An-Najah National University
Faculty of Graduate Studies

Electrical Energy Planning for the West Bank Under Uncertainties

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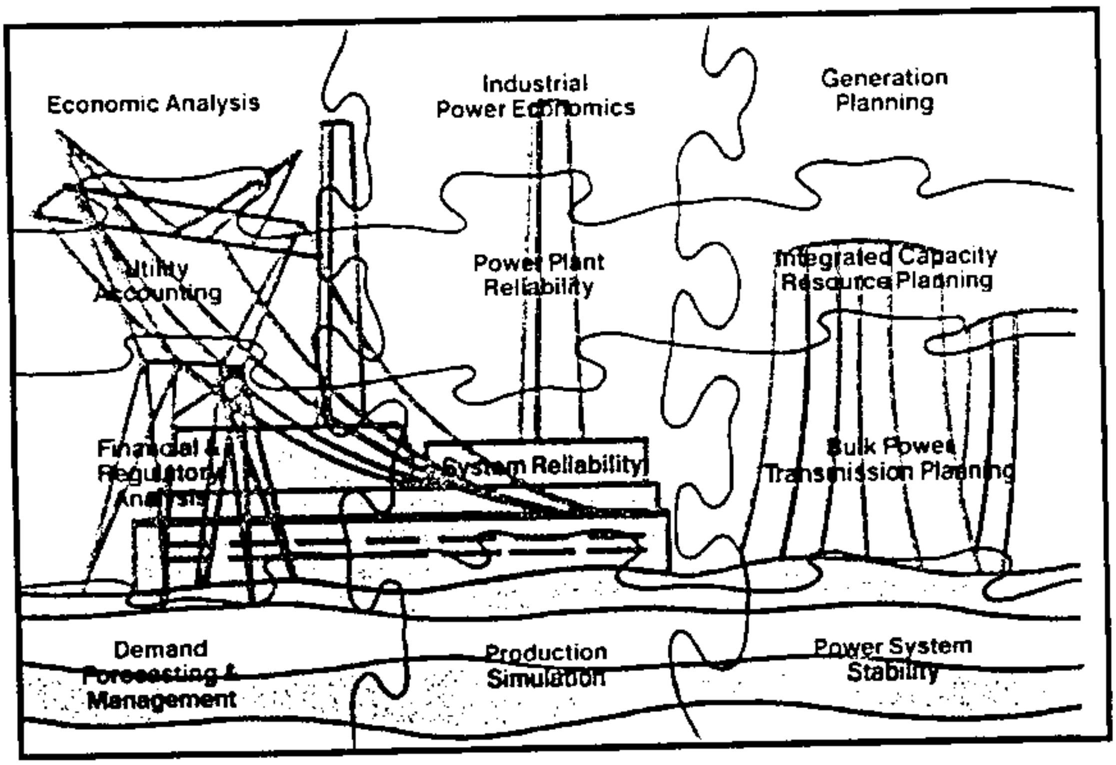

ENERGY PLANNING

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Preface

After thirty years of Israeli occupation over the West Bank. electricity sector was one of the main public services and infrastructure that has been badly damaged. As a result of the Palestinian/Israeli peace process agreement (Oslo agreement) signed in Washington in 1993, the Palestinian National Authority (PNA) took over the responsibility of this important sector. Within the PNA the responsibly of this sector was given to the Palestinian Energy Authority (PEA). which was established in 1994.

Since establishing the PEA hard efforts had been made to improve the electrical situation in the West Bank. The PEA tried hard and started taking urgent actions to overcome the obstacles and deficiencies caused by the Israeli occupation.

Despite these efforts, more work must be done in order to build our independent electricity system, which can meet the growing demand on electricity, and can supply all people in the West Bank with least- cost reliable electricity service.

Since it is the responsibility of power system planner, for planning the reliable and efficient operation a multi-million-dollar high technology power system, this study has been carried out as part of a master degree in Urban and Regional Planning Program from An-Najah National University. We tried in this study to examine and analyze different planning scenarios based upon different uncertainties in order to come up with the best lease- cost, reliable and clean power generation system.

Abstract

At present Israel supplies approximately 97% of total electrical energy consumption in the West Bank of Palestine and approximately 13% of total population are completely or partially non-electrified. Electrical energy prices per kWh to consumers are very high. Electricity system is not reliable with many occasions of electricity service interruptions. Electrical energy consumption per capita is very low and technical losses are high.

This study aims to put a technical strategic plan for the electricity sector in the West Bank of Palestine, in order to ensure supplying reliable least- cost and clean electricity service to all people. This study addresses this technical strategic plan in three stages.

The first stage involves the formulation of four different scenarios of maximum power demand and energy consumption in the West Bank for the period 1999-2020, based upon aggregate analysis of population dynamics and general domestic product (GDP) per capita.

The second stage involves the formulation of four different scenarios of generation planning in the West Bank for the period 2001-2020, based upon the integration between the four power demand scenarios, different fuel types and different generation units. Also each of the four generation scenarios was examined and analyzed based on financial and Cost Benefit analysis.

The final stage examines the effect of implementing the demand side management programs (DSM) on the electricity sector, in terms of cost, benefit, reliability and pollution

Chapter 1

Introduction

1. Introduction

At present Israel supplies approximately 97% of total electrical energy consumption in the West Bank of Palestine and approximately 13% of total population are completely or partially non-electrified. Energy prices per kWh to consumers are very high. Electricity system is not reliable with many occasions of electricity service interruptions. Electrical energy consumption per capita is very low and technical losses are very high.

All these facts were behind preparing this study. The aim of this study is to come out with an electrical energy plan for the West Bank (appendix 1) for the planning period 1999- 2020. This plan aims to ensure supplying continuos secure, reliable, least-cost and clean electricity to all people, taking into consideration all possible future uncertainties.

Our electrical energy planning for the West Bank is not a straight forward as there are serious obstacles that affect this planning. Dealing with uncertainties is a major serious problem in our energy and power planning, because planning deals with the future and the only thing we know for certain about the future is that it is uncertain. Energy planning at this period of history is planning under various kinds of uncertainties. It is a dynamic year –by-year process. A part from other places in the world we as Palestinians have a special uncertain situation.

Energy planning in the West Bank depends on various parameters including demographic issues, economical issues, load demand, fuel prices, fuel availability, plant cost and political issues. Unfortunately, the forecast of these parameters is subject to uncertainty. Each has a likelihood of assuming a range of values in the future. A plan that is least- cost under a reference set of parameters today may not be so in the future under alternative set of forecast parameters.

The future demography of Palestinian people is uncertain due to the political situation in the area. Palestinian demography will continue to be uncertain until the Palestinian refugees issue comes to an end. Economic situation in Palestine as well as in the West Bank is also uncertain because it is affected by the political and economical circumstances in the region. Once the area is stable, more investments will come to the West Bank, free trade and development of industrial zones are highly expected. Our economy is not independent as it is affected by changes in other economies, mainly the Israeli and the Jordanian economies .We do not have yet our own currency as we still use other currencies like Israeli, Jordanian and US currencies.

Our load demand is also uncertain. Load demand depends mainly on demographic, economic and social factors, which are uncertain in the West Bank.

Uncertainty in the fuel availability, fuel prices and plant cost is an obstacle for energy planning. Choosing between different alternatives of generators is linked to fuel types, generator types and prices. Estimating investment and operating costs of a power plant is also linked to fuel and generator prices.

Another serious uncertain point is the political situation in the region. Future political situation in the region is uncertain. Since the political situation affects the demographic and economic issues, uncertainty in the political situation will be a major impediment for power and energy planning in the West Bank. Political uncertainty affects the electrical interconnection between the neighboring countries. For example implementing the proposed electricity interconnection project between Egypt, Palestine, Jordan and Israel is tightly attached to the development of the peace process in the area.

The problem of adequate data is another major impediment that faces any planner in any sector including energy sector. One important thing to be stressed on is that, lack of data should not give us an excuse to stop planning and wait for all necessary data. The best way is to carry out policy analysis and planning with what available and to look for the necessary data for the next stage. This is true because energy planning is a continuos and iterative activity

1.1Methodology

In this study our methodology and wide policy of analysis and planning of electrical energy in the West Bank will be an analytical scheme as represented in fig 1.1. Our methodology is based on a normative scenario approach. This approach is normative in that its purpose is to determine what is the desirable polices for the West Bank and also to predict the future power demand and energy consumption. It is based on scenarios in order to be able to take into account the wide range of possible future uncertainties over the time of interest and to be able to analyze a wise set of programs and polices that may be of interest to decision makers

The proposed energy plan as shown in fig 1.1 is an interaction between national and energy goals in two points. First, the starting point of the energy system analysis is a combination of national goals (i.e. national prestige, self-reliance, environmental issues, economic and social goals) and energy goals (i.e. supplying all people with least cost continuos and clean electricity service).

Second, results and output of the energy system analysis are affecting not only the energy sector but also the national economy. If this plan leads to a successful energy model, which is the best least- cost, reliable alternative, the burden on the local economy will be less. Moreover, supplying energy to the community with least- cost and reliable manner will encourage industrial, commercial and other sectors to investment in the West Bank.

Based on the schematic diagram shown in fig 1.1 this study is divided into 6 chapters including this introduction chapter.

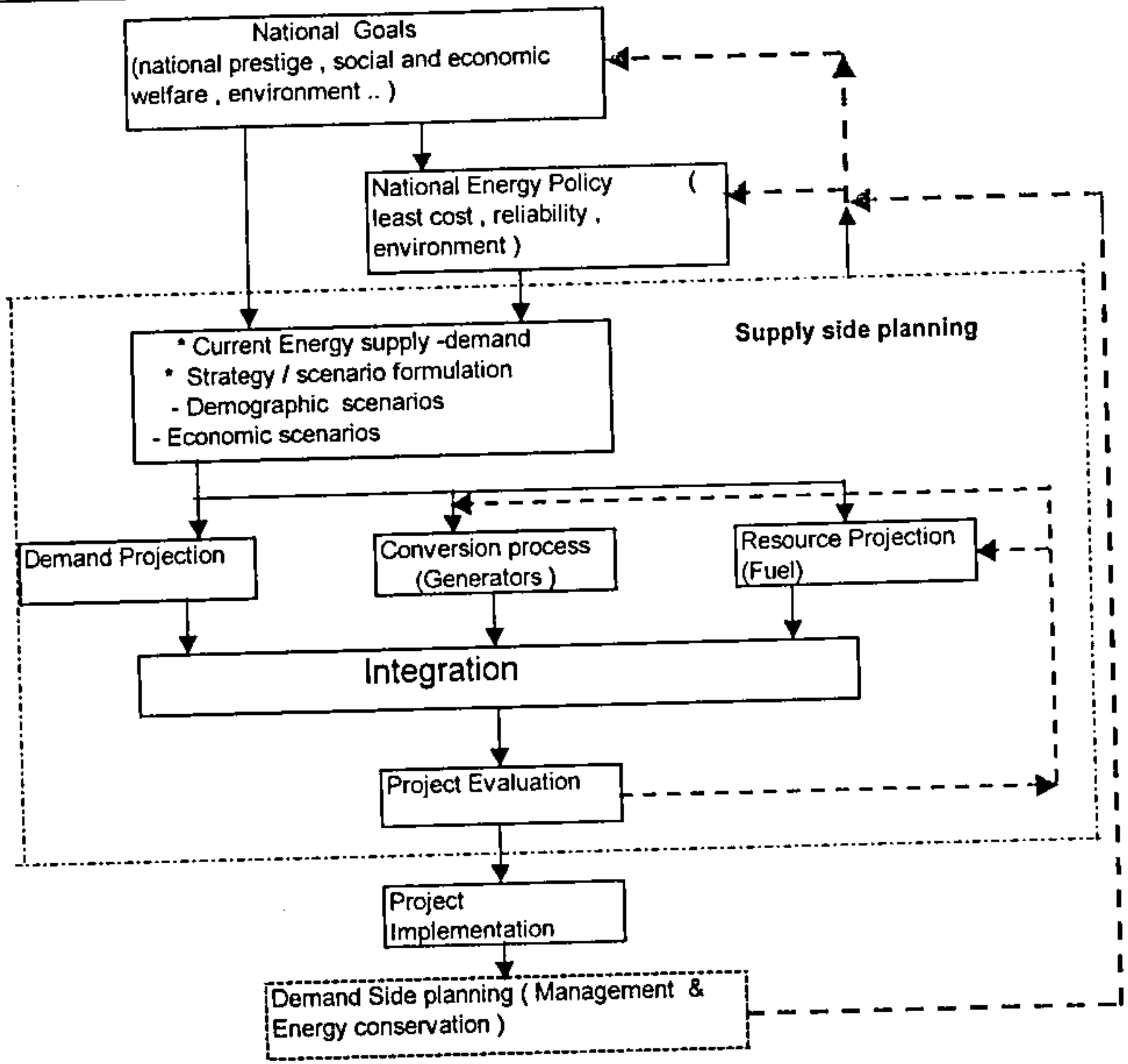

Fig 1.1:Prosposed Structure of Electrical Energy Planning in the West Bank

Chapter 2 presents the historical development of the electrical system in the West Bank starting from the British mandate, through the Jordanian rule, the Israeli occupation and the Palestinian National Authority (PNA). It also determines the current energy supply-demand; obstacles due to occupation and accomplishments that took place during the Palestinian Energy Authority (PEA) partially control over the electricity system.

Chapter 3 presents the foundations of electrical energy planning in the West Bank, where scenarios about the future are formulated. Scenarios about the future demography and the future economy in the West Bank represented by the gross domestic product (GDP) per capita are formulated. Based on demographic and economic scenarios, forecasts of the maximum power demand and total energy consumption are also formulated for the period 1999- 2020.

According to fig.1.1 Chapter 4 provides an overview of resources projection, conversion process, integration and projects evaluation. Resources projection deals with the determination of different possible fuel types and costs of these fuels that can be used in power generation. Conversion process or generation is to determine the possible generators and costs of generators that could be used in producing electricity.

Integration is a major element in national energy system as it is the key element that combines demands, fuels and conversion technologies together to find the optimal combination of generation units and their output capacity needed to meet the demand with an appropriate reserve.

Also in this chapter, feasibility studies and an evaluation for each of the generation-integrated scenarios are done based on financial analysis. Based on finical and cost benefit analysis chapter 4 gives an order of the most feasible and beneficial generation projects that could be implemented

Chapter 5 presents the principle of Demand Side Management (DSM) that could be used at the demand side to reduce total costs of establishing and running the proposed generation power plant. This chapter gives an idea about the Demand Side Management Program (DSM) in terms of definition, structure, benefits and obstacles. Moreover in this chapter an economic evaluation is carried out for two cases of implementing the DSM program in the West Bank. First case is the peak clipping technique and second case is the load shift technique. Also in this chapter we introduced the expert system as a tool in forecasting the weighting factor of population and GDP on power demand for the period 1999-2020.

Chapter 6 presents the conclusion of this study, besides recommendations to electrical energy decision-makers and to energy planners and researchers.

Chapter 2

Historical Background & Existing Situation

2 Historical Background & Existing Situation

2.1 Historical Background

The first electric company in the West Bank and also in Palestine was established in Jerusalem in 1928 during the British mandate over Palestine. The major electricity supplier in the West Bank were Jerusalem District Electricity Company (JDEC) and Nablus Municipality Electricity Undertaking (NMEU). other electricity suppliers included a number of small municipalities, village councils and local community based organizations.

Following is a brief historical background of electricity services in different districts of the West Bank.

- Jerusalem District

In 1950, Jerusalem electric company started its new generation station in Wad El-Jouz with small diesel generators of 60 kW capacity for each unit. Other generating units were established in Bethlehem and Ramallah. In 1956, the cities of Ramallah, Bethlehem and Beit Sahour became within the service area of the JDEC. In 1957 the service area expanded to include Jericho. A new generation station was established in Shu'fat in 1961. In 1967 the new Jewish settlements became within the service area of the JDEC.

After 1967 the JDEC was responsible for supplying electricity to Jerusalem district, Bethlehem, Jericho, Ramallah and about 161 villages in the area. JDEC was responsible for generation (Shoafat generation plant as the main unit and other smaller plants in Ramallah and Jericho), transmission and distribution. Maximum output generation of the JDEC was in 1984 and reached about 35 MW. This capacity was not enough to meet the desired demand, which was about 75 MW at that time. Due to deficiency of generation the JDEC was forced to buy electricity from the Israeli Electric Corporation (IEC).

The Israeli Government put many restrictions on JDEC as the Israeli authorities denied permissions for adding new generation units to the company and preventing buying necessary spare parts for the existing units. All these restrictions aimed to decrease the efficiency of the JDEC so as to force it to buy electricity from the IEC.

Due to the Israeli obstacles the efficiency of the generation and transmission systems sharply decreased, the generated output capacity was less than the increasing load demand. This forced the JDEC in 1988 to stop generation and completely depend on the IEC to supply electricity to its customers. In 1988, the JDEC's concession for exclusive rights to generate and distribute electricity in its service area that was granted by the Jordanian Government, has expired. The Israeli government put many restrictions on the company to extend its rights to distribute electricity (only) in its service area to the year 1999. Currently, JDEC is purchasing 100% of its energy from the IEC grid for resale to its customers.

- Hebron District

In Heron the first generation station was established in 1954 with few diesel generators with capacities ranging between 40 and 150 kW each. This power station provided electricity to the cities of Hebron and Halhoul only. After 1967 the military administration did not allow any expansion of local generation which forced the two cities to be connected to the Israeli grid in 1973. The only responsibility of Hebron municipality was to maintain the electricity grid within its service area.

- Nablus District

In Nablus the municipality was responsible for electricity generation, transmission and distribution. NMEU provided electricity to the city of Nablus, other surrounding villages, and camps in addition to the town of Anabta. The first power generation plant in Nablus started in 1958 with 900 kW capacity. During the period from 1963 to 1974 new generation units of 7 MW total capacity were added. In 1979 a generation unit of 900kw and in 1981 another unit with 4.8 MW were added to the system. In 1981 the maximum generation capacity of the NMEU reached 23.5 MW while the maximum power demand was 7 MW.

Due to the Israeli restrictions, the efficiency of the generation units sharply decreased. NMEU was prevented from adding new generation units and from buying the necessary spare parts .As a result starting from 1984 the power demand became more than the generation capacity and the NMEU was forced to buy the difference from the IEC. Currently the NMEU completely buy electricity from the IEC and resale it to its customers.

- Tulkarim and Jenin

In Tulkarem, the municipality power station was established in 1953 with a capacity of 0.5 MW and expanded in 1954, 1962 and 1964. It reached its maximum in 1974 with 1.5 MW. The service area of the power station was limited to the city and its suburbs. Starting from 1974 local generation became unreliable and not enough for the needs of the people in the serviced area and it was connected to the Israeli grid in the same year.

As for Jenin the first power station was established in 1957 with a total capacity of 120 kW. Local generation was expanded in 1961,1969 and 1971 with other small generators. In 1981 a new generating unit of 1.2 MW capacity was added to the station. This project reached its maximum output of 2.4 MW in year 1984/85. However local generation did not continue to be enough nor reliable and it was eliminated in 1985/86 when the station was connected to the Israeli grid.

- Qalqilya

In Qalqilya local generation started in 1962 with small diesel generators until 1971 when it was connected to the Israeli grid.

- Rural Areas

Rural areas in the West Bank did not get similar services as the cities for a long time. With the exception of the service area of the JDEC, some villages in the service area of the NMEU in Nablus district and two villages (Ramin and Beit leed) and town of Anabta in Tulkarem district, very few villages did have electric power before 1975. After 1970 electric cooperation and village councils established small power stations with small diesel generators in their villages. After 1975 many villages were connected to the Israeli grid.

2.2 Electricity Sector Before the Palestinian National Authority (PNA)

Energy sector in Palestine since the Israeli occupation till the PNA took over the energy responsibility faced severe technical, financial and management obstacles. The imposed severe restrictions by the Israeli occupation on the power generation plants reduced their efficiency and prevented them from meeting the desired demand. Most of these plants were prevented from expanding or even sustaining their existing generating capacity.

Before the PNA took over the responsibility of the West Bank, electricity sector has sustained extensive damage as a result of the severely restrictive measures imposed by the Israeli occupation. The bad electricity situation due to Israeli occupation can be summarized in the following points:

- No local generation, around 100% of the electricity were and still supplied by the IEC (97% supplied from the IEC and 3% partially generated locally).

- Old fashion over loaded transmission networks.

- Usage of old fashions safety and control devices.

- High electricity losses which were more than 20%. High technical losses cost the local economy millions of dollars per year.

- Low power factor due to unconventional electrical services as low voltage and non-efficient electricity for industrial projects. Low power factor costs the national economy millions of US dollars per year.

- Poor system reliability due to continuous interruption of electricity services. Interruption of electricity service was due to over loaded network, old fashion control devices, and some times for political reasons. Low reliability is a burden on our economy.

- High prices of electricity supplied to customer due to high tariff determined by the IEC. In 1995 average price per kWh to customers was 14 cents, while in Israel it was 7.2 US Cents and in Jordan was 7.8 US Cents (Abdul-Malik Al-Jaber, 1996). High electricity tariff has bad effects on customers and on local economy.

- High maintenance costs due to old low efficient distribution networks.

- Very low per capita energy consumption, which was about 496 kWh per year.

- A round 20% of population were completely or partially not supplied with continuous electricity service, mainly in the rural areas of Hebron , Jenin and Tubas districts.

- Statistics and data related to electricity were not available.

- No implementation of renewable energy projects.

- No projects or programs in efficiency and energy management.

2.3 Electricity Sector Under the PEA Control

As known electricity has impacts on the development of all aspects of life as industry, agriculture, education, and other sectors and so it has impacts on the national economy. It became clear that electrical energy consumption is an indication of the community welfare. Within individual countries historical data shows reasonably smooth trends in the ratio of energy consumed to real GNP (gross national product) or GDP (gross domestic product)

Moreover energy is considered of comprehensive development and most often, it is regarded the chief source of power for economic progress and development. Due to these facts the decision was made to establish the Palestinian Energy Authority (PEA) on November 1994 to look after this important sector.

The PEA took over the responsibility of a damaged electricity sector. Since establishing the PEA, hard efforts had been made to improve the electrical situation in the West Bank. The PEA tried hard and started taking urgent actions to overcome the obstacles and deficiencies caused by the Israeli occupation.

Right now some significant changes and development in this sector took place in the following fields:

1. Technical and Feasibility Studies

- For the first time in 1995 in cooperation with a British consultant company

Called Kennedy & Donkin Power Limited, PEA prepared the first comprehensive technical and feasibility study for the electricity sector – generation, transmission and distribution for Palestine.

- In 1996 the PEA prepared the Palestinian master plan which is part of feasibility and technical study for regional interconnection of the electricity grids in Jordan Egypt, Israel and Palestine.
  The above two studies are considered the first comprehensive technical studies for the electricity sector in the West Bank.

2. Rehabilitation and Electrifying Projects

- The rehabilitation project in the north of the West Bank. The main objectives of this project were to upgrade the existing electrical network, construction of new electric networks, minimizing network technical losses and building new distribution transformer substations.
- Northern region rural electrification project. The object of this project is to connect about 29 villages in northern region of the West Bank to the electricity grid.
- Bethlehem 2000 project. The objective of this project is to meet the growing demand on electricity as a result of the 2000 ceremonies. This project is expected to be completed by the end of 1999.
- Tubas project. The objective of this project is to electrify 19 villages near Tubas. This project will be in four stages. The third stage is expected to complete by the end of 1999.
- Sear and AL-Shuogh project. The objective of this project is to connect about 20000 inhabitants to the electricity grid.
- Noba project. Main objective of this project is to connect this village to the electricity grid

3. Renewable Energy

- Regarding renewable energy sources, in 1998 the PEA installed a solar energy unit in Arab Al-Kaabneh village, south of Hebron. Maximum capacity of this unit is 4kw and can generate in average 20 kWh of AC power per day.
- In cooperation with the Palestinian Standard Institute the PEA will establish a lab to test the flat plate solar collectors that are made locally.

4. Energy Management and Conservation Projects

- As for energy management and efficiency programs the PEA started this year working on a three years project called: energy efficiency improvement and green house reduction. The main objective of this project is efficiency improvement and loss reduction, adoption and implementation of energy conservation programs.

Due to actions taken by the PEA some improvements in the current electricity sector took place in some fields and in other fields more efforts still needed. Current situation of electricity sector in the West Bank can be described in the following points.

- Population Connected to the Grid

In 1999 total number of population completely or partially non-electrified decreased from 20% before the PEA to 13% of total population, mainly in the north and south parts of the West Bank. Table 2.1 shows the number of people who are completely or partially non- electrified in each district and total number in the West Bank. As given in table2.1 the worst case is in Tubas and Jenin districts where many villages are not connected to the electricity grid. Most of these villages have local generation units, which use the diesel as the main source for short periods of time.

Table 2.1: Number of population completely or partially non-electrified in1999

District	Total population Completely or Partially non-Electrified	% of population Completely or Partially non-electrified	Total Population
Jenin	86,918	44.5	195,299
Tubas	33,260	94.4	35,216
Tulkarem	12,181	9.4	129,030
Nablus	13,978	5.5	251,392
Salfeet	3,837	8.2	46,688
Ramallah	1,703	0.8	205,448
Beithlehem	9,074	6.9	132,090
Hebron	18,854	4.8	390,272
Qalgiliya	19,546	2.8	69,268
Jerusalem (out)	0	0	113,896
Total	**199,351**	**12.7 %**	**1,568,599**
Note : Regarding Tubas, data shown above is taken before the end of Tubas Electrification project			

Fig 2.1 shows the distribution of non-or partially electrified population. As shown in table 2.1, 12.7% are not connected to the electricity grid. However this percent is still high. For example in Jordan 99.2% of population in 1995 (Eenel, Cesi, 1997) were connected to the grid. In Israel the situation is better where around 100 % is connected to the grid. Fig 2.2 shows the non-or partially electrified population in each district as a percentage.

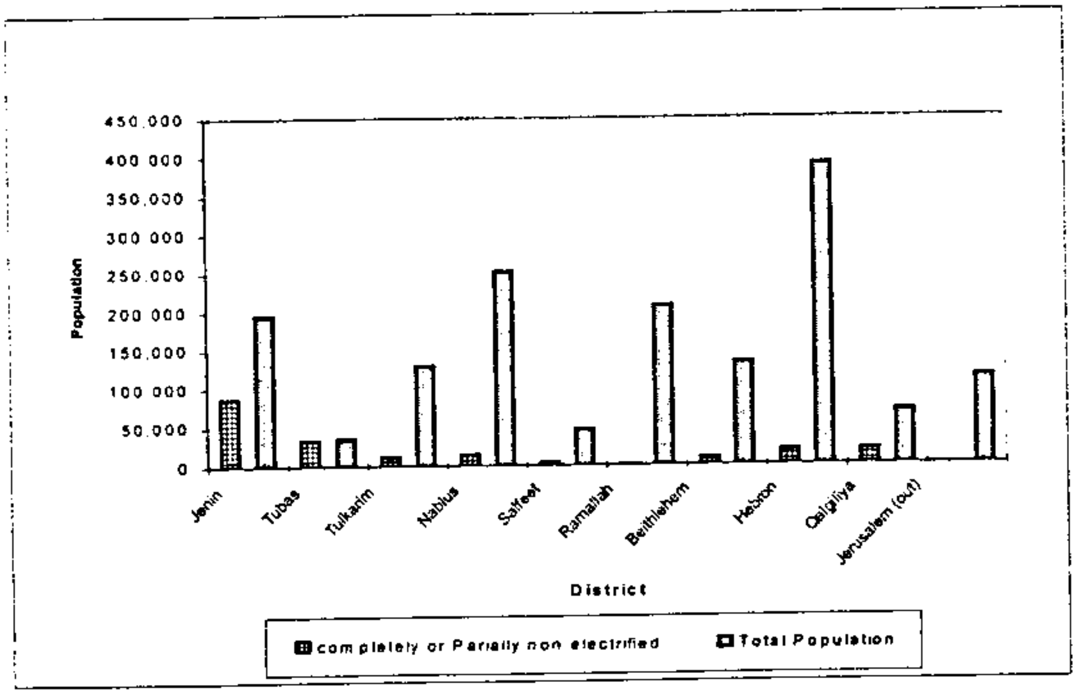

Fig 2.1 Non-electrified population in the West Bank Districts (1999)

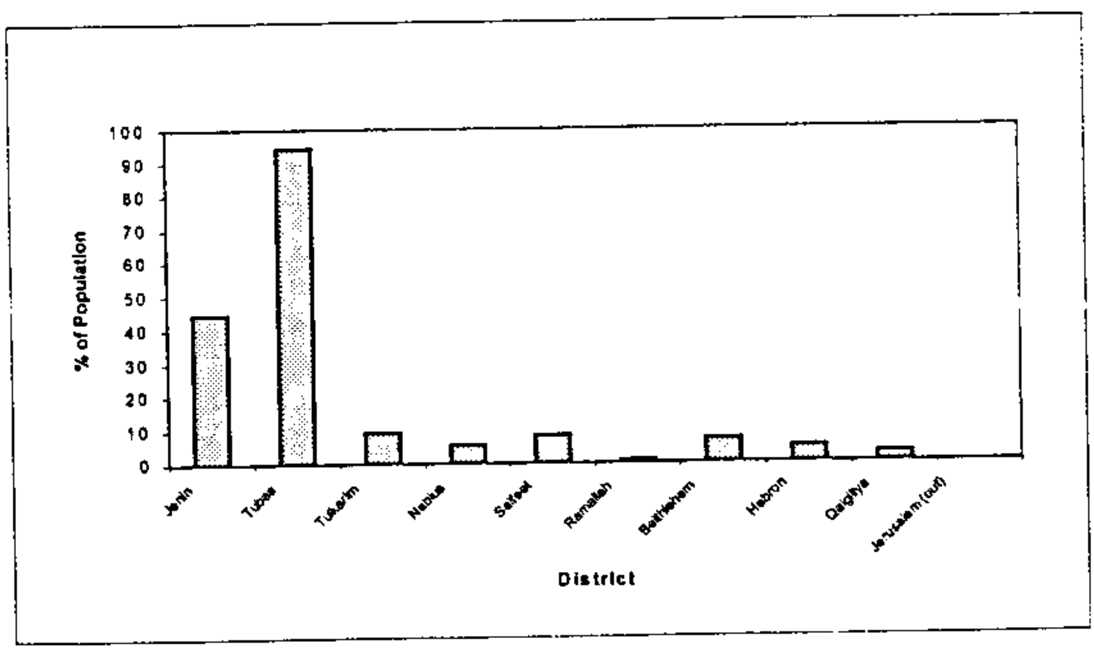

Fig 2.2: Percentage of non -electrified population in the West Bank Districts (1999)

• Maximum Power Demand and Energy Consumption

Values of energy consumption and power demand in the West Bank are as shown in Table 2.2.

Table 2.2: Energy consumption and maximum power demand in the West Bank (1995 - 1998)

Year	Energy Consumption (GWH)	Max demand (MW)	Load Factor %
95	1008	199	57.8
96	1104	218	57.8
97	1223	277	57.2
98	1411	274	58.8

(PEA, 1997)

Table 2.3 shows total energy consumption, energy consumption per capita and maximum demand in Palestine in 1997.

Table 2.3: Energy consumption, energy consumption per capita and max demand for some countries in the area (1997).

Country	Energy consumption in 1997 (GWH)	Energy consumption per capita in 1997 (kWh)	Maximum demand in 1997 (MW)
UAE	20152	8547	5479
Bahrain	4780	7624	1044
KSA	92228	5425	17995
Qatar	6457	10089	1475
Kuwait	26082	15760	4350
Syria	14347	950	3259
Lebanon	7325	1733	1450
Palestine	1577	550	408
Jordan	5281	1147	1003
Yemen	1734	104	387
Egypt	52779	838	9235
Libya	7784	1646	2140
Tunisia	6563	713	1300
Algeria	16561	565	3940
Morocco	10238	374	2123
Sudan	1452	52	-
Israel	32000	-	6200

(Arab union of producers, transports and distributors of electricity, 1997)

As shown in table2.3 total energy consumption, energy consumption per capita (although it increased from 496 kWh in 1995 to 550 kWh in 1997) and maximum demands in Palestine and so in the West Bank are still very low.

There are some reasons for this, as total number of population is small, the industrial sector is not strong, about 15% of total population of the West Bank in 1997 was completely not or partially electrified, high costs of electricity and high values of suppressed demand.

Fig 2.3 shows the energy consumption in some countries in the region in 1997.

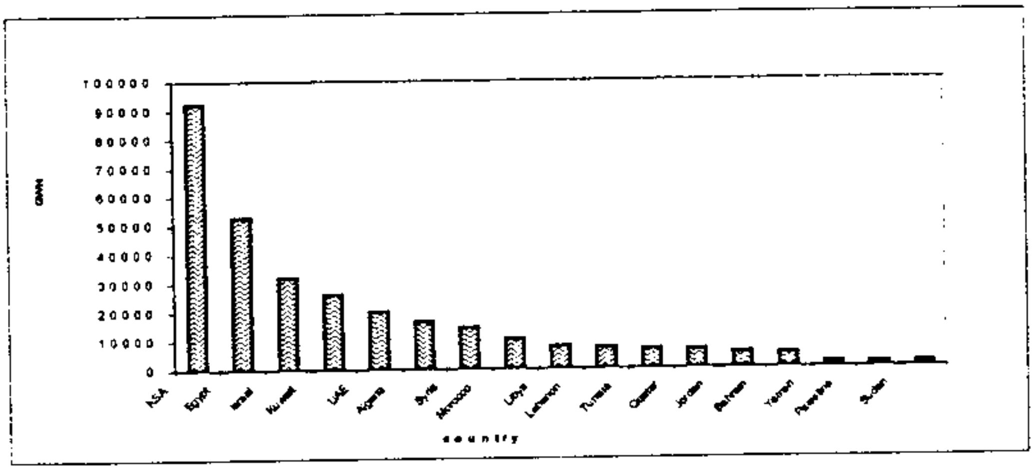

Fig 2.3: Total Electrical Energy Consumption in some countries in the region in 1997.

Fig 2.4 presents the energy consumption per capita in some countries in the region in 1997. Fig 2.5 shows the maximum demand in some countries in 1997.

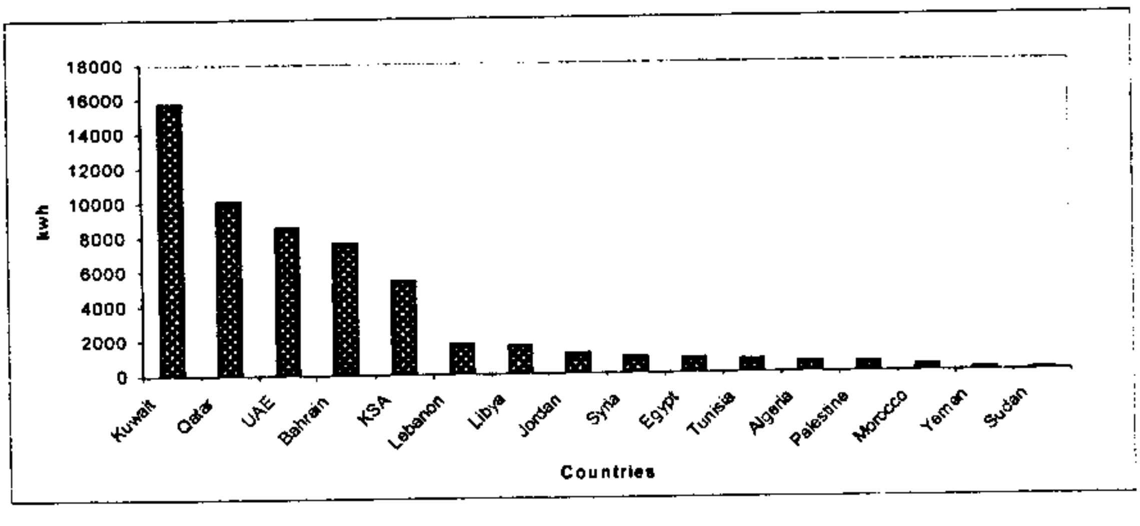

Fig 2.4: Energy Consumption per capita in some countries in the region (1997)

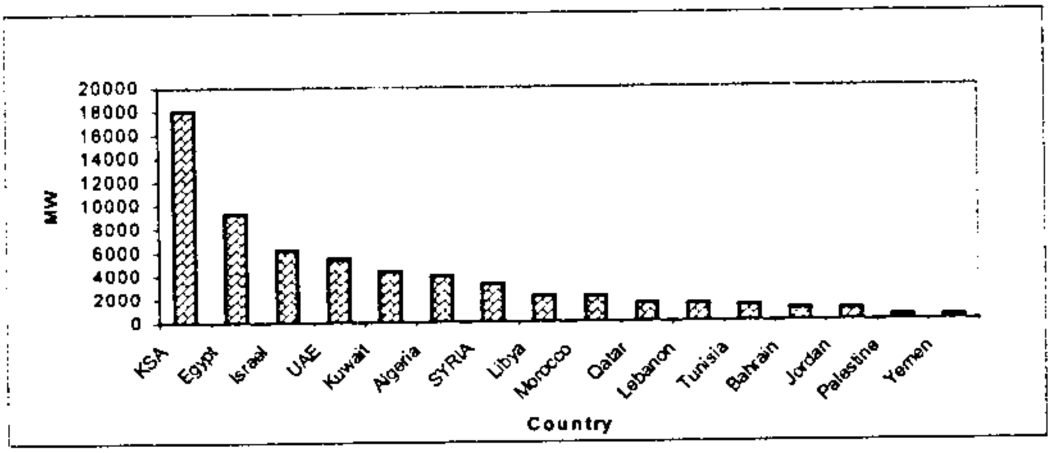

Fig 2.5 Maximum demand in some countries in the region in 1997.

Forecasted maximum demand, energy consumption and load factor from 1995 to 2015 prepared by the PEA in 1997 is as shown in table 2.4.

Table 2.4: Estimated Maximum demand and Energy Consumption in the West Bank (1995-2015)

Year	Estimated peak demand (MW)	Estimated energy consumption (GWH)	Load Factor
1995	199	1008.2	0.578
1996	218	1104.3	0.578
1997	244	1222.6	0.572
1998	274	1411.1	0.588
1999	306	1614.3	0.602
2000	338	1827.6	0.617
2001	367	1989.7	0.619
2002	398	2161.3	0.620
2003	430	2340.8	0.621
2004	464	2530.7	0.623
2005	499	2727.6	0.624
2006	530	2897.7	0.624
2007	562	3073.9	0.624
2008	595	3254.8	0.624
2009	629	3737.9	0.678
2010	663	3626.9	0.624
2011	698	3817.2	0.624
2012	734	4011.5	0.624
2013	770	4209.6	0.624
2014	806	4409.4	0.625
2015	843	4610.2	0.624

(PEA,1997)

- Electricity Prices

One point to emphasize on is that, although the PEA took over the responsibility of the energy sector in the West Bank, the IEC still the only supplier of electricity to the West Bank. We have no generation units in the West Bank and as a result electricity prices did not decrease after the PEA. Electricity prices in the West Bank (no single tariff) are very high compared with prices in neighboring countries.

- Electricity Technical Losses

Due to rehabilitation, electrifying projects and losses reduction programs carried out by the PEA, technical electricity losses decreased from more than 20% before the PEA to 15.6 % in 1996 and around 12% in 1998. Loss reduction programs as expected, will save a lot of money because reduction in losses can balance the demand growth and so will decrease the need for adding new generation units or the need for buying electricity at high prices.

To sump up, we can't say that our electricity system in the West Bank is completely independent because the Israelis control power generation, which is the most important part of electricity sector. Having generation with the Israeli is a serious problem for the local economy and for the system reliability.

As mentioned in this chapter electricity price to the PEA and to customers is very high because the Israeli put the tariff. Moreover our system is not reliable because the IEC can interrupt electricity service for no reason and some times for political reasons without any notice as happened in Gaza strip last summer, where electricity service was interrupted for many times for long periods*

The next step in this study will be carried out in the next chapter through formulation of different scenarios for energy and maximum demand forecasting in the West Bank for the period (1999 – 2020).

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*Source: Al-QUDD News paper , No. 10574, 31 Jan.1998 & No. 10577, 3 Feb.1999, Jerusalem, Palestine.

Chapter 3

Electricity-Load Demand Forecasting

3. Electricity Load - Demand Forecasting

Load demand growth is one of the key forecast parameters that are subject to uncertainty. Load growth is influenced by many factors, including the demographic growth, the local economy, energy prices and energy conservation. The forecast of future load growth over midterm (5-10) years and long-term (10-20) years is subject to abroad uncertainty

Energy and power utility industry planning process begins with power and energy load demand forecasting. Load demand forecasting is of very important as the demand for electricity initiates actions by utilities to add or retire generation, transmission, or distribution capacity. Because of the lead-time required to construct new utility equipment, decisions must be made from 2-10 years in advance of the need for a new utility plant. Table 3.1 illustrates a typical range of decision lead times for several types of new utility equipment

Table 3.1: Decision Lead Times of Some Utility Equipment

Utility Activity	**Lead time (years)**
Coal Fired Power Plant	6-10
Combustion-Turbine Power Plant	2-3
Transmission Line	2-4
Distribution Network Expansion	1-2

Typically, the load-forecast task is performed in two steps. First, an economic and demographic forecast is prepared and the electricity usage forecast is developed. An accurate forecast requires both an accurate economic forecast and an accurate demographic forecast. If the economic forecast or the demographic projections are in error, then probably the load forecast will be in error.

3.1 Overview of Load Forecasting Methods

The output from a load forecast includes a forecast of the annual energy sales (in kilowatt-hours) and the annual peak demand (in kilowatts). In general we first forecast the annual energy sales and then use the energy sales forecast in determining the annual peak demand forecast. The annual energy sales data is the integration of the hourly loads during the year and therefore less prone to weather and spurious effects.

The peak demand forecast (kW) is typically derived by analysis of the load factor. Once the load factor is forecast, the peak demand (MW) forecast is derived as shown in equation 3.1.

$$Peak\ Demand = \frac{Enegy\ Consumption}{(8760 * Load\ Factor)} \quad \text{...(3.1)}$$

In this study we will use different approach, based on the econometric model. First, for the planning period we will estimate the peak demand and the energy consumption then using equation 3.1 load factor for the same period will be calculated. The three widely used methods (models) in power & energy forecasting are as follows.

1. Econometric Model.

Econometric model develops forecasts of a time series using one or more related time series and possibly past values of the time series. This approach involves developing a regression model in which the time series is forecast as the dependent variable (in our case the peak power demand or the energy consumption); the related time series as well as the past values of the time series are the independent variables (the total population & GDP/capita). Depending on past series values of total population and total national economy (GDP/capita) peak power demand and total energy forecast is made.

2. Appliance Saturation Model

It is an engineering type methodology. Load research surveys are made to determine the number of customers with a certain appliance (i.e. central air conditioning) and the typical annual energy used by the appliance. Then forecasting the number of appliances expected in the future together with a forecast of how the annual energy usage per appliance will change, the energy load forecast is made.

3. End-Use Energy Model

It is like the appliance saturation method but it looks for the end use process as commercial, residential, industrial and so on.

The usefulness of any method depends on data availability. As for the appliance saturation and the end use methods, it seems difficult to adopt in this study because of lack of data. As for the End- Use method it is clear that in the West Bank as in other least developing countries data about end uses mainly the industrial end uses are generally unreliable, unavailable or not enough. Also the future is not clear as there are talks and studies about future industrial zones in the West Bank. but still nothing took place on the ground.

In this study we will use the first method, as it will be the most practical available method to predict the electricity demand up to year 2020 based on a macroeconomic forecast. The macroeconomic variables or drivers include the total population, the gross domestic product (GDP), industrial production and electricity price.

In this study we used only two main uncertainty variables to forecast the load growth, the demographic variable including the total population, natural growth rate and, migration rate and the economic variable represented by GDP per capita. We did not use the industrial index as a driving variable because, industrial sector in the West Bank is not active, besides the lack of data and statistics about this sector. Also we excluded energy price as a driving variable because; right now in the West Bank we do not have a single electrical energy tariff.

3.2 Population Dynamics

One of the most important factors associated with economic development and energy consumption is population dynamics. This is why increasing effort is being made in studying population dynamics. Because of the complexity of population growth, such projections are always uncertain and they must be used with considerable care and understanding.

Age distribution groups, fertility, mortality, immigration, emigration, natural catastrophes, standard of living and education are major factors that influence over all population growth rates. In the past it was very complex to carry out population projections, taking into account the above listed population parameters because, most of the work was done manually. However calculating population projections became less difficult due to using computer.

In this study for population projections we used a computer program called FIVFIV software. The reason why we used this software is because it gives an accurate projection results, moreover, it gives the facility to formulate different population projections based on different migration, fertility and mortality assumptions.

FIVFIV software is based on having for a certain year information regarding six-age groups, fertility, mortality and migration rates. The output of the FIVFIV gives population projections (i.e. six age groups in five-year steps, the grand total of population, the natural growth per year, the migration growth rate and the total growth).

During the 27 years of the Israeli occupation over the West Bank, no population census was conducted except what was announced by the Israelis. Due to political reasons statistics issued by the Israelis were underestimation less than the actual numbers. Moreover estimations were done without taking into account Palestinian refugees. As a result most of these studies about electricity forecast in the West Bank that based on population were misleading due to incorrect estimation of population. Lucky we are, as we managed to use the first real population statistics of the West Bank carried out by the Palestinian Bureau of Statistics in 1997.

3.2.1 Migration Assumptions

Migration is a function of the socio-economic and political nature of a country. Since the future development of a country is itself uncertain and data on migration generally is lacking, migration becomes very difficult factor to be considered for population projection. In our case the assumption of migration is very difficult due to our special situation in Palestine where millions of Palestinians are living outside Palestine and considered as refugees.

In this study we discussed four different migration scenarios. Based on these assumptions population projections are calculated and so the maximum power demand and energy consumption are forecasted.

First scenario assumes zero immigration, second scenario assumes 3000 returnees per year during the period 1997 up to 2020, third scenario assumes total returnees of about 275,0000 during the period 1997-2020 and the fourth scenario assumes around one million returnees during the period 1997-2020.

3.3 Gross Domestic Product (GDP)

This is an important factor in economic and in electrical energy analysis. It gives an indication about the strength of the economy and the rate of energy consumption in residential, industrial, commercial and other sectors. High values of GDP are an indication that income per capita is high. High values of GDP per capita mean that people have money and are ready to buy more electrical residential appliance equipment which in total leads to an increase in residential energy consumption. The more electrical equipment used the more the energy consumption. Also high GDP values indicate that industrial, commercial and service sectors are active. Active industrial and commercial sectors need more electrical machines, work more hours and so their total energy consumption will sharply increase.

