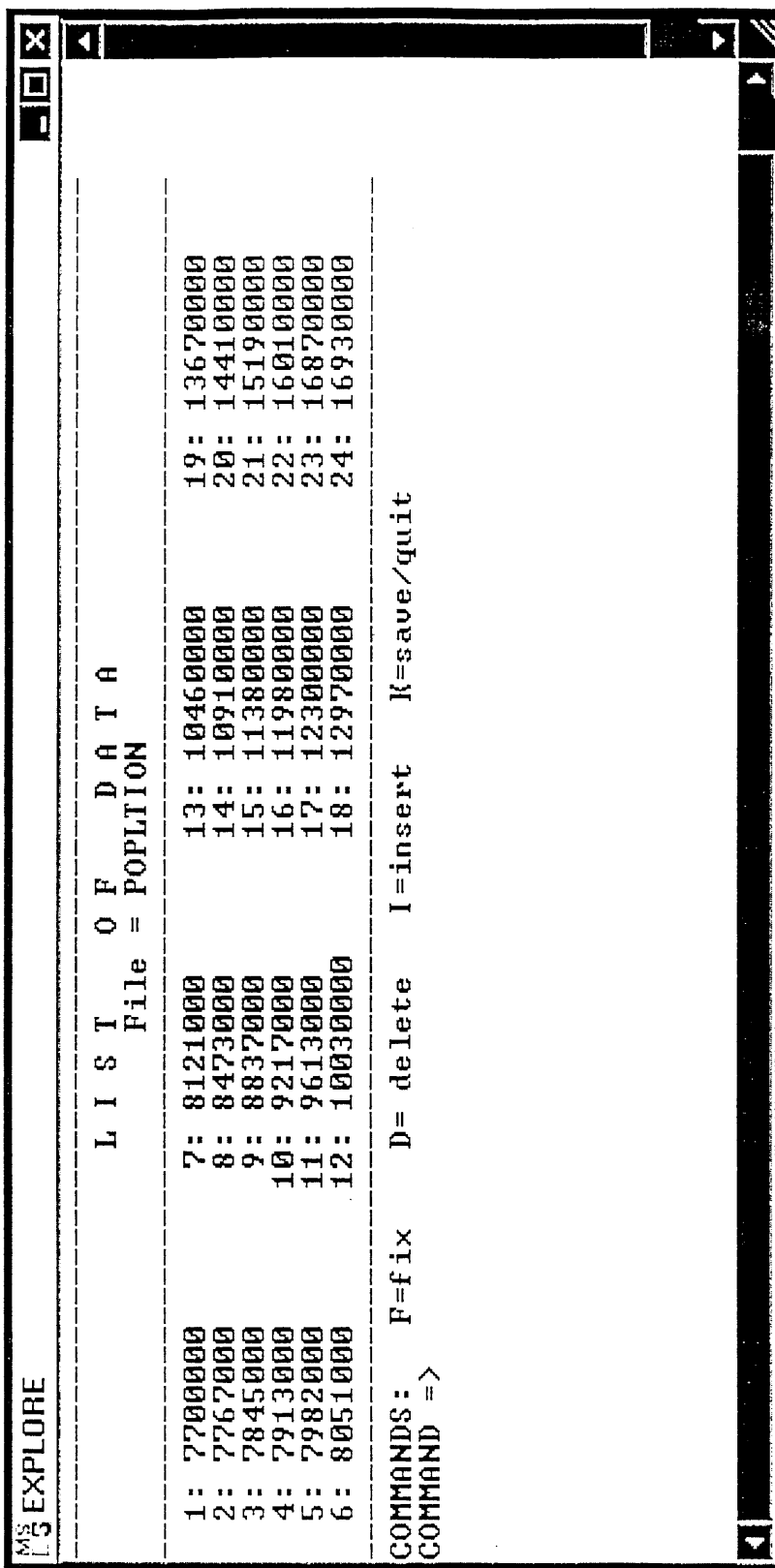
Hijra	Year	Amount
1394-1395	1974	11,500
1395-1396	1975	11,500
1396-1397	1976	11,500
1397-1398	1977	11,500
1398-1399	1978	11,500
1399-1400	1979	9,732
1400-1401	1980	9,732
1401-1402	1981	9,732
1402-1403	1982	9,732
1403-1404	1983	7,953
1404-1405	1984	7,953
1405-1406	1985	7,953
1406-1407	1986	7,953
1407-1408	1987	5,800
1408-1409	1988	5,800
1409-1410	1989	5,800
1410-1411	1990	5,800
1411-1412	1991	7,900
1412-1413	1992	7,900
1413-1414	1993	7,900
1414-1415	1994	9,510
1415-1416	1995	9,510
1416-1417	1996	9,510
1417-1418	1997	10,600