Generally GDP forecasting is not an easy task. As a special case in the West Bank this task is more difficult because we do not have our own independent economy. Our economy is still affected by the Israeli economy .We do not yet have our own currency. Also historical values of GDP may not be real values as the increase in the GDP may be due to inflation or due to donation money.

3.4 Maximum Demand Forecasting

Maximum load demand is very important for utility capacity planning. Peak load demands are the result of coincident electric demand consumption by all end users. Peak load data are difficult to forecast directly from macroeconomic variables. Historical peak-load data series have considerable variation from year to year, which makes analysis procedures difficult. In order to forecast the peak demand up to year 2020 we will use the econometric model.

3.4.1 Econometric Load Forecasting Model

This load forecasting method goes through the following four steps.

1. Defining the likely or most strong driving variables. in our case the total population and the GDP per capita.
2. Defining the best functional relationship between the driving variables (independent) and the dependent variable (Peak demand or energy consumption) , which is called the curve fit technique, based on available historical data.
3. Perform multiple regression analysis to find parameters of relationship.
4. Test & validate the model analytically.
5. Test & validate the model using expert system. This will be discussed in more details in chapter 5.

3.4.1.1 Defining the Driving (independent) variables.

The two main driving variables we will use to forecast the maximum demand are total population and GDP per capita. One thing, which should be mentioned is that, some times one of the driving variables may not have the same effect as the other driving variables but it may have the same effect or even more in the future.

3.4.1.2 Defining the Functional Relationship between Variables

In order to find the best relationship between the independent variables (total population and GDP per capita) and the dependent variable that is the peak demand. we should have historical data about the three variables. Historical data is available only for the period from 1992 to 1998 as shown in table 3.2.

To estimate the best relationship between the variables whether it is linear or non-linear (quadratic. log, inverse, exponential, compound...), we used what called the relationship or curve fit technique. It is necessary to quantify how good the fit is between the regression line and the actual data. One measure that can be calculated is called the R^2 coefficient. The quantity R^2 is defined as the proportion of the variation of the data about the mean explained by the regression equation, that is the explained variation divided by the total variation as expressed in equation 3.2.

$$R^2 = \frac{Explanied\ Variation}{Total\ Variation} = \frac{\sum(\hat{Y}-\bar{Y})^2}{\sum(Y-\bar{Y})^2} \quad \text{.......................................(3.2)}$$

Y = actual value, $\hat{Y}$= Predicted value of Y, $\bar{Y}$= average of actual values

Table 3.2: Historical Data of Peak Demand, Population & GDP in the West Bank for the Period (1992- 1998).

Year	Peak (MW)	Population	GDP Per Capita ($)
1992	148	1271724	1314
1993	162	1323360	1368
1994	176	1488785	1409
1995	199	1579151	1624
1996	218	1600100	1690
1997	244	1657384	1740
1998	274	1714065	1775

Sources of data

- ***Date for Peak***

  - *1992-1994. (الطواقم الفنية ١٩٩٢،)*
  - *1995-1998. (PEA : 1997)*

- ***Data of the GDP***

  - *1992-1993. (Central Bureau of Statistics ,Israel)*
  - *1994-1996. (Palestinian Central Bureau Of Statistics,1997)*
  - *1997-1998. (Calculated according to the formula (the GDP for a year equals the GDP for previous year plus average of GDP during previous five years plus the population increase due to migration multiplied by the GDP per capita of the previous year) (source: (PEA:1997)*

- ***Data of population***

  - *1992-1995. (PEA: 1997)*
  - *1996-1997. (Palestinian Central Bureau Of Statistics, 1997)*
  - *1998. (Calculated using FIVFIV software)*

- *Note: Total population of 1997 and 1998 did not included completely or partially non-electrified population (mainly in villages) which was about 15% of total population.*

Values of R^2 for good fit varies from 0.9 to 1, this depends on the quantity of data and its variability. If there is only four pieces of data, fitting straight line through four pieces of data could yield R^2 of 0.9, which could be entirely unacceptable in some cases. In other case R^2 of 0 .7 would be significant accomplishment if the line was to fit through 100 data points. Thus, it is desirable to obtain values of R^2 as close to 1 as possible.

To calculate for the curve fit manually is not an easy task, instead some times, as the case of non-linear multiple coefficients, it is very difficult and impossible, so we used the SPSS software to do the job automatically. In automatic curve fitting technique real data of dependent and independent variables is tested against some well-known functions {i.e. linear (Y=B0+B1*X), quadratic ($Y=B0+B1*X+B2*X^2$), compound ($Y=B0*B1^X$), logarithmic (Y=B0+(B1*ln x)), growth ($Y= e^{(B0+B1*X)}$), exponential ($Y= e^{(B1*X)}$), Power ($Y=B0 * X^{B1}$), S ($Y= e^{(B0+B1/X)}$) and inverse (Y= B0+(B1/X))} in order to find the best relationship.

In this study historical data shown in table 3.2 is tested against some well-known functions in order to find the best relation between maximum demand and GDP and the best relation between maximum demand and population. Curve fit Results of peak-GDP relation is as shown in table 3.3.

Table 3.3: Peak –GDP Curve fit results
B0, B1, B2 are equation coefficients

Independent Variable	Dependent Variable	Curve fit Function	R^2	Bo	B1	B2
GDP	Peak MW	Linear	0.911	-150.6	0.227	
	Peak MW	Logarithmic	0.899	-2334.5	345.44	
	Peak MW	Inverse	0.886	542.62	-522809	
	Peak MW	**Quadratic**	**0.955**	**1114.7**	**-1.4347**	**.000538**
	Peak MW	Compound	0.943	34.138	1.001	
	Peak MW	Power	0.935	0.0006	1.7255	
	Peak MW	S	0.927	6.9928	-2618.3	
	Peak MW	Growth	0.943	3.5304	0.0011	
	Peak MW	Exponential	0.943	34.138	0.001	

Figure 3.1 shows graphs of different fit curves and the actual Peak – GDP graph. Fig 3.2 shows the graph of the best-fit function (quadratic function) and the graph of the actual Peak – GDP relationship. Results of curve fit of Peak - Population relation is shown in table 3.4.

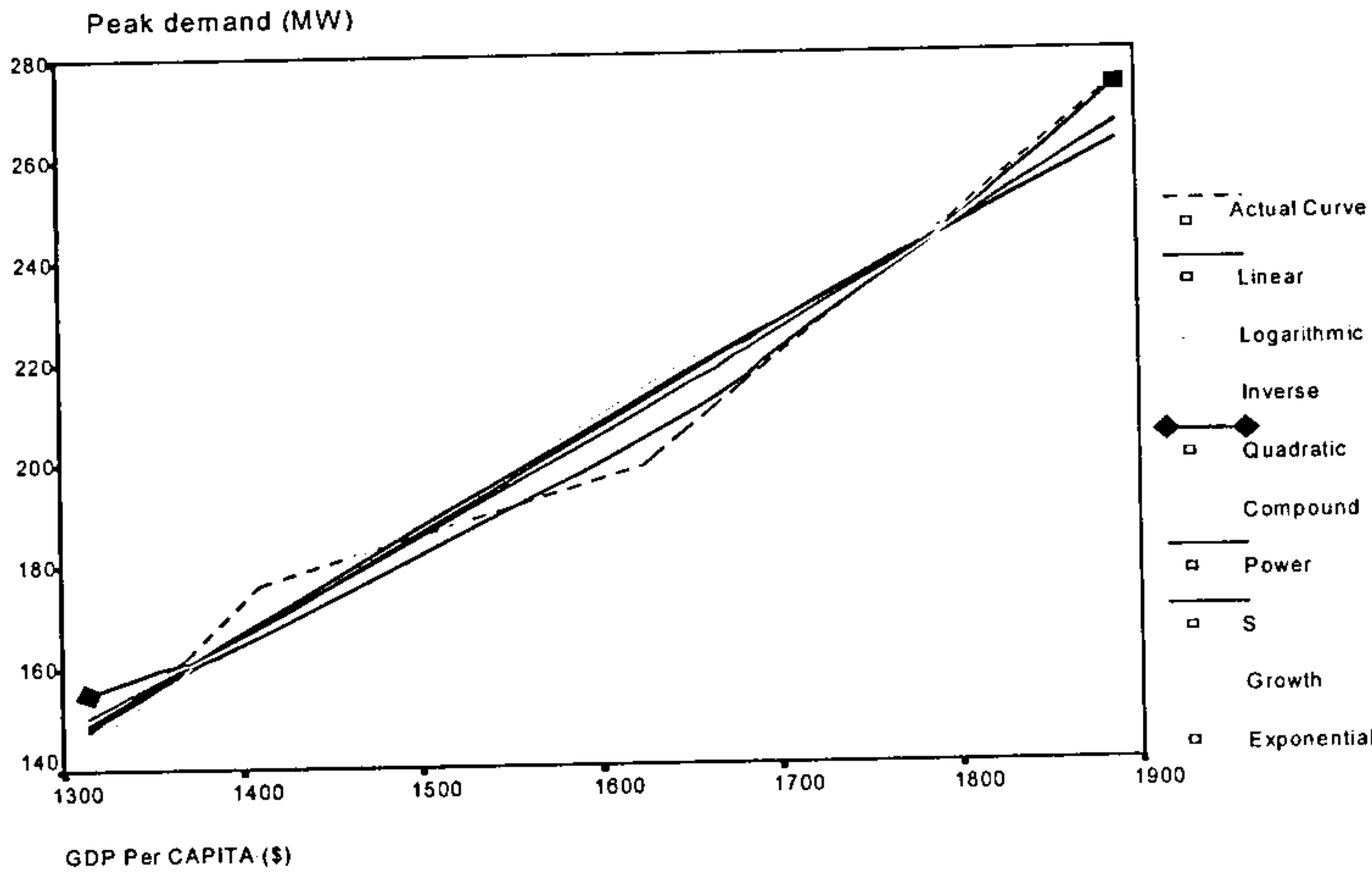

Fig 3.1: Curve fit graphs and actual Peak-GDP graph for the period (1992-1998)

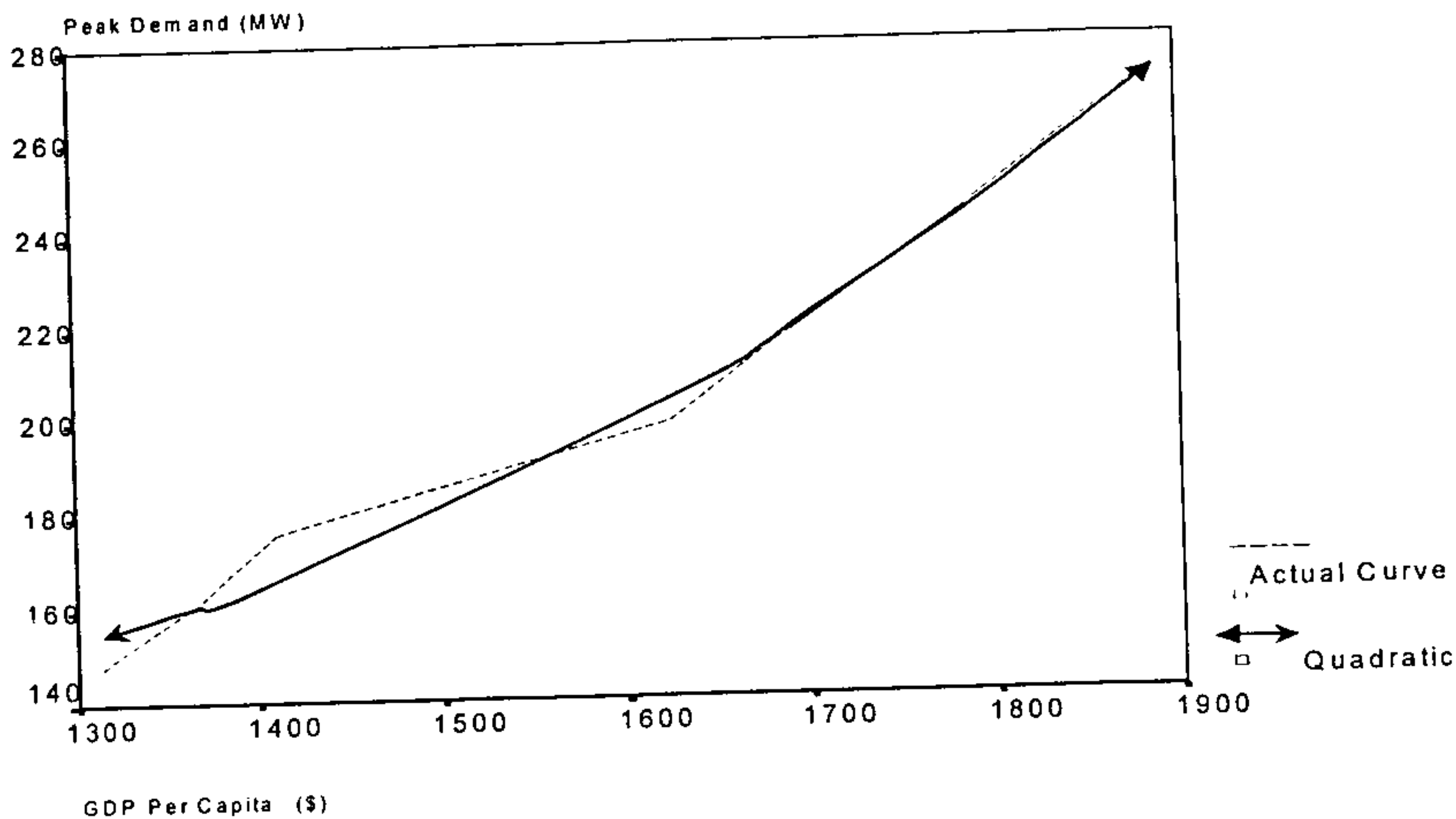

Fig 3.2 graph of quadratic function (best fit function) and actual Peak-GDP graph for the period (1992-1998)

Table 3.4: Peak-Population Curve fit results.
B0, B1, B2 are equation coefficients

Independent Variable	Dependent Variable	Curve fit Function	R^2	Bo	B1	B2
Population	Peak MW	Linear	0.943	-240.1	0.0003	
	Peak MW	Logarithmic	0.931	-5968.8	434.7	
	Peak MW	Inverse	0.917	630.4	-6.E+08	
	Peak MW	**Quadratic**	**0.977**	**996.6**	**-.0014**	**65.8E-10**
	Peak MW	Compound	0.973	21.9485	1	
	Peak MW	Power	0.966	8.6E-12	2.168	
	Peak MW	S	0.957	7.429	-3E+06	
	Peak MW	Growth	0.973	3.0887	1.5E-06	
	Peak MW	Exponential	0.973	21.9485	1.5E-06	

Figure 3.3 shows graphs of different fit functions and the actual Peak-Population graph. Fig 3.4 shows the graph of the best curve fit (quadratic function) and the graph of the actual Peak – Population relation.

As shown in tables 3.3 and 3.4 the best function that fits the relation is the quadratic function with the highest R^2 value of 0.955 for Peak-GDP relation (table 3.4) and 0.977 for the second case Peak-Population relation (table3.5)

Based on curve fit results best function that can represent the relation between the dependent variable (Peak demand) and independent variables (population and GDP) is the quadratic function as in equation 3.3.

$Y = A+B*X+C*Z+D*X^2 +E*Z^2$ .... (3.3)

Y = Predicted Peak demand in MW

A, B, C, D, E are equation coefficients

X= total population

Z= GDP per capita

3.4.1.3 Non Linear Regression Analysis

To solve for the coefficients A, B, C, D and E of equation 3.3 we used the regression technique. One way of determining the values of A, B, C, D,E is to select these values according to a criteria called least square criteria. Least-square criteria is to minimize the error squared (equation 3.5) over all data points.

$\varepsilon = (Y_i - \hat{Y})$.. (3.4)

ε = Error

Y_i = actual value

$\hat{Y}$ = predicted or estimated value

$\sum_i (\varepsilon^2_i)$ is to be minimum..(3.5)

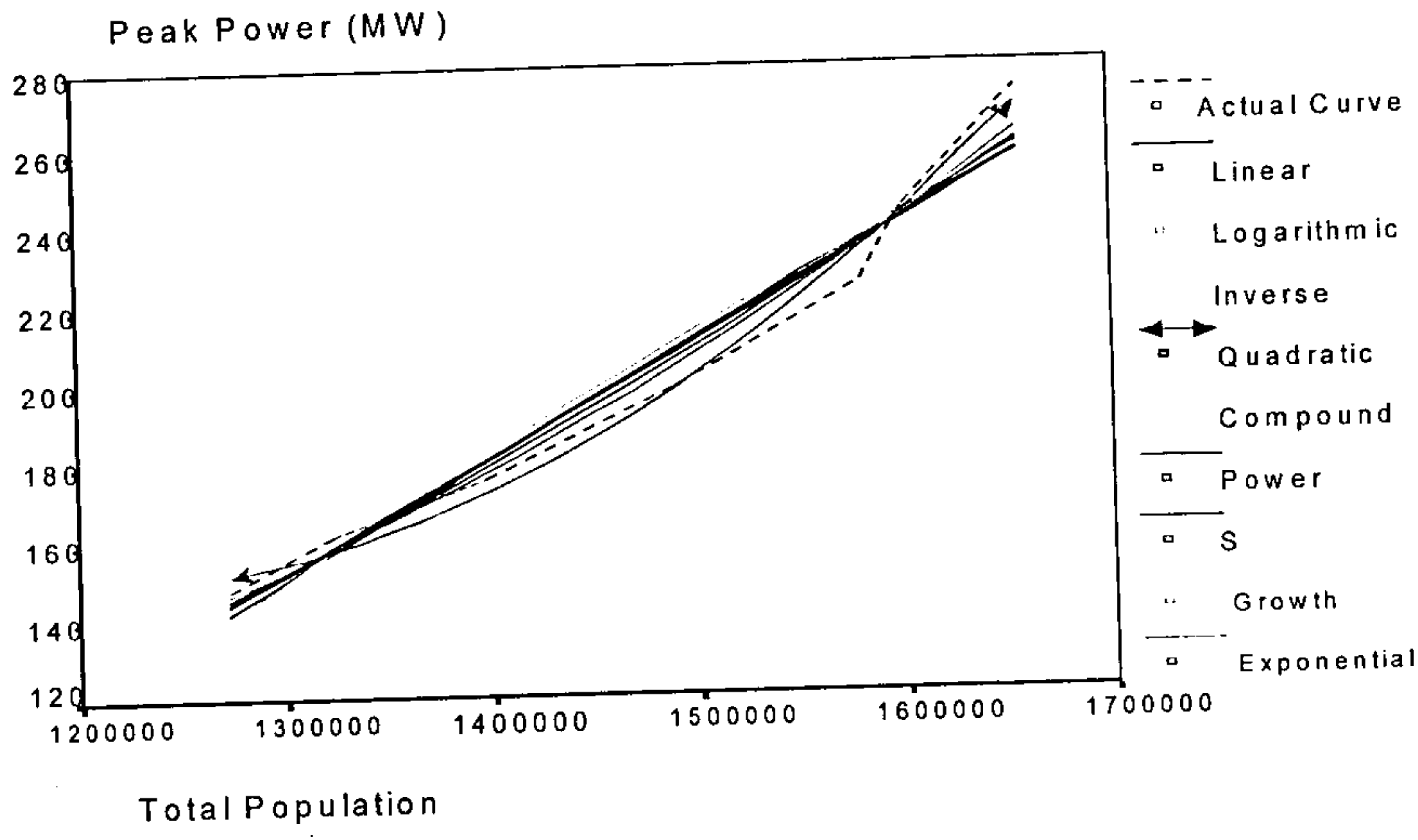

Fig 3.3 Curve fit graphs and actual Peak-Population graph (1992-1998)

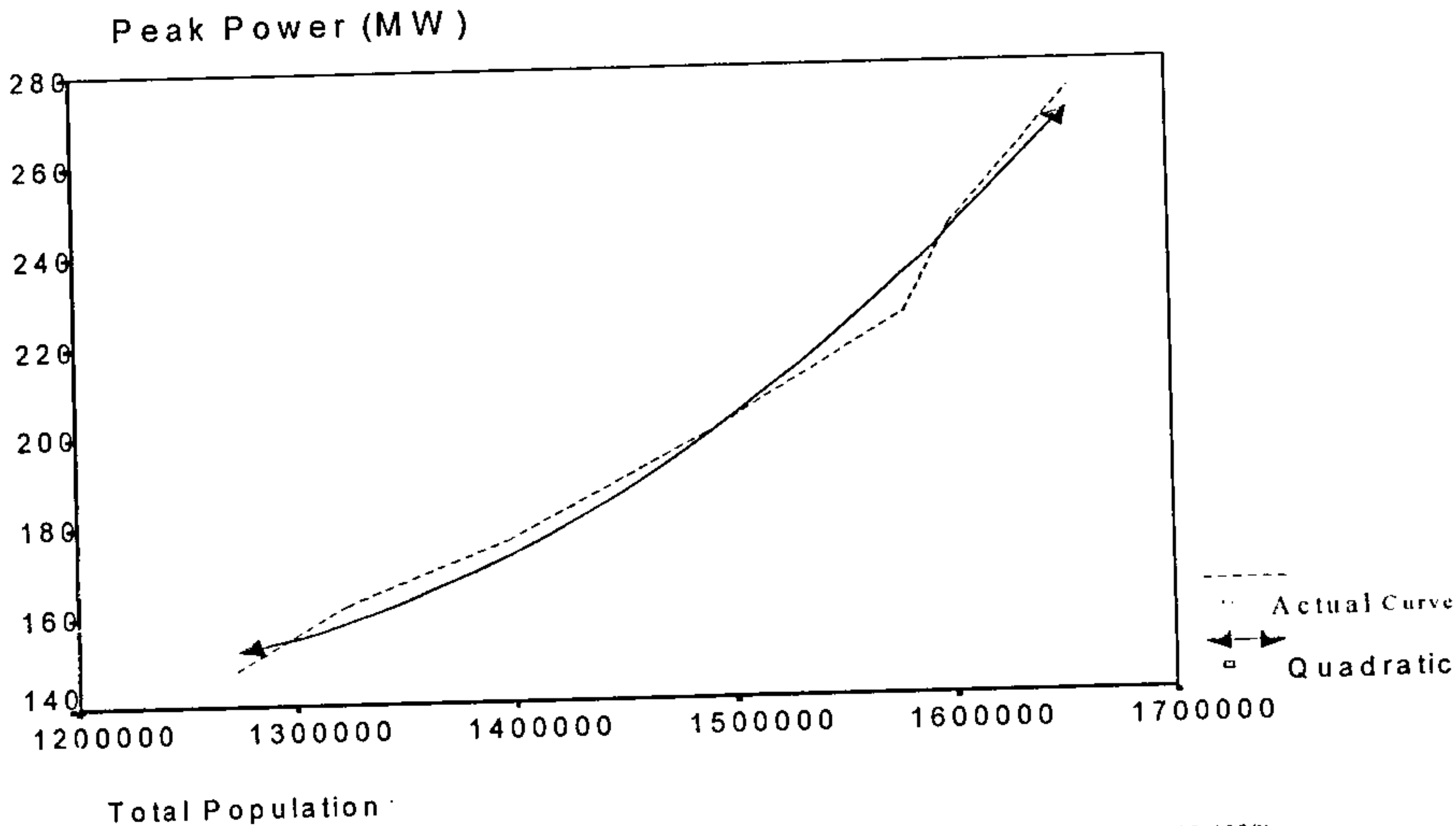

Fig 3.4: graph of quadratic function (best fit function) and actual Peak-Population graph for the period (1992-1998).

In order to solve equation 3.5 we used the non-linear regression technique of the SPSS Software. Non linear regression technique was applied to historical data (table 3.2) of GDP, population and the peak demand. Results of regression analysis gave the coefficients values as shown bellow.

A= 840.7268, B= 0.001737, C= -2.783115, D = -4.94303E-10, E= 0.000903263
Also R^2 is found to equal 0.98155. Substituting values of coefficients in equation 3.3 ends with equation 3.6

Y = 840.7268+0.001737*X - 2.783115*Z - 4.94303E-10*X^2+9.033E-4*Z^2 ...... (3.6)

3.4.1.4 Test and validate the Model Analytically.

To test this model (equation3.6) we used two measures, absolute percentage error measure and the R^2 measure. For equation 3.6, R^2 was calculated automatically and found to be 0.98155. R^2 of 0.98155 value is an indication that the quadratic function is a good representation of the relation between the driving variables (GDP & population) and dependent variable the maximum demand. To calculate the error we used equation 3.7.

Error = predicted value of peak – actual value................................. (3.7)

Applying equations 3.6 and 3.7 to data of table 3.2, the predicted values of peak, the absolute error and the percentage error are calculated as shown in table 3.5

Table 3.5: Estimated values of Peak demand in the West Bank (1992 to 1998)

Year	Population	GDP/capita ($)	Actual peak (MW)	Forecasted peak (MW)	Absolute error (MW)	% error
1992	1271724	1314	148	152.62	4.62	3.12
1993	1323360	1368	162	156.58	5.42	3.35
1994	1397212	1409	176	174.26	1.74	0.99
1995	1488785	1624	199	193.18	5.82	2.93
1996	1579151	1690	218	221.10	3.1	1.42
1997	1600100	1740	244	246.12	2.12	0.87
1998	1657384	1775	274	267.08	6.92	2.53

As shown in table 3.5 value of percentage error is between 0.87% and 3.35% which is a good value. Value of the percentage error is acceptable if it is below 5% especially if we are dealing with a limited number of data points as in this study.

Based on reasonable values of R^2 and of percentage error we can say that this model, the quadratic model is the best representation for the relation between the driving variables and the peak demand. Later on this relation (equation 3.6) will be used to forecast maximum power demand.

Fig 3.5 shows the graph of the actual peak demand and the forecasted peak for the period from 1992 t0 1998.

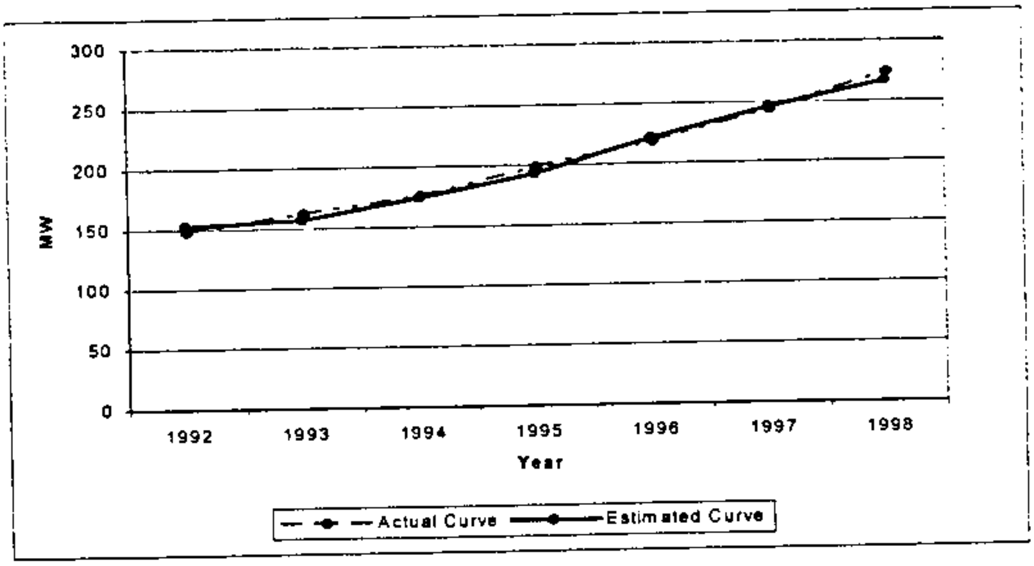

Fig. 3.5 Actual & Estimated Peak demand curves (1992-1998)

3.4.2 Scenarios of Maximum Demand Forecasting

In this study four different scenarios are studied based on four different migration and GDP assumptions. In order to forecast maximum power demand during the period 1999 –2020, first we should have population and GDP projections for the same period.

Population projections are calculated automatically using the FIVFIV software based on age group data (table 3.6) for the starting year, fertility and mortality assumption for the planning period. Regarding total fertility we assumed a decline of 33 % (5.544 to 3.77) during the period (1997 – 2020). This assumption is based on the assumption that in the future women will have better education and more job opportunities which means the number of children per family will decrease.

As for mortality an increase is assumed in life expectancy for women from 73 to 76 years and for men from 70 to 73 years during the period (1997-2020). This assumption is based on the assumption that the health situation in the West Bank is expected to be better in the future.

Table 3.6: Population by Age Groups for the West Bank (1997)

Age group	Male	Female
0-4	143916	136538
5-9	126841	120317
10-14	99177	93503
15-19	87334	81374
20-24	77542	71971
25-29	65079	60085
30-34	54181	50455
35-39	41559	38635
40-44	27975	27832
45-49	21359	20242
50-54	16997	19622
55-59	12011	15820
60-64	12150	15213
65-69	9914	12823
70-74	7444	9391
75-79	4534	5533
80-84	2674	2874
85-89	1461	1536
90-94	1009	930
95+	547	558
Not stated	631	504

(Palestinian Central Bureau of Statistics,1998)

3.4.2.1 Maximum Demand Forecasting – Scenario1

Assumptions

- **Population:** This scenario is based on natural population growth and zero immigration.

- **GDP**:
  - (1997 –2010) , GDP = (GDP of previous year + the average of the changes in the GDP of the previous 5 years)
  - (2010-2020) , GDP = 1.02 * GDP of previous year

  . Regarding GDP the assumption for the period (1997-2010) takes into account changes in the GDP of the previous 5 years, for this period this is important, as there will be money coming from the donors. For (2010-2020) we assume that donors will stop giving money and so the economy will develop by its own force. GDP growth is assumed to be 2% per year like the situation in Jordan.**

For this scenario to forecast population projections using FIVFIV software, we used age group data (table 3.6) and the above demographic assumptions (zero immigration). Input data to FIVFIV software is shown in appendix 3.1. Output data of the FIVFIV gives the population projections the migration rate, natural growth rate and total growth rate as shown in appendix 3.2. Based on population projections (Appendix 3.2) the GDP (per capita) projections were calculated and the results are presented in table 3.7.

Applying equation 3.6 to data of population and GDP projections the forecasted peak demand (1999-2020) for this scenario was calculated and results are as shown in table 3.7.

3.4.2.2 Maximum Demand Forecasting – Scenario 2

Assumptions

- **Population:** This scenario is based on the assumption that 3000 returnees per year are expected for the period (1997-2020).
- **GDP**:
  - (1997 –2010) , GDP = (GDP of previous year + the average of the changes in the GDP of the previous 5 years + GDP of previous year * migration rate)
  - (2010-2020) , GDP = 1.02 * GDP of previous year

  . For the GDP the assumption for (1997-2010) takes into account changes in the GDP of the previous 5 years, also it takes into account the

**Source: Al-QUDS News paper , No. 10826, October 13,1999, Jerusalem, Palestine.

migration rate. The reason why migration rate is considered in estimating the GDP/Capita is based on the assumption that some of the wealthy returnees will invest in the area, which will increase the GDP.

For (2010-2020) we assumed that donors will stop giving money and so the economy will develop by its own force. GDP growth is assumed to be 2% per year like the situation in Jordan

Same as for scenario 1 total population projections, natural growth, migration and total growth rates were calculated as shown in appendix 3.3. Based on population projections and migration rates, forecasted GDP was calculated up to year 2020.

Applying equation 3.6 to data of population and GDP projections the forecasted peak demand for this scenario was calculated. Table 3.8 presents the population projections, forecasted GDP and peak demand up to year 2020.

3.4.2.3 Maximum Demand Forecasting – Scenario 3

Assumptions:

- **Population:** This scenario is based on the assumption that during the period (1997-2020), 277,000 returnees are expected as follows {(3000 /year (1997-2002), 20000/year (2002-2012), 10000 /year (2012-2017) and 3000/year (2017-2020)}.
- **GDP:**
  - (1997 –2010) , GDP = (GDP of previous year + the average of the changes in the GDP of the previous 5 years + GDP of previous year * migration rate)
  - (2010-2020) , GDP = 1.02 * GDP of previous year

Same as for scenario 2, total population projections, natural growth, migration and total growth rates are calculated using FIVFIV software as shown in appendix 3.4.

Based on population projections and migration rates, forecasted GDP is calculated up to year 2020. Applying equation 3.6 to data of population and GDP projections, the forecasted peak demand for this scenario was calculated. Table 3.9 presents population projections, forecasted GDP and peak demand for scenario 3 up to year 2020.

Table 3.7: Estimation of Peak Demand in the West Bank for the period (1999- 2020) - Scenario 1

Year	Total Population	GDP/capita ($)	Actual Peak (MW)	Forecasted Peak (MW)	Error %	Peak Growth rate (%)
1992	1271724	1314	148	152.61	3.12	
1993	1323360	1368	162	156.57	-3.35	2.5
1994	1397212	1409	176	174.25	-0.99	10.1
1995	1488785	1624	199	193.17	-2.93	9.8
1996	1579151	1690	218	221.10	1.42	12.6
1997	1600100	1740	244	246.12	0.87	10.2
1998	1657384	1775	274	267.07	-2.53	7.8
1999	1711418	1811		287.34		7.1
2000	1769949	1858		313.21		8.3
2001	1830481	1900		336.27		6.9
2002	1898076	1940		356.49		5.7
2003	1952930	1982		379.22		6.0
2004	2008979	2024		401.86		5.6
2005	2066637	2065		423.14		5.0
2006	2125949	2106		443.58		4.6
2007	2186777	2147		462.92		4.2
2008	2242515	2188		484.11		4.4
2009	2300372	2230		505.36		4.2
2010	2359952	2271		524.14		3.6
2011	2421075	2316		547.03		4.2
2012	2487267	2362		567.71		3.6
2013	2549600	2410		594.05		4.4
2014	2616909	2458		616.49		3.6
2015	2686258	2507		638.49		3.4
2016	2758250	2557		659.28		3.2
2017	2838642	2608		672.46		2.0
2018	2899295	2661		710.46		5.3
2019	2968878	2714		739.23		3.9
2020	3040132	2768		768.40		3.8

** Note : Completely or partially non- electrified population are not included in peak estimation*

Table 3.8: Estimation of Peak Demand in the West Bank for the period (1999 – 2020) - Scenario 2

Year	Total Population	GDP/capita ($)	Actual Peak (MW)	Forecasted Peak (MW)	Error %	Peak Growth rate (%)
1992	1271724	1314	148	152.62	3.12	
1993	1323360	1368	162	156.58	-3.35	2.6
1994	1397212	1409	176	174.26	-0.99	11.3
1995	1488785	1624	199	193.18	-2.93	10.9
1996	1579151	1690	218	221.10	1.42	14.5
1997	1600100	1740	244	246.12	0.87	11.3
1998	1657384	1775	274	267.08	-2.53	8.5
1999	1714065	1811		287.47		7.6
2000	1775428	1861		314.86		9.5
2001	1838988	1907		340.21		8.1
2002	1913865	1952		362.95		6.7
2003	1970505	2000		390.30		7.5
2004	2028832	2050		420.02		7.6
2005	2088885	2101		451.34		7.5
2006	2151552	2153		483.88		7.2
2007	2219020	2208		518.84		7.2
2008	2275268	2263		560.58		8.0
2009	2336018	2322		607.71		8.4
2010	2399090	2381		656.01		7.9
2011	2463866	2428		686.13		4.6
2012	2536260	2477		713.62		4.0
2013	2599216	2526		748.17		4.8
2014	2670695	2577		779.21		4.1
2015	2743872	2628		808.25		3.7
2016	2819328	2682		840.47		4.0
2017	2905151	2735		858.46		2.1
2018	2968702	2789		903.41		5.2
2019	3042325	2845		941.60		4.2
2020	3117778	2902		980.09		4.1

** Note : Completely or partially non- electrified population are not included in peak estimation*

Table 3.9: Estimation of Peak Demand in the West Bank for the period (1999- 2020) - Scenario 3

Year	Total Population	GDP/capita ($)	Actual Peak (MW)	Forecasted Peak (MW)	Error %	Peak Growth rate (%)
1992	1271724	1314	148	152.60	3.11	
1993	1323360	1368	162	156.60	-3.33	2.6
1994	1397212	1409	176	174.30	-0.97	11.3
1995	1488785	1624	199	193.20	-2.91	10.8
1996	1579151	1690	218	221.10	1.42	14.4
1997	1600100	1740	244	246.10	0.86	11.3
1998	1657384	1775	274	267.08	-2.53	8.5
1999	1714065	1811		288.32		8.0
2000	1775428	1861		315.76		9.5
2001	1838988	1906		340.49		7.8
2002	1913865	1954		365.44		7.3
2003	1985635	2020		405.00		10.8
2004	2060096	2092		452.48		11.7
2005	2137350	2169		508.46		12.4
2006	2217500	2254		578.18		13.7
2007	2307365	2345		658.06		13.8
2008	2384893	2444		765.64		16.3
2009	2465025	2551		897.71		17.2
2010	2547604	2665		1056.38		17.7
2011	2633204	2729		1119.57		6.0
2012	2715889	2784		1165.39		4.1
2013	2794650	2839		1213.96		4.2
2014	2875695	2890		1249.56		2.9
2015	2959090	2954		1313.63		5.1
2016	3047863	3010		1350.07		2.8
2017	3128159	3073		1415.25		4.8
2018	3203235	3135		1485.82		5.0
2019	3280113	3198		1558.05		4.9
2020	3358836	3262		1631.79		4.7

** Note : Completely or partially non- electrified population are not included in peak estimation*

3.4.2.4 Maximum Demand Forecasting – Scenario 4

Assumptions

- **Population:** This scenario is based on the assumption that during the period (1997-2020) 995,000 returnees are expected as follows {(3000 /year (1997-2002), 60000/year (2002-2017), 20000 /year (2017-2020)}.
- **GDP:**
  - (1997 –2007) , GDP = (GDP of previous year + the average of the changes in the GDP of the previous 5 years + GDP of previous year X migration rate)
  - (2007-2002) , GDP = 1.04 X GDP of previous year
  - (2012-2020), GDP= 1.03 X GDP of previous year.

Total population projections, natural, migration and total growth rates are calculated using FIVFIV software as shown in appendix 3.5.

Based on population projections and migration rates forecasted GDP is calculated up to year 2020. Applying equation 3.6 to data of population and GDP projections, the forecasted peak demand for this scenario is calculated. Table 3.10 presents the population projections, forecasted GDP and peak demand for scenario 4 up to year 2020. Table 3.11 shows the forecasted peak of the four scenarios before connecting non-or partially electrified villages to the grid.

3.4.3 Maximum Demand Forecasting due to Connecting Non-Or Partially Electrified Villages to the Grid.

As presented in chapter 2 total number of population who are completely or partially not connected to the electricity grid is about 199357 (12.7%) of total population in 1999. It was planned by the PEA that population without continuous electricity service (mainly in villages), during the period from year 1997 up to year 2003 will be completely connected to the electricity Grid. But due to freeze in the peace process we estimate that those people will be completely connected to electricity grid during the period (2001-2005).

To calculate the effect of connecting non- electrified people (mainly in villages) to the grid on the peak demand we used a special equation (equation 3.9)* developed by the PEA.

$$P_v = R * 0.3 + C*5 \quad (3.9)$$

P_v= Peak demand of villages to be connected to the grid
R= number of residential consumers
C= number of commercial consumers

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*Source: Oral report from Eng.Zaki Affani , Head of Rural Electrification Departement.PEA.May.1999

Table 3.10: Estimation of Peak Demand in the West Bank for the period (1999- 2020) Scenario 4

Year	Total Population	GDP/capita ($)	Actual Peak (MW)	Forecasted Peak (MW)	Error %	Peak Growth rate (%)
1992	1271724	1314	148	152.60	3.1	
1993	1323360	1368	162	156.60	-3.3	2.6
1994	1397212	1409	176	174.30	-1.0	10.2
1995	1488785	1624	199	193.20	-2.9	9.8
1996	1579151	1690	218	221.10	1.4	12.6
1997	1600100	1740	244	246.12	0.9	10.2
1998	1657384	1775	274	267.08	-2.5	7.8
1999	1714065	1811		288.32		7.4
2000	1775428	1861		315.76		8.7
2001	1838988	1906		340.49		7.3
2002	1913865	1954		365.44		6.8
2003	2019510	2051		424.50		13.9
2004	2131189	2153		492.82		13.9
2005	2249044	2261		572.40		13.9
2006	2373640	2375		664.25		13.8
2007	2515233	2494		760.22		12.6
2008	2627412	2593		849.30		10.5
2009	2745120	2697		948.68		10.5
2010	2867553	2830		1115.52		15.0
2011	2996019	2917		1175.84		5.1
2012	3138544	3034		1294.53		9.2
2013	3263772	3125		1368.76		5.4
2014	3394322	3218		1439.90		4.9
2015	3530096	3315		1513.47		4.9
2016	3671299	3414		1582.33		4.4
2017	3825860	3517		1636.22		3.3
2018	3913605	3587		1707.33		4.2
2019	4011445	3660		1768.70		3.5
2020	4111731	3733		1824.55		3.1

** Note : Completely or partially non- electrified population are not included in peak estimation*

Table 3.11: Estimation of Peak Demand in the West Bank for the period (1999-2020) For Scenarios 1,2,3 and 4

Year	Actual Peak (MW)	Forecasted Peak SC.1 (MW)	Forecasted Peak SC.2 (MW)	Forecasted Peak SC.3 (MW)	Forecasted Peak SC.4 (MW)
1992.0	148.0	152.6	152.6	152.6	152.6
1993.0	162.0	156.6	156.6	156.6	156.6
1994.0	176.0	174.3	174.3	174.3	174.3
1995.0	199.0	193.2	193.2	193.2	193.2
1996.0	218.0	226.9	226.9	226.9	226.9
1997.0	244.0	246.1	246.1	246.1	246.1
1998.0	274.0	267.1	267.1	267.1	267.1
1999.0		287.3	287.3	288.3	288.3
2000.0		313.2	314.9	315.8	315.8
2001.0		336.3	340.2	340.5	345.7
2002.0		356.5	363.0	365.4	375.0
2003.0		379.2	390.3	405.0	438.8
2004.0		401.9	420.2	452.5	511.9
2005.0		423.1	451.3	508.5	596.7
2006.0		443.6	483.9	578.2	688.2
2007.0		462.9	518.8	658.1	784.1
2008.0		484.1	560.6	765.6	873.2
2009.0		505.4	607.7	897.7	972.6
2010.0		524.1	656.0	1056.0	1138.9
2011.0		547.0	686.1	1119.6	1199.7
2012.0		567.7	713.6	1165.4	1318.4
2013.0		594.1	748.2	1214.0	1392.7
2014.0		616.5	779.2	1249.6	1463.8
2015.0		638.5	808.3	1313.6	1537.4
2016.0		659.3	840.5	1350.1	1606.2
2017.0		672.5	858.5	1415.3	1660.1
2018.0		710.5	903.4	1485.8	1731.2
2019.0		739.2	941.6	1558.1	1792.6
2020.0		768.4	980.1	1631.8	1848.5

* *Note : Completely or partially non- electrified population are not included in peak estimation*

$R = T.P / 6 = 199375/6 = 33229$ .... (3.10)

$C = T.P / 65 = 199375/65 = 3067$ .... (3.11)
T.P = Total population of villages totally or partially not connected to the grid.

Substituting equations 3.10 and 3.11 in equation 3.9 we get the P_v Value

$P_v = 33229*0.3 \text{ kW} + 3067* 5 \text{ kW}$
$P_v = 9969 + 15335 = 25.3 \text{ MW}$

25.3 MW will be supplied by the grid in 5 years, equally, that is 5 MW each year starting from year 2001 due to connecting non-electrified villages to the grid. To calculate for the effect of connecting non-electrified villages to the grid starting from year 2001we added each year the value of 5 MW to each of the four peak demand scenarios (tables 3.7,3.8,3.9 and 3.10).

Table 3.12 presents summary of the peak power demand scenarios before and after connecting non-or partially electrified villages to the grid.

Fig 3.6 shows the graphs of forecasted peak demand of the 4 scenarios.

3.5 Energy Consumption Forecasting

Same as peak demand forecasting, energy forecasting is calculated based on an econometric method using historical data shown in table (3.15)

Table 3.13: Energy Consumption in the West Bank for the period (1994-1998)

Year	Energy (GWH)
1994	916576
1995	1008234
1966	1104340
1997	1222651
1998	1411116

Source of data:

- Data of (1994) : estimated by author , based on year1995 data.
- Data of (1995-1998) (Enel, Tractebel,Cesi,1997)

3.5.1 Econometric Energy Consumption Forecasting Model

To forecast energy consumption total population and GDP per capita were used as the driving variables.

Table 3.12: Estimation of Peak Demand (before and after electrifying all villages) in the West Bank For the period (1999-2020). For Scenarios 1,2,3 and 4

Year	SC.1 Peak (MW)	SC.1' Peak (MW)	SC.2 Peak (MW)	SC.2' Peak (MW)	SC.3 Peak (MW)	SC.3' Peak (MW)	SC.4 Peak (MW)	SC.4' Peak (MW)
1992.0	152.6	152.6	152.6	152.6	152.6	152.6	152.6	152.6
1993.0	156.6	156.6	156.6	156.6	156.6	156.6	156.6	156.6
1994.0	174.3	174.3	174.3	174.3	174.3	174.3	174.3	174.3
1995.0	193.2	193.2	193.2	193.2	193.2	193.2	193.2	193.2
1996.0	226.9	226.9	226.9	226.9	226.9	226.9	226.9	226.9
1997.0	246.1	246.1	246.1	246.1	246.1	246.1	246.1	246.1
1998.0	267.1	267.1	267.1	267.1	267.1	267.1	267.1	267.1
1999.0	287.3	287.3	287.3	287.3	288.3	288.3	288.3	288.3
2000.0	313.2	313.2	314.9	314.9	315.8	315.8	315.8	315.8
2001.0	336.3	341.1	340.2	345.0	340.5	345.3	340.5	345.7
2002.0	356.5	366.0	363.0	372.5	365.4	375.0	365.4	375.0
2003.0	379.2	393.6	390.3	404.6	405.0	419.3	424.5	438.8
2004.0	401.9	421.0	420.2	439.1	452.5	471.6	492.8	511.9
2005.0	423.1	447.0	451.3	475.2	508.5	532.4	572.8	596.7
2006.0	443.6	467.5	483.9	507.8	578.2	602.1	664.3	688.2
2007.0	462.9	486.8	518.8	542.7	658.1	682.0	760.2	784.1
2008.0	484.1	508.0	560.6	584.5	765.6	789.5	849.3	873.2
2009.0	505.4	529.3	607.7	631.6	897.7	921.6	948.7	972.6
2010.0	524.1	548.0	656.0	679.9	1056.0	1079.9	1115.0	1138.9
2011.0	547.0	570.9	686.1	710.0	1119.6	1143.5	1175.8	1199.7
2012.0	567.7	591.6	713.6	737.5	1165.4	1189.3	1294.5	1318.4
2013.0	594.1	618.0	748.2	772.1	1214.0	1237.9	1368.8	1392.7
2014.0	616.5	640.4	779.2	803.1	1249.6	1273.5	1439.9	1463.8
2015.0	638.5	662.4	808.3	832.2	1313.6	1337.5	1513.5	1537.4
2016.0	659.3	683.2	840.5	864.4	1350.1	1374.0	1582.3	1606.2
2017.0	672.5	696.4	858.5	882.4	1415.3	1439.2	1636.2	1660.1
2018.0	710.5	734.4	903.4	927.3	1485.8	1509.7	1707.3	1731.2
2019.0	739.2	763.1	941.6	965.5	1558.1	1582.0	1768.7	1792.6
2020.0	768.4	792.3	980.1	1004.0	1631.8	1655.7	1824.6	1848.5

- SC.1 , SC.2, SC.3 and SC.4 :Peak demand scenarios before electrifying completely or partially non-electrified population .
- SC.1', SC.2' , SC.3' , and SC.4' , Peak demand scenarios after connecting completely or partially non-electrified population to electricity grid.

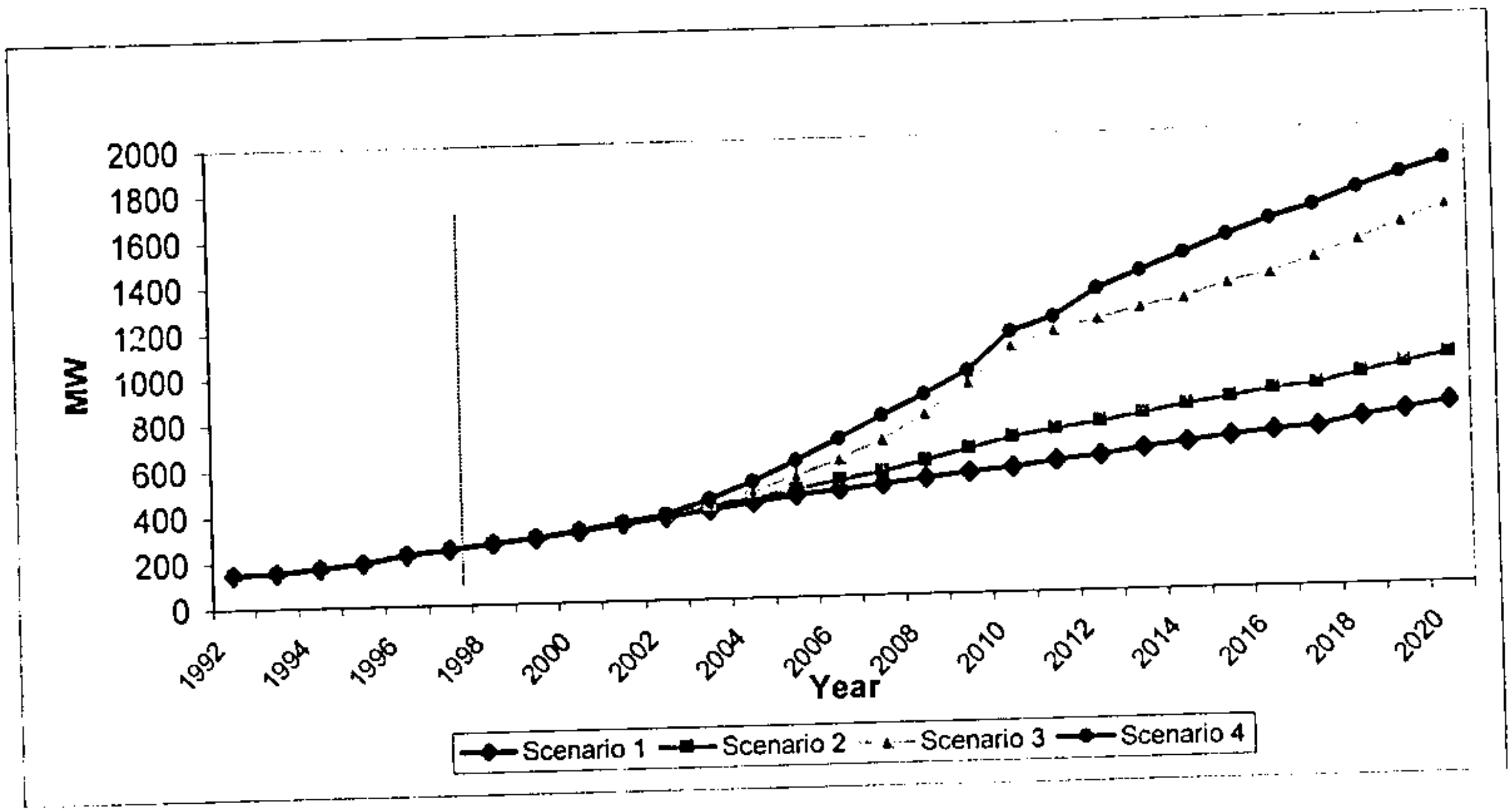

Fig 3.6: Forecasted Peak Demand graphs (for the four scenarios) of the West Bank .

Based on population and GDP historical data (table 3.2) and Energy data (table 3.17) the best functional relationships were determined using the curve fit technique of the SPSS software (same technique applied in section 3.4.1).

Results of Energy - GDP Curve fit analysis are shown in table 3.14.

Table 3.14*: *Energy – GDP curve fir results.
B0, B1, B2 are equation coefficients

Independent Variable	**Dependent Variable**	**Curve fit Function**	R^2	**Bo**	**B1**	**B2**
GDP	Energy consumption	Linear	0.755	-770441	1155.03	
	Energy consumption	Logarithmic	0.729	-1E07	1790889	
	Energy consumption	Inverse	0.704	2820129	-3E09	
	Energy consumption	**Quadratic**	**0.977**	**1.5E07**	**-19018**	**6.3672**
	Energy consumption	Compound	0.805	202489	1.001	
	Energy consumption	Power	0.781	7.3042	1.6127	
	Energy consumption	Growth	0.805	12.218	.001	
	Energy consumption	Exponential	0.805	202489	.001	

Fig.3.7 shows graphs of different fit curves and the actual Energy – GDP graph.

Fig.3.8 shows the graph of the best curve fit function (quadratic function) and the actual Energy – GDP relationship. Energy- Population curve fit results are as shown in table 3.15.

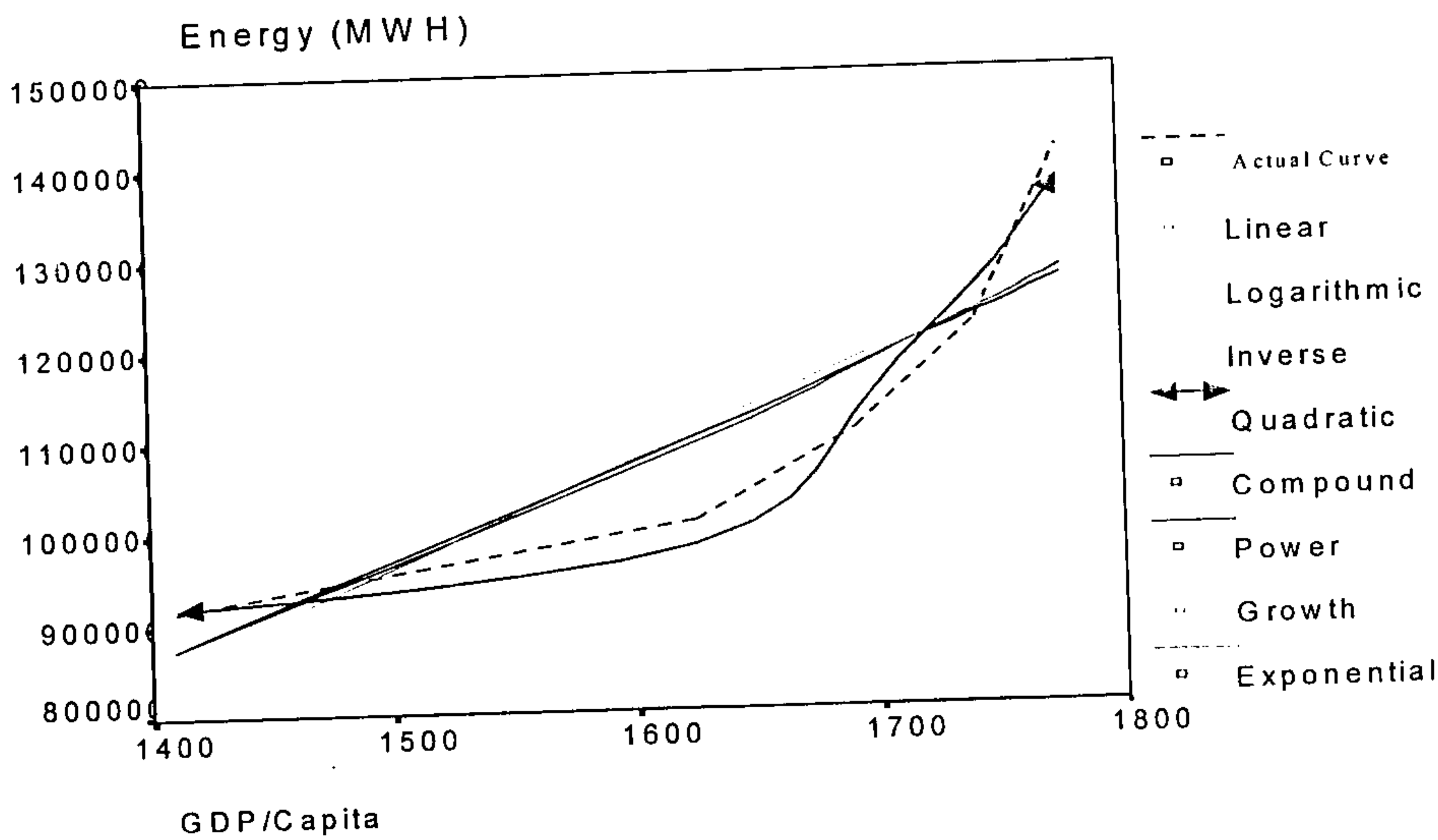

Fig 3.7 Curve Fit graphs and Energy-GDP graph for the period (1994-1998)

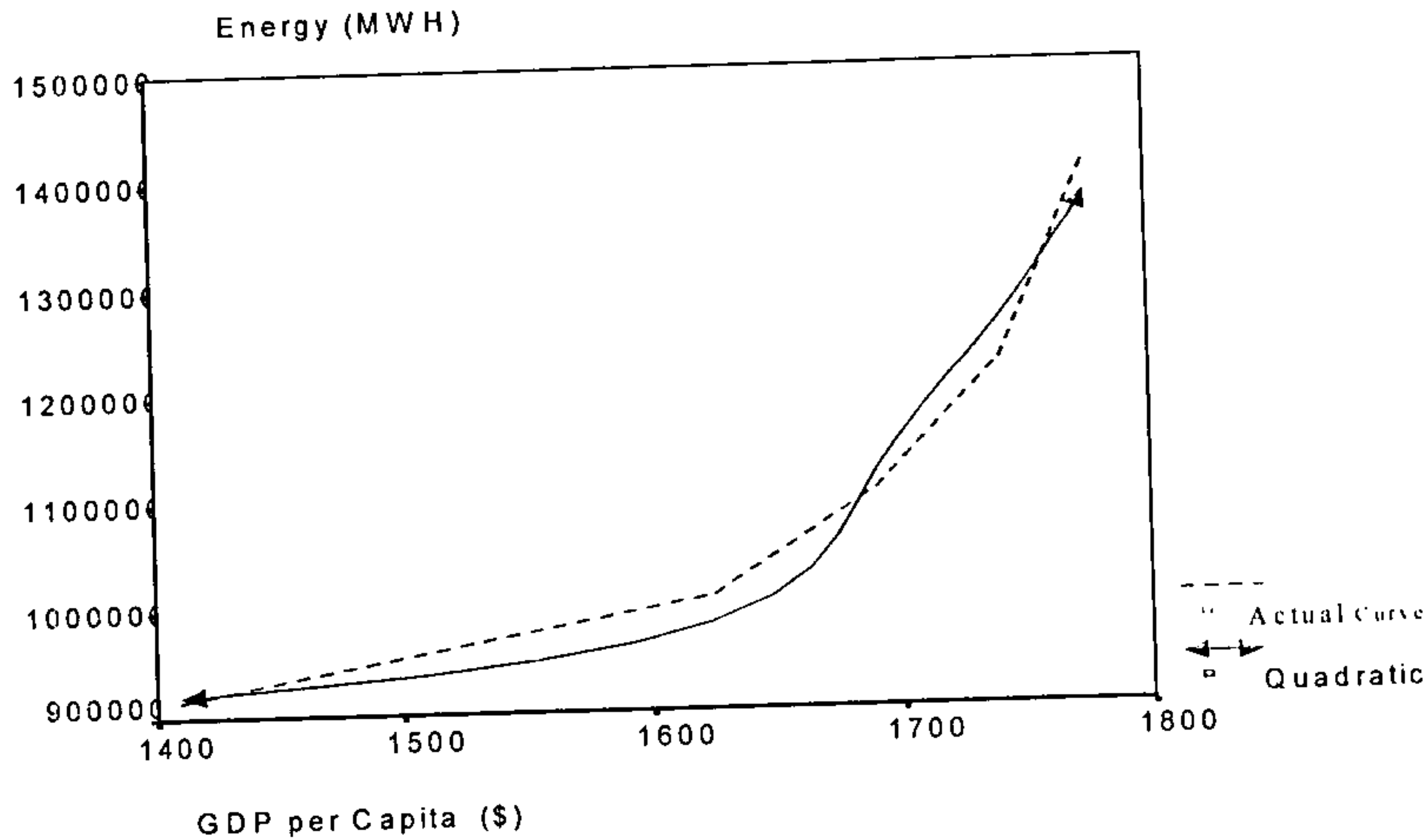

Fig 3.8 graph of quadratic function (best fit function) and actual Energy-GDP graph for the period (1994-1998)

Table 3.15: Energy – Population curve fit results.
B0, B1, B2 are equation coefficients

Independent Variable	Dependent Variable	Curve fit Function	R^2	Bo	B1	B2
Population	Energy consumption	Linear	0.881	-2.E06	1.7814	
	Energy consumption	Logarithmic	0.867	-4.E07	2684822	
	Energy consumption	Inverse	0.852	3754594	-4.E12	
	Energy consumption	**Quadratic**	**0.975**	**1.7E07**	**-22.391**	**7.9E-06**
	Energy consumption	Compound	0.917	97404.5	1	
	Energy consumption	Power	0.906	1.9E-09	2.3875	
	Energy consumption	Growth	0.917	11.4866	1.6E-06	
	Energy consumption	Exponential	0.917	97404.5	1.6E-06	

Fig.3.9 shows graphs of different fit function curves and the real Energy – Population graph. Fig. 3.10 shows the graph of the best curve fit function (quadratic function) and the graph of actual Energy – population relationship.

As presented in tables 3.14 and 3.15 the best function that fits the relation is the quadratic function with the highest R^2 value of 0.977 for Energy –GDP relation (table 3.14) and 0.975 for the Energy - Population relation (table 3.15). As a result relation between dependent variable (Energy) and independent variables (population and GDP) will have the following form.

$$\mathbf{E_n\hat{} = A_1+B_1*X+C_1*Z+D_1*X^2+E_1*Z^2} \qquad (3.12)$$

$E_n\hat{}$ = total forecasted energy consumption (GWH)
A_1, B_1, C1, D_1, E_1 are equation coefficients
X = total population
Z= GDP/ capita

To solve for the coefficients A_1, B1, C1, D1 and E_1 of equation 3.12, the non-linear regression analysis technique of the SPSS Software was used, where we came up with the following coefficient values

A_1 = 0.00001, B_1 = 0.00001, C_1= -207.287, D_1 = 7.47E-07,
E_1=- 0.1105298.

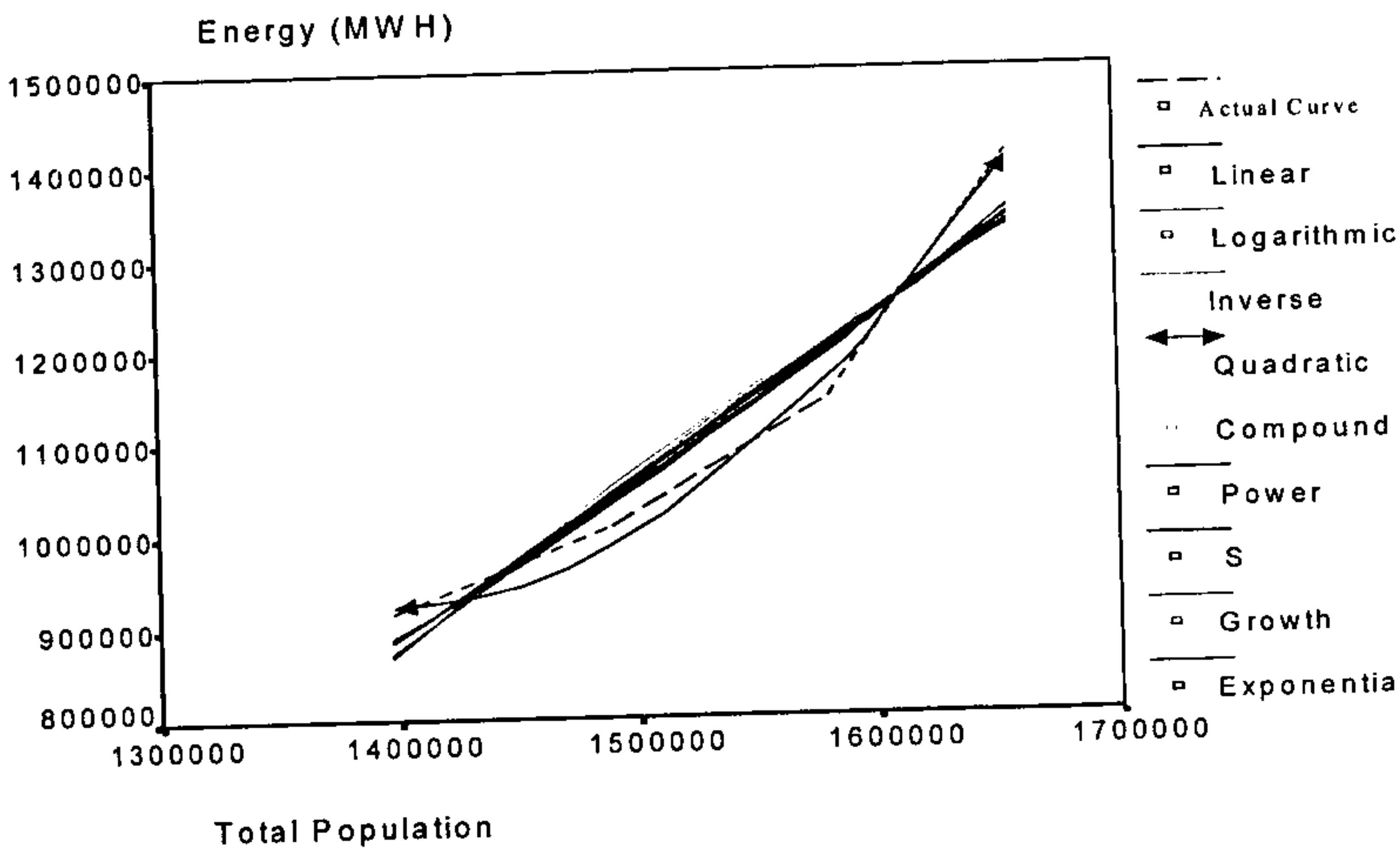

Fig 3.9 Curve fit graphs and actual Energy-Population graph for the period (1994-1998)

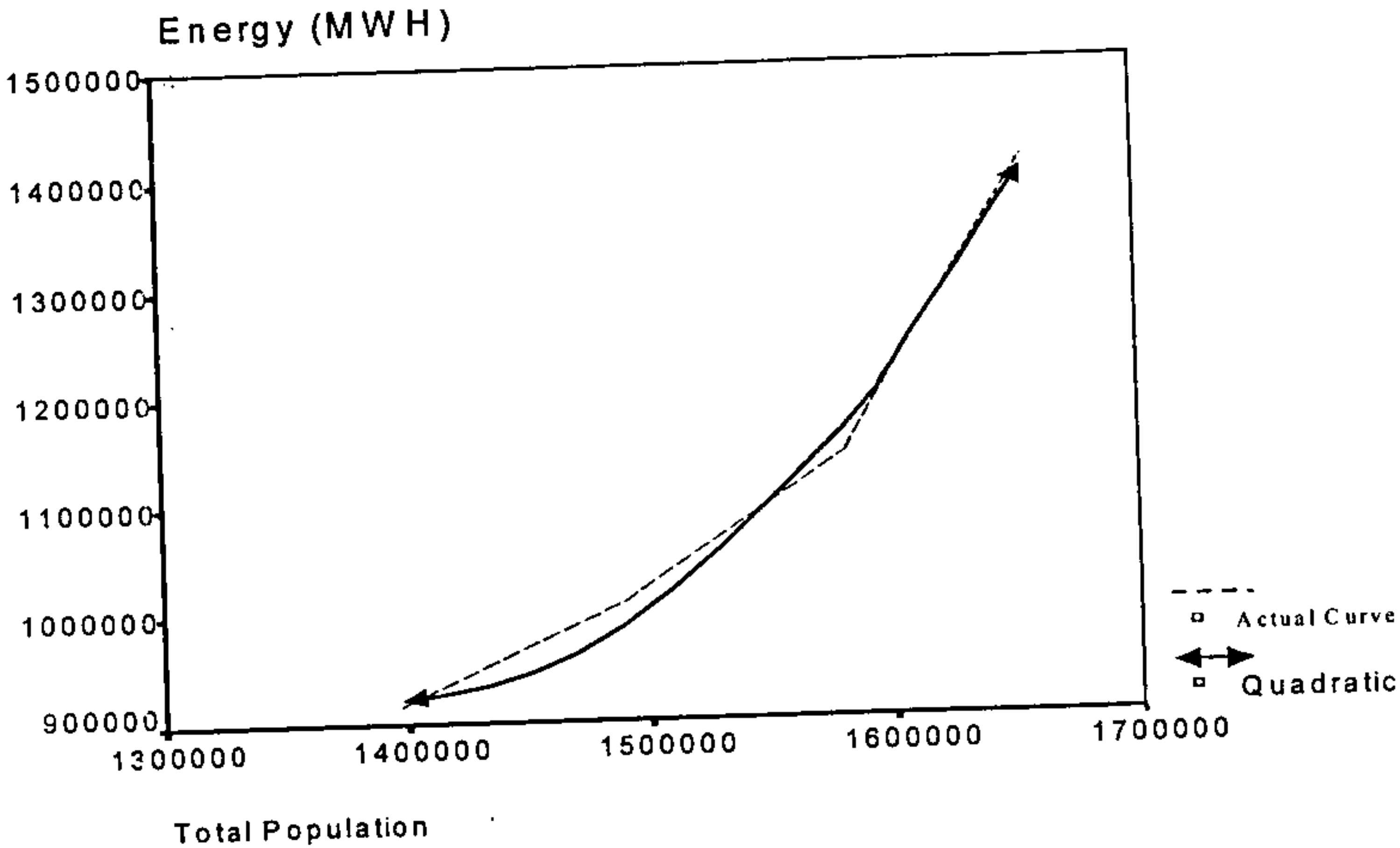

Fig 3.10 graph of quadratic function (best fit function) and actual Energy-Population graph for the period (1994-1998)

Substitution of above coefficients in equation 3.12 ends with the best relation ship (equation 3.13) between energy as dependent variable and independent variables (Population and GDP)

$$\hat{E_n} = 1E\text{-}05 + 1E\text{-}05*X - 207.287*Z + 7.47E\text{-}07*X^2 - 0.1150298*Z^2 \quad \ldots\ldots\ldots \quad (3.13)$$

To test this model (equation 3.13), we used two measures, the absolute error measure and the R^2 measure. For equation 3.13, R^2 was calculated automatically and found to be 0.93919 which is an indication that the quadratic relation is a good representation of the relation between the driving variables (GDP and population) and independent variable (Energy).

Absolute error was calculated using equation 3.7, but first forecasted data of energy consumption was calculated by applying equations 3.13 to data of table 3.2.

Table 3.16 presents the forecasted energy consumption data, error (forecasted minus actual) and % error.

Table 3.16: Forecasted Energy Consumption in the West Bank (1994- 1998)

year	Population	GDP/capita ($)	Actual energy (GWH)	Forecasted energy (GWH)	Absolute error (GWH)	Absolute Error (%)
1994	1397212	1409	916.6	946.8	30.2	3.3
1995	1488785	1624	1008.2	1027.6	19.3	1.92
1966	1579151	1690	1104.3	1137.0	32.6	2.96
1997	1600100	1740	1222.7	1217.3	5.4	0.44
1998	1657384	1775	1411.1	1366.6	44.6	3.16

As shown in table 3.16 percentage error is between 0.44% and 3.3%, which is reasonable. The value of the percentage error is acceptable if it is below 5%, especially if we are taking about a limited number of data points as our case.

Based on reasonable values we got for R^2 and of error we can say that this model, the quadratic model (equation 3.13) is the best representation for the relation between the driving variables and the energy consumption. Later on, this model (equation 3.13) will be used to forecast electrical energy consumption.

3.5.2 Energy Consumption Forecasting Scenarios

To forecast energy consumption for the period (1999-2020) we used the same four population and GDP scenarios, that used to forecast maximum demand (section 3.4.2).

3.5.2.1 Energy Consumption Forecasting -Scenario 1 (Zero immigration for the period 1997-2020)

Applying equation 3.13 to data of population and GDP (table 3.7) gave the forecasted energy consumption in the West Bank for the period (1999-2020) as presented in table 3.17.

3.5.2.2 Energy Consumption forecasting -Scenario 2 (3000 returnees/year for the period 1997-2020)

Applying equation 3.13 to data of population and GDP (table 3.8) gave the forecasted energy consumption in the West Bank for the period (1999-2020) as presented in table 3.18.

3.5.2.3 Energy Consumption forecasting -Scenario 3 (277,000 returnees for the period 1997-2020)

Applying equation 3.13 to data of population and GDP (table 3.9) gave the forecasted energy consumption in the West Bank for the period (1999-2020) as presented in table 3.19.

3.5.2.4 Energy Consumption forecasting -Scenario 4 (995,000 returnees for the period 1997-2020)

Applying equation 3.13 to data of population and GDP shown in table 3.10 gave the forecasted energy consumption in the West Bank for the period (1999-2020) as presented in table 3.20.

3.5.3 Energy Consumption Forecasting due to Connecting Non-Or Partially Electrified Villages to the Grid.

Total peak demand was calculated to be 25 MW (section 3.4.3) and to be satisfied during the period (2001-2005). Assuming that L.F for this period will be 0.58 like that in 1998. Energy consumption due to connecting non-electrified villages to the grid will be as follows.

Energy consumption due to connecting non electrified villages to the grid

= Peak demand *8760*L.F

= 25 MW*8760*0.58= 127 GWH

Each year the addition (from 2001) in energy consumption will be 127 \5 = 25.4 GWH. Referring to energy consumption scenarios (tables 3.17, 3.18, 3.19,3.20) and adding the value 25.4 GWH starting from year 2001 to each value in these four tables we came up with table 3.21. Table 3.21 shows the total electrical forecasted energy consumption before and after connecting the non-or partially electrified villages to electricity grid. Fig 3.11shows graphs of energy consumption in the West Bank for the four scenarios.

Table 3.17: Estimation of Energy Consumption in the West Bank For the period (1999-2020) - Scenario 1

Year	Total Population	GDP/ Capita ($)	Energy (GWH)	Growth rate of energy Consumption %
1994.0	1397212.0	1409.0	946.808	
1995.0	1488785.0	1624.0	1027.583	8.5
1996.0	1579151.0	1690.0	1136.974	10.6
1997.0	1600100.0	1740.0	1217.255	7.1
1998.0	1657384.0	1775.0	1366.560	12.3
1999.0	1711418.0	1811.0	1450.040	6.1
2000.0	1769949.0	1858.0	1573.453	8.5
2001.0	1830481.0	1900.0	1710.104	8.7
2002.0	1898076.0	1940.0	1873.103	9.5
2003.0	1952930.0	1982.0	2003.989	7.0
2004.0	2008979.0	2024.0	2142.567	6.9
2005.0	2066637.0	2065.0	2291.077	6.9
2006.0	2125949.0	2106.0	2449.434	6.9
2007.0	2186777.0	2147.0	2545.220	3.9
2008.0	2242515.0	2188.0	2690.000	5.7
2009.0	2300372.0	2230.0	2798.151	4.0
2010.0	2359952.0	2271.0	2875.421	2.8
2011.0	2421075.0	2316.0	3045.710	5.9
2012.0	2487267.0	2362.0	3201.022	5.1
2013.0	2549600.0	2410.0	3423.212	6.9
2014.0	2616909.0	2458.0	3542.541	3.5
2015.0	2686258.0	2507.0	3725.451	5.2
2016.0	2758250.0	2557.0	3824.573	2.7
2017.0	2838642.0	2608.0	3942.512	3.1
2018.0	2899295.0	2661.0	4215.742	6.9
2019.0	2968878.0	2714.0	4325..421	2.6
2020.0	3040132.0	2768.0	4435.712	2.5

• *Note: Completely or partially non-electrified population is not included in Energy consumption Estimation forecasting.*

Table 3.18: Estimation of Energy Consumption in West Bank For the period (1999 – 2020) - Scenario 2

Year	Total Population	GDP/ Capita ($)	Energy (GWH)	Growth rate of energy Consumption (%)
1994.0	1397212.0	1409.0	946.808	
1995.0	1488785.0	1624.0	1027.583	8.5
1996.0	1579151.0	1690.0	1136.974	10.6
1997.0	1600100.0	1740.0	1217.255	7.1
1998.0	1657384.0	1775.0	1366.560	12.3
1999.0	1714065.0	1811.0	1456.813	6.6
2000.0	1775428.0	1861.0	1586.108	8.9
2001.0	1838988.0	1907.0	1729.026	9.0
2002.0	1913865.0	1952.0	1910.413	10.5
2003.0	1970505.0	2000.0	2043.845	7.0
2004.0	2028832.0	2050.0	2185.351	6.9
2005.0	2088885.0	2101.0	2336.100	6.9
2006.0	2151552.0	2153.0	2499.376	7.0
2007.0	2219020.0	2208.0	2681735	7.3
2008.0	2275268.0	2263.0	2831.993	5.6
2009.0	2336018.0	2322.0	2999..125	5.9
2010.0	2399090.0	2381.0	3179.320	6.0
2011.0	2463866.0	2428.0	3379903	6.3
2012.0	2536260.0	2477.0	3613..580	6.9
2013.0	2599216.0	2526.0	3817839	5.7
2014.0	2670695.0	2577.0	4059.888	6.3
2015.0	2743872.0	2628.0	4315.954	6.3
2016.0	2819328.0	2682.0	4586.642	6.3
2017.0	2905151.0	2735.0	4910.918	7.1
2018.0	2968702.0	2789.0	5145.602	4.8
2019.0	3042325.0	2845.0	5429.706	5.5
2020.0	3117778.0	2902.0	5728.889	5.5

* *Note: Completely or partially non-electrified population is not included in Energy consumption Estimation forecasting.*

Table 3.19: Estimation of Energy Consumption in the West Bank For the period (1999 –2020) -Scenario 3

Year	Total Population	GDP/ Capita ($)	Energy (GWH)	Growth rate of energy Consumption (%)
1994.0	1397212	1409.0	946.808	
1995.0	1488785	1624.0	1027.583	8.5
1996.0	1579151	1690.0	1136.974	10.6
1997.0	1600100	1740.0	1217.255	7.1
1998.0	1657384	1775.0	1366.560	12.3
1999.0	1714065	1811.0	1456.813	6.6
2000.0	1775428	1861.0	1586.108	8.9
2001.0	1838988	1906.0	1729.655	9.1
2002.0	1913865	1954.0	1919.135	11.0
2003.0	1985635	2020.0	2075.526	8.1
2004.0	2060096	2092.0	2252.911	8.5
2005.0	2137350	2169.0	2442.915	8.4
2006.0	2217500	2254.0	2747330	12.5
2007.0	2307365	2345.0	2994.275	9.0
2008.0	2384893	2444.0	3514.297	17.4
2009.0	2465025	2551.0	3874.005	10.2
2010.0	2547604	2665.0	4457.677	15.1
2011.0	2633204	2729.0	4801.401	7.7
2012.0	2715889	2784.0	5150.513	7.3
2013.0	2794650	2839.0	5491.591	6.6
2014.0	2875695	2890.0	5858.088	6.7
2015.0	2959090	2954.0	6237.001	6.5
2016.0	3047863	3010.0	6663.471	6.8
2017.0	3128159	3073.0	7049.859	5.8
2018.0	3203235	3135.0	7417.952	5.2
2019.0	3280113	3198.0	7804.840	5.2
2020.0	3358836	3262.0	8211.477	5.2

* *Note: Completely or partially non-electrified population is not included Energy consumption Estimation forecasting.*

Table 3.20: Estimation of Energy Consumption in the West Bank For the period (1999 –2020) - Scenario 4

Year	**Total Population**	**GDP/ Capita** (\$)	**Energy** (GWH)	**Growth rate of energy Consumption** (%)
1994.0	1397212.0	1409.0	946.808	
1995.0	1488785.0	1624.0	1027.583	8.5
1996.0	1579151.0	1690.0	1136.974	10.6
1997.0	1600100.0	1740.0	1217.255	7.1
1998.0	1657384.0	1775.0	1366.560	12.3
1999.0	1714065.0	1811.0	1456.813	6.6
2000.0	1775428.0	1861.0	1586.108	8.9
2001.0	1838988.0	1906.0	1729.654	9.1
2002.0	1913865.0	1954.0	1919.135	11.0
2003.0	2019510.0	2051.0	2156.500	12.4
2004.0	2131189.0	2153.0	2434.230	12.9
2005.0	2249044.0	2261.0	2744.779	12.8
2006.0	2373640.0	2375.0	3092.982	12.7
2007.0	2515233.0	2494.0	3521.370	13.9
2008.0	2627412.0	2593.0	3876.128	10.1
2009.0	2745120.0	2697.0	4266.157	10.1
2010.0	2867553.0	2830.0	4670.661	9.5
2011.0	2996019.0	2917.0	5160.057	10.5
2012.0	3138544.0	3034.0	5711.971	10.7
2013.0	3263772.0	3125.0	6230.067	9.1
2014.0	3394322.0	3218.0	6794.892	9.1
2015.0	3530096.0	3315.0	7407.040	9.0
2016.0	3671299.0	3414.0	8072.482	9.0
2017.0	3825860.0	3517.0	8837.826	9.5
2018.0	3913605.0	3587.0	9275.640	5.0
2019.0	4011445.0	3660.0	9781.249	5.5
2020.0	4111731.0	3733.0	10315.003	5.5

* *Note : Completely or partially not electrified population are not included in Energy consumption forecasting*

Table 3.21: Estimation of Energy Consumption (before and after electrifying all villages) in the West Bank For the period (1999-2020). For Scenarios 1,2,3 and 4

Year	SC.1 Energy (GWH)	SC.1' Energy (GWH)	SC.2 Energy (GWH)	SC.2' Energy (GWH)	SC.3 Energy (GWH)	SC.3' Energy (GWH)	SC.4 Energy (GWH)	SC.4' Energy (GWH)
1994	946.8	946.8	946.8	946.8	946.8	946.8	946.8	946.8
1995	1027.6	1027.6	1027.6	1027.6	1027.6	1027.6	1027.6	1027.6
1996	1137.0	1137.0	1137.0	1137.0	1137.0	1137.0	1137.0	1137.0
1997	1217.3	1217.3	1217.3	1217.3	1217.3	1217.3	1217.3	1217.3
1998	1366.6	1366.6	1366.6	1366.6	1366.6	1366.6	1366.6	1366.6
1999	1450.0	1450.0	1456.8	1456.8	1456.8	1456.8	1456.8	1456.8
2000	1573.5	1573.5	1586.1	1586.1	1586.1	1586.1	1586.1	1586.1
2001	1710.1	1738.6	1729.0	1757.5	1729.7	1757.5	1729.7	1757.5
2002	1873.1	1930.0	1910.4	1967.3	1919.1	1976.0	1919.1	1976.0
2003	2004.0	2089.3	2043.8	2129.2	2075.5	2160.9	2156.5	2241.9
2004	2142.6	2256.4	2185.4	2299.2	2252.9	2366.7	2434.2	2548.0
2005	2291.7	2433.3	2336.1	2478.4	2442.9	2585.2	2744.8	2887.0
2006	2449.4	2591.7	2499.4	2641.6	2747.3	2889.6	3093.0	3235.2
2007	2545.2	2687.5	2681.7	2824.0	2994.3	3136.5	3521.4	3663.6
2008	2690.0	2832.3	2832.0	2974.3	3514.3	3656.6	3876.1	4018.4
2009	2798.2	2940.4	2999.1	3141.4	3874.0	4016.3	4266.2	4408.4
2010	2875.4	3017.7	3179.3	3321.6	4457.7	4599.9	4670.7	4812.9
2011	3045.7	3188.0	3379.9	3522.2	4801.4	4943.7	5160.1	5302.3
2012	3201.0	3343.3	3613.6	3755.8	5150.5	5292.8	5712.0	5854.2
2013	3423.2	3565.5	3817.8	3960.1	5491.6	5633.9	6230.1	6372.3
2014	3542.5	3684.8	4059.9	4202.2	5858.1	6000.4	6794.9	6937.2
2015	3725.5	3867.7	4316.0	4458.2	6237.0	6379.3	7407.0	7549.3
2016	3824.6	3966.8	4586.6	4728.9	6663.5	6805.7	8072.5	8214.7
2017	3942.5	4084.8	4910.9	5053.2	7049.9	7192.1	8837.8	8980.1
2018	4215.7	4358.0	5145.6	5287.9	7418.0	7560.2	9275.6	9417.9
2019	4325.4	4467.7	5429.7	5572.0	7804.8	7947.1	9781.2	9923.5
2020	4435.7	4578.0	5728.9	5871.2	8211.5	8353.7	10315.0	10457.3

- SC.1 , SC.2, SC.3 and SC.4 :Energy consumption scenarios before electrifying completely or partially non-electrified population .
- SC.1'. SC.2' , SC3' , and SC.4' , Energy consumption scenarios after electrifying completely or partially non-electrified population .

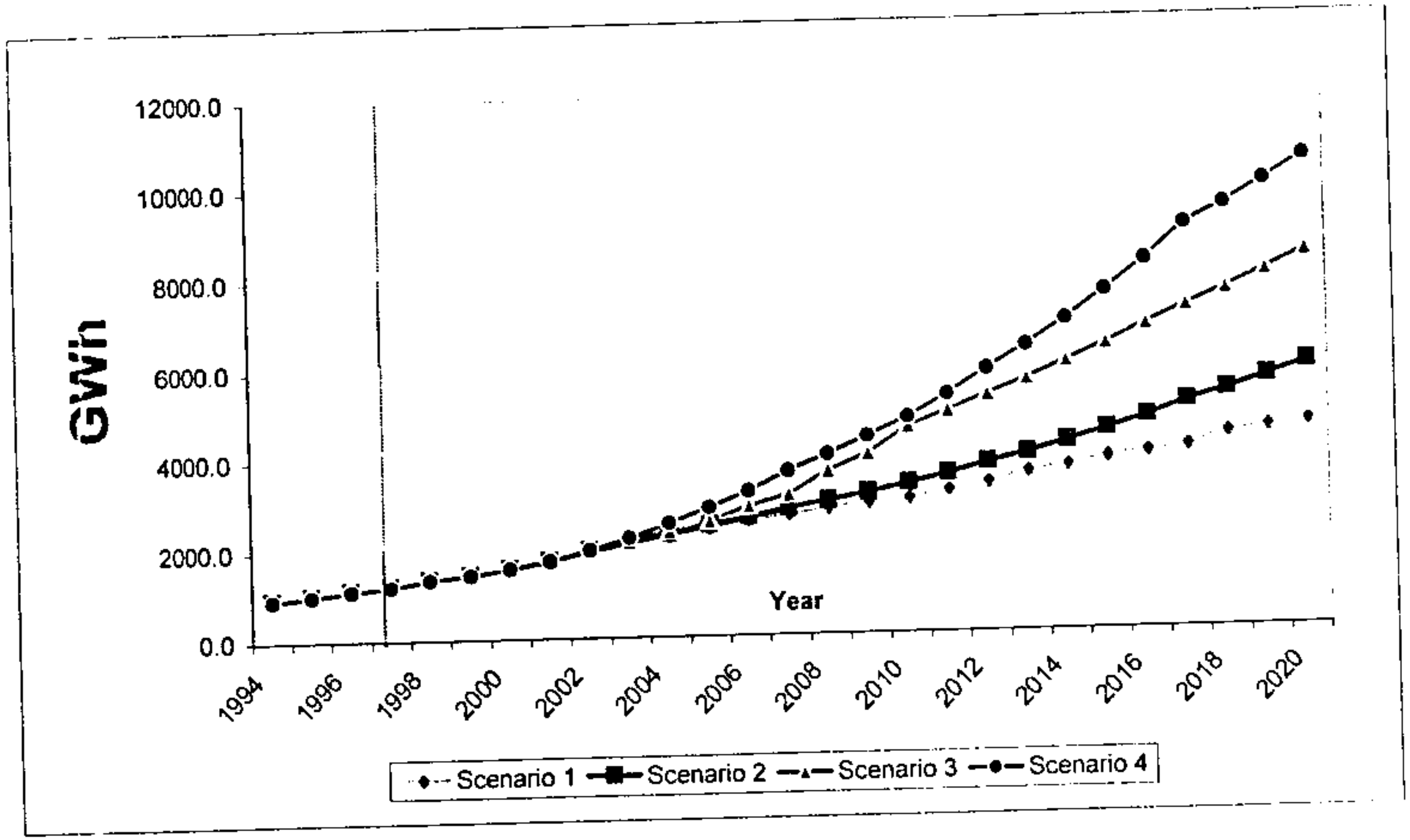

Fig 3.11: Estimation of Energy consumption in the West Bank (Four scenarios)

3.6 Load Factor Calculation

Load factor is very important as it gives an indication of power system behavior. Higher values of load factor indicate that the gap is small between the base values and the peak values of the load curve. Load factor is an indication of how much of the total energy available is used.

L.F is obtained by dividing the total energy used per year (kWh) by the amount that would have been used if it had been consumed at maximum demand for every hour in the year. While it is good to have a high load factor, the numerical values are not as important as the constant values. If there are wild swings in this number from year to year, it indicates high demand or low utilization of the equipment or both. For example, if a plant closes down for vacation for a period of time during the year, the load factor will dip to reflect this.

To forecast the annual load factor during the period 1999-2020 we used equation 3.1. Applying equation 3.1 to forecasted data of peak demand (table 3.12) and energy consumption (table 3.21), the load factor was calculated as shown in table 3.22. Table 3.22 shows the load factor for the four scenarios before connecting the non-or partially electrified villages to the grid and after connection.

For scenarios 1 and 2, as shown in table 3.22 the fluctuation or the gap in the load factor is moderate (0.6 to 0.66). This is a good indication that the power demand is not so high. The reason is that in scenario1 there will be no immigration, demand growth will not be high. As a result L.F values will increase. Also in scenario 2, there will be some immigration with some development in GDP, which at the beginning of immigration will cause some drop in the L.F, but soon it will increase again.

For scenarios 3and 4 the high gap in load factor from year to year indicates that the load demand will be high. For the first 10 years (2001-2010) there will be drop in the load factor, this is because in this period the assumption is that the immigration rate will be high and so the load will be residential. As known residential loads usually have low load factor. For the period (2010-2020) the load factor is expected to increase, this is because in this period the GDP will increase and so the load will be industrial with higher Load factor values.

As shown in table 3.22, for scenarios1and 2, load factor before connecting non-electrified villages to the grid is higher than the case after connection. The explanation is due to the fact that in villages, pattern and amount of energy consumption are different and less than in cities.

As given in table 3.22 L.F for scenarios 3 and 4, after connecting non-electrified villages to the gird is nearly same as or even little bit higher than before connection. Explanation for this behavior is due to the fact that in scenarios 3 and 4

Table 3.22: Estimation of Load Factor (L.F) in the West Bank For the period (1999-2020) - For Scenarios 1,2,3 and 4

Year	SC.1 L.F	SC.1′ L.F	SC.2 L.F	SC.2′ L.F	SC.3 L.F	SC.3′ L.F	SC.4 L.F	SC.4′ L.F
1994	0.62028	0.62028	0.62028	0.62028	0.62028	0.62028	0.62028	0.62028
1995	0.60726	0.60726	0.60726	0.60726	0.60726	0.60726	0.60726	0.60726
1996	0.57192	0.57192	0.57192	0.57192	0.57192	0.57192	0.57192	0.57192
1997	0.56459	0.56459	0.56459	0.56459	0.56459	0.56459	0.56459	0.56459
1998	0.58412	0.58412	0.58412	0.58412	0.58412	0.58412	0.58412	0.58412
1999	0.57608	0.57608	0.57877	0.57877	0.57680	0.57680	0.57680	0.57680
2000	0.57347	0.57347	0.57506	0.57506	0.57342	0.57342	0.57342	0.57342
2001	0.58054	0.58192	0.58016	0.58154	0.57990	0.58107	0.57990	0.58038
2002	0.59981	0.60197	0.60086	0.60288	0.59949	0.60153	0.59949	0.60153
2003	0.60325	0.60603	0.59779	0.60068	0.58502	0.58825	0.57992	0.58317
2004	0.60863	0.61185	0.59368	0.59770	0.56838	0.57289	0.56386	0.56818
2005	0.61809	0.62137	0.59086	0.59532	0.54846	0.55435	0.54700	0.55230
2006	0.63036	0.63287	0.58964	0.59387	0.54243	0.54787	0.53155	0.53669
2007	0.62765	0.63019	0.59004	0.59398	0.51942	0.52503	0.52877	0.53337
2008	0.63431	0.63644	0.57670	0.58090	0.52397	0.52868	0.52099	0.52533
2009	0.63207	0.63421	0.56337	0.56776	0.49263	0.49747	0.51335	0.51743
2010	0.62625	0.62858	0.55325	0.55769	0.48188	0.48626	0.47819	0.48241
2011	0.63558	0.63742	0.56233	0.56628	0.48957	0.49354	0.50096	0.50452
2012	0.64366	0.64511	0.57805	0.58134	0.50452	0.50803	0.50370	0.50688
2013	0.65782	0.65866	0.58252	0.58553	0.51640	0.51955	0.51959	0.52233
2014	0.65597	0.65685	0.59478	0.59730	0.53517	0.53788	0.53870	0.54100
2015	0.66607	0.66656	0.60957	0.61158	0.54200	0.54446	0.55868	0.56056
2016	0.66223	0.66283	0.62297	0.62453	0.56343	0.56545	0.58238	0.58382
2017	0.66927	0.66962	0.65304	0.65375	0.56865	0.57049	0.61659	0.61750
2018	0.67738	0.67745	0.65020	0.65096	0.56992	0.57165	0.62019	0.62101
2019	0.66795	0.66831	0.65827	0.65880	0.57185	0.57347	0.63130	0.63194
2020	0.65898	0.65960	0.66727	0.66756	0.57445	0.57597	0.64537	0.64581

- SC.1 , SC.2, SC.3 and SC.4 :L.F Scenarios before electrifying completely or partially non-electrified population .
- SC.1′ , SC.2′ , SC.3′ , and SC.4′ , L.F scenarios after electrifying completely or partially non-electrified population .

immigration rate will be high. Due to high rates of immigration, existing crowded cities will not be able to accept all returnees. As a result and from physical planning point view a lot of those returnees will live or invest in the near by least- cost villages or suburbs.