Reference: The World Almanac the book of facts (1974 to 1997)



Appendix 1.4
Saudi Arabia
Population

Hijra	Year	Population
1394-1395	1974	7,700,000
1395-1396	1975	7,767,000
1396-1397	1976	7,845,000
1397-1398	1977	7,913,000
1398-1399	1978	7,982,000
1399-1400	1979	8,051,000
1400-1401	1980	8,121,000
1401-1402	1981	8,473,000
1402-1403	1982	8,837,000
1403-1404	1983	9,217,000
1404-1405	1984	9,613,000
1405-1406	1985	10,030,000
1406-1407	1986	10,460,000
1407-1408	1987	10,910,000
1408-1409	1988	11,380,000
1409-1410	1989	11,980,000
1410-1411	1990	12,300,000
1411-1412	1991	12,970,000
1412-1413	1992	13,670,000
1413-1414	1993	14,410,000
1414-1415	1994	15,190,000
1415-1416	1995	16,010,000
1416-1417	1996	16,870,000
1417-1418	1997	16,930,000



MS EXPLORE

LIST OF DATA

File = ENRG SOLD

1: 3826340	7: 21172863	13: 48905941	19: 74112883
2: 5298330	8: 27143782	14: 51530686	20: 82198157
3: 6352783	9: 31152475	15: 55200892	21: 85908297
4: 8464629	10: 36111124	16: 58972475	22: 89641328
5: 13456008	11: 40319532	17: 63632003	23: 92227609
6: 17451867	12: 45795932	18: 67436756	24: 97050250

COMMANDS:

COMMAND =>

F=fix

D= delete

I=insert

K=save/quit

MS EXPLORER			
TABLE OF MEANS AND STANDARD DEVIATIONS			
Variable	Mean	St. Dev.	Cases
ENRGSOLD	4.680679E+07		3.021691E+07
24			
GDP1	52575.38	12435.55	24
OIL\$1	19.125	7.066839	24
INCOME\$	8927.917	1928.998	24
POPLTION	1.102621E+07		3106945
			24
Note: In this table, the standard deviation uses (n-1)			
Wait ... calculations continuing ... Press any key to continue			

M3 EXPLORE					
MATRIX OF CORRELATION COEFFICIENTS					
	ENRGOLD	GDP1	OIL\$1	INCOME\$	POPLTION
ENRGOLD	1.000	0.763	0.026	-0.464	0.976
GDP1	0.763	1.000	0.144	-0.304	0.735
OIL\$1	0.026	0.144	1.000	-0.180	-0.101
INCOME\$	-0.464	-0.304	-0.180	1.000	-0.306
POPLTION	0.976	0.735	-0.101	-0.306	1.000
Where now: E=EXPLORE menu R=Run MATCOR again X=exit ?					

103

—

Variable	Mean	St. Dev.
ENRGSD	4.680679E+07	3.021691E+08
GDP1	52575.38	12435.55
POPLION	1.102621E+07	3106945

Wait ... inverting the matrix ...