Ramllah district is a good example for this case as a lot of returnees moved to live in the near by villages or suburbs like Betonia, Jefna and Beteen. Since most returnees used to live either in the Gulf or in Jordan, where they used to use electricity heavily, energy consumption in villages will sharply increase and so L.F will increase. Fig 3.12 shows graphs of load factor for the four different scenarios.

As presented in tables 3.14 and 3.19 for the next 20 years Maximum demand and total energy consumption are expected to increase dramatically, especially if total number of returnees will be high as in scenarios 3 and 4. Also right now about 12.7% of total population still without continuous electricity service.

Due to these facts and in order to meet the increasing demand, to supply all people living in the West Bank, and who are expected to return, with least-cost, secure and clean electricity service it is urgent to start building our own independent power plant. Planning for this power plant will be our aim in the next chapter (chapter 4).

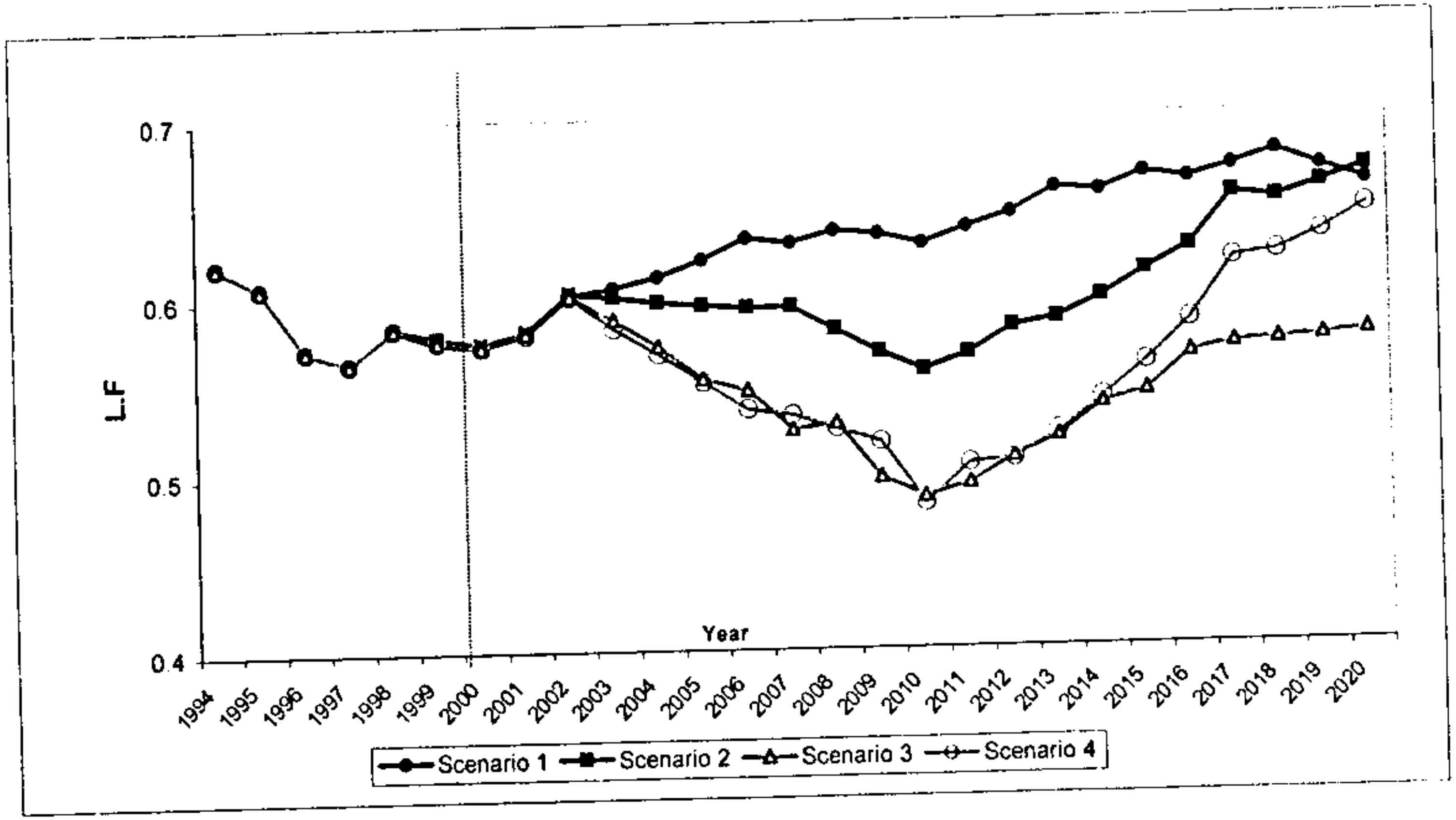

Fig3.12 Load Factor Estimation in the West Bank

3.7 Energy Consumption Per Capita.

As shown in table 2.3 of chapter 2 in Palestine energy consumption per capita is very low compared with other neighboring countries.

Estimated values of energy consumption per capita are calculated by dividing total yearly energy consumption (table 3. 21) by total population.

For each scenario, energy consumption per capita is calculated and results are as shown in table 3. 23.Figure 3.13 show graphs of energy consumption per capita for each of the four scenarios.

Energy consumption per capita became a measure of the community welfare. Referring to table 2.3 of chapter 2 we can see that energy consumption per capita for Israel and for Kuwait is very high even total population of each is very low. On the other hand energy consumption per capita for countries like Morocco, Sudan and Algeria of high population is very low.

This means that countries with strong economy, strong industry, strong trade and agriculture, like Israel, have very high-energy consumption per capita even though their population is very low. Also Kuwait has verb high-energy consumption per capita because of petroleum which means very high GDP per capita values and as a result very high-energy consumption.

Countries like Algeria and Sudan are with low energy consumption per capita and this is due to the fact that their economy is very week even though their population is high.

Table 3.23: Estimation of energy consumption per capita in the West Bank (1999-2020) for Scenarios 1,2,3 and 4

Year	Energy Consumption per capita - SC1 KWh	Energy Consumption per capita -SC2 KWh	Energy Consumption per capita-SC3 KWh	Energy Consumption per capita – SC4 KWh
1997	761	761	761	761
1998	825	825	825	825
1999	847	850	850	850
2000	889	893	893	893
2001	950	956	956	956
2002	1017	1028	1032	1032
2003	1070	1081	1088	1110
2004	1123	1133	1149	1196
2005	1177	1186	1210	1284
2006	1219	1228	1303	1363
2007	1229	1273	1359	1457
2008	1263	1307	1533	1529
2009	1278	1345	1629	1606
2010	1279	1385	1806	1678
2011	1317	1430	1877	1770
2012	1344	1481	1949	1865
2013	1398	1524	2016	1952
2014	1408	1573	2087	2044
2015	1440	1625	2156	2138
2016	1438	1677	2233	2237
2017	1439	1739	2299	2347
2018	1503	1781	2360	2406
2019	1505	1831	2423	2474
2020	1506	1883	2487	2543

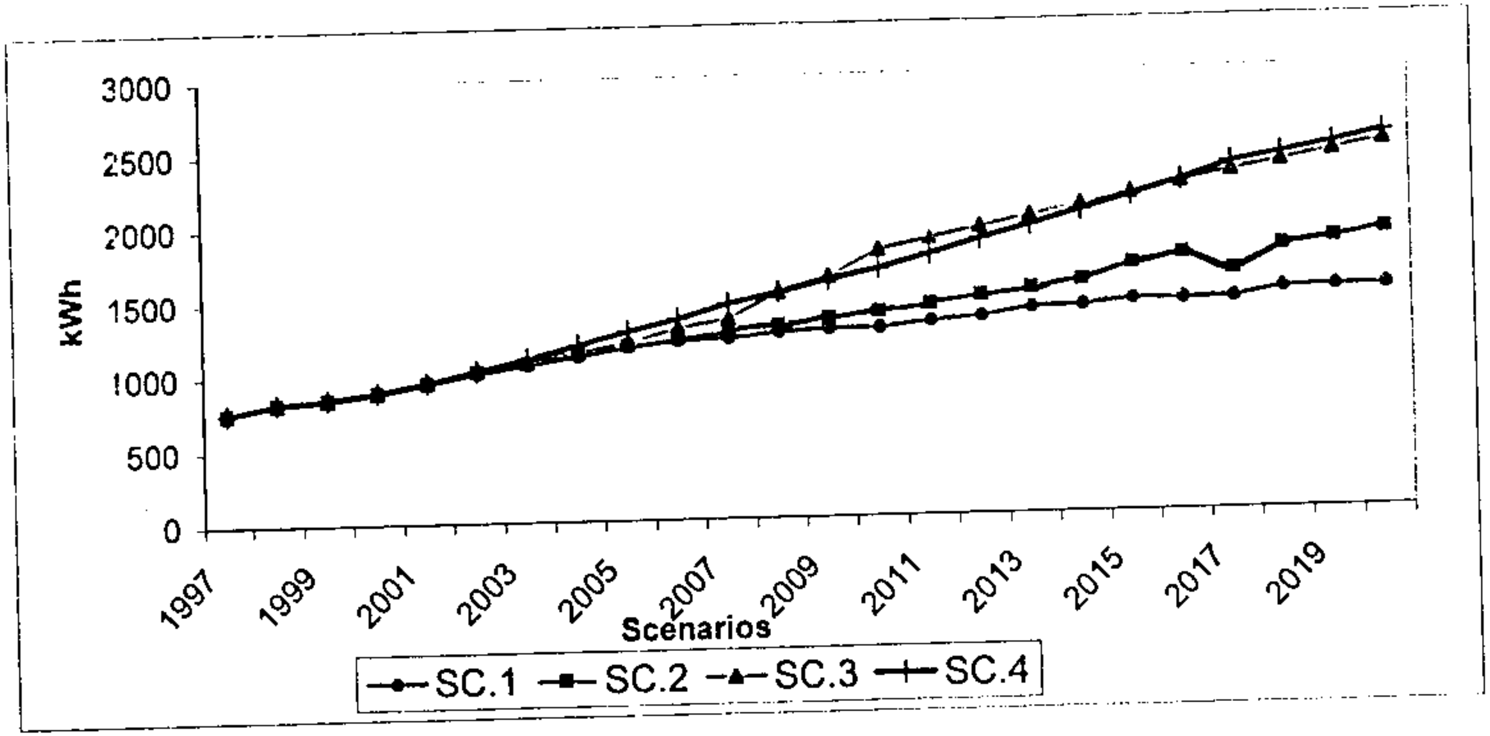

Fig.3.13 Estimation of Energy consumption per capita in the West Bank (1999-2020)

Chapter 4

Generation Planning

4. Generation Planning

Issues in generation planning are when and how much generation equipment needs to be installed as well as what kind of equipment it should be (i.e. coal, gas turbine, diesel, nuclear, and combined cycle). Total costs, financial implications of a generation plan, location of generation plant are also of imported issues.

At this point it may be well to emphasize the essential difference between the unit commitment and economic dispatch problem. The economic dispatch problem assumes that there are N units already connected to the system, the purpose of the economic dispatch problem is to find the optimum operating policy for these N units. On the other hand, the unit commitment problem is more complex. We may assume that we have N units available to us and that we have a forecast of the demand to be served. The question that is asked in the unit commitment problem area is as follows:

Given that there are a number of subsets of the complete set of N units that would satisfy the expected demand, which of these subsets should be used in order to provide the minimum operating cost.

The issue of what kind of generating equipment would be the most economical addition is addressed by combining a production cost analysis with an investment cost analysis. In order to determine which kind of generating equipment is most economically suitable for our application, certain parameters and factors of each type should be known. Parameters and factors include capitalized plant cost ($/kW), construction lead-time (years), heat rate (BTU/kWh), fuel cost ($/MBTU), equivalent forced outage rate (%), equivalent scheduled outage rate (%), O&M fixed costs ($/kW/year) and variable cost ($/MWH).

For an electrical power system the total load on the system will generally be higher during the daytime and early evening when industrial loads are high, lights are on and so forth and lower during the late evening and early morning when most of the population is asleep. In addition the use of electric power has weekly cycles, the load being lower in the weekend days than weekdays. But why is this a problem in the operation of an electric power system? Why not just simply commit enough units to cover the maximum system load and leave them running. Note that to commit a generating unit is to turn it, that is, to bring the unit up to speed, to synchronize it to the system, and connect it so it can deliver power to the network.

The problem with " commit enough units and leave them on line " is one of economics as it is quite expensive to run too many generation units. A great deal of money can be saved by turning units off (decomitting them) when they are not needed.

Power Generation planning goes through two main steps. First step is site location of the power plant or plants, second is the generation capacity planning.

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4.1 Site Location

Site location of the power plant is very important as it is finally calculated as money and added to the initial costs of the plant and so forth to the total investment cost. Important factors that will affect the site location of power plants in the West Bank are as follows:

- Fuel transport

  Fuel types that may be used in electricity generation include natural gas (NG), gas oil (GO), and heavy fuel (HF) or coal. Some assumptions about fuel sources, types and transports were discussed and suggested for the West Bank. Proposed fuel sources are Egypt, Jordan, Qatar, and Iraq. Depending on the fuel source, transport type might be through one of the following.

- Pipe lines from Egypt or Jordan to the West Bank.
- By sea Tanker to Gaza port or to Israeli ports then by road tankers to West Bank.
- Road tankers from Jordan to the West Bank.

Depending on fuel sources, types, transport and routing of fuel pipelines, site location of the power station will be determined.

- Water Availability

  Water plays a significant factor in power plant site location mainly for a combined cycle plant. As known water has two applications. Fresh water is used for boiler make up; also fresh or desalinated seawater is used for cooling the power plant.

- Geotechnical and Topographical Factors

  - Altitude of the site from the sea level .The efficiency of thermal plant is decreased by 0.01% per meter above sea level.
  - Temperature. The efficiency of the thermal plant is decreased by 0.8% per 1C (deviation from 15C)
  - Location of rocks in site. It is important to locate the site where the rocks are near the ground so as to support the plant, other wise additional costs are added to develop suitable structure to support the power plant
  - Topography. Some times if the land is not level additional cost will be added for leveling work

- Availability of Land

  As known the generation power plant needs huge space of land, so it is essential to have enough space for existing equipment and for future expansion.

Moreover the cost of land plays a role in the choose of site as the value of land is to be added to the initial investment cost

- Access to the Site

Good access should be provided for the delivery of materials and equipment to the site during its construction. particularly with respect to large, heavy items also for delivery of spare parts and for supplying maintenance.

Access to the site is especially important if we are taking about road tanker delivery. If access is not good, delivery of oil through road tankers will be more difficult and more expensive.

According to the above-mentioned factors, different sites were suggested to be the site of the power plant. One of these proposals was to have the site near the city of Ramallah (Kennedy & Donkin, Aug. 1995). Another proposal was to have the site in the north of the West Bank near the city of Qalqiliya. (PEA, 1997).

First of all, it is convenient to install the new generation capacity of the West Bank up to year 2020 in one place only in order to minimize operation, maintenance and logistic costs.

In this study we will adopt the second option that is to have the site in the north of the West Bank near the city of Qalqiliya (see appendix 4.1) for the following reasons:

- Altitude of Qalqiliya is only 60 meters above the sea level while the altitude of Ramallah in average is about 800 meters. As a result the efficiency of the plant in Qalqiliya will not be decreased while in Ramallah it will be reduced by 8% due to altitude.

- Available of Water Resources (PEA,1997)

Fresh water Ramallah: 2.6MCM /year from 4 wells
Qalqiliya: 16MCM/Year from 123wells

Moreover it may be possible in the future under the umbrella of the peace process to put an agreement with the Israelis to supply the power plant near Qalqiliya with seawater from the Mediterranean Sea near Natania which is only 10 km far from Qalqiliya through a water pipeline. If cooling water became available, water cooling combined cycle units could be used instead of the air cooling units. Using water cooling CC units instead of air cooling CC, will increase the over all plant efficiency by 5%, while it is not possible to have this option in Ramallah and the only option is to build the air cooling system with 5% loss in the efficiency.

• Topography and Availability of Land

Topography of Qalqiliya is better than that of Ramallah as the site is plain need no more leveling while in Ramallah the topography is more difficult and needs additional costs for leveling the land. Moreover prices of land in Qalqiliya are cheaper than that in Ramallah as the level of living is higher in Ramallah than in Qalqiliya

• Fuel Transport

Fuel transport to Qalqiliya is easier and less expensive than to Rramallah. Qalqiliya is only 5 km far from the suggested gas pipeline from Egypt to Haifa through the Palestinian Autonomy o Amman. while Ramallah is about 100 km. Moreover if fuel is to be imported by sea tankers through Israeli ports. Qalqiliya is less far than Ramallah. Also if oil will come by road tankers from Jordan (Al Zarqa refinery) or from Gaza, the distance to Qalqiliya and to Ramallah will be the same but the accessibility to Qalqiliya will be better than to Ramallah due to altitude.

• Accessibility to Site

Qalqiliya is more accessible for delivery of heavy equipment either from proposed Gaza port or from the Israeli ports. where it is nearer and more accessible.

4.2 Basic Planning Data, Investment and Operation Costs.

In order to carry out generation planning basic data and assumptions should be defined as shown in tables 4.1&4.1.1. Investment costs and variable costs were calculated based on basic and assumed data shown in tables (4.1) and (4.1.1), all costs are projected to year 2001 prices, the initial year of generation planning. Investment costs are calculated for three cases. First using natural gas (NG) as shown in table 4.2, second using gas oil (GO) as given in table 4.3 and third using heavy fuel (HF) as given in table 4. 4

4.3 Generation capacity planning

Generation capacity planning goes into four sequence steps starting from the determination of the load duration and step curves, system reliability through screen curve analysis and ends with automatic generation planning.

4.3.1 Load Duration Curve of the West Bank

A load duration curve expresses the period of time (say number of hours) in a fixed interval (day, week, month, or year) that the load is expected to equal or exceed a given megawatt value. It is usually plotted with the load on the vertical axis and the time period on the horizontal axis. In this study we will deal with the yearly load duration curve. In order to plot the yearly load curve of the West Bank we should have the hourly load demand for all year, that is 8760 data points .The only yearly load duration data available is that prepared in 1995 by the PEA.

Fig 4.1 shows the graph of the yearly load duration curve of the West Bank for the year 1995.

Table 4.1 Basic Data for generation planning in the West Bank

Basic Data	**Source of data**
Economic life of the project : 20 years (2001-2020)	*Assumed by author*
Generation planning period : 2001 to 2020	*Assumed by author*
Site of power plant : • Location : North of West Bank , near the city of Qalqiliya	*Assumed by author*
• Altitude of the site: 60 m above sea level	*Oral report from Palestinian Geographical Center ., June . 1999*
• Average yearly temperature at site: 19C	*Oral report from Mr.Yousef Abou Assad .Palestinian Metreological Center. June , 1999*
Generators • Types of generators : Gas Turbine (GT) Air cooling Combined Cycle (CC) • Prices of generators ■ GT (K$) = 645.275-90.764*Ln (POWER) FOB prices based on 1996 market prices ■ CC (K$) =1120.584-104.863*Ln (power. MW) Turnkey prices based on 1996market prices.	*(Enenl –Tractebel-cesi,1997)*
- **Efficiency of generators** GT : 32 % CC : 55%	Oral report from *Dr. Rafiq Maleha , PEA , 1999 , Gaza*
■ Contingencies : 10%	*Assumed by author*
■ Yearly increase in Generators prices : 2.5%	*(International financial statistics ,1999)*
■ Fixed operation & maintenance cost(O&M) : 3.5%of investment cost ■ Forced outage rate Hours (FOH): 6% ■ Scheduled outage hours (SOH) : 6% ■ Availability (100%-(FOH+SOH))= 88%	*(PEA,: Preliminary Evaluation of Electricity Sector In the Palestine , Ramallah , Palestine ,1997)*
■ Correction Factor in generation efficiency - Altitude (above see level) : 0.01% per meter -Temp. (above 15 C) : 0.8% per 1 C	*(PEA :Preliminary Evaluation of Electricity Sector In the Palestine , Ramallah . Palestine ,1997)*
Lead time of Generators : GT (1-2 Years) , CC (2-4 Years)	*(Harry G.Stoll,1989)*
Fuel ■ Types of fuel : NG , GO , HF ■ Source of fuel : Egypt	*Assumed by author*
--Fuel prices ■ NG: 2.34 US$/GJ for year 2001 (based on 2.25 USD/GJ FOR1997 prices, inflation rate: 1%/year) ■	*(Enenl-Tractebel-cesi, 1997)*

Table 4.1 .1 Basic Data for generation planning in the West Bank

Basic Data	Sources of Data
■ Gas oil: 4.96 USD/GJ for year 2001(based on 4.51 USD/GJ FOR1997 prices, inflation rate: 2.3% /year) ■ HF: 3.59 USD/GJ for year 2001 (based 3.27 USD/GJ on 1997 prices, inflation rate: 2.4%/year)	*(Enenl-Cesi-,Tractebel, 1997)*
■ Correction for fuel : NG (0%) , GO(0%) , HF(10%) (SOURCE : 2)	*(PEA: Preliminary Evaluation of Electricity Sector In the Palestine , Ramallah , Palestine ,1997)*
■ Distance from well heads : 370 KM	
• Correction for transportation = 0.0005USC/GJ/KM	
- **LOLP** : (0.1-1) Day per year = (15-25)% of peak	*(Harry G.Stoll, 1989).*
- Interest rate on loan : 10% - Interest rate on deposit : 5% - Net profit for private sector : 15 % - Net profit for Public sector : 10 & - Net profit for municipalities and government : 5%	*Oral report fromDR. Bassem Makhool : Najah University ,1999 , Nablus , Palestine*
- **Average rate increase in consumer prices** : 2.5%	*(International financial statistics,1999)*
- **Inflation rate** : 3% - **Depreciation** : 7%	*Oral report from DR. Bassem Makhool : Najah University, Nablus , Palestine, 1999.*
- **Transmission net work prices** (NPV) • For scenario1 : 200 Million $ • For scenario2 : 250 Million $	*(PEA: Preliminary Evaluation of electricity Sector In the Palestine , Ramallah , Palestine ,1997)*
• For scenario 3 : 400 Million $ • For Scenario 4 : 500 Million $	*Estimated by author*
- Cost of energy (kWh) purchased from the IEC : 0.067 US $ per kWh , 1999 prices , 3% inflation rate	*Oral report from Eng. Jamal Abu choosh , PEA , Ramallah, Palestine, 1999.*
- Fresh water availability : Qalqilieh : 16 MCM / Year from 24 wells Ramallah : 2.6MCM/ year from 123 well	*(Rust,Kennedy and Donkin,1995)*

Table 4.2: Investments in GT and CC Power Plant Using Natural Gas

	Natural Gas		GT [MW]		CC [MW]	
			60	80	180	240
1	**Fixed costs**					
2	Average standard costs	[kUS$]	23340	28080	117180	147840
3	Contingencies	[kUS$]	2334	2808	11718	14784
4	Pipeline cost	[kUS$]	0	0	0	0
5	Total capita cost (2+3+4)	[kUS$]	25674	30888	128898	162624
7	Fixed O&M cost		3.5%	3.5%	3.5%	3.5%
8	Capitalsed O&M (5.7)	[kUS$]	7650	9204	38408	48458
9	**Total cost incl. cap. O&M (5+8)**	**[kUS$]**	**33324**	**40092**	**167306**	**211082**
11	**Power Output**					
12	Rated output	[MW]	60	80	180	240
13	Derating factor altitude	[pu]	1.00	1.00	1.00	1.00
14	Derating factor temperature	[pu]	0.97	0.97	0.97	0.97
15	Derating factor fuel	[pu]	1.00	1.00	1.00	1.00
16	Available output (12*13*14*15)	[MW]	58.08	77.44	174.24	232
18	**Unit cost for PRELE (5/16)**	**[US$/kW]**	**442**	**399**	**740**	**700**
20	**Variable costs**					
21	Basic fuel cost (Egypt)	[USD/GJ]	2.34	2.34	2.34	2.34
22	Incl. transportation cost to border	[USD/GJ]	2.53	2.53	2.53	2.53
24	**Efficiencies**					
25	Basic efficiency (ISO) water cond.	[pu]	0.32	0.32	0.55	0.55
26	Reduction air condenser	[pu]	1.00	1.00	0.95	0.95
27	Correction for temperature	[pu]	0.99	0.99	1.00	1.00
28	Correction for fuel	[pu]	1.00	1.00	1.00	1.00
29	Net efficiency (25*26*27*28)	[pu]	0.32	0.32	0.52	0.52
31	Variable fuel cost	[USc/kWh]	2.86	2.86	1.74	1.74
32	Variable maintainence	[USc/kWh]	0.50	0.50	0.40	0.40
33	**Total variable cost PRELE (31+32)**	**[USc/kWh]**	**3.36**	**3.36**	**2.14**	**2.14**
	Contingencies	10%				
	Cap. cost of gas pipeline	0	USD/kW*km			
	North	5	Km			
	Correction for altitude	0.01%	Per meter			
	North	60	m above sealevel			
	Correction for temperature	0.80%	Per 1C (deviation from 15 C)			
	North	19	C			
	Correction for fuel: NG/GO/FO	0%	0%	10%		
	Fixed O & M costs	3.50%	Of investment/year			
	Discount rate	10%				
	Economic lifetime	20	Years			
	Fuelprices/Var. cost maintenance GT/CC:					
	- Natural gas	2.34	USD/GJ	0.50	USc/kWh 0.40	USc/kWh
	- Gas oil	4.96	USD/GJ	0.70	USc/kWh 0.50	USc/kWh
	- Fuel oil	3.59	USD/GJ	1.60	USc/kWh 1.10	USc/kWh
	Correction for transportation	0.0005	USc/GJ/km			
	Distance from wellheads.	370	Km			
	Efficiency for GT/CC	32%	55%			
	Basic heatrate	0.0036	GJ/kWh			
	Correction for coolingsystem:					
	- water cooling, GT/CC	0.0%	0.0%			
	- humid tower, GT/CC	0.0%	2.0%			
	- dry tower, GT/CC	0.0%	5.0%			
	Correction for temperature GT/CC	0.2%	0.0%	per 1C (deviation from 15C)		
	Correction for fuel: NG/GO/FO	0%	0%	2.0%		

Table 4.3: Investments in GT and CC Power Plant Using GO

	Gas Oil		GT [MW]		CC [MW]	
			60	80	180	240
1	**Fixed costs**					
2	Average standard costs	[kUS$]	23340	28080	117180	147840
3	Contingencies	[kUS$]	2334	2808	11718	14784
4	Pipeline cost	[kUS$]				
5	Total capita cost (2+3+4)	[kUS$]	25674	30888	128898	162624
7	Fixed O&M cost		3.5%	3.5%	3.5%	3.5%
8	Capitaised O&M (5,7)	[kUS$]	7650	9204	38408	48458
9	**Total cost incl. cap. O&M (5+8)**	**[kUS$]**	**33324**	**40092**	**167306**	**211082**
11	**Power Output**					
12	Rated output	[MW]	60	80	180	240
13	Derating factor altitude	[pu]	1.00	1.00	1.00	1.00
14	Derating factor temperature	[pu]	0.97	0.97	0.97	0.97
15	Derating factor fuel	[pu]	1.00	1.00	1.00	1.00
16	Available output (12*13*14*15)	[MW]	58.08	77.44	174	232
18	**Unit cost for PRELE (5/16)**	**[US$/kW]**	**442**	**399**	**740**	**700**
20	**Variable costs**					
21	Basic fuel cost (Egypt)	[USD/GJ]	4.96	4.96	4.96	4.96
22	incl. Transportation cost to border	[USD/GJ]	5.15	5.15	5.15	5.15
24	**Efficiencies**					
25	Basic efficiency (ISO) water cond.	[pu]	0.32	0.32	0.55	0.55
26	Reduction air condenser	[pu]	1.00	1.00	0.95	0.95
27	Correction for temperature	[pu]	0.99	0.99	1.00	1.00
28	Correction for fuel	[pu]	1.00	1.00	1.00	1.00
29	Net efficiency (25*26*27*28)	[pu]	0.32	0.32	0.52	0.52
31	Variable fuel cost	[USc/kWh]	5.84	5.84	3.55	3.55
32	Variable maintainence	[USc/kWh]	0.70	0.70	0.50	0.50
33	**Total variable cost PRELE (31+32)**	**[USc/kWh]**	**6.54**	**6.54**	**4.05**	**4.05**

Contingencies	10%					
Cap. Cost of gas pipeline	0.75	USD/kW*km				
North	5	km				
Correction for altitude	0.01%	per meter				
North	60	m above sealevel				
Correction for temperature	0.80%	per 1C (deviation from 15 C)				
North	19	C				
Correction for fuel: NG/GO/FO	0%	0%	10%			
Fixed O & M costs	3.50%	of investment/year				
Discount rate	10%					
Economic lifetime	20	years				
Fuelprices/Var. cost maintenance GT/CC:						
- Natural gas	2.34	USD/GJ	0.50	USc/kWh	0.40	USc/kWh
- Gas oil	4.96	USD/GJ	0.70	USc/kWh	0.50	USc/kWh
- Fuel oil	3.59	USD/GJ	1.60	USc/kWh	1.10	USc/kWh
Correction for transportation	0.0005	USc/GJ/km				
Distance from wellheads.	370	km				
Efficiency for GT/CC	32%	55%				
Basic heatrate	0.0036	GJ/kWh				
Correction for coolingsystem:						
- water cooling, GT/CC	0%	0%				
- humid tower, GT/CC	0%	2%				
- dry tower, GT/CC	0%	5%				
Correction for temperature GT/CC	0%	0%	per 1C (deviation from 15C)			
Correction for fuel: NG/GO/FO	0%	0%	2.0%			

Table 4.4: Investments in GT and CC Power Plant Using H.F Oil

	Fuel Oil		GT [MW]		CC [MW]	
			60	80	180	240
1	**Fixed costs**					
2	Average standard costs	[kUS$]	23340	28080	117180	148040
3	Contingencies	[kUS$]	2334	2808	11718	14804
4	Pipeline cost	[kUS$]				
5	Total capita cost (2+3+4)	[kUS$]	25674	30888	128898	162844
7	Fixed O&M cost		3.5%	3.5%	3.5%	3.5%
8	Capitaised O&M (5,7)	[kUS$]	7650	9204	38408	48523
9	**Total cost incl. cap. O&M (5+8)**	**[kUS$]**	**33324**	**40092**	**167306**	**211367**
11	**Power Output**					
12	Rated output	[MW]	60	80	180	240
13	Derating factor altitude	[pu]	1.00	1.00	1.00	1.00
14	Derating factor temperature	[pu]	0.97	0.97	0.97	0.97
15	Derating factor fuel	[pu]	0.90	0.90	0.90	0.90
16	Available output (12*13*14*15)	[MW]	52	70	157	209
18	**Unit cost for PRELE (5/16)**	**[US$/kW]**	**491**	**443**	**822**	**779**
20	**Variable costs**					
21	Basic fuel cost (Egypt)	[USD/GJ]	3.59	3.59	3.59	3.59
22	Incl. Transportation cost to border	[USD/GJ]	3.78	3.78	3.78	3.78
24	**Efficiencies**					
25	Basic efficiency (ISO) water cond.	[pu]	0.32	0.32	0.55	0.55
26	Reduction air condenser	[pu]	1.00	1.00	0.95	0.95
27	Correction for temperature	[pu]	0.99	0.99	1.00	1.00
28	Correction for fuel	[pu]	0.98	0.98	0.98	0.98
29	Net efficiency (25*26*27*28)	[pu]	0.31	0.31	0.51	0.51
31	Variable fuel cost	[USc/kWh]	4.37	4.37	2.66	2.66
32	Variable maintainence	[USc/kWh]	1.60	1.60	1.10	1.10
33	**Total variable cost PRELE (31+32)**	**[USc/kWh]**	**5.97**	**5.97**	**3.76**	**3.76**

Contingencies	10%					
Cap. cost of gas pipeline	0.75	USD/kW*km				
North	5	Km				
Correction for altitude	0.01%	Per meter				
North	60	m above sealevel				
Correction for temperature	0.80%	Per 1C (deviation from 15 C)				
North	19	C				
Correction for fuel: NG/GO/FO	0%	0%	10%			
Fixed O & M costs	3.50%	Of investment/year				
Discount rate	10%					
Economic lifetime	20	years				
Fuelprices/Var. cost maintenance GT/CC:						
- Natural gas	2.34	USD/GJ	0.50	USc/kWh	0.40	USc/kWh
- Gas oil	4.96	USD/GJ	0.70	USc/kWh	0.50	USc/kWh
- Fuel oil	3.59	USD/GJ	1.60	USc/kWh	1.10	USc/kWh
Correction for transportation	0.0005	USc/GJ/km				
Distance from wellheads.	370	Km				
Efficiency for GT/CC	32%	55%				
Basic heatrate	0.0036	GJ/kWh				
Correction for coolingsystem:						
- water cooling, GT/CC	0.0%	0.0%				
- humid tower, GT/CC	0.0%	2.0%				
- dry tower, GT/CC	0.0%	5.0%				
Correction for temperature GT/CC	0.2%	0.0%	per 1C (deviation from 15C)			
Correction for fuel: NG/GO/FO	0%	0%	2.0%			

Since our generation planning will start from year 2001, we should have the load duration curve of this year. The reason why we choose year 2001 is the lead time of the generation unit, as the gas turbine (GT) needs 1-2 lead time before start generating and the combined cycle (CC) needs 2-4 years.

As it is very difficult to prepare this load duration curve we will make use of the load duration curve of the year 1995 with some modifications. To calculate the load duration curve for year 2001 depending on that of the year 1995 we used equation 4.1(Enel-Cesi-Tracteble-Elasmprojekt,1997)

$$P_i^{\backslash} = P_I + P_I \times tg(\Phi) \times (P_I - \bar{P}) \quad \ldots\ldots\ldots\ldots \quad (4.1)$$

$P_i^{\backslash}$ = adapted hourly load (of 2001).
P_I= current hourly load (of 1995).
$\bar{P}$= maximum load or peak load of the target year.

tg(Φ) = a correction factor , calculated as shown in equation 4.2

$$tg(\phi) = \frac{(Y * 8760 * \bar{P}) - \sum_{i=1}^{8760} p_i}{\sum_{i=1}^{8760} P_i^2 - \sum_{i=1}^{8760} P_i * \bar{P}} \quad \ldots\ldots\ldots\ldots (4.2).$$

Y= the target load factor

Applying equation 4.1 to the hourly load data of year 1995 and using estimated load factor of year 2001 which is 0.58 (table 3.22, chapter 3) we get the adopted hourly load duration curve of year 2001 as shown in fig 4.2.

4.3.2 Step Load Duration Curve

In generation capacity planning the load duration curve (fig.4.2) of year 2001 will be used.

In order to have the step duration curve of year 2001, the load duration curve (fig 4.2) was divided manually to 7 steps. Duration (hours), peak (MW) and height of each step (% of peak) are as illustrated in table 4.5. Fig 4.3 shows the step load curve of year 2001.

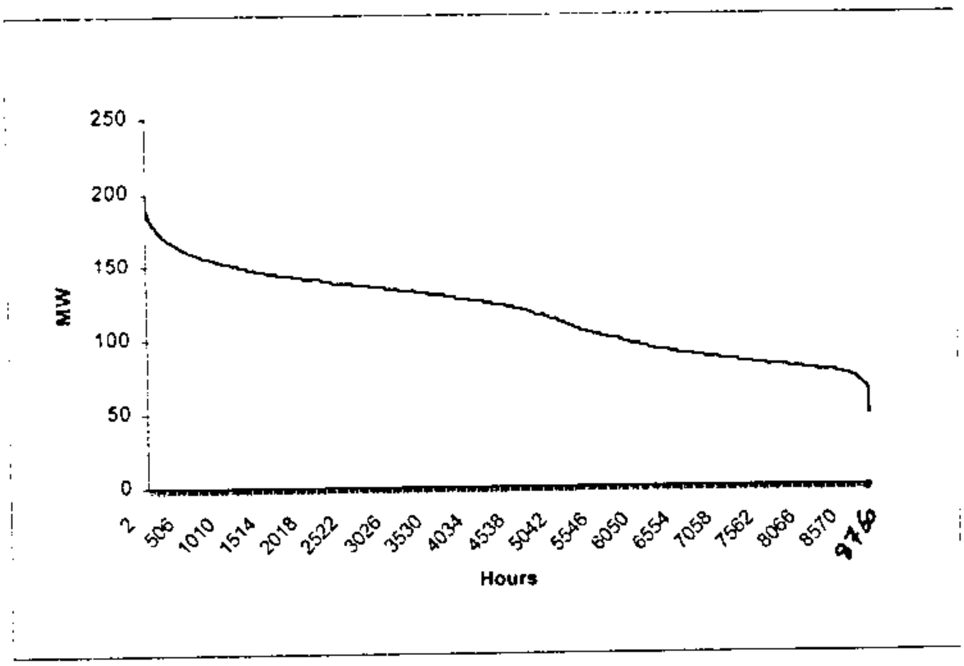

Fig.4.1 West Bank Load duration curve of year 1995.

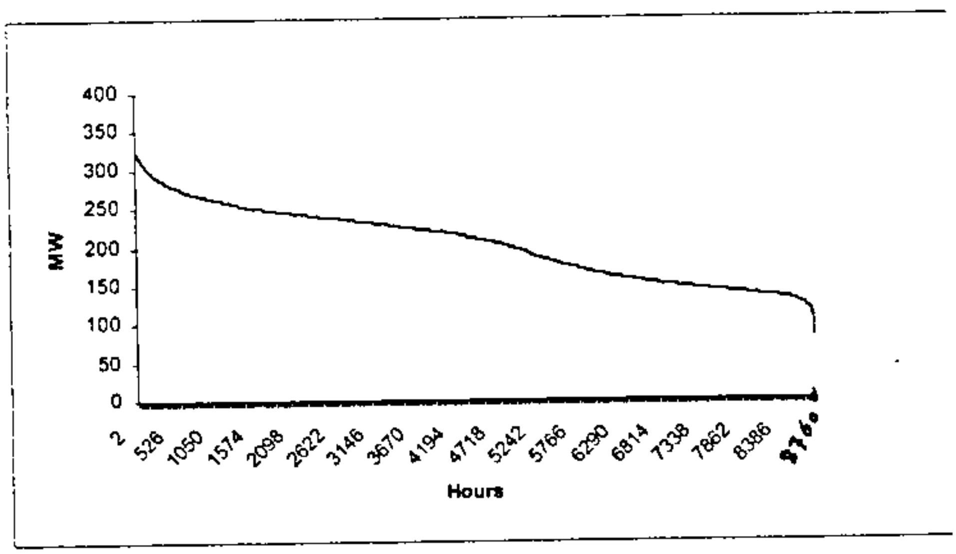

Fig.4.2 Estimated Load duration curve of year 2001

Table 4.5: Step duration data of Load duration curve of year 2001

Step NO.	Power of each step (MW)	Height of step (% of peak)	Duration of each step (Hours)
1	311	90.1	198
2	270	78.3	1318
3	239	69.3	2342
4	209	60.6	1378
5	167	48.8	1438
6	145	42	1574
7	125	36	512

4.3.3 Generation System Reliability

Generation system reliability analysis quantifies the electricity service reliability provided from the generation system. The quantity of generation capacity required to achieve a desired quality of electricity service is of key interest. The difference between a secure electric system and other insecure one is whether electricity is supplied continuos without interruption or the system supply electricity with many occasions without service. Electricity service interruption increases the consumer costs sharply. Consumer interruption cost data can be used as one factor in power system planning analysis for generation, transmission and distribution.

The effect of electricity interruption is significant with large-scale electrification mainly industrial and commercial establishments.
The impact of interruption on consumers can be listed in the following three points:

1. Direct consumer cost of an outage.
2. What would the consumer be willing to pay for a backup service that would eliminate the outage
3. What payment would the consumer accept for service that had a higher outage frequency

From experience residential consumers play a higher value on reliable service, interruption 2 rather than interruption 1. To industrial consumers the loss is in the form of production loss (wages &salaries), inventory loss and repair of damaged equipment .The cost of electricity interruptions is quoted on a cost per unserved load. For residential, commercial and industrial consumer there is a cost of interruption in the form of cost ($) per kWh. As known the value for industrial is higher than that of commercial and the lowest is the residential value.

It is known that interruption cost to consumer is tens of times of the average price of electricity. Due to electricity interruption, customers pay what called the total cost to the customer, which is the sum of the utility cost (which the consumer pays for through the electricity bill) and the consumer cost due to outages.

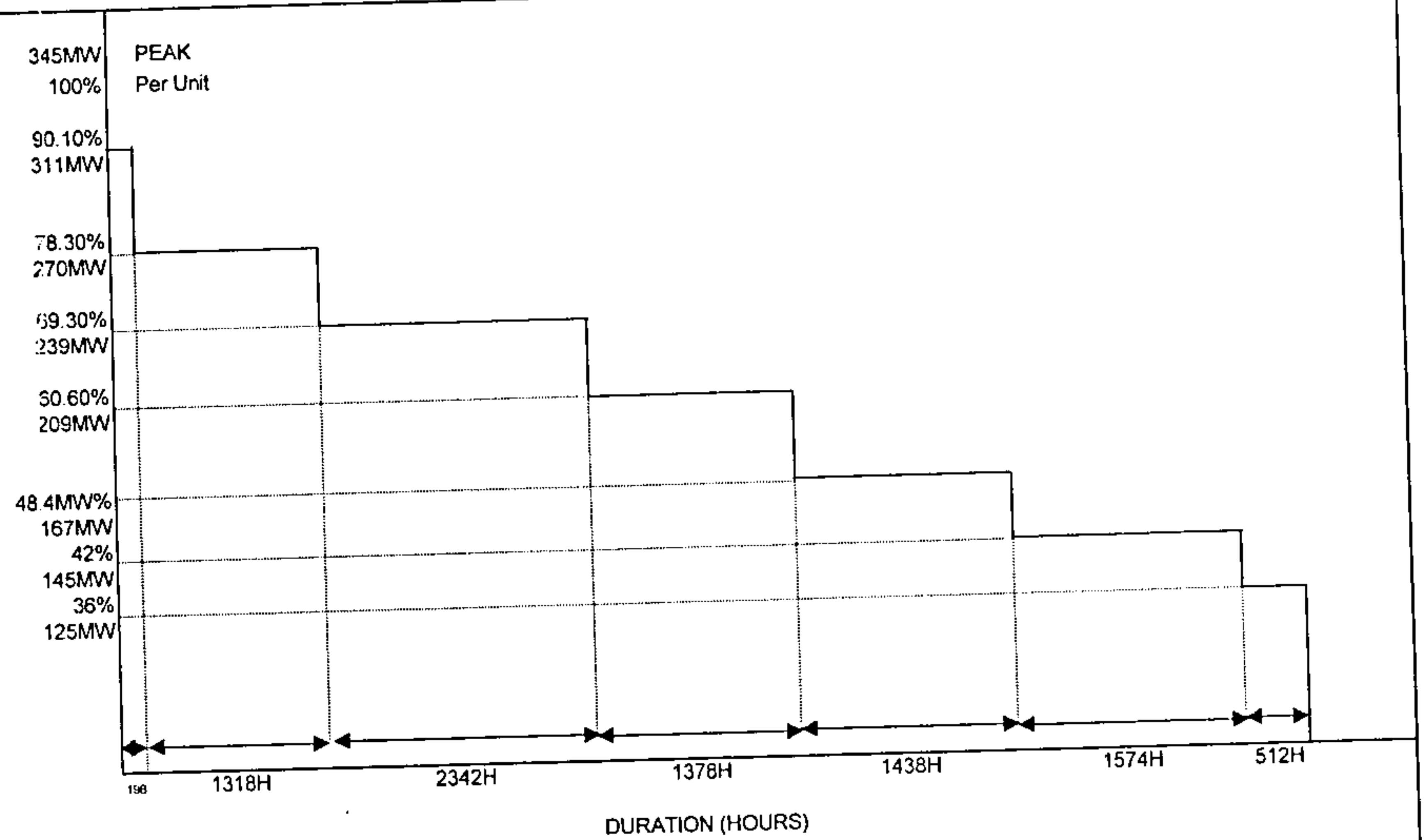

Fig 4.3: Step Load Duration Curve of the West Bank for year 2001.

When planning generation, the question naturally arises as to how much generation capacity and reserve is required to serve the demand and to ensure system security. Reserve is the term used to describe the total amount of generation available from all units synchronized on the system minus the present load plus losses being supplied. Generation reserve is mainly to overcome the following problems

1- Generation outage, either forced or scheduled outage, so the reserve will make up for the loss in a specified time period.

2- load uncertainty

3- Uncertainty in the installation dates for new generation including the lead-time of the generation units.

Three historical methods can be used to determine the capacity reserve as follows.

- Percent Reserve Method

This method computes the generation capacity exceeding actual peak. It is based on past experience requiring reserve margins in the range of 15-25% of the peak. On the other hand this method has some disadvantages as, it is insensitive to forced outage rates and unit size consideration, it is insensitive to differing load characteristics

- Loss-Of-The Largest Generating Unit Method

This method proved to give a better solution than the first one as it takes into account the impact of the single outage, that is the effect of the unit size on reserve requirement. With this method, required reserve margin is calculated by adding the size of the largest unit divided by the peak load plus constant reserve values. The main disadvantage of this method is when larger units are added to the system; where the percent reserves of the system are sharply increased.

- Loss-Of-Load Probability Method (LOLP)

This method gives an accurate and sensitive measure of generation system reliability. It is an expected value of the number of days per year of capacity deficient, or it simply evaluates the expected number of occurrences when the operating reserve is equal or less than zero. The name loss of load is miss leading as it is not loss of load but rather it is a deficiency of installed available capacity.

LOLP follows the percent reserve curve for small sizes of loads and for larger sizes it follows the loss of largest generating unit method.

The utility industries generally uses annual index LOLP which is summation of daily probabilities or daily risks over the entire year, typically LOLP lies between (0.1 –1) day/year, which is generally equivalent to 15-25% capacity reserve (Harry G.Stoll , 1989)

In this study we used the third method which is the LOLP index method to calculate our reserve. We used the typical value of the LOLP to be between 0.1-1 day/year, which is equivalent to 15-25 % of the capacity reserve

4.3.4 Screen Curve Analysis

Screen curve method is very useful in understanding the relative economic merits of alternative generation types. First of all data per year for each type of generators is plotted on a graph. Y-axis represents the total levelized annual owing cost in dollars per year and the X-axis represents the plant capacity factor.

In order to understand the relative economic merits of alternative generators we will test the GT, CC and the steam coal fired generators each of 60 MW Capacity using the screen curve method.

The " screen curve analysis method " is an extension of the levelized bus bar method to remove this restriction. A key assumption of the levelized bus-bar method is that the capacity factor of each generating unit is one constant value.

Levelizing is one simple method of a counting for inflation. The cost levelizing process converts a yearly escalating series of costs into a single constant, present worth equivalent value. Table 4.6 (based on data of table 4.1) shows the sample data that will be used to carry out the screen curve analysis, assuming that capacity factor (C.F) = 70% and NG will be used for electricity generation.

Table 4.6: Sample data of GT and CC (projected to year 2001)

Type	**Capacity Factor (C.F)**	**Investment Cost (K $) / kW**	**Fixed M& O Cost (3.5% of investment cost) ($/ kW)**	**Fuel Price in Year-2001 ($/GJ)**
GT unit	70%	386	13.51	3.61
CC unit	70%	780	27.3	2.36

To draw the Screen curve for GT, CC and steam coal fired units , based on levelized method we should first define the following terms .

Total cost of power plant = levelized investment cost + levelized (0&m) cost ....(4.3)
+ levelized fuel prices

levelized investment cost = investment cost * capacity factor * FCR ....(4. 4)

levelized O& M cost = O&M cost * levelized factor ....(4.5)

levelized fuel cost = fuel cost * levelized factor...(4.6)

FCR is called the fixed charge rate; it is defined as the annual owning costs of an investment as a percent of the investment. When an investment in utility plant is made and placed into service, the owning cost to the utility includes the following economic terms.

- interest on deposit/year
- Net profit / Year
- Depreciation rate / Year

FCR = Interest rate on deposit + Net Profit + Depreciation rate ....(4.7)

We can talk about three kinds of FCR. First FCR for the private sector, FCR for public and FCR for municipalities and government

Substituting for variables (data from table 4.1) in equation 4.7 gave the FCR values as follows, FCR is 27% for private –owned utility, 22% for public owned utility and 17% for municipality and government utilities. Levelizded factor was calculated as given in equation 4. 8

$$levelized\ factor = \frac{1-((1+a)/(1+i))^n}{(i-a)} * \frac{(1+i)^n-1}{i} \quad \text{.....................................(4.8)}$$

a : inflation rate (5%) / year on dollars
i = interest rate (10%)
n= project life (20 year)

Substituting values of the above variables (table 4.1) in equation 4.8 gives the value of levelizing factor, that is 1.423.
Assuming that this project will be private owned project as the case of the power plant to be built in Gaza with an FCR value of 27%.

Calculating levelized investment, (O&M) cost and levelized fuel price of GT and CC units is done by applying equations 4.3, 4.4 and 4.5 to data presented in table 4.1.
For Steam coal fired turbine to calculate the levelized costs we used the following assumptions (Harry G.Stoll, 1989).

Cost of steam coal fired turbine at 0 % C.F = 1.8 * cost of CC
Cost of steam coal fired turbine at 70 % C.F = 0.94 * Cost of CC

Cost of steam coal fired turbine at 40% C.F = 1.24 of that of CC
Cost of steam coal fired turbine at 100% C.F = 0.88 of that of CC

Table 4.7 gives the total levelized cost per year of the plant for the GT; CC and steam coal fired generators for different C.F.

Table 4.7: Annual investment costs of GT, CC, and Steam Coal-fired units (Prices projected to year 2001)

Type of Generator (60MW)	Total cost /year (Million $) 0% C.F	Total cost /year (Million $) 40% C.F	Total cost /year (Million $) 70% C.F	Total cost /year (Million $) 100% C.F
GT	6.2	22.19	33.32	44.45
CC	12.52	21.62	26.73	31.8
Steam coal Fired	22	25	27	29

Based on data of table 4.7, fig 4.4 is drawn. Fig 4.4 shows the screen curve for the three generation units. As shown in fig 4.6 for values of C.F less than 35 % the GT is the most economical choice. Similarly if the capacity factor of the future plant will be between 30 % and 72 % then CC will the most economical choice and if the unit is to work at a capacity factor above the 72 % then coal unit has the lowest owning cost.

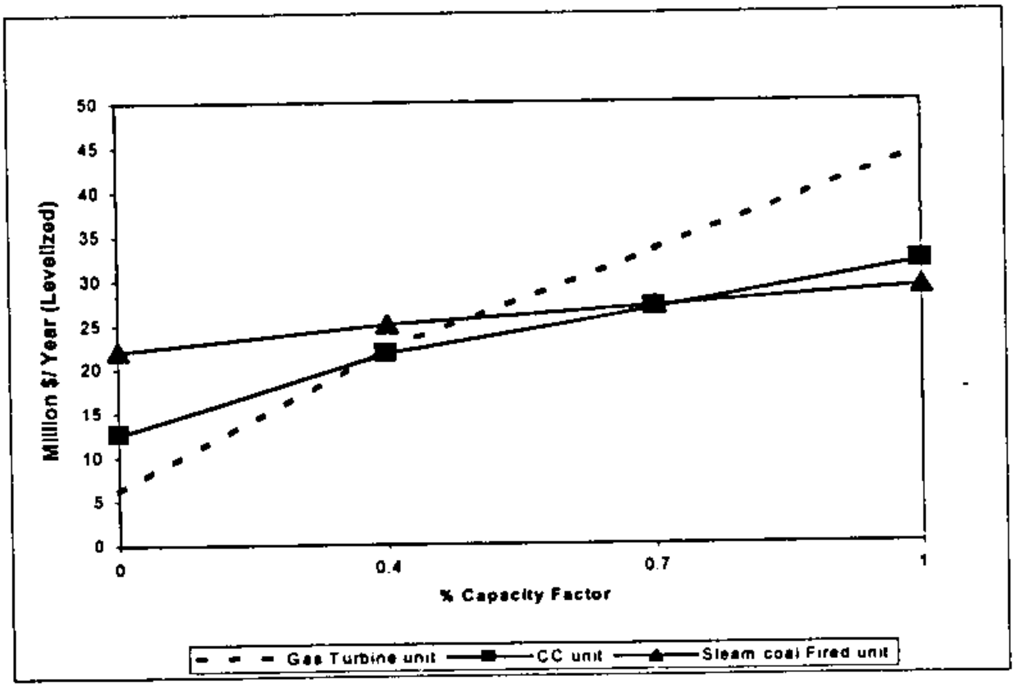

Fig.4.4 Screening Curve.

An approximated method for assessing an optimal generation mix uses annual load duration curve in conjunction with a screening curve, as illustrated in fig 4.5 The screen curve is plotted on the top of the graph, which shows the dollars per year versus capacity factor. On the bottom half of the graph, load duration curves plots the megawatt load versus the percent of the year. By projecting the intercepts of the screening curve onto the load duration curve, the optimal megawatt amount of each type of capacity can be evaluated as shown in fig 4.5.

Coal is not recommended for generation as the initial investment cost of coal fired generators is very high compared to GT and CC units. Coal is not available in the West Bank or in the near countries so cost of transportation is expected to be very high. Moreover the proposed power plant will be relatively small so that price of transportation will increase and so the variable operation cost will also increase.

One important thing to be mentioned is that using coal is harmful to environment. When coal is burned it releases gases called sulphur dioxide and nitrogen oxide which can stay in the air and blown by the wind for up to four days. They mix with water in the clouds and falls as rain or snow. This acid rain kills trees and plants, and skins into soil. It falls on lakes killing fish. Burning coal in a power plant leaves tones of ash containing sulphur, which must be disposed of, and often pollutes the water in the ground. All in all, burning coal to make electricity is really harmful to environment.

As presented in fig 4.5 if coal is to be excluded, GT units will work only for 30% of the load. GT units usually work to cover the peak and the spinning reserve while the CC units will work for a bout 72 % of the load as a base. As a result a combination of GT and CC units will be used for generation planning. Accurate percentage share of GT and CC units in total generation will be calculated accurately in following automatic generation planning technique.

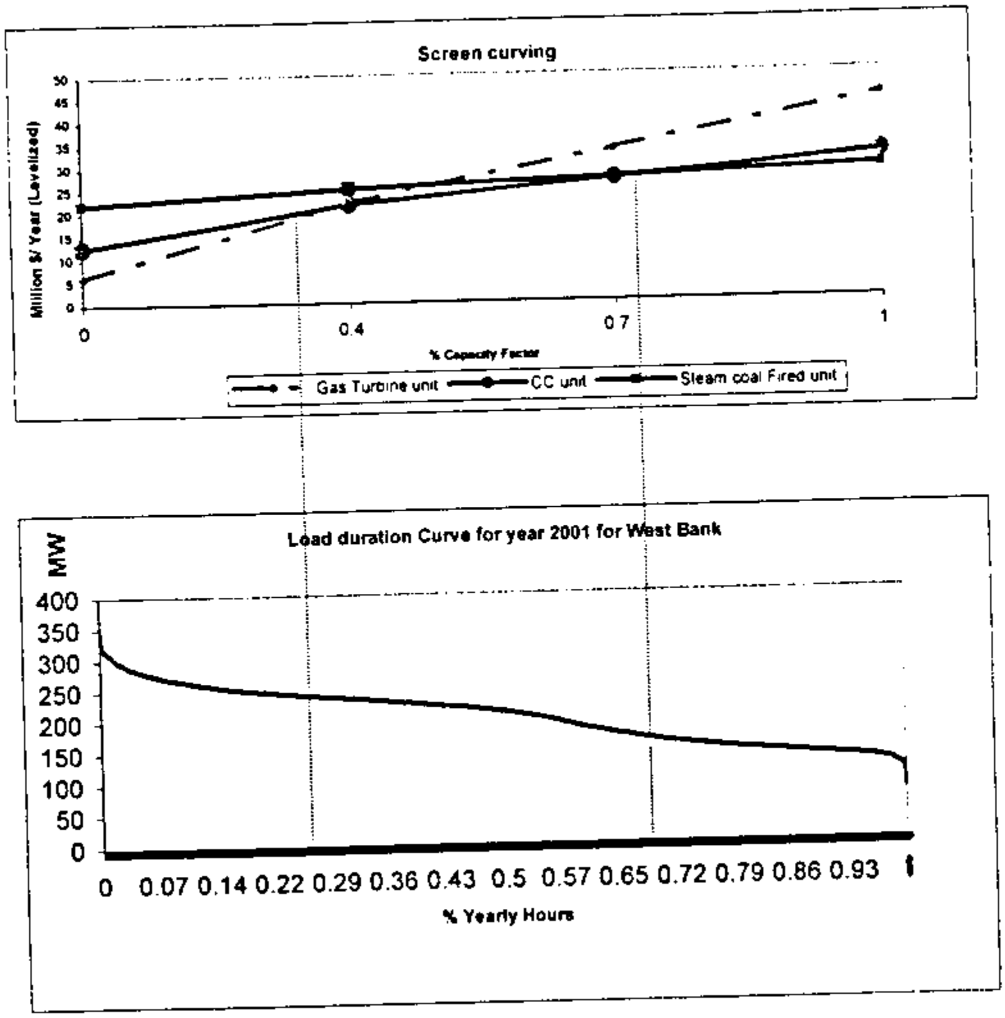

Fig 4.5 Screening curve and load-duration curve analysis

4.3.5 Automatic Generation planning

Since load duration curve, load step curve, system reliability (reserve) and screen curve analysis became available the next step is to carry out the automatic generation planning. Generation planning is not an easy task; instead it is very difficult and impossible to be done manually .The best and easy way to carry out generation planning is automatically by using computer. In this study we were lucky as we managed to use a specialized energy planning software package called PRELE (see appendix 4.2).

In order to use PRELE certain data should be available as follows.

- Peak load data for the planning period (2001 - 2020).
- Total investment cost and total variable cost USc / kWh.
- Steps of load duration curve (duration in hours).
- Height of each step (% of peak).
- Availability of generators.

The aim of automatic generation planning is to determine how much generation capacity needs to be installed as well as what kind of equipment it should be (i.e. nuclear, gas turbine, diesel, combined cycle), what kind of fuel (natural gas, gas oil, heavy fuel...) total costs, financial implications of a generation plan cost and benefit analysis.

4.4 Generation Planning Scenarios

Generation planning scenarios are based on the four peak power demand scenarios of chapter 3, table (3.14). In this chapter for automatic generation planning, four scenarios have been discussed as follows.

- Scenario 1, which is, called low scenario. It is based on scenario one of the forecasted peak demands of chapter 3 (table 3.7). In this scenario, GT units with 60MW unit capacity and CC units with 180MW unit capacity are used. NG is used to fire both GT and CC units.

- Scenario2 or called base scenario, which depends on scenario 2 of forecasted peak demand of chapter 3 (table 3.8). GT of 60MW and the CC of 180MW capacity are used for generation. For this scenario three cases are analyzed
  - The first case assumes that the Natural gas (NG) will be the fuel for the GT and the CC generators
  - The second case assumes that the Gas oil (GO) will be the fuel for the GT and the CC generators
  - The third case assumes that heavy fuel (HF) will be the fuel for the GT and the CC generators.

- Scenario 3, which is called high scenario, is based on scenario 3 of forecasted peak demand of chapter 3 (table 3.9). For this scenario NG will be the fuel of the GT and the CC generators. For this scenario two cases are analyzed.
  - First case assumes that GT of 60 MW and CC OF 180MW capacity will be used for generation
  - Second case assumes that GT of 80MW capacity and CC OF 240 MW capacity will be used for generation.

- Scenario 4, which is, called the very high scenario. It is based on scenario 4 of forecasted peak of chapter 3 (table 3.10) .The fuel will be Natural gas and generators will be GT of 80MW and CC of 240MW capacity.

4.4.1 Automatic Generation Planning Scenario 1

Basic data

- Fuel : NG
- Generators : 60MW GT and 180MW CC
- Unit investment cost (KUS $ /MW) and total variable cost (USc / KWH) of each generators are as shown in table 4.2
- Steps of load duration curve of year 2001 (table 4.7)
- Load demand data (table 3.7 of chapter 3)

Determination of the optimal (least cost) combination of units (GT & CC) that should be used to cover the load is done through automatic integration between load demand, fuel costs and generation costs. Automatic integration is done by PRELE . Optimal solution is summarized as given in tables 4.8, 4.9 and 4.10.

Table 4.8 gives the optimal power to be generated by GT and CC for each year; also the expected reserve is given. For the planning period 2001-2020 total optimal power generated by GT and CC generators for each step is given in table 4.9. As illustrated in table 4.9 GT units will work only for the first peak steps while CC units will work in all steps. This is because total cost of CC is less than that of GT. But for peak steps the GT is better because of its fast response, as it has a minimum up and a minimum down times.

Table 4.10 gives each year for GT and CC units optimal energy generated, total working hours. Moreover table 4.10 shows total energy generated for each year.

Optimal solution usually is not implemented, so it will be modified to what called discrete (actual) solution. The reason why we have to modify the optimal solution, is because the total optimal generators output power is not a multiple of its standard unit output capacity (58.08 MW) of GT and 174.42 MW for CC. Also average optimal reserve is less than the target reserve, in our case (15-25%). Moreover due to the lead-time of the CC (2-4 years) it is not possible to run the CC generator in year 2001.

Table 4.8: Optimal output power of GT and CC units - Scenario 1

Year	Power generated by GT units (MW)	Power generated by CC units (MW)	Total generated Power (MW)	Power Peak demand (MW)	Continuous reserve (%)
2001	207	182	389	341.0	14.1
2002	222	195	417	366.0	13.9
2003	239	210	449	393.6	14.1
2004	239	241	480	421.0	14.0
2005	239	270	509	447.0	13.9
2006	239	294	533	467.5	14.0
2007	249	316	565	486.8	16.1
2008	260	330	590	508.0	16.1
2009	269	343	612	529.3	15.6
2010	280	356	636	548.0	16.1
2011	290	371	661	571.0	15.8
2012	290	384	674	591.6	13.9
2013	303	401	704	618.0	13.9
2014	314	416	730	640.4	14.0
2015	325	430	755	662.4	14.0
2016	335	444	779	683.8	13.9
2017	341	452	793	696.4	13.9
2018	360	477	837	734.4	14.0
2019	374	495	869	763.1	13.9
2020	388	514	902	792.3	13.8

Table 4.9: Optimal yearly generated power for each step- Scenario 1

Year	Step 1		Step 2		Step 3		Step 4		Step 5		Step 6		STEP 7	
	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC
2001	136	171	95	171	65	171	37	171	0	164	0	143	0	123
2002	146	183	102	183	69	183	40	183	0	176	0	154	0	132
2003	157	197	10	197	75	197	43	197	0	189	0	165	0	142
2004	153	226	102	226	64	226	30	226	0	202	0	177	0	152
2005	148	254	94	254	54	254	18	254	0	215	0	188	0	161
2006	145	276	88	276	46	276	9	276	0	224	0	196	0	168
2007	141	297	83	297	39	297	0	297	0	234	0	204	0	175
2008	147	310	86	310	41	310	0	310	0	244	0	213	0	183
2009	153	323	90	323	42	323	0	323	0	254	0	222	0	191
2010	159	334	93	334	44	334	0	334	0	263	0	230	0	197
2011	166	348	97	348	46	348	0	348	0	274	0	240	0	206
2012	172	361	101	361	47	361	0	361	0	284	0	248	0	213
2013	179	377	105	377	49	377	0	377	0	297	0	260	0	222
2014	186	391	109	391	51	391	0	391	0	307	0	269	0	231
2015	192	404	113	404	53	404	0	404	0	318	0	278	0	238
2016	198	417	116	417	55	417	0	417	0	328	0	287	0	246
2017	202	425	118	425	56	425	0	425	0	334	0	292	0	251
2018	213	448	125	448	59	448	0	448	0	353	0	308	0	264
2019	221	465	130	465	61	465	0	465	0	366	0	321	0	275
2020	230	483	135	483	63	483	0	483	0	380	0	333	0	285

Table 4.10: Optimal yearly generated energy By GT and CC units - Scenario 1

	GT (60MW)		CC (180MW)		
YEAR	Generated Energy (GWH)	Time of operation (Hours)	Generated Energy (GWH)	Time of operation (Hours)	Total Energy Generated (GWH)
2001	357	1725	1416	7796	1773
2002	383	1725	1520	7796	1903
2003	412	1725	1634	7796	2046
2004	359	1503	1830	7598	2189
2005	308	1291	2015	7452	2323
2006	269	1125	2162	7258	2431
2007	231	969	2299	7280	2530
2008	241	967	2400	7280	2641
2009	251	967	2501	7280	2752
2010	260	967	2589	7280	2849
2011	271	967	2698	7280	2969
2012	280	967	2795	7280	3075
2013	293	967	2920	7280	3213
2014	304	967	3026	7280	3330
2015	314	967	3130	7280	3444
2016	324	967	3231	7280	3555
2017	330	967	3290	7280	3620
2018	348	967	3470	7280	3818
2019	362	967	3605	7280	3967
2020	376	967	3743	7280	4119
Total	**6273**	**22634**	**52274**	**147616**	**58547**

Actual solution is achieved by modifying the optimal solution through changing the arrangement of generated power so as to have the total generators output power a multiple of the unit output capacity while keeping the reserve between 15-25 %. Total generated energy in the actual solution will be same as in the optimal solution.

Table 4.11 shows the actual available number of GT and CC units and their total output capacity MW (each year)). As shown in table 4.11 due to CC lead-time, for the first year 2001 only GT units will work. In the actual solution for each year total output generated power is more than the optimal solution (table 4.8), this is because for optimal solution the reserve is about 14% while our target in the actual solution is to have the reserve between 15-25%.

In average the reserve for this scenario is about 20.3%. Also as shown in table 4.11 we used the technique of conversion (changing) from GT unit to CC unit, where 1 CC equals 2 gas units plus 1 steam unit.

Table 4.12 shows the actual power generated by GT and CC units for each step. According to data in table (4.12) CC units will be used first if they are available. If CC units are not available or not enough then the GT units will cover the deficiency.

It is important to determine power generated by GT and CC units for each step as this helps to know on-off times of generators. Knowing the on- off times of generators helps in planning the generators scheduled outage times.

Table 4.13 shows the actual generated energy each year by the GT and the CC and the total actual energy. As illustrated in table 4.13 most energy will be generated by CC units as they work most of the time of the year. Over the planning period 2001-2020 GT will generate 5958 GWH, work for 27911 hours while the CC units will generate 52687 GWH and work for 127739 hours. Total generated energy is 58547 GWH, so GT units will generate 10% of the total while CC units will generate 90% of the total. But in both actual and optimal solutions total generated energy will be the same value, 58547 GWH for this scenario.
Table 4.14 gives the discounted (NPV) of investment cost, variable operating cost and total cost of GT and CC units and NPV of total cost.

Table 4.14: Discounted costs of Scenario 1

Fuel : NG	**Unit Capacity (MW)**	**Discounted investment cost (Million $)**	**Discounted operating cost (Million $)**	**Total discounted cost (NPV) (Million $)**
Gas Turbine	60	134.800	109.703	244.503
CC Turbine- Air cooling	180	350.280	391.567	741.847

Table 4.11: Actual power generated each year by GT and CC units - Scenario 1

Year	Total power added by GT (MW)	Total power of GT units (MW)	Total Power converted from GT to CC (MW)	Total Power of CC units (MW)	Total generated Power (MW)	Peak demand (MW)	Discrete Reserve (%)
2001	7*58.08=406.7	406.65		0	406.65	341.1	19.2
2002		290.4	(2*58.08)= 116.16	174.24	464.64	366.0	27.0
2003		290.4		174.24	464.64	393.6	15.0
2004		174.24	(2*58.08)= 116.16	348.48	522.72	421.0	24.2
2005		174.24		348.48	522.72	447.0	16.9
2006	1*58.08=58.08	232.32		348.48	580.8	467.5	24.2
2007		232.32		348.48	580.8	486.8	19.3
2008	1*58.08=58.08	290.4		348.48	638.88	508.0	25.8
2009		290.4		348.48	638.88	529.3	20.7
2010		290.4		348.48	638.88	548.0	16.6
2011	1*58.08=58.08	348.48		348.48	696.96	571.0	22.1
2012		348.48		348.48	696.96	591.6	17.8
2013		232.48	(2*58.08)= 116.16	522.8	755.28	618.0	22.2
2014		232.32		522.8	755.12	640.4	17.9
2015	1*58.08=58.08	290.4		522.8	813.2	662.4	22.8
2016		290.48		522.8	813.28	683.8	18.9
2017		290.48		522.8	813.28	696.4	16.8
2018	1*58.08=58.08	348.48		522.8	871.28	734.4	18.6
2019	1*58.08=58.08	406.6		522.8	929.4	763.1	21.8
2020		406.6		522.8	929.4	792.3	17.3
Average reserve %							**20.3**

Table 4.12: Actual yearly power generated by GT and CC units for each step- Scenario 1

Year	Step 1		Step 2		Step 3		Step 4		Step 5		Step 6		STEP 7	
	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC
2001	307	0	266	0	235	0	208	0	164	0	143	0	123	0
2002	166	164	121	164	89	164	60	164	12	164	0	154	0	132
2003	191	164	143	164	108	164	77	164	25	164	0	164	0	142
2004	52	327	1	327	0	290	0	257	0	202	0	177	0	152
2005	75	327	22	327	0	308	0	273	0	215	0	188	0	161
2006	94	327	38	327	0	323	0	285	0	224	0	196	0	168
2007	111	327	53	327	9	327	0	297	0	234	0	204	0	175
2008	130	327	69	327	23	327	0	310	0	244	0	213	0	183
2009	149	327	86	327	38	327	0	323	0	254	0	222	0	191
2010	166	327	100	327	51	327	7	327	0	263	0	230	0	197
2011	187	327	118	327	67	327	21	327	0	274	0	240	0	206
2012	206	327	134	327	81	327	34	327	0	284	0	248	0	213
2013	65	492	0	426	0	377	0	377	0	297	0	260	0	222
2014	85	492	8	442	0	391	0	391	0	307	0	269	0	231
2015	105	492	25	457	0	404	0	404	0	318	0	278	0	238
2016	124	492	42	472	0	417	0	417	0	328	0	287	0	246
2017	135	492	52	481	0	425	0	425	0	334	0	292	0	251
2018	169	492	81	492	15	448	0	448	0	353	0	308	0	264
2019	195	492	104	492	35	465	0	465	0	366	0	321	0	275
2020	222	492	126	492	55	483	0	483	0	380	0	333	0	285

Table 4.13: Actual Energy generated by GT and CC units- Scenario 1

	GT (60MW)		CC (180MW)		
Year	**Generated Energy (GWH)**	**Time of operation (Hours)**	**Generated Energy (GWH)**	**Time of operation (Hours)**	**Total Energy Generated (GWH)**
2001	1773	7796	0	0	1773
2002	546	2878	1357	7796	1903
2003	689	3617	1357	7796	2046
2004	13	74	2176	6251	2189
2005	45	256	2279	6548	2324
2006	70	400	2360	6782	2430
2007	114	556	2416	2416	2530
2008	174	971	2467	7088	2641
2009	237	1093	2517	7233	2754
2010	297	1524	2552	7332	2849
2011	381	1723	2587	7434	2968
2012	456	2128	2618	7524	3074
2013	14	65	3198	6116	3212
2014	29	134	3300	6310	3329
2015	56	257	3388	6477	3444
2016	82	379	3473	6640	3555
2017	98	451	3524	6735	3622
2018	180	828	3638	6957	3818
2019	261	1203	3706	7083	3967
2020	343	1578	3776	7219	4119
Total	**5958**	**27911**	**52687**	**127739**	**58547**

Cost Benefit Analysis of Scenario 1

The aim of this analysis is to determine whether the project will be worth to be implemented or not, depending on costs and benefits. It will give an idea of the money that could be saved (financial analysis) during the planning period compared to other alternatives. For all scenarios the comparison will be with the current situation, that is buying electricity from Israel. For all scenarios analysis are based on the price of 0.067 US$ / kWh in 1999 and an inflation rate of 3% per year for energy supplied by the Israeli Electric Corporation (IEC).

Table 4.15 gives the total investment cost per year (output of PRELE), total cost of energy if to be purchased from Israel per year, total cost of transmission network (NPV) and the NPV of money that could be saved. Generation benefit per year is calculated as cost of energy supplied by the IEC less the total investment cost (generation & transmission). Cost of energy supplied by the IEC is equal to total generated energy times the unit cost of the kWh.

As shown in table 4.15 NPV for this scenario is 717.3 million $. This means that if the project is to be implemented the amount of money that could be saved is 717.3 million $ during the period (2001-2020).

Besides this big amount of money that could be saved, we will also have a secure reliable system with 20.3 % reserve. Having a system with about 20% reserve means that electricity will be supplied continuous without interruption, and we will have a new well-designed transmission network with less losses. While with the source from Israel many occasions of electricity interruption is expected. Electricity service interruption costs a lot of money and badly affects the national economy.

	Year		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1	Total investment cost	$	3.42E+08	6.86E+07	9.40E+07	6.05E+07	6.44E+07	6.77E+07	7.11E+07	7.50E+07	1.26E+08	1.29E+08
2	Total energy	kWh	1.77E+09	1.90E+09	2.05E+09	2.19E+09	2.32E+09	2.43E+09	2.53E+09	2.64E+09	2.75E+09	2.85E+09
3	Price /KWH (if to be supplied by the IEC)	$	0.0710	0.0731	0.0753	0.0776	0.0799	0.0823	0.0848	0.0873	0.0899	0.0926
4	Total cost of energy (if to be supplied by the IEC) (2*3)	$	1.26E+08	1.39E+08	1.54E+08	1.70E+08	1.86E+08	2.00E+08	2.15E+08	2.31E+08	2.48E+08	2.64E+08
5	Total saving in energy costs (4-1)	$	-2.16E+08	5.06E+07	6.01E+07	1.09E+08	1.21E+08	1.32E+08	1.43E+08	1.56E+08	1.22E+08	1.35E+08
6	NPV of saving in energy costs	$	917,275,390									
7	Cost of transmission network (NPV)	$	200,000,000									
8	Total saving in the whole electricity system (NPV) (6-7)	$	717,275,390									

	Year		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1	Total investment cost	$	1.22E+08	1.26E+08	1.09E+08	1.12E+08	1.04E+08	1.21E+08	1.37E+08	1.65E+08	1.99E+08	2.38E+08
2	Total energy	kWh	2.87E+09	3.08E+09	3.21E+09	3.33E+09	3.44E+09	3.56E+09	3.62E+09	3.82E+09	3.97E+09	4.12E+09
3	Price /KWH (if to be supplied by the IEC)	$	0.0954	0.0983	0.1012	0.1043	0.1074	0.1106	0.1139	0.1174	0.1209	0.1245
4	Total cost of energy (if to be supplied by the IEC) (2*3)	$	2.83E+08	3.02E+08	3.25E+08	3.47E+08	3.70E+08	3.93E+08	4.12E+08	4.48E+08	4.80E+08	5.13E+08
5	Total saving in energy costs (4-1)	$	1.62E+08	1.76E+08	2.17E+08	2.35E+08	2.66E+08	2.72E+08	2.75E+08	2.83E+08	2.81E+08	2.74E+08
6	NPV of saving in energy costs	$										
7	Cost of transmission network (NPV)	$										
8	Total saving in the whole electricity system (NPV) (6-7)	$										

* all above costs and benefits are to local economy (PNA) , not to end users

Table 4.15 Cost Benefit Analysis of Scenario 1

4.4.2 Automatic Generation Planning Scenario 2

For this scenario three different cases are discussed and analyzed as follows.

4.4.2.1 Automatic Generation Planning for Scenario 2 - Case 1

Basic data

- GT (60 MW) , CC (180 MW)
- Load demand data table (3.10)
- Fuel : Natural gas
- Investment and variable cost (table 4.2)

As for scenario 1 optimal solution is done through the integration between load demand fuel costs and generation cost using PRELE.

Table 4.16 gives the optimal solution of generated power by GT and CC units and the continuous reserve for each year. Table 4.17 Shows the actual available number of GT and CC units and their total output capacity (MW) each year, which is the best combination of GT and CC generators taking into account that the reserve for each year is kept between 15-25 % of the peak load. The average reserve as shown in table 4.17 for the planning period 2001-2020 is 19.5%.

Table 4.18 shows for each year the actual power generated per step by GT and CC units. Table 4.19 presents the actual energy generated each year by the GT and the CC units and the total actual generated energy.

Based on PRELE output, table 4.20 gives the total investment, total operating, total cost and NPV of total cost for the planning period 2001- 2020.

Table 4.20: Discounted costs of Scenario 2- case 1

Fuel : NG	Unit Capacity (MW)	Discounted investment cost (Million $)	Discounted operating cost (Million $)	Total Discounted cost (Million $)
Gas Turbine	60	126.657	105.679	232.336
CC Turbine. Air Cooling.	180	455.886	463.693	919.2579
Total		**582.543**	**569.372**	**1,151.915**
% of total		**50.6 %**	**49.4 %**	**100 %**

Table 4.16: Optimal yearly generated power By GT and CC units- (Scenario 2- Case 1)

Year	Power generated by GT units (MW)	Power generated by CC units (MW)	Total generated Power (MW)	Power Peak demand (MW)	Continuous reserve (%of peak)
2001	209	184	393	345.0	13.9
2002	226	198	424	372.5	13.8
2003	245	215	460	404.6	13.7
2004	266	234	500	439.1	13.9
2005	266	275	541	475.2	13.8
2006	266	312	578	507.8	13.8
2007	266	352	618	542.7	13.9
2008	287	379	666	584.5	13.9
2009	310	410	720	631.6	14.0
2010	333	441	774	679.9	13.8
2011	348	461	809	710.0	13.9
2012	368	472	840	737.5	13.9
2013	378	502	880	772.1	14.0
2014	394	521	915	803.1	13.9
2015	408	540	948	832.2	13.9
2016	424	561	985	864.4	14.0
2017	433	573	1006	882.2	14.0
2018	455	602	1057	927.3	14.0
2019	473	627	1100	965.5	13.9
2020	492	652	1144	1004.0	13.9

Table 4.17: Actual power generated each year by GT and CC units- (Scenario 2- Case 1)

Year	Total power added by GT (MW)	Total power of GT units (MW)	Total Power converted from GT to CC (MW)	Total Power of CC units (MW)	Total generated Power (MW)	Peak demand (MW)	Discrete Reserve (%)
2001	7*58.08=406.7	406.65		0	406.65	345	17.9
2002		290.4	(2*58.08)= 116.16	174.24	464.64	372.5	24.7
2003		290.4		174.24	464.64	404.6	15.0
2004		174.24	(2*58.08)= 116.16	348.48	522.72	439.1	19.0
2005	1*58.08=58.08	232.32		348.48	580.8	475.2	22.2
2006	1*58.08=58.08	290.4		348.48	638.88	507.8	25.8
2007		290.4		348.48	638.88	542.7	17.7
2008	1*58.08=58.08	348.48		348.48	696.96	584.5	19.2
2009		232.32	(2*58.08)= 116.16	522.72	755.04	631.6	19.5
2010	1*58.08=58.08	290.4		522.72	813.12	679.9	19.6
2011	1*58.08=58.08	348.48		522.72	871.2	710	22.7
2012		348.48		522.72	871.2	737.5	18.1
2013		232.32	(2*58.08)= 116.16	696.96	929.28	772.1	20.4
2014		232.32		696.96	929.28	803.1	15.7
2015	1*58.08=58.08	290.4		696.96	987.36	832.2	18.6
2016	1*58.08=58.08	348.48		696.96	1045.44	864.4	20.9
2017		348.48		696.96	1045.44	882.2	18.5
2018	1*58.08=58.08	406.65		696.96	1103.61	927.3	19.0
2019		290.4	(2*58.08)= 116.16	871.2	1161.6	965.5	20.3
2020		290.4		871.2	1161.6	1004	15.7
Average reserve %							**19.5**

Table 4.18: Actual yearly power generated by GT and CC units for each step- (Scenario 2-Case1)

	Step 1		Step 2		Step 3		Step 4		Step 5		Step 6		STEP 7	
Year	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC
2001	310	0	269	0	238	0	210	0	166	0	145	0	124	0
2002	172	164	127	164	93	164	64	164	15	164	0	156	0	134
2003	201	164	152	164	116	164	83	164	31	164	0	170	0	146
2004	68	327	15	327	0	303	0	268	0	211	0	184	0	158
2005	101	327	44	327	0	327	0	290	0	228	0	200	0	171
2006	130	327	69	327	23	327	0	310	0	244	0	213	0	183
2007	161	327	96	327	47	327	4	327	0	260	0	228	0	195
2008	199	357	129	327	76	327	29	327	0	281	0	245	0	210
2009	77	492	0	492	0	436	0	385	0	303	0	265	0	227
2010	120	492	39	492	0	469	0	415	0	326	0	286	0	245
2011	147	492	62	492	0	490	0	433	0	341	0	298	0	256
2012	172	492	84	492	17	492	0	450	0	354	0	310	0	266
2013	11	655	0	602	0	533	0	471	0	371	0	324	0	278
2014	68	655	0	626	0	554	0	490	0	385	0	337	0	289
2015	94	655	0	649	0	574	0	508	0	399	0	350	0	300
2016	123	655	19	655	0	596	0	527	0	415	0	363	0	311
2017	139	655	33	655	0	609	0	533	0	424	0	371	0	318
2018	179	655	68	655	0	640	0	566	0	444	0	389	0	334
2019	50	819	0	753	0	666	0	589	0	463	0	406	0	348
2020	85	819	0	753	0	693	0	612	0	482	0	422	0	361

Table 4.19: Actual Energy generated by GT and CC units –(Scenario 2- Case 1)

	GT (60MW)		CC (180MW)		
Year	Generated Energy (GWH)	Time of operation (Hours)	Generated Energy (GWH)	Time of operation (Hours)	Total Energy Generated (GWH)
2001	1793	6758	0	0	1793
2002	579	2748	1357	7796	1936
2003	745	3694	1357	7796	2102
2004	36	154	2247	6458	2283
2005	81	402	2390	6865	2471
2006	174	798	2466	7087	2640
2007	278	1281	2543	7309	2821
2008	430	1956	2608	7493	3038
2009	18	79	3265	6243	3283
2010	77	347	3457	6610	3534
2011	115	514	3576	6838	3691
2012	188	849	3646	6971	3834
2013	6	20	3944	6000	3950
2014	15	67	4160	5969	4175
2015	20	94	4306	6177	4326
2016	53	237	4441	6371	4494
2017	74	331	4513	6475	4587
2018	130	545	4691	6731	4821
2019	11	38	5008	5750	5019
2020	18	64	5201	5971	5219
Total	**4841**	**967**	**65176**	**126910**	**70017**

Distribution of investment, operation and total costs of scenario 2 using natural gas is shown in fig. 4.6.

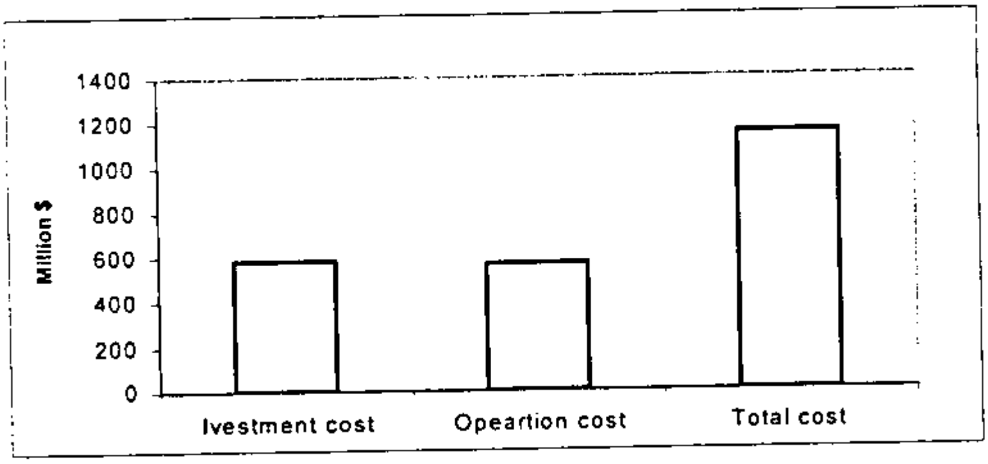

Fig. 4.6 Distribution of costs for scenario 2 using NG.

Cost Benefit Analysis of Scenario2 – Case 1.

Table 4.21 presents the cost benefit analysis for case 1 of scenario 2. In this table total investment cost, total generated energy, total cost of energy if to be purchased from IEC, NPV of the cost of the transmission network and NPV of the money that could be saved. As given in table 4.21 Using NG as fuel for the power plant for planning period 2001-2020 the amount of money that could be saved 809.4 million $ with an average reserve of about 19.5%.

	Year		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1	Total Investment cost	$	3 42E+08	8 97E+07	9 60E+07	6 29E+07	1 01E+08	1 20E+08	1 26E+08	1 22E+08	1 27E+08	1 35E+08	1 40E+08	1 45E+08	1 14E+08	1 24E+08	1 62E+06	1 81E+08	1 65E+08	2 14E+08	2 30E+08	2 69E+08
2	Total energy	kWh	1 79E+09	1 94E+09	2 10E+09	2 28E+09	2 47E+09	2 64E+09	2 82E+09	3 04E+09	3 28E+09	3 53E+09	3 69E+09	3 83E+09	3 95E+09	4 18E+09	4 33E+09	4 49E+09	4 59E+09	4 82E+09	5 02E+09	5 22E+09
3	Price /KWH (If to be supplied by the IEC)	$	0 071	0 07313	0 075324	0 0775836	0 079911	0 0823085	0 084778	0 087321	0 089941	0 0926389	0 095418	0 098281	0 10123	0 104266	0 107394	0 110616	0 113934	0 117352	0 1208727	0 1244989
4	Total cost of energy (If to be supplied by the IEC) (2*3)	$	127303000	1 42E+08	1 58E+08	177123398	1 97E+08	217294332	2 39E+08	2 65E+08	2 95E+08	327385859	3 52E+08	3 77E+08	4E+08	4 35E+08	4 65E+08	4 97E+08	5 23E+08	5 60E+08	[illegible]06660319	649759914
5	Total saving in energy costs (4-1)	$	-215103000	51833680	62449162	114242398	95928480	97027332	1 13E+08	1 44E+08	1 68E+08	192631859	2 12E+08	2 32E+08	2 9E+08	3 11E+08	3 02E+08	3 16E+08	3 38E+08	3 52E+08	376991319	380401914
6	NPV of saving in energy costs	$	1,059,393,384																			
7	Cost of transmission network (NPV)	$	250,000,000																			
8	Total saving in the whole electricity system (NPV) (6-7)	$	809,393,384																			

*** all above costs and benefits are to local economy (PNA) , not to end users

Table 4.21 Cost Benefit Analysis of Scenario 2- Case 1

4.4.2.2 Automatic Generation Planning for Scenario 2 - Case 2

Basic data

- GT 60 MW , CC 180 MW
- Load demand data (table 3.8)
- Fuel : GO
- Investment and variable costs (table 4.3)

Optimal generation solution is done through the integration between load demand fuel costs and generation costs using PRELE.

Table 4.22 shows the optimal continuous solution of generated power for GT and CC and the continuous reserve for each year. Table 4.23 presents the actual available number of GT and CC units and their total output capacity (MW) each year. Table 4.24 shows for each year the actual power generated per step by GT and CC units. Table 4.25 gives the actual generated energy each year by GT units and e CC units and total actual generated energy for the period 2001-2020.

Table 4.26 gives the discounted investment cost (NPV), discounted operating costs of GT and CC units and total discounted cost (NPV).

Table 4.26: Discounted costs of Scenario 2- Case 2.

Fuel : GO	**Unit Capacity (MW)**	**Discounted investment cost (Million $)**	**Discounted operating cost (Million $)**	**Total discounted cost (Million $)**
Gas Turbine	60	129.128	188.763	317.891
CC Turbine – Air Cooling	180	473.664	888.036	1,361.700
Total		**602.792**	**1,076.799**	**1,679.590**
% of Total		**35.9%**	**64.1%**	**100%**

Table 4.22: Optimal yearly generated Power By GT and CC units –(Scenario 2- Case 2)

Year	Power generated by GT units (MW)	Power generated by CC units (MW)	Total generated Power (MW)	Power Peak demand (MW)	Continuous reserve (%)
2001	140	253	393	345	13.9
2002	151	273	424	372.5	13.8
2003	164	297	461	404.6	13.9
2004	178	322	500	439.1	13.9
2005	193	349	542	475.2	14.1
2006	206	373	579	507.8	14.0
2007	220	398	618	542.7	13.9
2008	237	429	666	584.5	13.9
2009	256	464	720	631.6	14.0
2010	275	499	774	679.9	13.8
2011	288	521	809	710	13.9
2012	299	541	840	737.5	13.9
2013	299	541	880	772.1	14.0
2014	325	590	915	803.1	13.9
2015	337	611	948	832.2	13.9
2016	350	635	985	864.4	14.0
2017	358	648	1006	882.2	14.0
2018	376	681	1057	927.3	14.0
2019	391	709	1100	965.5	13.9
2020	407	737	1144	1004	13.9

Table 4.23: Actual power generated each year by GT and CC units –(Scenario 2- Case 2)

Year	Total power added by GT (MW)	Total power of GT units (MW)	Total Power converted from GT to CC (MW)	Total Power of CC units (MW)	Total generated Power (MW)	Peak demand (MW)	Discrete Reserve (%)
2001	7*58.08=406.7	406.65		0	406.65	345	17.9
2002		290.4	(2*58.08)= 116.16	174.24	464.64	372.5	24.7
2003		290.4		174.24	464.64	404.6	15.0
2004		174.24	(2*58.08)= 116.16	348.48	522.72	439.1	19.0
2005	1*58.08=58.08	232.32		348.48	580.8	475.2	22.2
2006	1*58.08=58.08	290.4		348.48	638.88	507.8	25.8
2007		290.4		348.48	638.88	542.7	17.7
2008		174.24	(2*58.08)=116.16	522.72	696.96	584.5	19.2
2009	1/58.08=58.08	232.32		522.72	755.04	631.6	19.5
2010		290.4		522.72	813.12	679.9	19.6
2011		174.24	(2*58.08)=116.16	696.96	871.2	710	22.7
2012		174.24		696.96	871.2	737.5	18.1
2013		232.32		696.96	929.28	772.1	20.4
2014		232.32		696.96	929.28	803.1	15.7
2015	1*58.08=58.08	290.4		696.96	987.36	832.2	18.6
2016	1*58.08=58.08	348.48		696.96	1045.44	864.4	20.9
2017		348.48		696.96	1045.44	882.2	18.5
2018	1*58.08=58.08	406.65		696.96	1103.61	927.3	19.0
2019	1*58.08=58.08	464.64		696.96	1161.6	965.5	20.3
2020		348.48	(2*58.08)= 116.16	871.2	1219.68	1004	21.5
Average reserve %							**19.8**

Table 4.24: Actual yearly power generated by GT and CC units for each step – (Scenario 2- Case 2)

	Step 1		Step 2		Step 3		Step 4		Step 5		Step 6		STEP 7	
Year	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC
2001	310	0	269	0	238	0	210	0	166	0	145	0	124	0
2002	172	164	127	164	93	164	64	164	15	164	0	156	0	134
2003	201	164	152	164	115	164	83	164	31	164	0	170	0	146
2004	68	327	15	327	0	303	0	268	0	211	0	184	0	158
2005	101	327	44	327	0	327	0	290	0	228	0	200	0	171
2006	130	327	69	327	47	327	0	310	0	244	0	213	0	183
2007	161	327	96	327	4	327	4	327	0	260	0	228	0	195
2008	199	357	0	456	0	357	0	357	0	281	0	245	0	210
2009	77	492	0	493	0	436	0	385	0	303	0	265	0	227
2010	120	492	39	492	0	469	0	415	0	326	0	286	0	245
2011	0	639	0	554	0	490	0	433	0	341	0	298	0	256
2012	9	655	0	575	0	509	0	450	0	354	0	310	0	266
2013	40	655	0	602	0	533	0	471	0	371	0	324	0	278
2014	68	655	0	626	0	554	0	490	0	385	0	337	0	289
2015	94	655	0	649	0	574	0	508	0	399	0	350	0	300
2016	123	655	19	655	0	596	0	527	0	415	0	363	0	311
2017	139	655	33	655	0	609	0	533	0	424	0	371	0	318
2018	179	655	68	655	0	640	0	566	0	445	0	389	0	334
2019	214	655	98	753	11	655	0	589	0	463	0	406	0	348
2020	85	819	0	783	0	693	0	612	0	482	0	422	0	361

Table 4.25: Actual Energy generated by GT and CC units – (Scenario 2- Case 2)

	GT (60MW)		CC (180MW)		
Year	**Generated Energy (GWH)**	**Time of operation (Hours)**	**Generated Energy (GWH)**	**Time of operation (Hours)**	**Total Energy Generated (GWH)**
2001	1793	6277	0	0	1793
2002	580	1797	1357	7796	1936
2003	747	4216	1357	7796	2104
2004	36	184	2247	6458	2283
2005	81	467	2389	6865	2470
2006	174	965	2466	7087	2640
2007	278	1556	2543	7309	2821
2008	8	43	3031	5795	3038
2009	18	85	3265	6243	3283
2010	77	441	3457	6610	3534
2011	0	0	3691	5295	3691
2012	2	10	3832	5497	3834
2013	6	20	3944	6000	3950
2014	15	63	4160	5969	4175
2015	20	90	4306	6177	4326
2016	53	182	4441	6371	4494
2017	74	259	4513	6475	4587
2018	130	450	4690	6731	4820
2019	101	731	4918	6912	5019
2020	18	65	5201	5971	5219
Total	**4211**	**17901**	**65808**	**123357**	**70017**

Cost Benefit Analysis of Scenario 2 – Case 2

Table 4.27 presents the cost benefit analysis for case 2 of scenario 2. In this table total investment cost, total generated energy, total cost of energy if to be purchased from the IEC, cost of the transmission network and NPV of the money that could be saved if the project is to be implemented. As given in table 4.27 if power plant will be built and to be run using GO as fuel for generation the amount of money that could be saved is 106.4 million $ with an average reserve of 19.8%.