Press any key to continue

MS EXPLORE

[-] [] [X]

ANOVA TABLE

Source of Variation	Sum of Squares	D.F.	Mean Square
Regression	2.011622E+16	2	1.005811E+16
Error	8.805767E+14	21	4.193222E+13
Total	2.09968E+16	23	

F for analysis of variance = 239.87
D.F. = 2 and 21 (for F-test)
R-Squared = 0.9581
Per cent of variation explained = 95.81
Multiple correlation coefficient = 0.9788
Standard error of estimate = 6475510

Press any key to continue



TABLE OF ESTIMATED COEFFICIENTS

Variable	Estimated Coefficient	Estimated St. Dev.	Computed t-value
GDP1	240.9454	160.0867	1.505
POPULATION	8.787499	0.640747	13.714
Intercept	-6.277048E+07		

Complete table of actual and estimated values (y/n)?

MS F:\Expstat\EXPSTAT\BIGRES.EXE

File	Cases	Mean	St. Dev.
YEARS	24	1985.5	7.071068
GDP1	24	52575.38	12435.55

Press any key to continue

MS F:\Expstat\EXPSTAT\BIGRES.EXE

TABLE OF SUMS

```

=====
File for X      YEARS
File for Y      GDP1
Sum X           47652
Sum Y           1261809
Sum X*X         9.461419E+07
Sum Y*Y         6.989686E+10
Sum X*Y         2.506886E+09
Mean of X       1985.5
Mean of Y       52575.38

Sum (X-X̄)*(X-X̄)  1150
Sum (Y-Ȳ)*(Y-Ȳ)  3.556785E+09
Sum (X-X̄)*(Y-Ȳ)  1564406
  
```

Estimated Line of Regression:
 $\hat{Y} = -2648405 + 1360.353 X$

Press any key to continue

MS

F:\Expstat\VEXPSTAT\BIGRES.EXE

File	Cases	Mean	St. Dev.
YEARS	24	1985.5	7.071068
POPLTION	24	1.102621E+07	3106945

*** WARNING ABOUT UNITS OF MEASUREMENT ***
 Re-scaling variables may be desirable because
 Y is too large ...
 Y is too large relative to X ...
 Press any key to continue

MS F:\Expstat\EXPSTAT\BIGRES.EXE



TABLE OF SUMS

=====

File for X YEARS
 File for Y POPLTION
 Sum X 47652
 Sum Y 2.64629E+08
 Sum X*X 9.461419E+07
 Sum Y*Y 3.139876E+15
 Sum X*Y 5.259092E+11
 Mean of X 1985.5
 Mean of Y 1.102621E+07

Sum $(X - \bar{X}) * (X - \bar{X})$ 1150
 Sum $(Y - \bar{Y}) * (Y - \bar{Y})$ 2.220214E+14
 Sum $(X - \bar{X}) * (Y - \bar{Y})$ 4.883415E+08

Estimated Line of Regression:

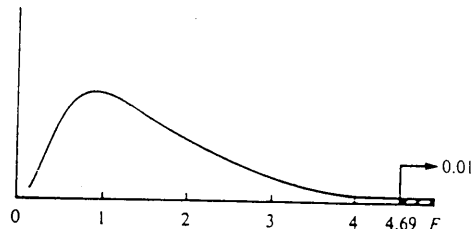
$$\hat{Y} = -8.321061E+08 + 424644.8 X$$