4.2.2.3 Automatic Generation Planning for Scenario 2 – Case 3

Basic data

- GT 60 MW , CC 180 MW
- Load demand data (table 3.8)
- Fuel : HF
- Investment and variable costs (table 4. 4)

Automatic integration of fuel costs, generation costs (table 4.4) and load demand (table 3.8) using PRELE gives the optimal generation solution.

Table 4.28 shows the optimal continuous solution of generated power with least-cost for GT and CC and the continuous reserve for each year. Table 4.29 shows the actual available number of GT and CC units and their total output capacity (MW) each year. Table 4.30 shows for each year the actual power generated per step by GT and CC units. Table 4.31 gives the actual generated energy each year by the GT and the CC units and the total actual generated energy for the period 2001-2020.

Table 4.32 gives the discounted investment cost (NPV), discounted operating costs of GT and CC units and total discounted cost (NPV).

Table 4.32: Discounted costs of Scenario 2 – Case 3

Fuel : HF	**Unit Capacity (MW)**	**Discounted investment cost (Million $)**	**Discounted operating cost (Million $)**	**Total discounted cost (Million $)**
Gas Turbine	60	187.072	210.749	397.821
CC Turbine- Air Cooling system	180	533.126	800.239	1,333.365
Total		**720.198**	**1,010.988**	**1,731.186**
% of Total		**41.6%**	**58.4 %**	**100 %**

	Year		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1	Total investment cost	$	4.0E+08	1.3E+08	1.5E+08	1.4E+08	1.5E+08	1.6E+08	2.1E+08	1.8E+08	1.9E+08	2.1E+08	2.0E+08	2.1E+08	2.1E+08	2.4E+08	2.4E+08	2.7E+08	2.6E+08	3.3E+08	3.8E+08	3.9E+08
2	Total energy	KWH	1.79E+09	1.94E+09	2.10E+09	2.28E+09	2.47E+09	1.62E+05	2.82E+09	3.04E+09	3.28E+09	3.53E+09	3.69E+09	3.83E+09	3.95E+09	4.18E+09	4.33E+09	4.49E+09	4.59E+09	4.82E+09	5.02E+09	5.22E+09
3	Price /KWH (if to be supplied by the IEC)	$	0.0710	0.0731	0.0753	0.0776	0.0799	0.0823	0.0848	0.0873	0.0899	0.0926	0.0954	0.0983	0.1012	0.1043	0.1074	0.1106	0.1139	0.1174	0.1209	0.1245
4	Total cost of energy (if to be supplied by the IEC) (2*3)	$	1.3E+08	1.4E+08	1.6E+08	1.8E+08	2.0E+08	1.6E+05	2.4E+08	2.7E+08	3.0E+08	3.3E+08	3.5E+08	3.8E+08	4.0E+08	4.4E+08	4.6E+08	5.0E+08	5.2E+08	5.7E+08	6.1E+08	6.5E+08
5	Total saving in energy costs (4-1)	$	-2.7E+08	7.0E+06	1.2E+07	3.6E+07	4.6E+07	-1.6E+08	3.2E+07	8.3E+07	1.0E+08	1.2E+08	1.5E+08	1.7E+08	1.9E+08	1.9E+08	2.3E+08	2.3E+08	2.5E+08	2.4E+08	2.3E+08	2.6E+08
6	NPV of saving in energy costs	$	356,357,932																			
7	Cost of transmission network (NPV)	$	250,000,000																			
8	Total saving in the whol elctricity system (NPV) (6-7)	$	106,357,932																			

*** All above costs and benefits are to local economy (PNA) , not to end users

Table 4.27 Cost Benefit Analysis of Scenario 2 - C

Table 4.28: Optimal yearly generated power By GT and CC units –(Scenario 2-Case 3)

Year	Power generated by GT units (MW)	Power generated by CC units (MW)	Total generated Power (MW)	Power Peak demand (MW)	Continuous reserve (%)
2001	209	184	393	345	13.9
2002	226	198	424	372.5	13.8
2003	245	215	460	404.6	13.7
2004	266	234	500	439.1	13.9
2005	266	275	541	475.2	13.8
2006	266	312	578	507.8	13.8
2007	266	352	618	542.7	13.9
2008	287	379	666	584.5	13.9
2009	310	410	720	631.6	14.0
2010	333	441	774	679.9	13.8
2011	348	461	809	710	13.9
2012	368	472	840	737.5	13.9
2013	378	502	880	772.1	14.0
2014	394	521	915	803.1	13.9
2015	408	540	948	832.2	13.9
2016	424	561	985	864.4	14.0
2017	433	573	1006	882.2	14.0
2018	455	602	1057	927.3	14.0
2019	473	627	1100	965.5	13.9
2020	492	652	1144	1004	13.9

Table 4.29: Actual power generated each year by GT and CC units-(Scenario 2-Case 3)

Year	Total power added by GT (MW)	Total power of GT units (MW)	Total Power converted from GT to CC (MW)	Total Power of CC units (MW)	Total generated Power (MW)	Peak demand (MW)	Discrete Reserve (%)
2001	8*52.27=418	418.2		0	418.2	345	21.2
2002		313.2	(2*52.27)= 105	156.2	469.4	372.5	26.0
2003		313.2		156.82	470.02	404.6	15.0
2004		209.08	(2*52.27)= 105	313.64	522.72	439.1	19.0
2005	1*52.27=52.27	261.35		313.64	574.99	475.2	21.0
2006	1*52.27=52.27	313.62		313.64	627.26	507.8	23.5
2007		313.62		313.64	627.26	542.7	15.6
2008		209.08	(2*52.27)= 105	470.46	679.54	584.5	16.3
2009	1*52.27=52.27	261.35		470.46	731.81	631.6	15.9
2010	1*52.27=52.27	313.62		470.46	784.08	679.9	15.3
2011		209.08	(2*52.27)= 105	627.28	836.36	710	17.8
2012	1*52.27=52.27	261.35		627.28	888.63	737.5	20.5
2013		261.35		627.28	888.63	772.1	15.1
2014	1*52.27=52.27	313.62		627.28	940.9	803.1	17.2
2015	1*52.27=52.27	365.89		627.28	993.17	832.2	19.3
2016		365.89		627.28	993.17	864.4	14.9
2017	1*52.27=52.27	418.16		627.28	1045.44	882.2	18.5
2018		313.62	(2*52.27)= 105	784.1	1097.72	927.3	18.4
2019	1*52.27=52.27	365.89		784.1	1149.99	965.5	19.1
2020	1*52.27=52.27	418.16		784.1	1202.26	1004	19.7
Average reserve %							**18.5**

Table 4.30:Actual yearly power generated by GT and CC units for each step –(Scenario 2- Case 3)

	Step 1		Step 2		Step 3		Step 4		Step 5		Step 6		STEP 7	
Year	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC
2001	310	0	269	0	238	0	210	0	166	0	145	0	124	0
2002	188	148	143	148	109	148	80	148	31	148	8	148	0	134
2003	217	148	168	148	132	148	99	148	47	148	22	148	0	146
2004	100	295	47	295	8	295	0	268	0	211	0	184	0	158
2005	133	295	75	295	33	295	0	290	0	228	0	200	0	171
2006	162	295	101	295	55	295	15	295	0	244	0	213	0	183
2007	193	295	128	295	79	295	36	295	0	260	0	228	0	195
2008	84	442	14	442	0	357	0	357	0	281	0	245	0	210
2009	127	442	51	442	0	436	0	385	0	303	0	265	0	227
2010	170	442	89	442	27	442	0	415	0	326	0	286	0	245
2011	50	589	0	554	0	490	0	433	0	341	0	298	0	256
2012	74	589	0	575	0	509	0	450	0	354	0	310	0	266
2013	106	589	13	589	0	533	0	471	0	371	0	324	0	278
2014	133	589	37	589	0	554	0	490	0	385	0	337	0	289
2015	160	589	60	589	0	574	0	508	0	399	0	350	0	300
2016	189	589	85	589	7	589	0	527	0	415	0	363	0	311
2017	205	589	99	589	19	589	0	533	0	424	0	371	0	318
2018	98	737	0	723	0	640	0	566	0	444	0	389	0	334
2019	132	737	16	723	0	666	0	589	0	463	0	406	0	348
2020	167	737	46	723	0	693	0	612	0	482	0	422	0	361

Table 4.31: Actual Energy generated by GT and CC units –(Scenario 2- Case 3)

	GT (60MW)		CC (180MW)		
Year	Generated Energy (GWH)	Time of operation (Hours)	Generated Energy (GWH)	Time of operation (Hours)	Total Energy Generated (GWH)
2001	1793	7796	0	0	1793
2002	712	3604	1224	7796	1936
2003	880	4470	1224	7796	2104
2004	110	543	2173	6943	2283
2005	204	1404	2266	7215	2470
2006	217	1617	2323	7397	2540
2007	546	2414	2376	7568	2922
2008	37	200	3001	6386	3038
2009	94	513	3188	6784	3282
2010	218	1180	3317	7057	3535
2011	11	58	3680	5869	3691
2012	17	86	3818	6089	3835
2013	6	20	3944	6000	3950
2014	78	413	4097	6534	4175
2015	114	433	4212	6718	4326
2016	170	578	4324	6896	4494
2017	220	1095	4366	6964	4586
2018	21	69	4798	6121	4819
2019	50	137	4969	6338	5019
2020	97	233	5122	6533	5219
Total	**5595**	**26863**	**64422**	**129004**	**70017**

Cost Benefit Analysis of Scenario 2- Case 3

Table 4.33 presents the cost benefit analysis for case 3 of scenario 2. In this table total investment cost, total cost of energy if to be purchased from IEC, total cost of transmission network and the NPV of the money that could be saved. As given in table 4.33 if the power plant will be built and to be run using HF as fuel for generation the amount of money that could be saved is 53.4 million $ and ensure supplying electricity over the period 2001-2020 with an average reserve of 18.5%.

Summary of the three cases of scenario 2 is given in table 4.34

Table 4.34: Summary of discounted costs of Scenario 2 (three cases)

	Case 1	**Case 2**	**Case 3**
Type of fuel	NG	GO	HF
Discounted Investment Cost (Million $)	582.5	602.8	720.2
Discounted Investment Cost (% of total cost)	50.6 %	35.9 %	41.6%
Total Discounted operating cost (Million $)	569.4	1,076.8	1,011.0
Discounted operating cost (% of total cost)	49.4 %	64.1%	58.4 %
Total discounted cost (Investment + operating) (Million $)	**1,152.0**	**1,679.6**	**1,731.2**
Average reserve over the planning period. (% of peak)	20.3	19.8	18.5
NPV of saved money (Million $)	**809.4**	**106.4**	**53.4**

As shown in table 4.34, NG is the best fuel for generation with the least total cost (Least investment and least operation cost), second alternative is GO and the third alternative is the HF.

One thing to be mentioned is that, since the investment cost of HF and GO are the same (tables 4.3 & 4.4) and the operating cost of the power plant using HF is less than using GO, we expected that using HF will be cheaper than using GO. But on the other hand as given in table 4.34, using GO (total discounted cost 1,679,590 KUS $) is proved to be better than using HF (total discounted cost 1,731,186 KUS $) for generation. This is because, if HF is to be used the generator's efficiency will be decreased by 10% (called correction due to fuel) as shown in table 4.4, which means that more units should be used to serve the same load. As a result total investment cost of the power plant using HF will increase (720,198 KUS $) compared with 602792 KUS $ using GO. While if either NG or GO is used the generator's efficiency will not be affected.

	Year		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1	Total investment cost	$	4.5E+08	1.4E+08	1.5E+08	1.4E+08	1.5E+08	1.8E+08	2.1E+08	1.8E+08	1.9E+08	2.2E+08	1.9E+08	2.0E+08	2.0E+08	2.4E+08	2.5E+08	2.6E+08	2.9E+08	3.2E+08	3.7E+08	4.1E+08
2	Total energy	KWH	1.8E+09	1.9E+09	2.1E+09	2.3E+09	2.5E+09	1.6E+05	2.8E+09	3.0E+09	3.3E+09	3.5E+09	3.7E+09	3.8E+09	4.0E+09	4.2E+09	4.3E+09	4.5E+09	4.6E+09	4.8E+09	5.0E+09	5.2E+09
3	Price /KWH (if to be supplied by the IEC)	$	0.0710	0.0731	0.0753	0.0776	0.0799	0.0823	0.0848	0.0873	0.0899	0.0926	0.0954	0.0983	0.1012	0.1043	0.1074	0.1106	0.1139	0.1174	0.1209	0.1245
4	Total cost of energy (if to be supplied by the IEC) (2*3)	$	1.3E+08	1.4E+08	1.6E+08	1.8E+08	2.0E+08	1.6E+05	2.4E+08	2.7E+08	3.0E+08	3.3E+08	3.5E+08	3.8E+08	4.0E+08	4.4E+08	4.6E+08	5.0E+08	5.2E+08	5.7E+08	6.1E+08	6.5E+08
5	Total saving in energy costs (4-1)	$	-3.2E+08	5.8E+06	1.2E+07	3.5E+07	4.5E+07	-1.6E+08	2.8E+07	8.5E+07	1.0E+08	1.1E+08	1.6E+08	1.7E+08	2.0E+08	1.9E+08	2.1E+08	2.3E+08	2.4E+08	2.5E+08	2.4E+08	2.4E+08
6	NPV of saving in energy costs	$	303,370,764																			
7	Cost of transmission network (NPV)	$	250,000,000																			
8	Total saving in the whol elctricity system (NPV) (6-7)	$	53,370,764																			

*** All above costs and benefits are to local economy (PNA) , not to end u

Table 4.33 Cost Benefit Analysis of scenario 2 - case 3

Moreover total amount of money that could be saved if NG is used is higher than that if either GO and HF is used. Also as given in table 4.34 for case1 (using NG) total investment cost and total operating cost are nearly the same, each bout 50% each of total cost. For each GO and HF the operating cost is about 60% of total cost and the investment cost is about 40% of total cost. Fig. 4.7 shows graphs of the discounted costs for SC.2 using different fuel types.

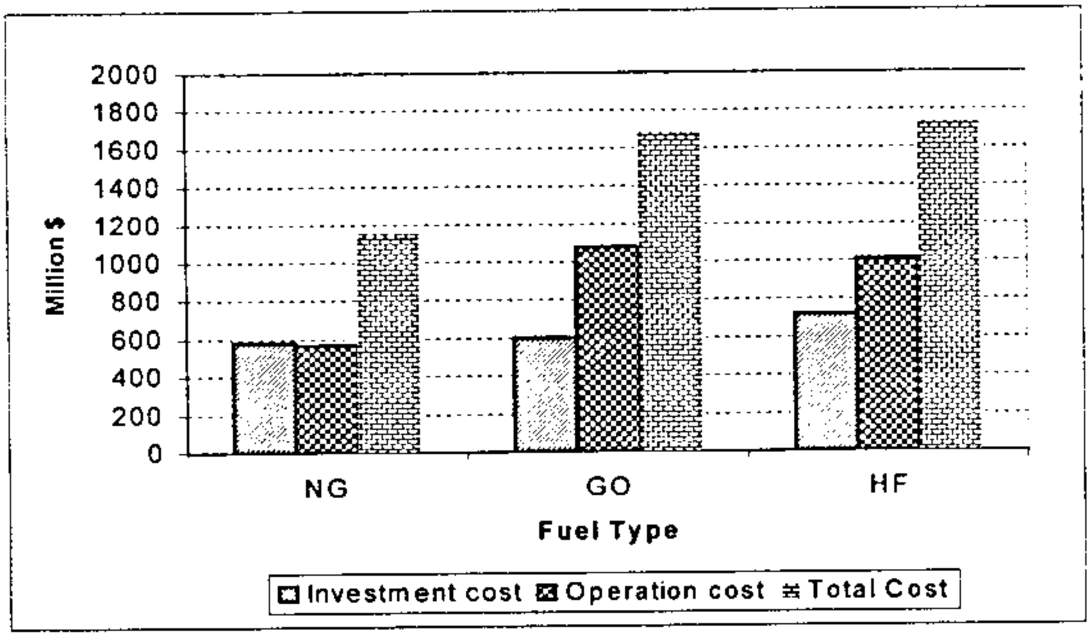

Fig.4.7 Discounted investment, operation and total costs of Scenario 2,for different fuel types

Because it was proved as given in table 4.34 that NG would be the best least-cost fuel for generation, for the next generation scenario analysis we will use NG as the only fuel for generation.

4.4.3 Automatic Generation Planning Scenario 3

For this scenario two cases are discussed and analyzed as follows.

4.4.3.1 Automatic Generation Planning for Scenario 3 - Case 1

Basic data

Fuel: NG
Load demand data (table 3.9)
Investment and variable cost (table 4.2)
Load duration data: table 4.7
Type of generators: GT (60 MW) & CC (180 MW) capacity

Automatic integration of fuel costs (table 4.2), generation costs (table 4.2) and load demand (table 3.9) using PRELE gives the optimal generation solution.

Table 4.35 shows the optimal continuous solution of generated power with least-cost for GT and CC and the continuous reserve for each year. Table 4.36 presents the actual available number of GT and CC units and their total output capacity (MW) each year. Table 4.37 shows for each year the actual power generated per step by GT and CC units. Table 4.38 gives the actual generated energy each year by the GT and the CC units and the total actual generated energy for the period 2001-2020.

Table 4.39 gives the discounted investment cost (NPV), discounted operating costs of GT and CC and total discounted cost (NPV).

Table 4.39: Discounted costs of Scenario 3- Case 1

Fuel : NG	**Unit Capacity (MW)**	**Discounted investment cost (Million $)**	**Discounted operating cost (Million $)**	**Total discounted cost (Million $)**
Gas Turbine	60	134.657	960.23	230.680
CC Turbine- Air Cooling system	180	644.4	672.530	1,316.918
Total		**779.045**	**768.553**	**1,547.598**
% of total		**50.4%**	**49.6%**	**100%**

Cost Benefit Analysis of Scenario 3 – case 1

Table 4.40 presents the cost benefit analysis for case 1 of scenario 3. In this table total investment cost, total cost of energy if to be purchased from IEC, total cost of transmission network and the NPV of the money that could be saved. As given in table 4.40 NPV of money that could be saved if power plant will be built using 60MW GT and 180MW CC units and to be run by NG is about 1,009.9 million $. Also the system will have an average reserve of about 18% which is a positive point for local generation planning issue.

4.4.3.2 Automatic Generation Planning for Scenario 3 – case 2

Basic data

Fuel: NG
Type of generators: GT (80 MW) & CC (240 MW) capacity
Load demand (table 3.9)

Table 4.41 shows the optimal solution of generated power for GT and CC units and the continuous reserve for each year. Table 4.42 presents the actual available number of GT and CC units and their total output capacity (MW) each year. Table 4.43 shows for each year the actual power generated per step by GT and CC units. Table 4.44 gives the actual generated energy each year by GT and the CC units and the total actual generated energy for the period 2001-2020.

Table 4. 35: Optimal yearly generated power By GT and CC units-(Scenario 3- Case 1)

Year	Power generated by GT units (MW)	Power generated by CC units (MW)	Total generated Power (MW)	Power Peak demand (MW)	Continuous reserve (%)
2001	209	184	393	345.0	13.9
2002	228	200	428	375.0	14.1
2003	254	223	477	419.3	13.8
2004	286	251	537	471.6	13.9
2005	286	320	606	532.4	13.8
2006	295	391	686	602.1	13.9
2007	334	443	777	682.0	13.9
2008	387	512	899	789.5	13.9
2009	452	598	1050	921.6	13.9
2010	529	701	1230	1079.9	13.9
2011	561	742	1303	1143.5	13.9
2012	583	772	1355	1189.3	13.9
2013	607	803	1410	1237.0	14.0
2014	624	826	1450	1273.0	13.9
2015	656	868	1524	1337.5	13.9
2016	674	892	1566	1374.0	14.0
2017	706	934	1640	1439.2	14.0
2018	740	980	1720	1509.7	13.9
2019	776	1027	1803	1582.0	14.0
2020	812	1074	1886	1655.7	13.9

Table 4.36: Actual power generated each year by GT and CC units- (Scenario 3- Case 1)

Year	Total power added by GT (MW)	Total power of GT (MW)	Total Power converted from GT to CC (MW)	Total power added by CC (MW)	Total Power of CC (MW)	Total generated Power (MW)	PeaK demand (MW)	Discrete Reserve (%))
2001	7*58.08=406.7	406.65			0	406.65	345	17.9
2002		290.4	(2*58.08)= 116.16		174.24	464.64	375	23.9
2003		174.24	(2*58.08)= 116.16		348.48	522.72	419.3	15.0
2004	1*58.08=58.08	232.32			348.48	580.8	471.6	23.2
2005	1*58.08=58.08	290.4			348.48	638.88	532.4	20.0
2006		174.24	(2*58.08)= 116.16		522.72	696.96	602.1	15.8
2007	2*58.08=116	290.4			522.72	813.12	682	19.2
2008	2*58.08=116	406.56			522.72	929.28	789.5	17.7
2009		406.6		1*174.24=174.42	696.96	1103.56	921.6	19.7
2010		406.6		1*174.24=174.42	871.2	1277.8	1079.9	18.3
2011	1*58.08=58.08	464.68			871.2	1335.88	1143.5	16.8
2012	1*58.08=58.08	522.76			871.2	1393.96	1189.3	17.2
2013	1*58.08=58.08	580.84			871.2	1452.04	1237.9	17.3
2014		464.8	(2*58.08)= 116.16		1045.4	1510.2	1273.5	18.6
2015	1*58.08=58.08	522			1045.4	1567.4	1338.5	17.1
2016	1*58.08=58.08	581			1045.4	1626.4	1374	18.4
2017	1*58.08=58.08	631			1045.4	1676.4	1439.2	16.5
2018		515	(2*58.08)= 116.16		1219.6	1734.6	1509.7	14.9
2019	2*58.08=116	631.2			1219.6	1850.8	1582	17.0
2020	1*58.08=58.08	681.3			1219.6	1900.9	1655.7	15.0
Average reserve %								**18.0**

Table 4.37: Actual yearly power generated by GT and CC units, for each step – (Scenario 3- Case 1)

	Step 1		Step 2		Step 3		Step 4		Step 5		Step 6		STEP 7	
Year	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC
2001	310	0	269	0	238	0	210	0	166	0	145	0	124	0
2002	174	164	118	164	95	165	65	164	16	164	0	158	0	135
2003	50	327	0	327	0	289	0	256	0	201	0	176	0	151
2004	97	327	0	327	0	325	0	288	0	226	0	198	0	170
2005	152	327	88	327	40	327	0	325	0	256	0	224	0	192
2006	50	492	0	470	0	415	0	367	0	289	0	253	0	217
2007	122	492	40	490	0	471	0	416	0	327	0	286	0	246
2008	219	492	124	492	53	492	0	482	0	379	0	332	0	284
2009	174	655	64	655	0	636	0	562	0	442	0	387	0	332
2010	153	819	24	819	0	745	0	659	0	518	0	454	0	389
2011	210	819	73	819	0	789	0	698	0	549	0	480	0	412
2012	252	819	109	819	2	819	0	725	0	571	0	500	0	428
2013	295	819	147	819	35	819	0	755	0	594	0	52	0	446
2014	164	982	11	982	0	879	0	877	0	611	0	535	0	458
2015	221	982	61	982	0	923	0	816	0	642	0	562	0	482
2016	254	982	89	982	2	982	0	838	0	660	0	577	0	498
2017	313	982	140	982	11	982	0	878	0	691	0	604	0	518
2018	212	1147	31	1147	0	1042	0	921	0	725	0	634	0	543
2019	277	1147	87	1147	0	1092	0	965	0	759	0	664	0	570
2020	343	1147	145	1147	0	1142	0	1010	0	795	0	695	0	596

Table 4.38: Actual Energy generated by GT and CC units- (Scenario 3- Case 1)

	GT (60MW)		CC (180MW)		
Year	Generated Energy (GWH)	Time of operation (Hours)	Generated Energy (GWH)	Time of operation (Hours)	Total Energy Generated (GWH)
2001	1793	7796	0	0	1793
2002	593	3394	1357	7796	1950
2003	11	64	2169	6232	2180
2004	76	367	2376	6829	2452
2005	243	1151	2524	7254	2767
2006	11	63	3119	5964	3130
2007	80	397	3465	6626	3545
2008	336	1540	3769	7206	4105
2009	122	562	4669	6698	4791
2010	64	300	5549	6371	5613
2011	142	562	5802	6661	5944
2012	204	751	5979	6865	6183
2013	341	1109	6094	6997	6435
2014	51	168	6570	6287	6621
2015	129	458	6824	6530	6953
2016	174	618	6969	6669	7143
2017	278	903	7203	6893	7481
2018	87	291	7761	6361	7848
2019	176	478	8048	6597	8224
2020	266	639	8341	6837	8607
Total	**5177**	**21611**	**98588**	**127673**	**103765**

	Year		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1	Total investment cost	$	3 6E+08	1 3E+08	9 3E+07	1 0E+08	1 4E+08	1 5E+08	1.8E+08	1 8E+08	1 7E+08	1 9E+08	2 2E+08	2 2E+08	2 2E+08	2 3E+08	2 5E+08	2 6E+08	2 8E+08	3 1E+08	3 7E+08	3 7E+08
2	Total energy	KWH	1 8E+09	1 9E+09	2 2E+09	2 5E+09	2 8E+09	3 1E+09	3 5E+09	4 0E+09	4 8E+09	5 6E+09	5 9E+09	6 2E+09	6 4E+09	6 6E+09	7 0E+09	7 1E+09	7 5E+09	7 8E+09	8 2E+09	8 6E+09
3	Price /KWH (if to be supplied by the IEC)	$	0 0710	0 0731	0 0753	0 0776	0 0799	0 0823	0 0848	0 0873	0 0899	0 0926	0 0954	0 0983	0 1012	0 1043	0 1074	0 1106	0 1139	0 1174	0 1209	0 1245
4	Total cost of energy (if to be supplied by the IEC) (2*3)	$	1 3E+08	1 4E+08	1 6E+08	1 9E+08	2 2E+08	1 6E+05	3 0E+08	3 5E+08	4 3E+08	5 2E+08	5 7E+08	6 1E+08	6 5E+08	6 9E+08	7 5E+08	7 9E+08	8 5E+08	9 2E+08	9 9E+08	1 1E+09
5	Total saving in energy costs (4-1)	$	-2 4E+08	8 3E+06	7 1E+07	9 0E+07	7 8E+07	-1 5E+08	1 4E+08	1 7E+08	2 6E+08	3 3E+08	3 5E+08	3 8E+08	4 3E+08	4 6E+08	5 0E+08	5 3E+08	5 7E+08	6 1E+08	6 2E+08	7 0E+08
6	NPV of saving in energy costs	$	1,409,874,708																			
7	Cost of transmission network (NPV)	$	400,000,000																			
8	Total saving in the whol elctricity system (NPV) (6-7)	$	1,009,874,708																			

*** All above costs and benefits are to local economy (PNA) , not to end users

table 4.40 Cost Benefit Analysis of Scenario 3- Case 1

Table 4.41: Optimal yearly generated power By GT and CC units –(Scenario 3- Case 2)

Year	Power generated by GT units (MW)	Power generated by CC units (MW)	Total generated Power (MW)	Power Peak demand (MW)	Continuous reserve (%)
2001	209	184	393	345.0	13.9
2002	228	200	428	375.0	14.1
2003	254	223	477	419.3	13.8
2004	286	251	537	471.6	13.9
2005	286	320	606	532.4	13.8
2006	295	391	686	602.1	13.9
2007	334	443	777	682.0	13.9
2008	387	512	899	789.5	13.9
2009	452	598	1050	921.6	13.9
2010	529	701	1230	1079.9	13.9
2011	561	742	1303	1143.5	13.9
2012	583	772	1355	1189.3	13.9
2013	607	803	1410	1237.0	14.0
2014	624	826	1450	1273.0	13.9
2015	656	868	1524	1337.5	13.9
2016	674	892	1566	1374.0	14.0
2017	706	934	1640	1439.2	14.0
2018	740	980	1720	1509.7	13.9
2019	776	1027	1803	1582.0	14.0
2020	812	1074	1886	1655.7	13.9

Table 4.42: Actual power generated each year by GT and CC units –(Scenario 3- Case 2)

Year	Total power added by GT (MW)	Total power of GT units (MW)	Total Power converted from GT to CC (MW)	Total Power of CC units (MW)	Total generated Power (MW)	Peak demand (MW)	Discrete Reserve (% of peak)
2001	6*77.44	464.6		0	464.6	345	34.7
2002		464 6		0	464.6	375	23.9
2003		310	(2*77.44)= 155	232	542	419.3	15.0
2004		310		232	542	471.6	15.0
2005		155	(2*77.44)= 155	464	619	532.4	16.3
2006	1*77.44=77.44	232.4		464	696.4	602.1	15.7
2007	2*77.44=155	387		464	851	682	24.8
2008		232	(2*77.44)= 155	696	928	789.5	17.5
2009	2*77.44=155	387		696.96	1083.96	921.6	17.6
2010	2*77.44=155	542		696.96	1238.96	1079.9	15.0
2011		387	(2*77.44)= 155	928	1315	1143.5	15.0
2012	1*77.44=77.44	464		928	1392	1189.3	17.0
2013	1*77.44=77.44	541		928	1469	1237.9	18.7
2014		541		928	1469	1273.5	15.4
2015	1*77.44=77.44	618		928	1546	1338.5	15.5
2016	1*77.44=77.44	695		928	1623	1374	18.1
2017	1*77.44=77 44	772		928	1700	1439.2	18.1
2018		618	(2*77.44)= 155	1160	1778	1509.7	17.8
2019	1*77.44=77.44	695		1160	1855	1582	17.3
2020	1*77.44=77.44	772		1160	1932	1655.7	15.0
Average reserve %							18.2

Table 4.43: Actual yearly power generated by GT and CC units for each step – (Scenario 3- Case 2)

	Step 1		Step 2		Step 3		Step 4		Step 5		Step 6		STEP 7	
Year	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC
2001	310	0	269	0	238	0	210	0	166	0	145	0	124	0
2002	338	0	292	0	259	0	229	0	180	158	158	0	135	0
2003	160	218	109	218	71	218	38	218	0	201	0	176	0	151
2004	206	218	150	218	107	218	70	218	8	218	0	198	0	170
2005	43	436	0	415	0	367	0	325	0	256	0	224	0	192
2006	106	436	33	436	0	415	0	367	0	289	0	253	0	217
2007	178	436	96	616	34	436	0	415	0	327	0	286	0	246
2008	56	654	0	654	0	545	0	482	0	379	0	332	0	284
2009	175	654	65	654	0	636	0	562	0	442	0	387	0	332
2010	318	654	188	872	91	654	4	654	0	518	0	454	0	389
2011	157	872	20	872	0	789	0	698	0	549	0	480	0	412
2012	198	872	55	872	0	821	0	725	0	571	0	500	0	428
2013	242	872	93	872	0	854	0	855	0	594	0	52	0	446
2014	274	872	121	872	6	872	0	777	0	611	0	535	0	458
2015	332	872	171	872	51	872	0	816	0	642	0	562	0	482
2016	364	872	199	872	76	872	0	838	0	660	0	577	0	498
2017	423	872	250	872	121	872	6	872	0	691	0	604	0	518
2018	268	1090	87	1090	0	1042	0	921	0	725	0	634	0	543
2019	333	1090	144	1090	1	1090	0	965	0	759	0	664	0	570
2020	400	1090	201	1090	52	1090	0	1010	0	795	0	695	0	596

Table 4.44: Actual Energy generated by GT and CC units- (Scenario 3- Case 2)

	GT (60MW)		CC (180MW)		
Year	Generated Energy (GWH)	Time of operation (Hours)	Generated Energy (GWH)	Time of operation (Hours)	Total Energy Generated (GWH)
2001	1793	7796	0	0	1793
2002	1950	7796	0	0	1950
2003	396	2353	1784	7688	2180
2004	643	3700	1809	7796	2452
2005	10	58	2758	5954	2768
2006	67	469	3063	6601	3130
2007	246	903	3300	7112	3546
2008	12	46	4092	5879	4104
2009	123	455	4667	6706	4790
2010	536	1949	5078	7297	5614
2011	61	219	5884	6341	5945
2012	116	424	6066	6537	6182
2013	177	640	6259	6745	6436
2014	235	850	6386	6818	6621
2015	416	1491	6537	7044	6953
2016	520	1849	6624	7137	7144
2017	711	2417	6770	7296	7481
2018	174	515	7674	6616	7848
2019	265	806	7959	6861	8224
2020	474	1646	8133	7011	8607
Total	**8925**	**36382**	**94843**	**123439**	**103768**

Table 4.45 gives the discounted investment cost (NPV), discounted operating costs of GT and CC units and total discounted cost (NPV).

Table 4.45: Discounted costs of Scenario 3- Case 2

Fuel : NG	Unit Capacity (MW)	Discounted investment cost (Million $)	Discounted operating cost (Million $)	Total discounted cost (Million $)
Gas Turbine	80	167.782	160.637	328.419
CC Turbine- Air Cooling system	240	566.098	672.530	1,197.476
Total		**733.880**	**792.015**	**1,525.895**
% of total		**48.1%**	**51.1%**	**100%**

Cost Benefit Analysis of Scenario 3 – Case 2

Table 4.46 presents total investment cost for each year, the total cost if energy is to be supplied by the IEC, the net benefit and the net present value for the money that will be saved if the project is to be implemented. As given in table 4.46 NPV of money that could be saved if the power plant is to be built using 80 MW GT units and 240 MW CC units is about 1,027.4 million $. Also the system will have an average reserve of about 18.2 which is a positive point for local generation planning issue.

Summary of both cases of scenario 3 is as given in table 4.47

Table 4.47: Discounted Costs of Scenario 3 (Two cases)

Fuel : NG	Case 1	Case 2
Capacity of GT (MW)	60	80
Capacity of CC (MW)	180	240
Total discounted cost (Million $)	**1,547.6**	**1,525.9**
NPV of saved money (Million $)	**1,009.9**	**1,027.4**
Average reserve %	**18**	**18.2**

As given in table 4.47 using higher capacity values of GT (80 MW) and CC (240 MW) is better than using lower values GT (60 MW) and CC (180MW) for this scenario. Also the amount of money that could be saved is higher in case 2 than in case 1of this scenario. The reason is that for this scenario the value of maximum demand is high, so using generators with higher capacity will be more economical, as the cost of generator per MW is decreased by increasing the generator output capacity. As a result for the next scenario (scenario four) which has higher power peak demand we will use GT units of 80MW unit capacity and CC units of 240MW unit capacity.

	Year		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2016	2016	2017	2018	2019	2020
1	Total invevtment cost	$	2 8E+08	1 7E+08	1 0E+08	1 5E+08	1 3E+08	1 4E+08	1 8E+08	1 9E+08	2 1E+08	2 0E+08	1 7E+08	1 8E+08	2 0E+08	2 7E+08	2 8E+08	2 7E+08	2 9E+08	2 6E+08	3 3E+08	3 4E+08
2	Total energy	KWH	1 8E+09	1 9E+09	2 2E+09	2 5E+09	2 8E+09	3 1E+09	3 5E+09	4 0E+09	4 8E+09	5 6E+09	5 9E+09	6 2E+09	6 4E+09	6 6E+09	7 0E+09	7 1E+09	7 5E+09	7 8E+09	8 2E+09	8 6E+09
3	Price /KWH (if to be supplied by the IEC)	$	0 0710	0 0731	0 0753	0 0776	0 0799	0 0823	0 0848	0 0873	0 0899	0 0926	0 0954	0 0983	0 1012	0 1043	0 1074	0 1106	0 1139	0 1174	0 1209	0 1245
4	Total cost of energy (if to be supplied by the IEC) (2*3)	$	1 3E+08	1 4E+08	1 6E+08	1 9E+08	2 2E+08	1 6E+05	3 0E+08	3 5E+08	4 3E+08	5 2E+08	5 7E+08	6 1E+08	6 5E+08	6 9E+08	7 5E+08	7 9E+08	8 5E+08	9 2E+08	9 9E+08	1 1E+09
5	Total saving in energy costs (4-1)	$	-1 5E+08	-2 4E+07	6 2E+07	3 5E+07	8 7E+07	-1 4E+08	1 2E+08	1 6E+08	2 2E+08	3 2E+08	4 0E+08	4 3E+08	4 5E+08	4 2E+08	4 7E+08	5 2E+08	5 6E+08	6 7E+08	6 7E+08	7 3E+08
6	NPV of saving in energy costs	$	1,427,358,924																			
7	Cost of transmission network (NPV)	$	400,000,000																			
8	Total saving in the whol elctricity system (NPV) (6-7)	$	1,027,358,924																			

*** All above costs and benefits are to local economy (PNA) , not to end users

Table 4.46 Cost Benefit Analysis of Scenario 3 - Cse 2

4.4.4 Automatic Generation Planning Scenario 4

Basic data

Fuel: NG
Type of generators: GT (80MW), CC (240MW)
Load duration curve (Table 4.7)
Load demand data (table 3.10)
Investment and variable costs (table 4.2)

Automatic integration of fuel costs (table 4.2), generation costs (table 4.2) and load demand (table 3.10) using PRELE gives the optimal generation solution.

Table 4.48 shows the optimal continuous solution of generated power with least cost for GT and CC units and the continuous reserve for each year. Table 4.49 presents the actual available number of GT and CC units and their total output capacity (MW) each year for scenario 4. Table 4.50 shows for each year the actual power generated per step by GT and CC units. Table 4.51 gives the actual generated energy each year by the GT and the CC units and the total actual generated energy for the period 2001-2020.

Table 4.52 gives the discounted investment cost (NPV), discounted operating costs of GT and CC units and total discounted cost (NPV).

Table 4.52: Discounted costs of Scenario 4

Fuel : NG	Unit Capacity (MW)	Discounted investment cost (Million $)	Discounted operating cost (Million $)	Total discounted cost (Million $)
Gas Turbine	80	197.8	160.6	358.4
CC Turbine- Air Cooling system	240	641.5	631.4	1,272.9
Total		**839.3**	**792.0**	**1,631.3**
% of total		**51.4%**	**49.6%**	**100%**

Cost Benefit Analysis of Scenario 4

Table 4.53 gives total investment cost for each year, the total cost if energy is to be supplied by the IEC, the net benefit and the net present value for the money that could be saved if the project is to be implemented. As given in table 4.53 NPV of money that could be saved is about 1,069.1 million $. Also the system will have an average reserve of about 18% which is a positive point for local generation planning issue.

Table 4.48: Optimal generated power By GT and CC units - Scenario 4

Year	Power generated by GT units (MW)	Power generated by CC units (MW)	Total generated Power (MW)	Power Peak demand (MW)	Continuous reserve (%)
2001	209	184	393	345	13.9
2002	228	200	428	375	14.1
2003	266	234	500	438.8	13.9
2004	311	273	584	511.9	14.1
2005	317	363	680	596.7	14.0
2006	337	447	784	688.2	13.9
2007	384	509	893	784.1	13.9
2008	428	567	995	873.2	13.9
2009	477	631	1108	972.6	13.9
2010	558	739	1297	1138.9	13.9
2011	588	779	1367	1199.7	13.9
2012	646	856	1502	1318.4	13.9
2013	683	904	1587	1392.7	14.0
2014	718	950	1668	1463.8	13.9
2015	754	998	1752	1537.4	14.0
2016	788	1042	1830	1606.2	13.9
2017	814	1077	1891	1660.1	13.9
2018	849	1123	1972	1731.2	13.9
2019	879	1163	2042	1792.6	13.9
2020	906	1200	2106	1848.5	13.9

Table 4.49: Actual power generated each year by GT and CC units- Scenario 4

Year	Total power added by GT (MW)	Total power of GT units (MW)	Total Power converted from GT to CC (MW)	Total Power of CC units (MW)	Total generated Power (MW)	Peak demand (MW)	Discrete Reserve (%)
2001	6*77.44	464.6		0	464.6	345	34.7
2002		464.6		0	464.6	375	23.9
2003		310	(2*77.44)= 155	232	542	438.8	15.0
2004	1*77.44=77.44	387		232	619	511.9	15.0
2005		232	(2*77.44)= 155	464	696	596.7	16.6
2006	2*77.44=155	387		464	851	688.2	23.7
2007		232	(2*77.44)= 155	696	928	784.1	18.4
2008	1*77.44=77.44	310		696	1006	873.2	15.2
2009	2*77.44=155	464		696.96	1160.96	972.6	19.4
2010	1*77.44=77.44	387	(2*77.44)= 155	928	1315	1138.9	15.0
2011	1*77.44=77.44	464		928	1392	1199.7	16.0
2012	2*77.44=155	618		928	1546	1318.4	17.3
2013	1*77.44=77.44	695		928	1623	1392.7	16.5
2014		540	(2*77.44)= 155	1160	1700	1463.8	16.1
2015	1*77.44=77.44	618		1160	1778	1537.4	15.6
2016	1*77.44=77.44	695		1160	1855	1606.2	15.5
2017	1*77.44=77.44	772		1160	1932	1660.1	16.4
2018	1*77.44=77.44	849		1160	2009	1731.2	16.0
2019		695	(2*77.44)= 155	1392	2087	1792.6	16.4
2020	1*77.44=77.44	772		1392	2164	1848.5	15.0
Average reserve %							**18.0**

Table 4.50: Actual yearly power generated by GT and CC units for each step – Scenario 4

	Step 1		Step 2		Step 3		Step 4		Step 5		Step 6		STEP 7	
Year	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC
2001	310	0	269	0	238	0	210	0	166	0	145	0	124	0
2002	338	0	292	0	259	0	229	0	180	0	158	0	135	0
2003	177	218	85	218	50	218	38	211	0	184	0	158	0	184
2004	243	218	181	218	135	218	0	218	28	218	0	215	0	215
2005	101	436	29	436	0	412	94	364	0	286	0	251	0	248
2006	183	436	101	436	39	436	0	420	0	330	0	289	0	282
2007	51	654	0	612	0	541	0	478	0	376	0	329	0	314
2008	132	654	27	654	0	603	0	533	0	419	0	367	0	350
2009	221	654	104	654	17	654	0	593	0	467	0	408	0	410
2010	153	872	16	872	0	786	4	695	0	547	0	478	0	432
2011	207	872	63	872	0	828	0	732	0	576	0	504	0	475
2012	314	872	165	872	37	872	0	804	0	633	0	554	0	501
2013	381	872	214	872	89	872	0	850	0	668	0	585	0	527
2014	227	1090	51	1090	0	1010	0	893	0	703	0	615	0	553
2015	294	1090	109	1090	0	1061	0	938	0	738	0	646	0	578
2016	356	1090	162	1090	18	1090	0	980	0	771	0	675	0	598
2017	404	1090	205	1090	55	1090	6	1013	0	797	0	697	0	623
2018	468	1090	260	1090	104	1090	0	56	0	831	0	727	0	654
2019	305	1308	90	1308	0	1237	0	1093	0	860	0	753	0	665
2020	355	1308	133	1308	0	1275	0	1128	0	887	0	776	0	596

Table 4.51: Actual Energy generated by GT and CC units - Scenario 4

	GT (60MW)		CC (180MW)		
Year	Generated Energy (GWH)	Time of operation (Hours)	Generated Energy (GWH)	Time of operation (Hours)	Total Energy Generated (GWH)
2001	1793	7796	0	0	1793
2002	1949	7796	0	0	1949
2003	472	2329	1809	7796	2281
2004	853	4158	1809	7796	2662
2005	60	293	3041	6554	3101
2006	262	1242	3315	7144	3577
2007	11	57	4065	5840	4076
2008	65	200	4475	6430	4540
2009	225	815	4831	6940	5056
2010	55	146	5866	6321	5921
2011	129	339	6108	6581	6237
2012	362	1648	6492	6996	6854
2013	572	1848	6668	7185	7240
2014	117	399	7492	6459	7609
2015	208	974	7784	6711	7992
2016	334	1441	8016	6910	8350
2017	486	2200	8142	7020	8628
2018	688	2774	8312	7165	9000
2019	185	274	9134	6562	9319
2020	254	343	9356	6721	9610
Total	**9080**	**37072**	**106715**	**123131**	**115795**

	Year		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1	Total invevtment cost	$	3.1E+08	1.5E+08	1.6E+08	1.2E+08	1.7E+08	1.6E+08	1.9E+08	1.9E+08	2.3E+08	2.4E+08	2.4E+08	2.3E+08	2.0E+08	2.7E+08	3.0E+08	2.9E+08	2.8E+08	3.5E+08	3.6E+08	3.6E+08
2	Total energy	KWH	1.8E+09	1.9E+09	2.3E+09	2.3E+09	3.1E+09	3.6E+09	4.1E+09	4.5E+09	5.1E+09	5.9E+09	6.2E+09	6.9E+09	7.2E+09	7.6E+09	8.0E+09	8.4E+09	8.6E+09	9.0E+09	9.3E+09	9.6E+09
3	Price /KWH (If to be supplied by the IEC)	$	0.0710	0.0731	0.0753	0.0776	0.0799	0.0823	0.0848	0.0873	0.0899	0.0926	0.0954	0.0983	0.1012	0.1043	0.1074	0.1106	0.1139	0.1174	0.1209	0.1245
4	Total cost of energy (If to be supplied by the IEC) (2*3)	$	1.3E+08	1.4E+08	1.7E+08	1.8E+08	2.5E+08	1.6E+05	3.6E+08	4.0E+08	4.5E+08	5.5E+08	6.0E+08	6.7E+08	7.3E+08	7.9E+08	8.6E+08	9.2E+08	9.8E+08	1.1E+09	1.1E+09	1.2E+09
5	Total saving in energy costs (4-1)	$	-1.9E+08	-3.2E+06	1.6E+07	5.7E+07	7.8E+07	-1.6E+08	1.6E+08	2.0E+08	2.3E+08	3.0E+08	3.6E+08	4.4E+08	5.3E+08	5.2E+08	5.6E+08	6.3E+08	7.0E+08	7.1E+08	7.6E+08	8.4E+08
6	NPV of saving in energy costs	$	1,569,085,720																			
7	Cost of transmission network (NPV)	$	500,000,000																			
8	Total saving in the whol elctricity system (NPV) (6-7)	$	1,069,085,720																			

*** All above costs and benefits are to local economy (PNA) , not to end users

Table 4.53 Cost Benefit Analysis of Scenario 4

Table 4.54 shows Summary of the four generation scenarios using NG. Table gives the total discounted cost and the NPV of the money that could be saved if the power plant project is to be implemented.

Table 4.54 Discounted costs of the four generation scenarios for West Bank for the period (2001-2020)

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Fuel	NG	NG	NG	NG
GT capacity (MW)	60	60	80	80
CC capacity (MW)	180	180	240	240
Total discounted cost over the project life (20years) **(Million $)**	**986.4**	**1,152.0**	**1,525.9**	**1,631.3**
Total money that could be saved over project life (20 years) (Million $)	**717.3**	**809.4**	**1,027.4**	**1,069.1**
Average reserve of the project life % of peak	**20.3**	**19.5**	**18.2**	**18**

Fig 4.8 shows graphs of the discounted total cost for each of the four scenarios and the amount of money that could be saved.

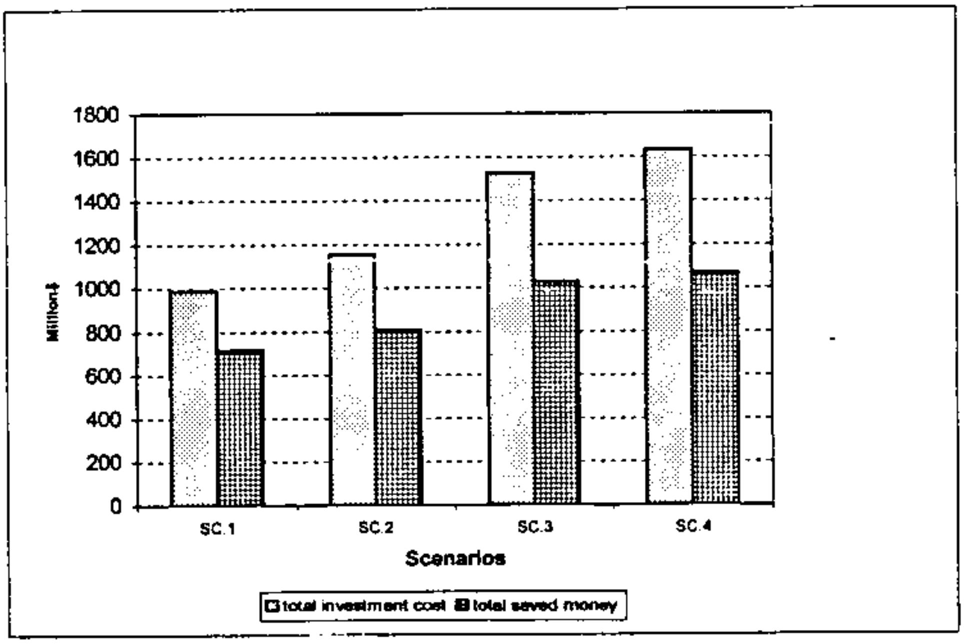

Fig.4.8 Total discounted cost and total money that could be saved for each scenario.

According to data given in table 4.54 we can say that implementing the power plant in the West Bank will save millions of US dollars over the period from year 2001 to 2020. Moreover we will have a secure reliable system of about 20 % reserve in average. Depending on cost and benefit analysis we think that it is urgent to start building this power plant so as to be independent in our power system.

Referring to the report issued by the World Bank (World Bank, 1993), where the recommendation was to continue buying electricity from IES as it is the most economic solution (according to the World Bank report). We can say without hesitate from economical and national point views that this is incorrect.

Having our own independent power plant in the West Bank will save a lot of money from one point and from another point our system reliability will be sharply improved. Moreover having our own independent power plant is a form of the national prestige, which is an aspect of the Palestinian national independent state like the airport and the power plant of in Gaza. Also this generation power plant will create thousands of job opportunities for engineers technicians and others which will increase the GDP and so will increase the community welfare.

4.5 Multi Area Reliability

Analysis carried out in this chapter was based on self-system reliability. As we proved in this analysis, in order to obtain a reliable system with a sufficient reserve, more money has to be invested. One way of reducing reserve costs is through multi area reliability. Multi area reliability is achieved through interconnection between utilities.

This technique is very important as it plays a significant role in reducing the reserve requirements of utilities, as the reliability of the connected utilities is improved by the interconnection. When other power systems have surplus capacity, through interconnection it is possible to provide this surplus to another in need utility. Interconnection principle proved to work well in the case of having diversity of outage and load demand between utilities. Having a diversity of outage and load demand between utilities make it possible to sell energy to a utility in need with lower prices than of peak price. Multi area reliability analysis is based on a transportation model of the interconnection.

This type of interconnection is specified as having a fixed megawatt transfer limit. The actual transfer limit is dependent on several factors including transmission network characteristics as what called the pooling effect, configuration, system load demand and power output of the generating units on line.

Multi area calculation using the transportation model proceeds by calculating the cumulative outage probability for each utility or area. The outage probability of each area is then convoluted to compute the outage probability table of one utility connected to another

As for the West Bank there are two possibilities of interconnection. First is the local interconnection with Gaza. This is a possible interconnection as both areas are considered as two different electricity systems. Second possibility is the regional interconnection.

Regional interconnection can be achieved through the suggested projects of interconnection between Palestine, Jordan, Egypt and Israel or through the regional interconnection of Jordan, Egypt, Turkey, Iraq and Syria. The interconnection between Jordan, Egypt, Palestine and Israel if it will implemented our system reliability will be improved taking into account that there is a peak shift between Palestine and Israel due to different week ends and different religious celebrations timing.

4.6 Fuel Uncertainty

Fuel uncertainty is one of the serious problems that face power planners. Fuel uncertainty problem may be cost uncertainly problem or availability uncertainty problem.

According to Cost benefit analysis carried out in this chapter, total operation cost which is mainly due to fuel cost is about 50 % of total power plant cost for gas fired and around 60% of the total cost for GO and HF fired plants. As a result uncertainty in fuel will have the significant part of total plant cost. In order all times to have the least-cost power plant we should use the least-cost fuel, that is the natural gas if it is available.

One way to overcome fuel uncertainty is through using a conversion generation technique. This conversion technique is based on running the power plant using the available fuel and later on when the least-cost fuel is available generators will be converted to use this new low cost fuel. This conversion process costs money but the expected money to be saved when using the least-cost fuel is expected to be more. According to PEA the power plant in Gaza will use this technique, as first it will use heavy fuel and later on it will convert to use natural gas when it is available.

This flexibility in conversion from one fuel type to another is a good recommended solution for the uncertainty in fuel prices and fuel availability.

It was found as shown in table 4.53 that for the period (2001-2020), costs of building and running the proposed power plant in the West Bank may range from 986 million $ for scenario 1 to 1631 million $ for scenario 4. This amount of money is very high taking into consideration that our economy is a weak one.

As a result it is the responsibility of power system planners to put strategies and adopt programs that can reduce power plant costs in order to decrease the burden on the local economy.

One way of decreasing investment and operation costs of the power plant is through reducing peak power demand and changing patterns of energy consumption.

The best least-cost way of achieving this is through energy efficiency, load management, and demand side management (DSM) programs. This will be our aim in chapter 5, in which we will discuss in more details the DSM program in terms of, definition, objectives, applications and benefits.

Chapter 5

Demand Side Management (DSM) Program

5. Demand Side Management (DSM)

Analysis carried out and results obtained in chapter 4 gave us an indication that establishing a new power plant in the West Bank will cost hundreds of millions of dollars for the next 20 years. This mount of money is considered to be very high for a weak economy like that of the West Bank. As a result it is urgent to take actions to reduce energy consumption and peak power demand to what degree possible. This is possible through adopting load management and conservation programs. One of these programs is a demand side management program (DSM).

DSM involves planning and implementation of cooperative activities that purposely designed to influence consumer's use of electricity in ways that will produce desired changes in the load shape (i.e., changes in the pattern and magnitude of load). Opportunities of DSM can be found in all consumer classes including residential, commercial, industrial, agricultural and wholesale .DSM alternatives should be specially considered by those who are involved with ambitious construction programs, those with high reserve margins and those facing high marginal costs. DSM program is a partnership between the utility and the consumers. The utility designs and offers programs to customers who decide whether or not to participate. Moreover DSM is one of the key variables in determining the load demand growth.

5.1 Why Consider DSM?

As known the dramatic increase in the uncertainty of key variables in the planning process is one of the most fundamental changes affecting electric utility plans. Due to these uncertainties there is a need for adopting a DSM program. DSM is not a cure-all for these changes but on the other hand it provides utility management with many additional problem-solving alternatives. For example load management and strategic conservation represents an effective means to reduce or postpone construction or purchase of new generation sources. Also it is a strong tool to reduce cost of purchased power during peak demand. It can also improve the load characteristics and optimize the reserve margin or power pooling arrangements. Aside from these DSM can reduce the load demand growth and so forth operating costs and the capita expenses for energy infrastructure and save consumers money.

Moreover energy efficiency and load management can reduce local environmental impacts due to reducing gas emissions .To the extent the DSM programs can help in making balance between supply and demand.

Applying DSM program in the West Bank is necessary for the following reasons:

1. Our electricity system faces a lot of uncertainty variables, demographic, economic, political and others.

2. Energy consumption and maximum demand growth are expected to grow rapidly in the West Bank during the next 20 years.

3. Our system load factor is low, less than 60% (fig. 3.12, chapter 4), and is expected to decrease due to expected high rate of immigration to the West Bank. This low value of L.F indicates that there is a room for integrated DSM activities.

4. Our economy is weak. Implementing the DSM program can postpone the need for new high cost generation units. Also DSM program can reduce the peak demand, which will reduce the cost of generated or purchased power.

5. We still completely buy energy from the IEC with high and increasing prices.

6. Low energy efficiency for most industrial projects in the West Bank, as they still use inefficient equipment.

7. Environmental issues. DSM program through using efficient equipment and through reducing the generation capacity helps in reducing gas emissions and so reducing pollution.

5.2 DSM Objectives

DSM program should have the following operational objectives.

- Minimize utility and consumer costs
- Increase system reliability
- Defer the need for generating units
- Reduce critical fuel dependency
- Minimize cost of purchased power
- Protect the environment through reducing gas emissions.

5.3 Structure of the DSM Program.

In the West Bank we strongly recommend adopting the DSM programs in all end uses mainly in the residential, commercial, agricultural and industrial sectors. In order to have a successful DSM, it should be carried out according to the following sequence steps.

- First step is to determine the current load curve (peak, base, load factor)

- Second step is selecting the load shape objectives, which is an important step in DSM activity. Choosing the best load shape objective depends mainly on the load shape problems, for example if the peak is very high, the peak clipping is the best choice, while if the base load is low the valley filling objective would be the solution.

The most popular combinations of load shapes that can be achieved are as follows:

1. Peak clipping, which is the reduction of the system peak loads. It is one form of load management. Peak clipping is achieved by direct load control of customer appliances.
2. Valley filling, this is another form of load management which means building off-peak loads. It is particularly desirable where long –run incremental cost is less than the average price of electricity. Adding properly priced off peak load decreases the average price.

3. Load shifting, this involves shifting load from on peak to off peak periods. It is achieved mainly by indirect load control through adopting pricing policy.

4. Conservation, this modification in the load shape involves reduction in sales as well as change in the pattern of uses.

In the West Bank since our energy situation is unstable, the load shape suffers from high peak, low base, low load factor and high-energy losses, any one - or a combination- of the four listed objectives could be applied.

- Once the load shape objective is achieved next is to have the needed data available. Data should include the major end uses (i.e. residential, commercial, industrial...) to be studied and to determine specified minor end uses within each major end use (i.e. space heating & cooling, cooking ...for residential, lightening, power factor correction for industrial and so on.).

- Fourth step is to determine types of technologies to be used for each end use to achieve the load shape objectives. Technologies could be direct or indirect control of the load, using efficient or /and thermal storage equipment.

- Final step in this process is to use the best possible methods that help implementing the DSM activities. Best methods include alternative pricing policies, advertising and promotion, direct contact and communication with the customers about the DSM program. Direct contact should emphasize on consumers' education through helding programs for customers so as to promote general consumer awareness of the program and to encourage them implementing it.

The systematic structure of the DSM program is as illustrated in fig 5.1. Fig 5.2 Shows each load objective and possible end uses that can achieve this objective. Fig 5.3 shows each end use and possible relevant technologies that could be used with each end use. In the West Bank we believe that the implementation of the DSM should start with the industrial and commercial sectors, as the response is expected to be better than in the residential sector.

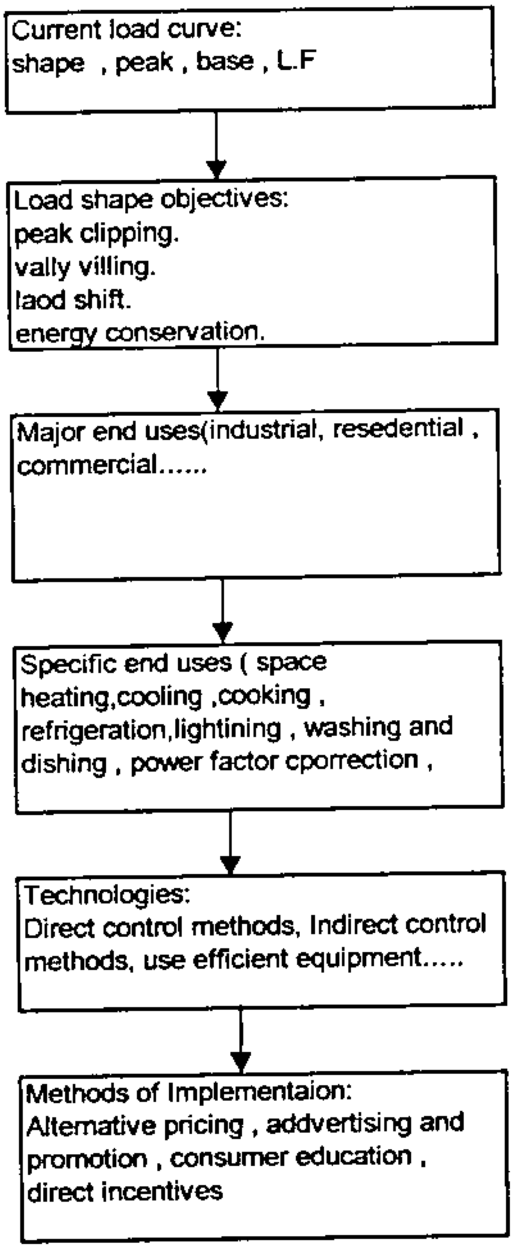

Fig 5.1 Structure of DSM Program.

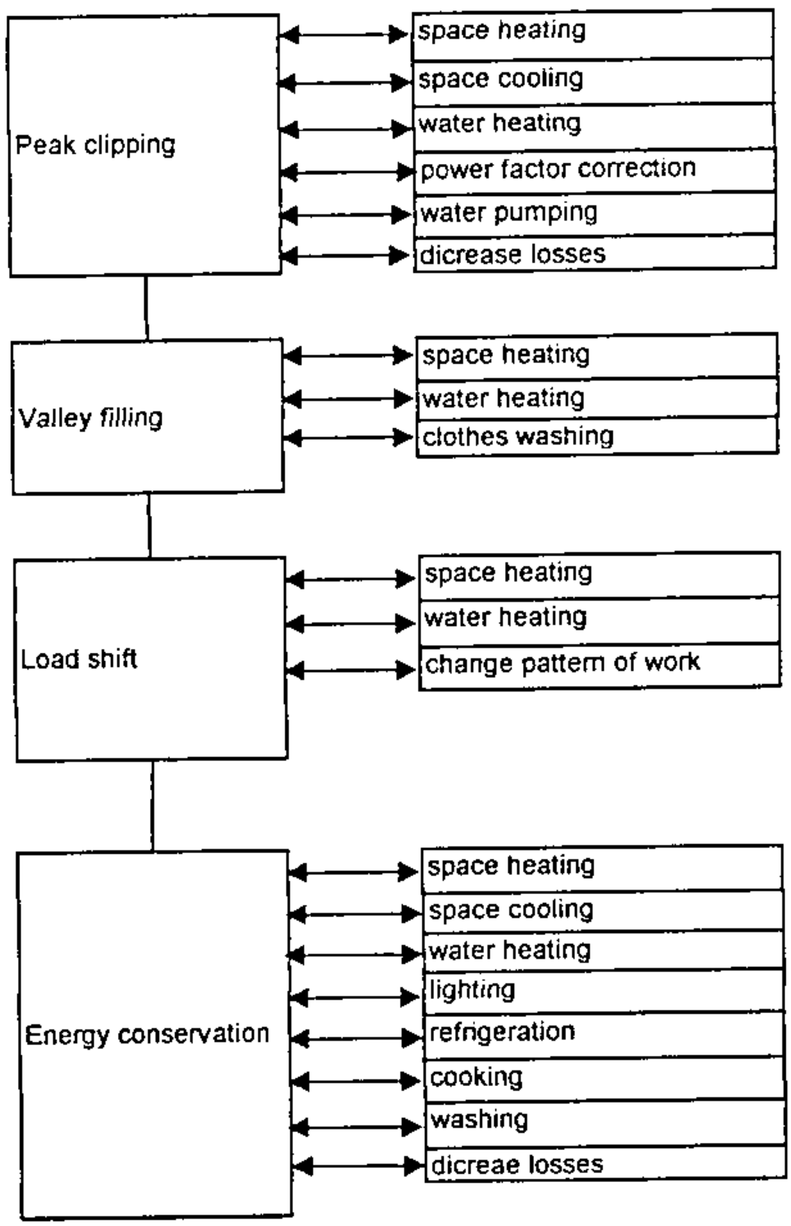

Fig 5.2:Load shape objectives of DSM program versus end uses.

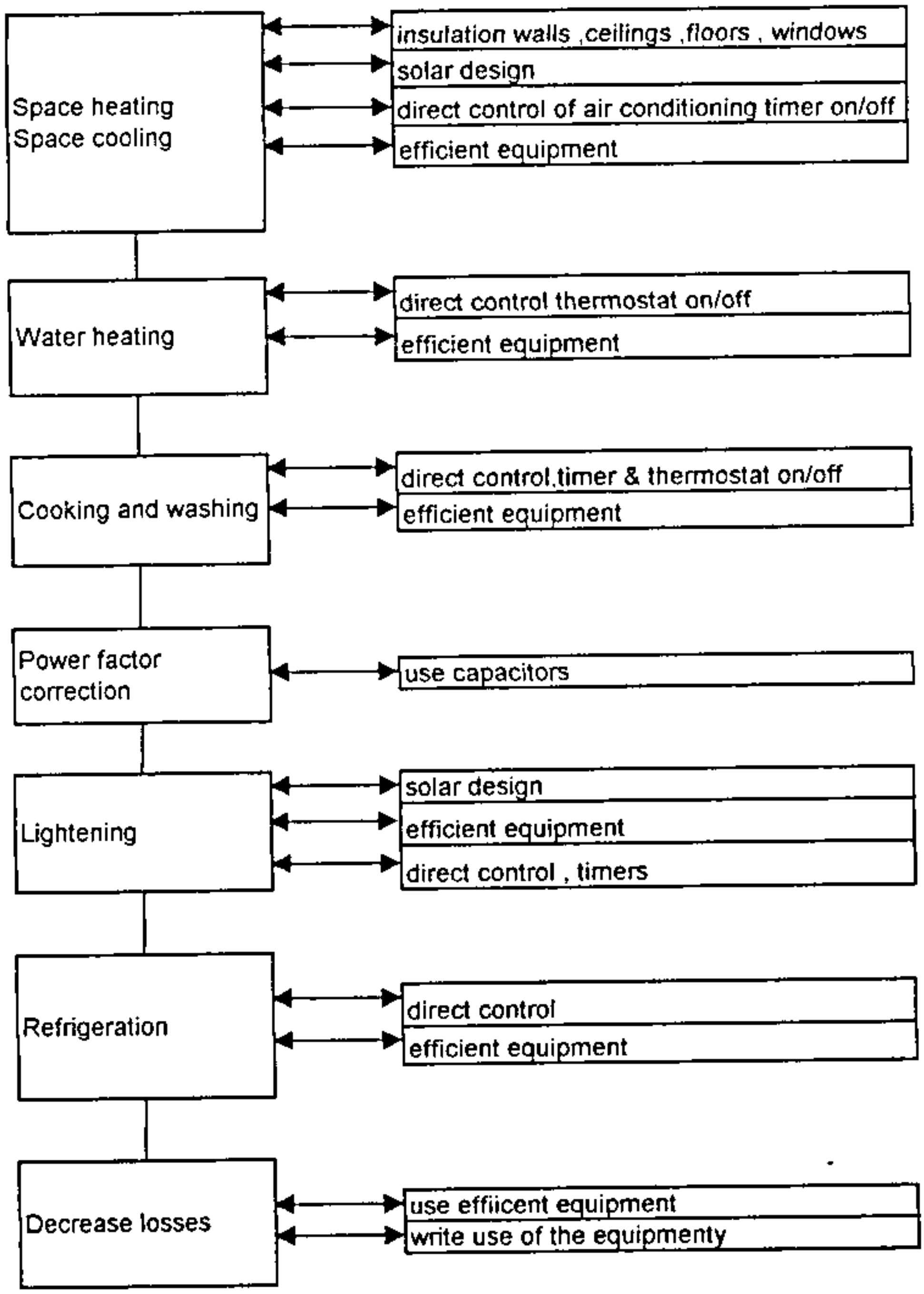

Fig 5.3 End uses of DSM program versus Technologies

5.3.1 Alternative Pricing Policy

Electricity is like any other service in which a customer performs an economic analysis to assess the quantity of electricity consumption as a function of price. If electricity price is high, customers may reduce their electricity consumption and on the other hand if price is low customers may increase their electricity consumption. In order to implement the DSM program properly in the West Bank we should try to overcome the above obstacles by offering advertising to consumers, which will encourage them to implement the program. One important action to overcome these obstacles is through putting alternative pricing policy.

Pricing policy is known as an indirect load control method. It is a key factor in DSM and energy efficiency programs. It focuses on providing customers with price signals as incentives to change their electricity usage pattern. The price signals may be one of the following rates:

- Time of use rates, variable rates can be used with higher per unit cost for peak periods and lower for off peak periods.

- Seasonal rates, seasons like humid summer with high peak due to cooling and winter with high peak due to heating will be with higher rates due to peak while other seasons will be with lower rates.

- Conservation rates, customers using efficient equipment, such as capacitors to correct power factor will pay lower costs.

- Environmental (pollution) rates, customers increase pollution or threaten the environment should pay higher rates and those protect environment should pay less.

Implementing pricing policy requires a well –designed rates tariff structure as well as customer metering capable of measuring the tariff-billing component. For industrial and commercial customers the cost of such metering will be low compared to the over all cost of electricity, so this technique will be accepted by them while for residential customers the cost of such meters for the first time will be high compared to the over all cost of electricity, as a result the acceptance for the program with the residential customers is expected to be less.

5.3.2 Obstacles for Implementing the DSM Program in the West Bank

Like other third world developing countries, applying the DSM programs in the West Bank may face a lot of obstacles for the following reasons:

- Lack of information about the efficient equipment
- High first cost of high efficient equipment
- High duty costs on efficient equipment
- Low return on investment (long pay back period)
- Lack of knowledge about energy management
- Lack of interest due to the absence of pricing policy
- Absence of incentives and motivations
- Absence of local standards for energy consumption equipment.

5.4 Cost Benefit Analysis of Applying the DSM Program in the West Bank.

Costs will be due to additional equipment to be installed on the customer site for controlling demand in direct load control and special metering system in indirect load control. Some times as in load shifting objective implementation of the DSM costs no more than changing the pattern and time of energy consumption.

To examine the economic benefit of the DSM program in the West Bank we discussed two load objective cases. First case is applying the peak clipping DSM technique to the load curve of the West Bank. Second case is applying the load shift technique. In order to calculate the economic benefit of the DSM we compared the generation cost of the power plant before and after implementing the DSM program to estimate the a mount of money that could be saved.

5.4.1 Peak Clipping Technique

For this case we used data of scenario 2 – (case 1) of chapter 4. We assumed that the peak power demand will be clipped by 5% by using DSM program through adopting methods shown in fig 5.1.

As expected peak clipping will change the load curve shape. New load duration curve of year 2001 after peak clipping is as shown in fig 5.4. For load duration curve of fig 5.4, the step duration curve was drawn as shown in fig 5.5. Table 5.1 shows the new peak power values up to year 2020 after peak clipping. Table 5.2 shows the peak of each step in MW, height of each step (% of peak) and load duration in hours of the load step curve (fig 5.5).

Comparing the load duration step curve before clipping (table 4.2) with the load duration step curve after clipping (table 5.2) shows that after peak clipping the duration time of base steps (steps 6 and 7) increased while duration time of peak steps (1&2) decreased.

To calculate the effect of peak clipping on power system we will analyze the automatic generation after clipping and compare it with original case (case 0) before clipping. Data to be used for analysis is that of scenario 2 (case 1) of chapter 4.

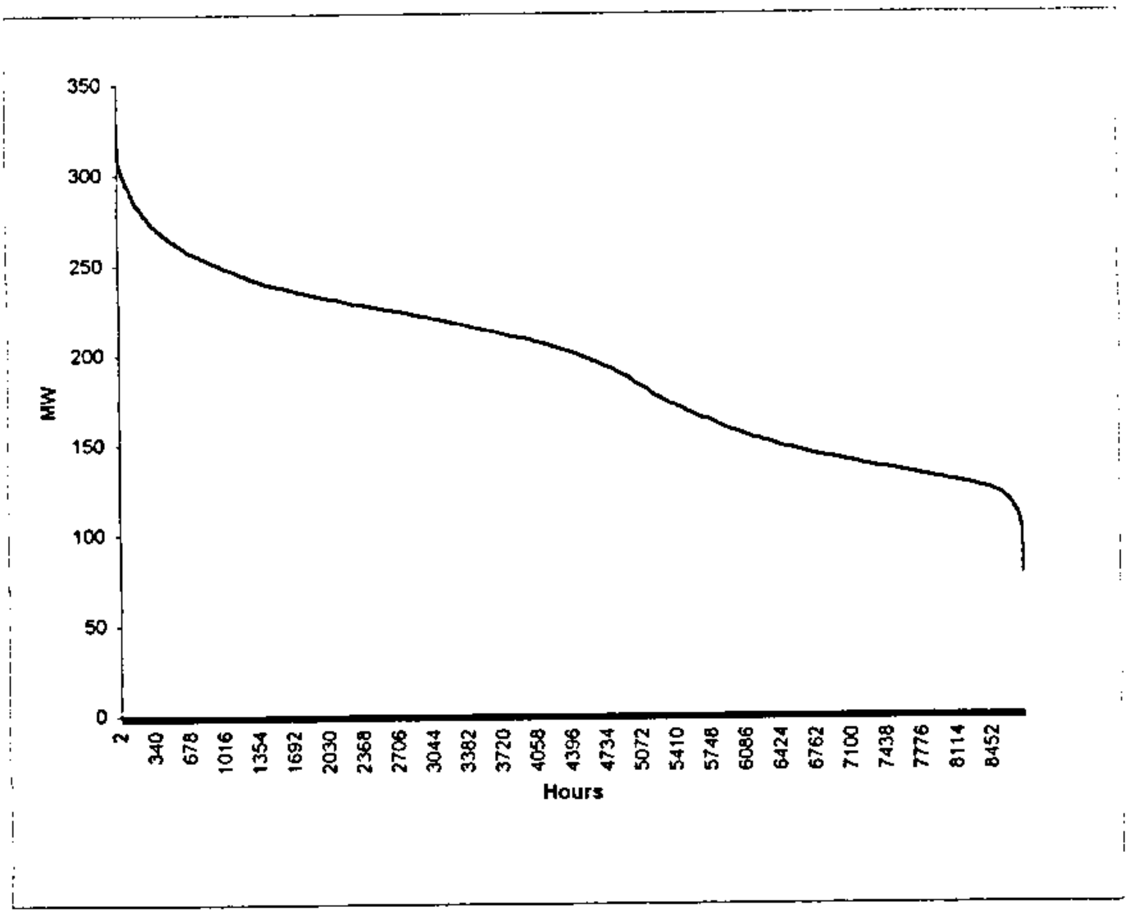

Fig 5.4:Load duration curve of the West Bank (year 2001) after 5% peak clipping

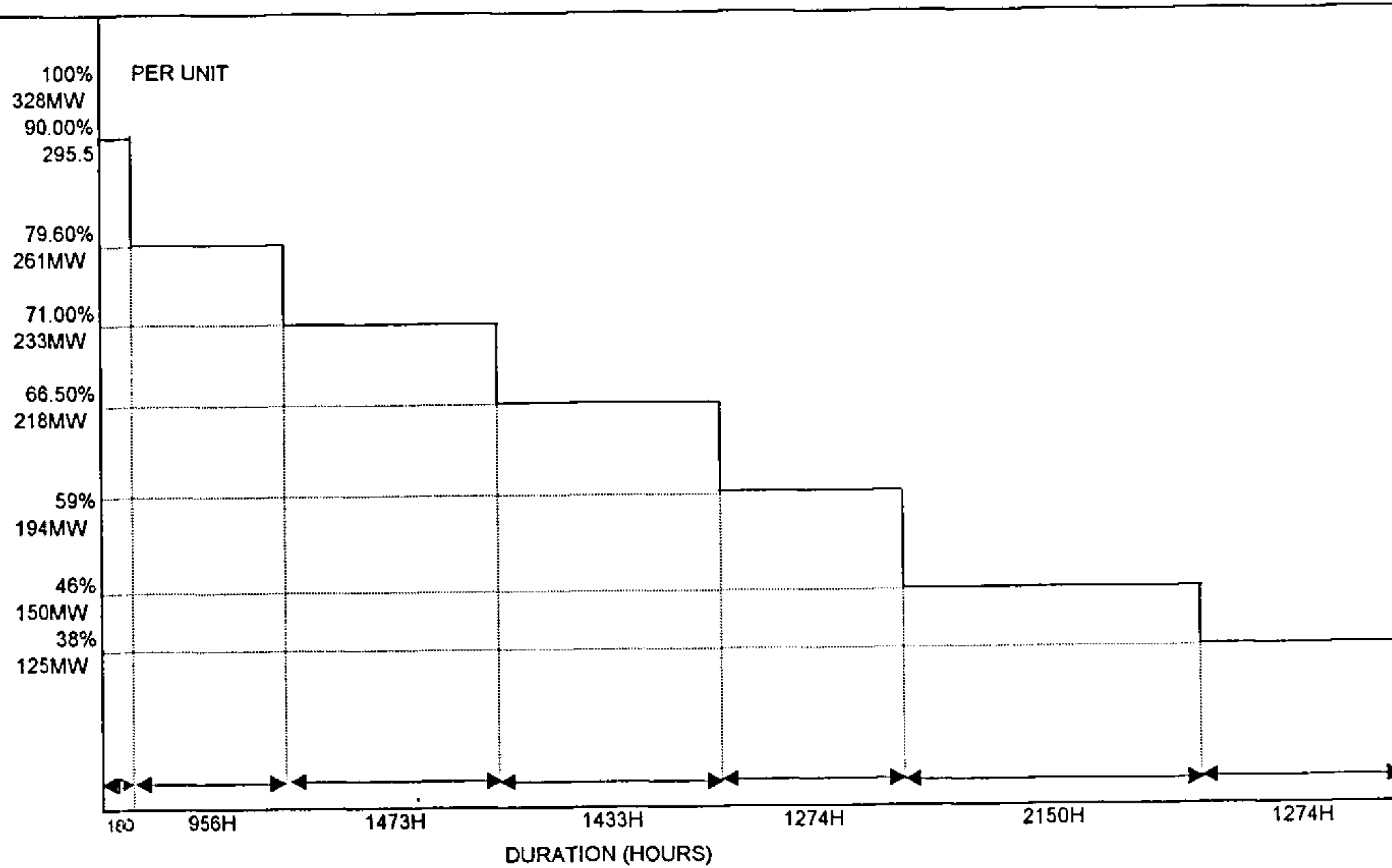

Fig 5.5: Step duration curve of the West Bank (Year 2001) after 5% Peak clipping

Table 5.1: Peak power demand of the West Bank due to 5% peak clipping.

Year	Peak demand before clipping (MW)	Peak demand after clipping (MW)
2001	345	328
2002	372.5	353.9
2003	404.6	384.5
2004	439.1	417.2
2005	475.24	451.5
2006	507.8	482.4
2007	542.7	515.6
2008	584.5	555.3
2009	631.6	600.0
2010	679.9	645.9
2011	710.9	674.5
2012	737.5	700.5
2013	772.1	733.5
2014	803.1	763.0
2015	832.2	790.5
2016	864.37	821.2
2017	882.4	838.2
2018	927.3	881.0
2019	965.5	917.2
2020	1004	953.8

Table 5.2: Step duration data of Load duration curve (year 2001) after peak clipping.

No of step	Peak of each step (MW)	Height of each step (% of Peak)	Duration of step (hours)
1	296	90	180
2	261	80	956
3	233	71	1473
4	218	67	1433
5	194	59	1274
6	150	46	2150
7	125	38	1294

For this case 60MW GT units and 180MW CC units will be used, NG will be used as fuel. Investment costs of power plant is as given in table 4.2

Automatic generation planning after peak clipping was carried out using PRELE software. Table 5.3 presents the actual available number of GT and CC units and their total output capacity (MW) each year. As given in table 5.3 the combination of generators will be 7 GT and 4 CC units. While before peak clipping (table 4.17) we had 5 GT and 5 CC units. As illustrated in table 5.3 over the project life, after peak clipping, number of GT units increased by two, while number of CC units decreased by one unit. Since each CC unit equals 2 GT units plus one steam unit, so after clipping we will save the cost of the steam unit.

Table 5.4 shows the actual power generated by GT and CC units for each step. As shown in table 5.4 for year 2002 we will not use the CC units as the GT units will cover the load. This is an advantage for the DSM program, where it defers the need for generating units or delay adding new generating units. Table 5.5 shows the actual generated energy each year by the GT and the CC units and total actual generated energy. Table 5.6 gives the investment cost, operating cost and total cost of the system after peak clipping.

Table 5.6: Discounted generation costs after peak clipping.

Fuel : NG	**Unit Capacity (MW)**	**Discounted investment cost (Million $**	**Discounted operating cost (Million $)**	**Total Discounted cost (Million $)**
Gas Turbine	60	166.299	178.278	344.577
CC Turbine-Air Cooling.	180	356.985	387,053	744.038
Total		**523.284**	**565.331**	**1,088,615**
% of total		**48.0 %**	**52.0 %**	**100 %**

Technical Comparison between generation results before clipping (table 4.19) and after peak clipping (table 5. 3) is as shown in table 5.7.

Table 5.7: Energy generated before and after peak clipping.

Fuel : NG	**Energy Before clipping (GWH)**	**Energy generated after clipping (GWH)**	**Time of operation before clipping (Hour)**	**Time of operation after clipping (Hour)**
Gas Turbine – (60MW)	4841	9253	967	41416
CC Turbine- Air Cooling (180 MW)	65176	56805	126910	125066
Total	**70017**	**66058**		

Table 5.3: Actual power generated each year by GT and CC units - Scenario 1(peak clipping)

Year	Total power added by GT (MW)	Total power of GT units (MW)	Total Power converted from GT to CC (MW)	Total Power of CC units (MW)	Total generated Power (MW)	Peak demand (MW)	Discrete Reserve (%)
2001	7*58.08=406.7	406.7		0	406.7	328	24.0
2002		406.7		0	406.7	354	15.0
2003		290.4	(2*58.08)= 116.16	174.24	464.64	384.4	15.0
2004	1*58.08=58.08	348.48		174.24	522.72	417.1	25.3
2005		348.48		174.24	522.72	451.5	15.8
2006		232.32	(2*58.08)= 116.16	348.48	580.8	482.4	20.4
2007	1*58.08=58.08	290.4		348.48	638.88	515.6	23.9
2008		290.4		348.48	638.88	555.3	15.1
2009	1*58.08=58.08	348.48		348.48	696.96	600	16.2
2010		232.32	(2*58.08)= 116.16	522.72	755.04	645.9	16.9
2011	1*58.08=58.08	290.4		522.72	813.12	674.5	20.6
2012		290.4		522.72	813.12	700.6	16.1
2013	1*58.08=58.08	348.48		522.72	871.2	733.5	18.8
2014	1*58.08=58.08	406.7		522.72	929.42	763	21.8
2015		406.7		522.72	929.42	790.5	17.6
2016	1*58.08=58.08	464.78		522.72	987.5	821	20.3
2017		464.78		522.72	987.5	838.2	17.8
2018		348.62	(2*58.08)= 116.16	696.96	1045.58	880.9	18.7
2019	1*58.08=58.08	406.7		696.96	1103.66	917.2	20.3
2020		406.7		696.96	1103.66	953.8	15.7
Average reserve %							**18.8**

Table 5.4: Actual yearly power generated by GT and CC units for each step- Scenario 1(peak clipping)

Year	Step 1		Step 2		Step 3		Step 4		Step 5		Step 6		STEP 7	
	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC
2001	295	0	262	0	233	0	220	0	197	0	177	0	157	0
2002	319	0	283	0	251	0	237	0	212	0	191	0	170	0
2003	182	164	144	164	109	164	94	164	67	164	44	164	21	164
2004	211	164	170	164	133	164	116	164	87	164	61	164	37	164
2005	243	164	197	164	157	164	139	164	107	164	80	164	53	164
2006	107	327	59	327	15	327	0	323	0	289	0	260	0	232
2007	137	327	85	327	39	327	18	327	0	309	0	278	0	247
2008	173	327	117	327	67	327	45	327	0	327	0	300	0	267
2009	213	327	158	327	99	327	75	327	33	327	0	324	0	288
2010	91	491	26	491	0	459	0	433	0	388	0	349	0	310
2011	116	491	49	491	0	479	0	452	0	405	0	364	0	324
2012	140	491	70	491	7	491	0	469	0	420	0	378	0	336
2013	169	491	96	491	30	491	1	491	0	440	0	396	0	352
2014	196	491	120	491	51	491	21	491	0	458	0	412	0	366
2015	221	491	142	491	71	491	39	491	0	474	0	427	0	379
2016	248	491	166	491	92	491	59	491	2	491	0	443	0	394
2017	264	491	180	491	104	491	71	491	12	491	0	453	0	402
2018	139	654	50	654	0	625	0	590	0	529	0	476	0	423
2019	171	654	80	654	0	651	0	615	0	550	0	495	0	440
2020	204	654	109	654	23	654	0	639	0	572	0	515	0	458

Table 5.5: Actual Energy generated by GT and CC units, For Scenario 1(peak clipping)

	GT (60MW)		CC (180MW)		
Year	Generated Energy (GWH)	Time of operation (Hours)	Generated Energy (GWH)	Time of operation (Hours)	Total Energy Generated (GWH)
2001	1692	7796	0	0	1692
2002	1826	7796	0	0	1826
2003	626	3054	1357	7796	1983
2004	795	4003	1357	7796	2152
2005	972	4795	1357	7796	2329
2006	100	519	2388	6861	2488
2007	192	869	2467	7089	2659
2008	310	1480	2554	7340	2864
2009	475	2270	2620	7529	3095
2010	43	213	3288	6299	3331
2011	70	295	3409	6530	3479
2012	105	465	3509	6722	3614
2013	172	497	3612	6919	3784
2014	258	822	3677	7044	3935
2015	339	1542	3738	6738	4077
2016	429	1934	3806	7291	4235
2017	483	1863	3839	7355	4322
2018	76	364	4467	4467	4543
2019	111	278	4620	6683	4731
2020	179	561	4740	6811	4919
TOTAL	**9253**	**41416**	**56805**	**125066**	**66058**

As given in table 5.7 energy generated by GT units increased from 4841GWH to 9253 GWH and also their operation time increased from 967 hours to 41406 hours. Energy generated by CC units decreased from 65176 to 56805. In total energy generated by the power plant decreased from 70017 to 66022 GWH.

The explanation for the increase in GT generated energy and the decrease in CC generated energy is due to peak clipping, where the maximum demand decreased. As a result and as given table 5.3 there will be no need to add CC units in year 2002, as GT units will cover the load and the reserve, while before peak clipping (table 4.19) CC units will be started in 2002.

Because of the delay in putting the CC units in service, GT units are forced to work more time. As a result the combination of GT and CC units is changed to 7 GT and 4 CC units (table 5.6) after peak clipping, while before peak clipping it was 5 GT and 5 CC units (table 4.17).

From environmental point view, since total energy generated is decreased after peak clipping therefore, the mount of pollution either gas or water pollution will also be decreased, which is an advantage for the DSM and energy conservation programs.

Due to the decrease in power demand and energy generated after peak clipping we expect that total cost will also decrease. Economic comparison between the case before peak clipping (table4.22) and after peak clipping (table 5.6) is as shown in Table 5.8

Table 5.8: Discounted generation costs before and after peak clipping

Fuel : NG	Discounted investment cost before clipping (Million $)	Discounted investment cost after clipping (Million $)	Discounted operating cost before clipping. (Million $)	Discounted operating cost after clipping (Million $)	Total cost before clipping (Million $)	Total cost after clipping (Million $)	Net Benefit (T. Cost Before clipping Minus T.Cost after) (Million $)
Gas Turbine	126.657	166.299	105.679	178.278	232.336	344.577	
CC units	455.886	356.985	463.693	387.053	919.579	744.038	
Total	**582.543**	**523.284**	**569.372**	**565.331**	**1,151.915**	**1,088.615**	**63.300**

Data shown in table 5.8 can be explained as follows:

- Investment cost in GT units increased (126.7 to 166.3 Million $), this is because number of GT units increased from 5 units before peak clipping to 7 units after peak clipping.

- Investment cost in CC units decreased (455.9 to 356.9 Million $), this is because number of CC units decreased from 5 to 4 after peak clipping.

- Operation cost of GT units increased (178.3 to 232.3 Million $), this is because the total operation time and total generated energy of GT units increased (table 5.7).

- Operation cost of CC units decreased (919.6 to 744.0 Million $), this is because the total operation time and total generated energy of CC units decreased (table 5.7).

- All in all, total cost of the plant decreased from (1,152 to 1,088 Million $), this is because the decrease in the cost of CC units was more than the increase in the cost of GT units. As after peak clipping we add tow GT units and cancel 1 CC unit. Since 1 CC equals 2 GT plus steam unit, so after peak clipping we save the cost and the operation of the steam turbine.

- In total, the net benefit (NPV) of the applying the DSM program (peak clipping by 5%) is around 63.3 Million $. This means that if the peak is clipped by more than 5% the amount of money to be saved will be more.

5.4.2 Load Shift Technique

A sensitive case for power generation is when applying load management technique by displaying the certain hours of peak load to the off-peak load periods for each day .It is assumed that the load shift decreases the peak load while maintaining the total system energy. Therefor optimally, this reduces the need for more generators.

Same as case one (peak clipping), load shift technique was applied to data of scenario 2 (case 1) of chapters 4. For this scenario, Load shift was achieved by reducing (clipping) the peak by 5% and increasing the base by a certain value while keeping generated energy the same. Peak values will be same as in table 5. 1. Step duration curve after load shift is as shown in fig 5.6.

Table 5.9 shows step values (Peak (MW), height and duration (hours) of the load duration curve after load shift.

Table 5.9: Step duration data of Load duration curve of year 2001 after peak clipping

No of step	Peak power of each step (MW)	Height of the step (%)	Duration of the step (Hours)
1	296	90	180
2	262	80	956
3	233	71	1473
4	220	67	1433
5	197	60	1274
6	177	54	2150
7	157	48	1274

To evaluate the effect of load shift on power system we analyzed automatic generation after load shift and compared it with the case before load shift. Data to be used for analysis is that of scenario 2 (case 1) of chapter 4. For this case 60MW GT and 180MW CC units are used, NG is used as fuel. Investment costs of power plant is as given in table 4.2. Automatic generation after load shift was carried out using PRELE program.

Table 5.10 presents the actual available number of GT and CC units and their total output power capacity each year. Table 5.11 shows the actual power generated by GT and CC units for each step. Table 5.12 gives the actual generated energy each year by GT and the CC units and the total actual generated energy. Table 5.13 shows the discounted investments operation and total costs after load shift.