Press any key to continue

Multiple Regression Calculation

b1		240.95		b2		8.79		$\hat{Y} = -6.277048E+07$				
		Y1(GDP)				Y2(POPULATION)				$\hat{Y} = b0+b1y1+b2y2$		
YRS	b0	bx	value y1	b1 x y1	b0	bx	value of Y2	b2 x y2	b0	b1 x y1	b2 x y2	TOTAL
1998	2 648 405.00	1 360.35	69 580.29	16 765 051.77	832 106 100.00	424 644.80	16 334 210.40	143 536 857.56	62 770 480.00	16 765 051.77	143 536 857.56	97 531 429.33
1999	2 648 405.00	1 360.35	70 940.65	17 092 822.57	832 106 100.00	424 644.80	16 758 855.20	147 268 423.31	62 770 480.00	17 092 822.57	147 268 423.31	101 590 765.88
2000	2 648 405.00	1 360.35	72 301.00	17 420 593.37	832 106 100.00	424 644.80	17 183 500.00	150 999 989.07	62 770 480.00	17 420 593.37	150 999 989.07	105 650 102.43
2001	2 648 405.00	1 360.35	73 661.35	17 748 364.16	832 106 100.00	424 644.80	17 608 144.80	154 731 554.82	62 770 480.00	17 748 364.16	154 731 554.82	109 709 438.98
2002	2 648 405.00	1 360.35	75 021.71	18 076 134.96	832 106 100.00	424 644.80	18 032 789.60	158 463 120.58	62 770 480.00	18 076 134.96	158 463 120.58	113 768 775.54
2003	2 648 405.00	1 360.35	76 382.06	18 403 905.76	832 106 100.00	424 644.80	18 457 434.40	162 194 686.33	62 770 480.00	18 403 905.76	162 194 686.33	117 828 112.09
2004	2 648 405.00	1 360.35	77 742.41	18 731 676.56	832 106 100.00	424 644.80	18 882 079.20	165 926 252.09	62 770 480.00	18 731 676.56	165 926 252.09	121 887 448.64
2005	2 648 405.00	1 360.35	79 102.77	19 059 447.35	832 106 100.00	424 644.80	19 306 724.00	169 657 817.84	62 770 480.00	19 059 447.35	169 657 817.84	125 946 785.20
2006	2 648 405.00	1 360.35	80 463.12	19 387 218.15	832 106 100.00	424 644.80	19 731 368.80	173 389 383.60	62 770 480.00	19 387 218.15	173 389 383.60	130 006 121.75
2007	2 648 405.00	1 360.35	81 823.47	19 714 988.95	832 106 100.00	424 644.80	20 156 013.60	177 120 949.35	62 770 480.00	19 714 988.95	177 120 949.35	134 085 458.30
2008	2 648 405.00	1 360.35	83 183.82	20 042 759.75	832 106 100.00	424 644.80	20 580 658.40	180 852 515.11	62 770 480.00	20 042 759.75	180 852 515.11	138 124 794.86
2009	2 648 405.00	1 360.35	84 544.18	20 370 530.54	832 106 100.00	424 644.80	21 005 303.20	184 584 080.86	62 770 480.00	20 370 530.54	184 584 080.86	142 184 131.41
2010	2 648 405.00	1 360.35	85 904.53	20 698 301.34	832 106 100.00	424 644.80	21 429 948.00	188 315 646.62	62 770 480.00	20 698 301.34	188 315 646.62	146 243 467.96
2011	2 648 405.00	1 360.35	87 264.88	21 026 072.14	832 106 100.00	424 644.80	21 854 592.80	192 047 212.38	62 770 480.00	21 026 072.14	192 047 212.38	150 302 804.52
2012	2 648 405.00	1 360.35	88 625.24	21 353 842.94	832 106 100.00	424 644.80	22 279 237.60	195 778 778.13	62 770 480.00	21 353 842.94	195 778 778.13	154 362 141.07
2013	2 648 405.00	1 360.35	89 985.59	21 681 613.74	832 106 100.00	424 644.80	22 703 882.40	199 510 343.89	62 770 480.00	21 681 613.74	199 510 343.89	158 421 477.62
2014	2 648 405.00	1 360.35	91 345.94	22 009 384.53	832 106 100.00	424 644.80	23 128 527.20	203 241 909.64	62 770 480.00	22 009 384.53	203 241 909.64	162 480 814.18
2015	2 648 405.00	1 360.35	92 706.29	22 337 155.33	832 106 100.00	424 644.80	23 553 172.00	206 973 435.40	62 770 480.00	22 337 155.33	206 973 435.40	166 540 150.73
2016	2 648 405.00	1 360.35	94 066.65	22 664 926.13	832 106 100.00	424 644.80	23 977 816.80	210 705 041.15	62 770 480.00	22 664 926.13	210 705 041.15	170 599 487.28
2017	2 648 405.00	1 360.35	95 427.00	22 992 696.93	832 106 100.00	424 644.80	24 402 461.60	214 436 606.91	62 770 480.00	22 992 696.93	214 436 606.91	174 658 823.83
2018	2 648 405.00	1 360.35	96 787.35	23 320 467.72	832 106 100.00	424 644.80	24 827 106.40	218 168 171.66	62 770 480.00	23 320 467.72	218 168 172.66	178 718 160.39
2019	2 648 405.00	1 360.35	98 147.71	23 648 238.52	832 106 100.00	424 644.80	25 251 751.20	221 899 738.42	62 770 480.00	23 648 238.52	221 899 738.42	182 777 496.94
2020	2 648 405.00	1 360.35	99 508.06	23 976 009.32	832 106 100.00	424 644.80	25 676 396.00	225 631 304.17	62 770 480.00	23 976 009.32	225 631 304.17	186 836 833.49

Upper 1% Probability
(or 1% Area under F -Distribution Curve)



Example.

D_1 (degrees of freedom for
numerator of F ratio)
= 5,

D_2 (degrees of freedom for
denominator) = 14:

The tail above $F = 4.69$
represents 0.01 or 1% of
the area under the curve.

$D_2 \backslash D_1$	1	2	3	4	5	6	7	8	10	12
1	4.052	4.999	5.403	5.625	5.764	5.859	5.928	5.981	6.056	6.106
2	98.49	99.00	99.17	99.25	99.30	99.33	99.34	99.36	99.40	99.42
3	34.12	30.82	29.46	28.71	28.24	27.91	27.67	27.49	27.23	27.05
4	21.20	18.00	16.69	15.98	15.52	15.21	14.98	14.80	14.54	14.37
5	16.26	13.27	12.06	11.39	10.97	10.67	10.45	10.27	10.05	9.89
6	13.74	10.92	9.78	9.15	8.75	8.47	8.26	8.10	7.87	7.72
7	12.25	9.55	8.45	7.85	7.46	7.19	7.00	6.84	6.62	6.47
8	11.26	8.65	7.59	7.01	6.63	6.37	6.19	6.03	5.82	5.67
10	10.04	7.56	6.55	5.99	5.64	5.39	5.21	5.06	4.85	4.71
12	9.33	6.93	5.95	5.41	5.06	4.82	4.65	4.50	4.30	4.16
14	8.86	6.51	5.56	5.03	4.69	4.46	4.28	4.14	3.94	3.80
16	8.53	6.23	5.29	4.77	4.44	4.20	4.03	3.89	3.69	3.55
20	8.10	5.85	4.94	4.43	4.10	3.87	3.71	3.56	3.37	3.23
24	7.82	5.61	4.72	4.22	3.90	3.67	3.50	3.36	3.17	3.03
30	7.56	5.39	4.51	4.02	3.70	3.47	3.30	3.17	2.98	2.84
40	7.31	5.18	4.31	3.83	3.51	3.29	3.12	2.99	2.80	2.66
50	7.17	5.06	4.20	3.72	3.41	3.18	3.02	2.88	2.70	2.56
100	6.90	4.82	3.98	3.51	3.20	2.99	2.82	2.69	2.51	2.36
200	6.76	4.71	3.88	3.41	3.11	2.90	2.73	2.60	2.41	2.28
∞	6.64	4.60	3.78	3.32	3.02	2.80	2.64	2.51	2.32	2.18

$D_2 \backslash D_1$	14	16	20	24	30	40	50	100	200	∞
1	6.142	6.169	6.208	6.234	6.258	6.286	6.302	6.334	6.352	6.366
2	99.43	99.44	99.45	99.46	99.47	99.48	99.48	99.49	99.49	99.50
3	26.92	26.83	26.69	26.60	26.50	26.41	26.35	26.23	26.18	26.12
4	14.24	14.15	14.02	13.93	13.83	13.74	13.69	13.57	13.52	13.46
5	9.77	9.68	9.55	9.47	9.38	9.29	9.24	9.13	9.07	9.02
6	7.60	7.52	7.39	7.31	7.23	7.14	7.09	6.99	6.94	6.88
7	6.35	6.27	6.15	6.07	5.98	5.90	5.85	5.75	5.70	5.65
8	5.56	5.48	5.36	5.28	5.20	5.11	5.06	4.96	4.91	4.86
10	4.60	4.52	4.41	4.33	4.25	4.17	4.12	4.01	3.96	3.91
12	4.05	3.98	3.86	3.78	3.70	3.61	3.56	3.46	3.41	3.36
14	3.70	3.62	3.51	3.43	3.34	3.26	3.21	3.11	3.06	3.00
16	3.45	3.37	3.25	3.18	3.10	3.01	2.96	2.86	2.80	2.75
20	3.13	3.05	2.94	2.86	2.77	2.69	2.63	2.53	2.47	2.42
24	2.93	2.85	2.74	2.66	2.58	2.49	2.44	2.33	2.27	2.21
30	2.74	2.66	2.55	2.47	2.38	2.29	2.24	2.13	2.07	2.01
40	2.56	2.49	2.37	2.29	2.20	2.11	2.05	1.94	1.88	1.81
50	2.46	2.39	2.26	2.18	2.10	2.00	1.94	1.82	1.76	1.68
100	2.26	2.19	2.06	1.98	1.89	1.79	1.73	1.59	1.51	1.43
200	2.17	2.09	1.97	1.88	1.79	1.69	1.62	1.48	1.39	1.28
∞	2.07	1.99	1.87	1.79	1.69	1.59	1.52	1.36	1.25	1.00

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APPENDIX 2

REFERENCES TO RESEARCH PROJECT 540

Appendix 2.1

Data Analysis used in the Research Project 540

Data consisting of 24 observations (1395-1418) on energy generated and demand were analysed and forecasts generated using the following three models:

- (a) Moving average with linear trend.
- (b) Exponential smoothing with linear trend
- (c) Linear regression

The results generated by these models were examined through three (3) forecast accuracy-measuring criteria: Bias, MSE and MAD, which are described under Methodology.

These are summarized as follows:

Particulars	Bias	MSE	MAD
-------------	------	-----	-----

ENERGY GENERATED (refer to Appendix 1)

Linear Regression	-1,506,182	194E11	2,706,242
Exponential Smoothing	-350,518	776E10	2,109,415
Moving Average (5 years)	-298,897	122E11	3,080,056

w/ linear trend.

ENERGY SOLD (refer to Appendix 2)

Linear Regression	-2,087,990	789E10	2,283,601
Exponential Smoothing	-266,109	268E10	1,325,735
Moving Average (5 years)	-195,089	456E10	1,658,419

w/ linear trend.

Looking at these criteria, it was noted that moving average with Linear Trend Method generates better forecast than the other two methods. Therefore, forecast generated by this method are adopted and stated as follows:

**Energy Generated in the Kingdom of Saudi Arabia
For the Next 10 Years.**

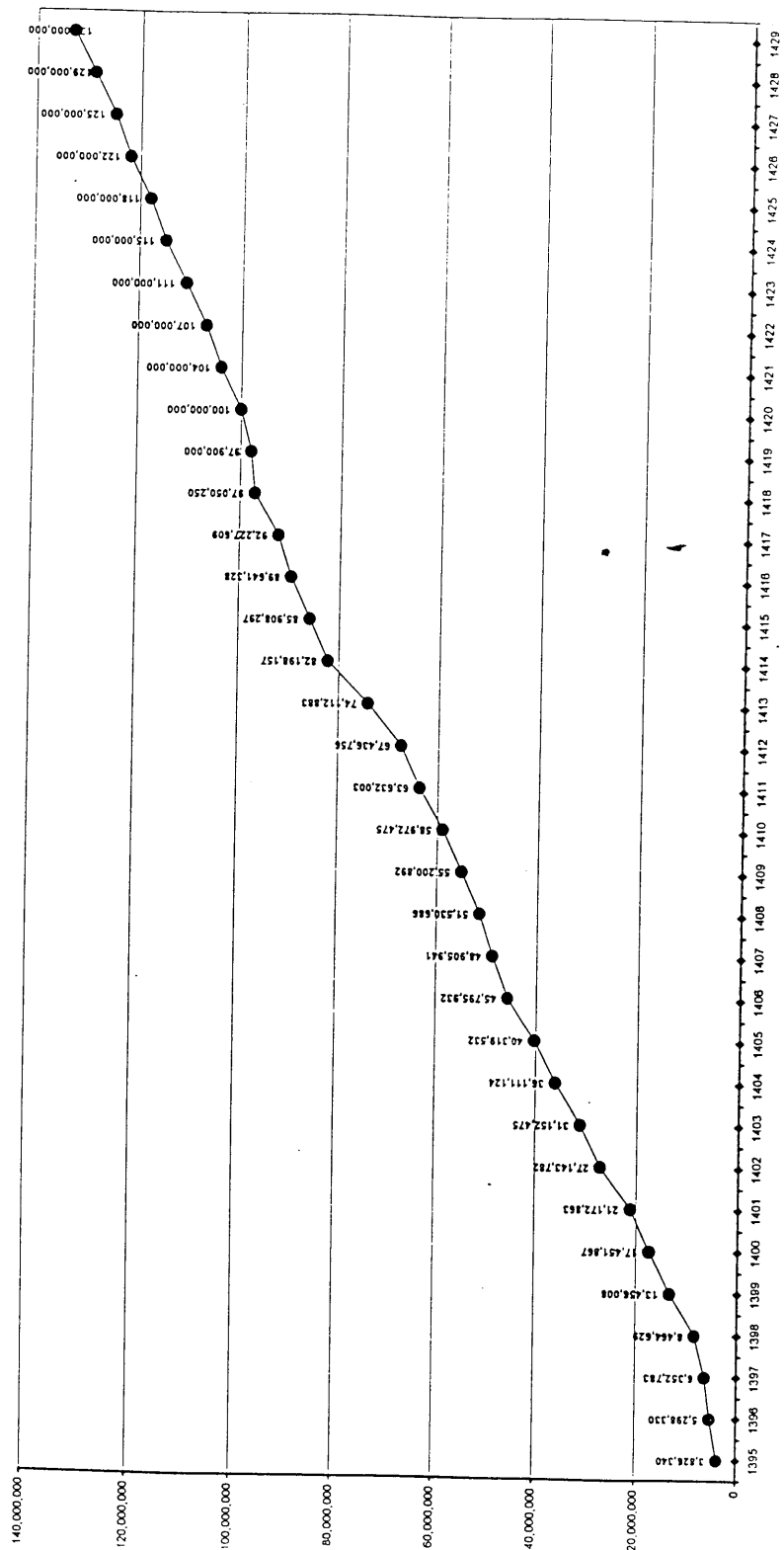
Years	Forecast
1419	85,500,000
1420	89,800,000
1421	94,100,000
1422	98,300,000
1423	103,000,000
1424	107,000,000
1425	111,000,000
1426	115,000,000
1427	120,000,000
1428	124,000,000
1429	128,000,000

**Energy Sold in the Kingdom of Saudi Arabia
For the Next 10 Years**

Years	Forecast
1419	97,900,000
1420	100,000,000
1421	104,000,000
1422	107,000,000
1423	111,000,000
1424	115,000,000
1425	118,000,000
1426	122,000,000
1427	125,000,000
1428	129,000,000
1429	133,000,000

Refer to Appendix 2.

**Energy Sold
In The Kingdom of Saudi Arabia
1395 to 1429**



BOOK REFERENCES

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