Table 5.13: Discounted generation costs after load shift

Fuel : NG	**Unit Capacity (MW)**	**Discounted investment cost (Million $)**	**Discounted operating cost (Million $)**	**Total cost (Million $)**
Gas Turbine units	60	166.299	195.019	361.318
CC units – Air Cooling	180	356.985	408.076	765.061
Total		**523.284**	**603.095**	**1,126.379**
% of total		**46.4 %**	**53.6 %**	**100 %**

As given in tale 5.13 the combination of generators after load shift will be 7 GT and 4 CC generators, while before load shift (table 4.17) we have 5 GT and 5 CC units. So of the project life number of GT units will increase by 2 units while number of CC units will decrease by 1 unit Since each CC unit equals 2 GT units plus one steam unit, this means that for the second case (after load shift) we will save the price of the steam unit.

Technical Comparison of energy generated before load shift (table 4.17) and after load shift (table 5.13) is as shown in table 5. 14.

Table 5.14: Energy generated before and after load shift.

Fuel : NG	**Energy Before load shift (GWH)**	**Energy generated After load shift. (GWH)**	**Time of operation after load shift (Hour)**	**Time of operation after load shift (Hour)**
Gas Turbine - (60MW)	4841	9939	967	48696
CC Turbine- Air Cooling (180 MW)	65176	60076	126910	133747
Total	**70017**	**70015**		

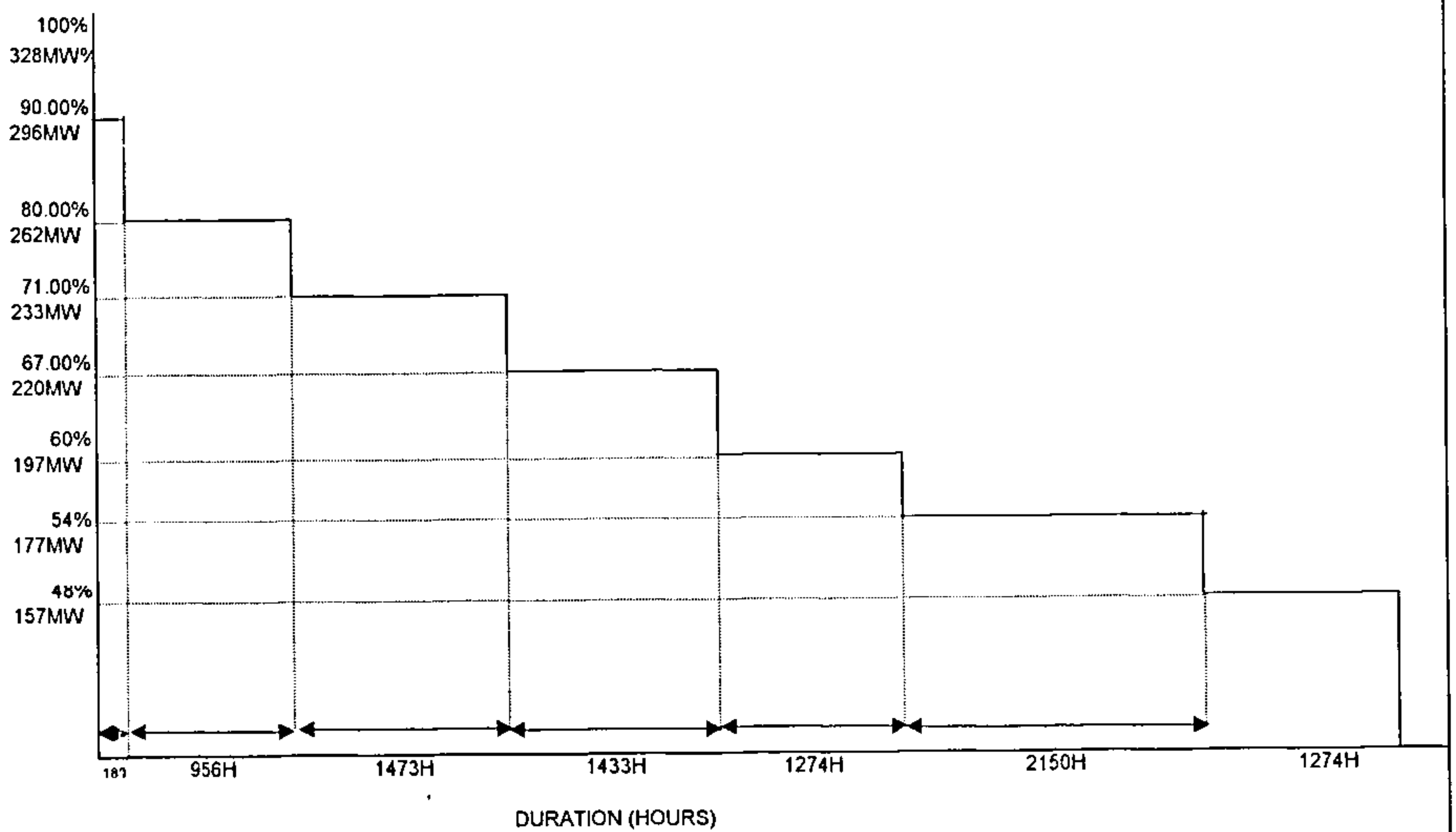

Fig 5.6: Step duration curve of the West Bank (year 2001) after load shift

Table 5.10: Actual power generated each year by GT and CC units - Scenario 2(Load shift)

Year	Total power added by GT (MW)	Total power of GT units (MW)	Total Power converted from GT to CC (MW)	Total Power of CC units (MW)	Total generated Power (MW)	Peak demand (MW)	Discrete Reserve (%)
2001	7*58.08=406.7	406.7		0	406.7	328	24.0
2002		406.7		0	406.7	354	15.0
2003		290.4	(2*58.08)= 116.16	174.24	464.64	384.4	15.0
2004	1*58.08=58.08	348.48		174.24	522.72	417.1	25.3
2005		348.48		174.24	522.72	451.5	15.8
2006		232.32	(2*58.08)= 116.16	348.48	580.8	482.4	20.4
2007	1*58.08=58.08	290.4		348.48	638.88	515.6	23.9
2008		290.4		348.48	638.88	555.3	15.1
2009	1*58.08=58.08	348.48		348.48	696.96	600	16.2
2010		232.32	(2*58.08)= 116.16	522.72	755.04	645.9	16.9
2011	1*58.08=58.08	290.4		522.72	813.12	674.5	20.6
2012		290.4		522.72	813.12	700.6	16.1
2013	1*58.08=58.08	348.48		522.72	871.2	733.5	18.8
2014	1*58.08=58.08	406.7		522.72	929.42	763	21.8
2015		406.7		522.72	929.42	790.5	17.6
2016	1*58.08=58.08	464.78		522.72	987.5	821	20.3
2017		464.78		522.72	987.5	838.2	17.8
2018		348.62	(2*58.08)= 116.16	696.96	1045.58	880.9	18.7
2019	1*58.08=58.08	406.7		696.96	1103.66	917.2	20.3
2020		406.7		696.96	1103.66	953.8	15.7
Average reserve %							**18.8**

Table 5.11: Actual yearly power generated by GT and CC units for each step- Scenario 2(Load shift)

	Step 1		Step 2		Step 3		Step 4		Step 5		Step 6		STEP 7	
Year	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC	Power generated (MW) by GT	Power generated (MW) by CC
2001	295	0	262	0	233	0	220	0	197	0	177	0	157	0
2002	319	0	283	0	251	0	237	0	212	0	191	0	170	0
2003	132	164	144	164	109	164	94	164	67	164	44	164	21	164
2004	211	164	170	164	133	164	116	164	87	164	61	164	37	164
2005	243	164	197	164	157	164	139	164	107	164	80	164	53	164
2006	107	327	59	327	15	327	0	323	0	289	0	260	0	232
2007	137	327	85	327	39	327	18	327	0	309	0	278	0	247
2008	173	327	117	327	67	327	45	327	0	327	0	300	0	267
2009	213	327	158	327	99	327	75	327	33	327	0	324	0	288
2010	91	491	26	491	0	459	0	433	0	388	0	349	0	310
2011	116	491	49	491	0	479	0	452	0	405	0	364	0	324
2012	140	491	70	491	7	491	0	469	0	420	0	378	0	336
2013	169	491	96	491	30	491	1	491	0	440	0	396	0	352
2014	196	491	120	491	51	491	21	491	0	458	0	412	0	366
2015	221	491	142	491	71	491	39	491	0	474	0	427	0	379
2016	248	491	166	491	92	491	59	491	2	491	0	443	0	394
2017	264	491	180	491	104	491	71	491	12	491	0	453	0	402
2018	139	654	50	654	0	625	0	590	0	529	0	476	0	423
2019	171	654	80	654	0	651	0	615	0	550	0	495	0	440
2020	204	654	109	654	23	654	0	639	0	572	0	515	0	458

Table 5.12: Actual Energy generated by GT and CC units, For Scenario 2 (Load shift)

	GT (60MW)		CC (180MW)		
Year	Generated Energy (GWH)	Time of operation (Hours)	Generated Energy (GWH)	Time of operation (Hours)	Total Energy Generated (GWH)
2001	1794	7796	0	0	1794
2002	1936	7796	0	0	1936
2003	746	3618	1357	7796	2103
2004	925	4762	1357	7796	2282
2005	1113	5463	1357	7796	2470
2006	100	435	2539	7294	2639
2007	192	873	2628	7551	2820
2008	325	1552	2713	7796	3038
2009	568	4461	2715	7796	3283
2010	42	179	3492	6685	3534
2011	70	236	3620	6933	3690
2012	108	526	3727	7140	3835
2013	110	505	3841	7358	3951
2014	258	1259	3915	7500	4173
2015	340	1451	3987	7633	4327
2016	431	4256	4062	7776	4493
2017	515	2439	4071	7796	4586
2018	76	364	4744	6813	4820
2019	111	278	4909	7049	5020
2020	179	447	5039	7239	5218
TOTAL	**9939**	**48696**	**60073**	**133747**	**70012**

As given in table 5.14 energy generated by GT units increased from 4841 to 9939 GWH and also their operation time increased from 967 hours to 48696 hours. Energy generated by CC units decreased from 65176 to 60076. All in all, total generated energy before and after load shift will be nearly same (70017 GWH).

The explanation for the increase in GT generated energy and the decrease in CC generated energy is due to load shift, where the maximum demand decreased. As a result, as given table 5.13 there will be no need to add CC units in year 2002 because GT units will cover the load and the reserve. Because of this delay in putting the CC units in service in year 2002, GT units will work more time. The best combination of GT and CC units after load shift will be 7 GT units and 4 CC units (table 5.6); while before the load shift it will be 5 GT and 5 CC units (table 4.19).

Economic comparison in generation costs before load shift (table 4.22) and after load shift (table 5.14) is as shown in Table 5.15

Table 5.15: Discounted generation costs before and after Load shift.

Fuel: NG	Discounted investment cost before load shift (Million $)	Discounted investment cost after load shift (Million $)	Discounted operating cost before load shift (Million $)	Discounted operating cost after load Shift (Million $)	Total cost before load shift (Million $)	Total cost After Load Shift (Million $)	Net Benefit (T. Cost before shift– T.Cost after) (Million $)
Gas Turbine	126.657	166.299	105.679	195.019	232.336	361.318	
CC	455.886	356.985	463.693	408.076	919.579	765.061	
Total	**582.543**	**523.2844**	**569.372**	**603.094**	**1,151.915**	**1,126.372**	**25.54**

As shown in table 5.15 total cost of GT units is increased from 232. 3 to 361.3 Million $, this is because number of GT units increased from 5 to 7. On the other hand total cost of CC decreased from 919.6 to 765.1 Million $, because number of CC decreased from 5 to 4. In total, total cost after load shift (1,126.372 Million $) is less than that before load shift (1,151,915) .The net benefit of the applying the DSM program by shifting the load is about 25.54 (NPV) Million $.

Table 5.16 presents financial and technical summary of the system for the three cases; original load curve, peak clipped curve and load shifted curve.

Table 5.16: summary of discounted generation costs for original, peak clipped and load shifted Curves.

Fuel : NG	Discounted investment cost (Million $)	Discounted operating cost (Million $)	Total discounted cost (Million $)	Discounted saved money compared to original curve (Million $)	Total generated energy (GWH)
Original curve (case 0)	582.543	569.372	**1,151.915**	**0**	70017
Peak clipped curve (case 1)	523.284	565.331	**1,088.615**	**63.3**	66022
Load shifted curve (case 2)	523.284	603.094	**1,126.372**	**25.54**	70015

Data given in table 5.16 can be explained as follows:

1- Investment costs of case 1 and 2 are equal, as both have the same number of units (7 GT and 4 CC units).

2- Investment cost of case 0 is higher than of case 1 and case 2. This is because in case 0 we have 5 GT units and 5 CC units. This means that case 0 has 2 GT units less and 1 CC unit more compared with cases 1 and 2. Since 1 CC equals 2 GT units plus 1 steam unit, so case 0 will have one steam turbine more than each case 1 and case 2, so its investment cost will be more.

3- Operation cost of case 2 is the lowest. This is because in total its generated energy is the lowest.

4- Operation cost of case 2 is higher than case 0 even they have the same generated energy. This is due to load shift where CC units will work more hours (133747-hour) instead of 126910 hours for case 0.

5.5 Using Expert System to Predict Weighting of Population and GDP on Max. Power Demand

5.5.1 Why to predict the GDP and Population Weighting Factors?

Estimation of the weighting factor of both population and GDP is very important, and helpful in power planning and energy management. When population-weighting factor is high this means that the load curve is mostly residential with fewer losses and higher power factor. Having a residential load curve means that energy management is to be concentrated on and directed to the residential end users. Also when the population-weighting factor is higher than the GDP weighting factor this indicates that local or national economy (industrial, commercial and service sectors) is not strong.

As a result and from the physical planning point view there will be no need for new industrial zones and from power planning point view there will not be much need for new generation units, instead concentration will be toward managing the load through DSM programs mostly for residential sector.

On the other hand high values of GDP weight on maximum demand indicates that industrial, commercial and service sectors are active. Having active industrial and commercial services means that our load curve will be mostly inductive with low power factor. Poor power factor costs a lot of money, so there will be need for power factor correction and load management should look for industrial and commercial sectors.

From physical planning point view higher forecasted GDP weighting factor is an indication that industrial, commercial and service sectors are expected to be active .As a result it will be necessary to direct physical planning towards building new industrial and commercial zones. As for power planning high forecasted GDP weighting factor indicates that there will be a need for building new substations and adding new more generation unites instead of only managing the load.

To sum up, predicting weighting factors of GDP and population on maximum demand is useful for national planning as it gives an indication of the future trend of the local economy, whether it will be strong with high GDP per capita or weak with low GDP and high demographic growth.

In the West Bank the effect of population and GDP on power (MW) differs from year to year due to different factors, which can be summarized on the following three main factors:

- Demographic Factor
  - Population growth rate. High total population and population growth rates increase the population-weighting factor on power demand.
  - Migration. High immigration rate increases the population-weighting factor on power demand.

- Economic Factor.
  - Strong industrial, commercial and service sectors increase the weighting factor of GDP on power demand.

- Political Factor
  - Stable political situation encourages investment in different sectors (industrial, commercial, service and housing sectors). Also as a specialty for the West Bank, stable political situation in our area means that more donation will be granted and as a result the GDP per capita will increase and so its weighting factor on power demand will also increase.

In the West Bank the above mentioned factors are uncertain. Our future demography is uncertain, our economy is fluctuating and the political situation is still unstable. Because of this our planning for power and energy will be uncertain and so uneasy task.

To estimate weighting factor of GDP and population on peak power demand, we should first find the relation between power demand (dependent variable) due to population as the only independent variable and power demand due to GDP as the only independent variable.

Relationship between peak power demand and population was proved to be a quadratic relationship as shown in chapter 3 (section 3.4.1.2, table 3.4). Equation 5.1 shows the Peak –Population relation.

$P_1 = 996.6 + -0.0014 * X_1 + 5.8E\text{-}10 * X_1^2$ ....(5.1)

P_1= power demand due to population

X_1= total population

To calculate the maximum power demand due to population only, we applied equation 5.1 to data of population (table 3.2). Table 5.17 shows the maximum power demand with population as the only variable.

Also the best curve that fits the relation between the maximum demand and the GDP as the only variable was proved to be the quadratic relation as shown in chapter 3 (section 3.4.1.2 table 3.3). Equation 5.2 shows the Peak-GDP relation.

$P_2 = 114.7 + -1.434 * Y + 0.000583 * Y^2$....................................... (5.2)

P_2= power demand due to GDP

Y= GDP/capita

Applying equation 5.2 to GDP data (table 3.3), the maximum power demand data with GDP as the only variable, was obtained as shown in table 5.17.

For each year best weighting factors of GDP and population on maximum demand are achieved when the absolute maximum demand error is minimum. Absolute maximum demand error is calculated using equation 5.3.

% (Absolute Peak demand error) = ((P3-P)/ P) * 100%...................(5.3)

P = Actual peak demand

P3 = Forecasted peak demand due to both variables

$P_3 = (1-n) * P_1 + n * P_2$ ....(5.4)

P_1= forecasted peak demand due to population

P_2= Forecasted peak demand due to GDP

P_3= total forecasted peak due to both variables

n = weighting factor of the GDP

1-n = weighting factor of population

Values of absolute peak demand errors for the period (1992-1998) were calculated by applying equation 5.3 to peak demand data (table 5.17). Absolute error values are tabulated in table 5.18. For each year, best value of GDP factor is defined to be the value of n that gives the least absolute peak demand error (table5.18). Results of best weighting factor for each year obtained from table 5.18 are tabulated as shown in table 5.19.

Table 5.17: Maximum demand due to population & maximum demand due to GDP.

Year	Total population	Power due to population (P1) (MW)	GDP per capita (US $)	Power due to GDP (P2) (MW)	Actual peak (P) (MW)
1992	1271724	154.2029207	1314	158.392848	148
1993	1323360	159.63238	1368	158.836512	162
1994	1397212	172.7729963	1409	161.268878	176
1995	1488785	197.8528502	1624	203.635488	199
1996	1579151	232.1379709	1690	226.6188	218
1997	1600100	241.4386058	1740	247.1508	244
1998	1654823	268.1355136	1775	263.12375	274

Table 5.19: weighting factor of GDP and population for the period (1992-1998)

Year	Minimum absolute error %	GDP weighting coefficient (n)	Population weighted coefficient (1-n)
1992	4.47	0.1	0.9
1993	1.518	0.1	0.9
1994	2.487	0.1	0.9
1995	0.00468	0.2	0.8
1996	4.08	0.9	.0.9
1997	0.0037	0.45	0.55
1998	2.32	0.1	0.9

Data illustrated in table 5.19 can be explained as follows:

- For the period (1992-1994) the effect of the population (weighting factor = 0. 9) was much higher than that of the GDP (weighting factor =0 .1).

Table 5.18: Calculation of Best weighting factors of GDP & Population based on absolute error calculations.

Weighting Factor n	Total Population	Power due to population (MW)	GDP per capita (US $)	Power due to GDP (MW)	Actual peak (MW)	Absolute error for 1992 (%)	Absolute error for 1993 (%)	Absolute error for 1994 (%)	Absolute error for 1995 (%)	Absolute error for 1996 (%)	Absolute error for 1997 (%)	Absolute error for 1998 (%)
0.10	1271724	154.2029	1314	158.3928	148	[redacted]	[redacted]	[redacted]	0.285874	6.232147	0.815648	[redacted]
0.15	1323360	159.6324	1368	158.8365	162	4.615800676	1.535432099	2.813985795	0.140595	6.10556	0.698594	2.414692
0.20	1397212	172.773	1409	161.2689	176	4.757351351	1.56	3.140806818	[redacted]	5.978972	0.581541	2.506146
0.25	1488785	197.8529	1624	203.6355	199	4.898902027	1.584567901	3.467627841	0.149962	5.852385	0.464488	2.5976
0.30	1579151	232.138	1690	226.6188	218	5.040452703	1.609135802	3.794448864	0.295241	5.725798	0.347434	2.689055
0.35	1600100	241.4386	1740	247.1508	244	5.182003378	1.633703704	4.121269886	0.44052	5.599211	0.230381	2.780509
0.40	1654823	268.1355	1775	263.1238	274	5.323554054	1.658271605	4.448090909	0.585799	5.472624	0.113328	2.871964
0.45						5.46510473	1.682839506	4.774911932	0.731078	5.346037	[redacted]	2.963418
0.50						5.606655405	1.707407407	5.101732955	0.876357	5.21945	0.120779	3.054872
0.55						5.748206081	1.731975309	5.428553977	1.021636	5.092862	0.237832	3.146327
0.60						5.889756757	1.75654321	5.755375	1.166915	4.966275	0.354885	3.237781
0.65						6.031307432	1.781111111	6.082196023	1.312193	4.839688	0.471939	3.329235
0.70						6.172858108	1.805679012	6.409017045	1.457472	4.713101	0.588992	3.42069
0.75						6.314408784	1.830246914	6.735838068	1.602751	4.586514	0.706045	3.512144
0.80						6.455959459	1.854814815	7.062659091	1.74803	4.459927	0.823098	3.603599
0.85						6.597510135	1.879382716	7.389480114	1.893309	4.333339	0.940152	3.695053
0.90						6.739060811	1.903950617	7.716301136	2.038588	4.206752	1.057205	3.786507
0.95						6.880611486	1.928518519	8.043122159	2.183867	[redacted]	1.174258	3.877962

This was due to the political situation in the area at that time where the West Bank was under the Israeli occupation. The long period of the Intefada, the closures of the territories affected badly the local economy and so forth the GDP per capita.

- For 1995, the PNA took over the control in parts of the West Bank, political situation became little bet stable, the donors started giving money to the PNA, investments started in the area so forth the GDP increased. Due to these facts, power demand increased and so the weighting factor of the GDP increased from .1 to 0.2

- For 1996 the area became more stable, more money were granted by the donors, more public services and ministries were established, a lot of people were hired and so the GDP increased to its maximum where its weight on power demand came up to 0.9

- For 1997 the Leekode came to the power in Israel, where the peace process was frozen. Territories were closed for long periods, the investment environment became unstable, a lot of investors left a way, less money were given to the PNA from the donors. All these actions badly affected the local economy and so forth GDP decreased and so its weighting factor on maximum power demand also decreased to 0.45.

- For 1998 the freeze in the piece process caused a lot of troubles where the industrial, commercial, housing sectors reached their bad situation, the GDP decreased and as a result its weighting factor reached its lowest values of 0.1.

Fig 5.7 shows the weighting factor of both the GDP and the population for the period 1992 to 1998.

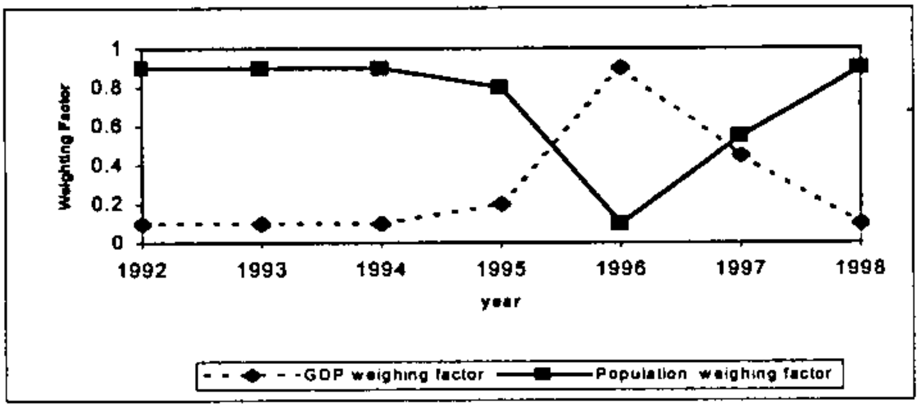

Fig. 5.7 Population & GDP weighting factors on Max.demand (1992-1998)

5.5.2 GDP and population weighting factor scenarios (1999 –2020).

To predict the weighting factor for both the GDP and the population we used the expert system, which depends mainly on the past experience. Results of weighting factor of both GDP and population (table 5.19) gave us an indication and some kind of experience about how the trend of the weighting factor will be in future according to the political, demographic and economic factors. Expert system is based on assigning weights to different IF statements depending on the demographic, economic and political factors as listed in table 5.20

Table 5.20: criteria for assigning weighting factors for GDP and population.

IF statement	Population weighting factor	GDP weighting Factor
If population growth rate is high with bad economical situation	0.8 – 0.9	0.1-0.2
If the donors continue giving money	0.1-0.2	0. 8-0.9
If the political station is unstable	0.8-0.9	0.1-0.2
If migration rate is high with some money from donors.	0.6	0.4
If migration rate is high with no money from donors	0.9	0.1
If the area is stable , less migration , less money from donors , some investments in industrial and commercial and housing sectors.	0.6-0.7	0.3-0.4

To estimate the weighting factor for the period (1999 – 2020) we studied two different scenarios.

5.5.2.1 Estimation of GDP and Population Weighting Factors on Peak Demand - Scenario 1

For this scenario we assumed that there will be no progress in the piece process, no money from the donors, no investment in the area. In this scenario future situation is expected to be as the situation during the occupation. In this case up to year 2020 population weight factor will be 0.9 and GDP factor will be 0.1. Fig. 5.8 shows the graph of the weighting factors of both GDP and population for this scenario.

5.5.2.2 Estimation of GDP and Population Weighting Factors on Peak Demand - Scenario 2

In this scenario development we assumed some kind of development in the piece process, higher rate of immigration, more money from the donors, more investment in housing, commercial, industrial and service sectors, a lot of jobs will be created which leads to a stable dependent society with some kind of advanced technology. For this scenario based on expert system we estimated the weighting factors as shown in table 5.21.

Table 5.21: Estimation of GDP and population weighting factors for the period (1999-2020) - scenario 2

Year	**Population. Weighting factor**	**GDP weighting factor**	**Situation**
1999	0.9	0.1	Freeze in the peace process , less investment in the area
2000	0.8	0.2	Little development in the peace process
2001-2010	0.8-0.4	0.2-0.6	Starting investment in the industrial , commercial and housing sectors , more money from donors , creating jobs , starting migration
2011-2015	0.4 -0.6	0.6-0.4	Starting getting benefits from the investment projects , less money from the donors, more migration
2016-2020	0.5-0.6	0.4-0.5	Stable situation with less population growth , some kind of advanced industry and business sector , depending on the situation the GDP weight will be either .4 or .5

Fig 5.9 shows the graph of the forecasted weighting factor of GDP and population up to year 2020 for scenario 2.

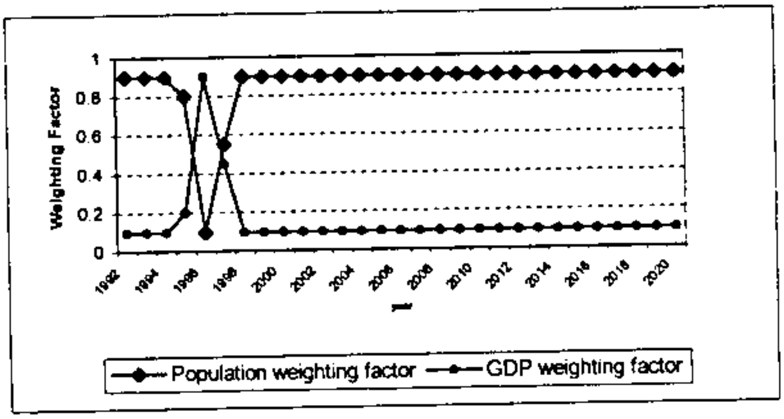

Fig.5.8 Estimated weighting factors of GDP & Population on maximum power demand - Scenario 1.

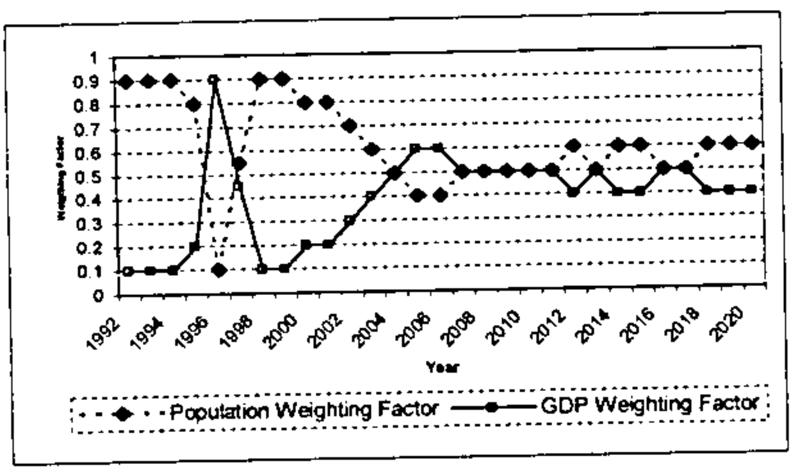

Fig.5.9 Estimated weighting Factors of GDP and Population on maximum power demand – scenario 2

Chapter 6

Conclusion & Recommendations

6- Conclusion and Recommendations

6.1 Conclusion

In this study, we tried to develop a planning technique for the electrical system in the West Bank of Palestine. Most types of uncertainties affecting the planning process were considered and analyzed.

Our aim was to produce a strategic plan for the period 1999-2020. So four scenarios for planning with uncertainties (demographic, economic and technical) were developed in this study. For these scenarios we can conclude that our needs of power in the West Bank may range from (287 – 792 MW) for scenario 1 which is the least scenario to (287-1848MW) for scenario 4, which is the highest scenario.

As for energy consumption we found that it may range from (1450-4578 GWH) for scenario 1 to (1450-10457 GWH) for scenario 4.

Also it was found that demographic changes in certain years, will have the major role in power demand, meanwhile for other years GDP changes will have the major role. This change in the weighting factor of population and GDP in power demand was proved to be mainly due to demographic, economic and political factors.

Regarding the proposed power plant it was found that total discounted cost of establishing this power plant may range from 986 million $ for scenario 1, which is the least scenario to 1613 million $ for scenario 4, which is the highest scenario.

Also establishing the power plant, over the planning period, is expected to save hundreds of millions of dollars to local economy. The amount of money that the local economy could save -compared with the existing situation- may range between 717 million $ for scenario 1 to 1069 million $ for scenario 4.

One thing which should be mentioned regarding costs and benefits of establishing the power plant in the West Bank is that, all results obtained in chapter four are with the condition that fuel is available especially natural gas.

As for system reliability it was proved that establishing a power plant in the West Bank could ensure supplying reliable electricity service to all people. Reserve capacity may range between 20.3% for scenario 1 to 18 % for scenario 4.

For fuel it was found that the best least –cost fuel would be natural gas, second option would be gas oil and third option would be heavy fuel.

Also it was proved that implementing DSM programs during the project life would have positive impacts on the electricity sector. Implementing DSM programs can reduce the total plant cost, can defer or postpone the need for new generating units can reduce environmental pollution and also can reduce customer's costs.

6.2 Recommendations

Since planning is an interaction between planners and decision-makers, depending on results of this study we can put the following recommendation for our energy decision-makers in the West Bank.

- Based on Cost Benefit analysis as shown in chapter 4, we strongly recommend start building a new power plant in the West Bank. Establishing this power plant will save a lot of money to the local economy. It will ensure supplying reliable electricity service to all people. It will strengthen the national prestige and it will create thousands of job opportunities.

- For Generators we recommend using a combination of GT and CC (Air cooling system) units in the proposed electrical power plant.

- For fuel, we recommend using NG as the first option, gas oil as a second and HF as a third option.

- To overcome uncertainties due to fuel (Prices and availability) we recommend using special types of generators that have the facility to change from one fuel to another depending on prices and on availability of fuel.

- We strongly recommend implementing energy conservation and DSM programs.

- To have a comprehensive energy system in the West bank we recommend an energy structure hierarchy as shown in fig 6.1

As shown in fig.6.1, the first level of this hierarchy is the macroeconomic development planning that is the national economic planning. National planning is aiming to define the path for the economy as a whole. A planning commission (members from related ministers) represents the national economic level.

The second level is the energy sector wide planning. In the West Bank the PEA is responsible for this level. The role of P.E.A is to serve as a bridge between the macroeconomic and the subsectoral levels both in the sense of institutional coordinators as well as in the role of forcing consistency of planning assumptions across the institutions involved in the energy sector.

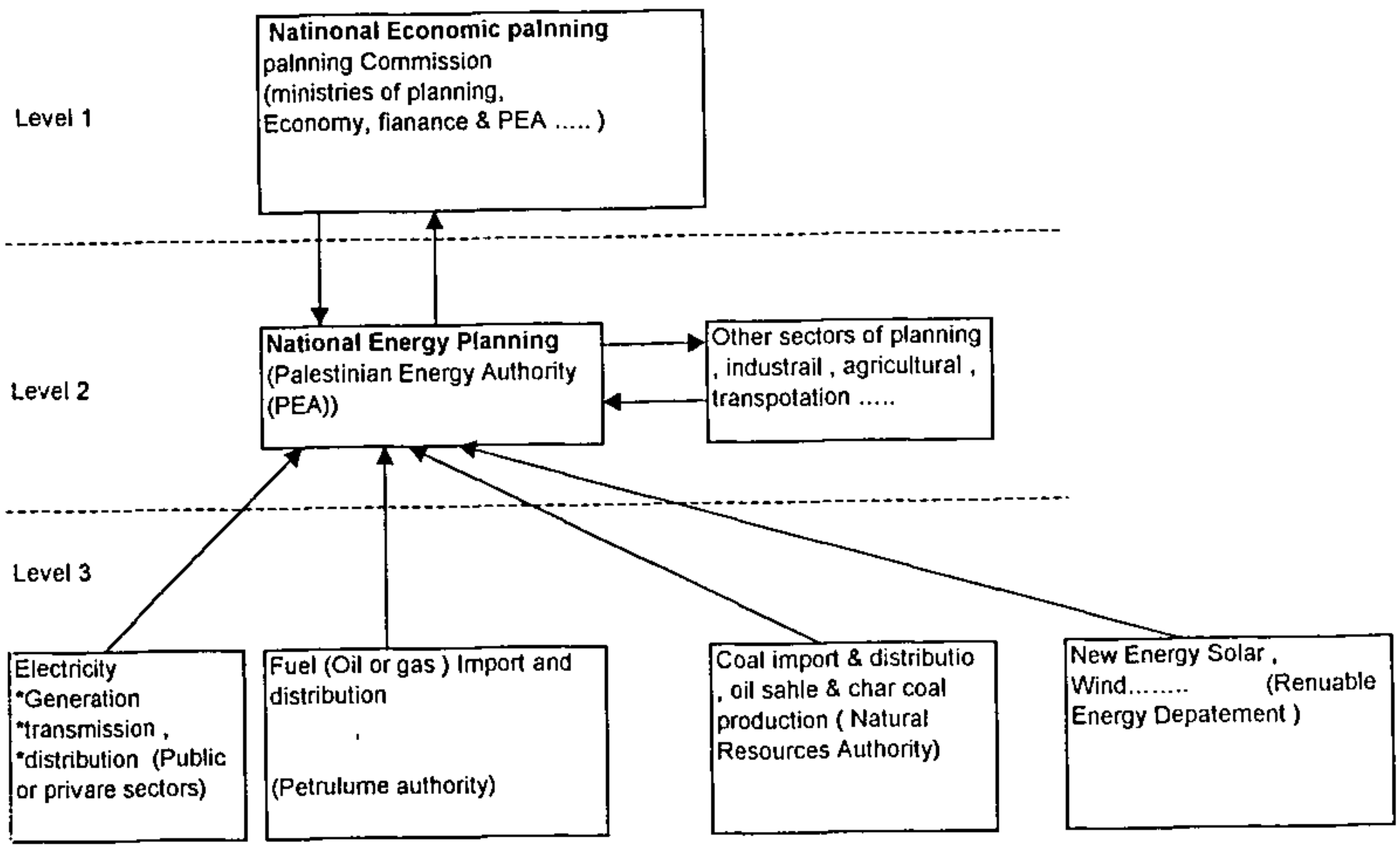

Fig 6.1: Proposed Hierarchy of Energy in the West Bank.

In order to have a good energy system, our recommendation to PEA, who is the decision-maker is to emphasize on and to adopt the following issues and polices.

1- Energy resource development policy

As known the high increase in the world oil price was behind the search for other sources of a variety of indigenous renewable and non-renewable energy resources. Some of the basic questions regarding resources development depends on the characteristics of the resource it self (location, quality, potential level of production as a function of cost, investment requirements, etc.). Others depend also on the characteristics of the future demands (location, level, type of energy required, computing fuels, etc.).

In our area unfortunately there was no singe that there will be a potential source of fuel, but this year there are some indications that there may be a source of gas near Gaza coast*. Regarding renewable energy sources we can think of solar energy, as this kind of energy may be practical and may have potential in the future. We strongly recommend using solar energy as a renewable source of energy.

2- Energy investment policy

To significant degree energy planning and analysis aim at improving the quality of energy investment decisions. Some of the most concrete questions that our PEA should take care of are those dealing with potential investment in establishing refineries and fuel pipelines.

Analysis carried out in chapter 4 proved that fuel prices share between 50-60% (depending on fuel type) of the total plant cost. Investment in the suggested gas pipeline from Egypt to Israel may reduce fuel cost. Also building a refinery in Palestine will supply Palestine with its needs of all types of fuels for generation use and for other uses. The analysis should base on economical Cost Benefit studies in terms of comparison between different alternatives.

4- Energy pricing policy

One of the most important points in building a good energy planned system in the West Bank is to adopt a proper energy pricing policy. The most important factors in adopting energy pricing policy are economic and social factors. This means it is important to perform not only the financial analysis that concerns with the financial profit but also to emphasize on cost benefit analysis (CBA) which aims at increasing the community and the social welfare. The main purpose of the energy plan is to supply energy to all people in all places at reasonable price and with the

*Source: Al-QUDS Daily Newspaper, Talks with British companies to look for Gas near Gaza Cost, No.10862, Jerusalem, October 13 1999.

best reliability. Pricing policy in the West Bank should take into account on peak – off peak tariff, seasonal tariff and the environmental tariff.

4-Energy conservation policy

The main objective of the our national energy planning level, that is the PEA is to assure the availability of energy to meet the citizens demand. One of the most direct and least expensive methods that we can adopt in the West Bank is to increase the availability of energy by increasing the overall efficiency of the energy system. Since a unit of energy saved through conservation is made available to the energy system generally, a joule saved is a joule earned. Studies have shown that joules can be earned through the conservation measures with less investment and at lower overall cost than through increasing supply.

5- Statistics, data and R&D

One of the serious obstacles that we faced in this study, and other energy planners may face, was the lack and most often the absence of data and statistics. As known having data and statistics about energy sector is the key factor in energy planning. It is the concern of the PEA to establish a specialized department for data and statistics towards building our own national energy research and development (R&D) policy. The importance of such data is that it can be used to solve and address not only current planning problems but also policy concerns that will come to the fore in the future.

The third level encompasses the subsectoral planning efforts conducted by the energy delivery organizations as, electric utilities, petroleum authority etc.

For an energy sector model to be useful it must be designed not only in such a way as not to duplicate existing modeling effort, but also to serve as an interface between them, because conflict between agencies can encounter difficulties.

Our recommendation to researchers and planners is to follow on energy management programs in more details, on transmission network planning, on the effect of temperature on energy consumption and power demand, on local and regional electrical interconnection and on power plant site location.

Due to the distinguish role that electricity has in our life, as we rely on it to make our home comfortable, to support our leisure activities and to help run our businesses, industries and institutions. Because many of the activities that enhance our quality of life depend on an adequate and reliable supply of electricity. However producing and delivering electricity can affect our natural environment as well as aspects of our social and economic well –being. Considering these interests we hope that this study can set out a starting point for a comprehensive national energy strategy to meet our electricity needs in the West Bank during the coming century.

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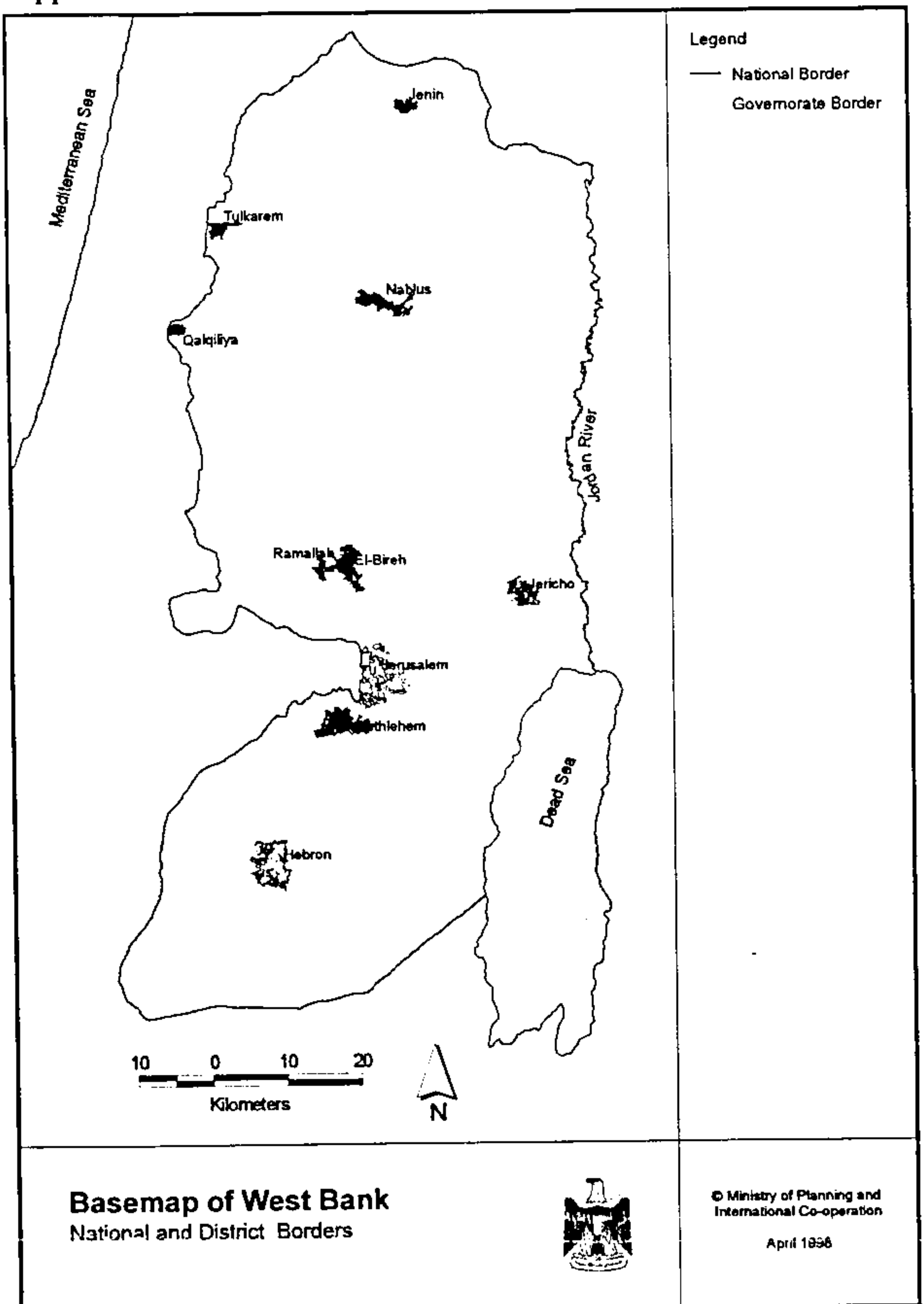
Appendices

Appendix 1.1


Legend
National Border
Governorate Border
Mediterranean Sea
Jenin
Tulkarem
Nablus
Qalqiliya
Jordan River
Ramallah
El-Bireh
Jericho
Jerusalem
Bethlehem
Dead Sea
Hebron
10 0 10 20
Kilometers
N
Basemap of West Bank
National and District Borders
© Ministry of Planning and International Co-operation
April 1998

APPENDIX 3.1

POPUALTION PROJECTION SCENARIO 1, INPUT DATA FIVFIV SOFTWARE

```
INPUT CONTROL FILE FOR PROJECTION  1

         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
EAST

YEAR.TITLE
YR.1997.projection
INIT.POP
INIT.F.A     136538.00 120317.00  93503.00  81374.00  71971.00  60085.00  50455.00
INIT.F.B      38635.00  27832.00  20242.00  19622.00  15820.00  15213.00  12823.00
INIT.F.C       9391.00  11935.00
INIT.M.A     143916.00 126841.00  99177.00  87334.00  77542.00  65079.00  54181.00
INIT.M.B      41559.00  27975.00  21359.00  16997.00  12011.00  12150.00   9914.00
INIT.M.C       7444.00  10865.00

MORTALITY
MORT.EZ.F        73.70     74.00     74.00     75.00     75.00     76.00     76.00
MORT.EZ.M        70.00     71.00     71.00     72.00     72.00     73.00     73.00

FERTILITY
TOTAL.FERT      5.4400    4.5000    4.0000    3.9000    3.5000    3.0000    3.0000
FERDIST1.7    113.0000  271.0000  299.0000  248.0000  142.0000   92.0000   19.0000
FEND

MIGRATION
MIGLEVEL.F         .00       .00       .00       .00       .00       .00       .00
MIGLEVEL.M         .00       .00       .00       .00       .00       .00       .00
MIGRF1.7.A        1.00      1.00      1.00      1.00      1.00      1.00      1.00
MIGRF1.7.B        1.00      1.00      1.00      1.00      1.00      1.00      1.00
MIGRF1.7.C        1.00      1.00
MIGRM1.7.A        1.00      1.00      1.00      1.00      1.00      1.00      1.00
MIGRM1.7.B        1.00      1.00      1.00      1.00      1.00      1.00      1.00
MIGRM1.7.C        1.00      1.00
MEND

END PROJECTION
```

APPENDIX 3.2

POULATION PROJECTION SCENARIO 1, OUTPUT DATA FIVFIV SOFTWARE

POPULATION PROJECTION

FEMALES	1997	2002	2007	2012	2017	2022
0-4	136538.0	161528.0	158082.1	166207.8	192762.1	201854.7
5-9	120317.0	136089.0	161019.8	157584.8	165764.0	192247.5
10-14	93503.0	120127.1	135880.7	160773.4	157368.9	165537.0
15-19	81374.0	93323.9	119904.9	135629.4	160511.4	157112.4
20-24	71971.0	81140.8	93065.2	119572.5	135295.7	160116.5
25-29	60085.0	71703.3	80848.7	92730.1	119189.9	134862.8
30-34	50455.0	59808.7	71383.9	80488.6	92362.0	118716.7
35-39	38635.0	50144.8	59451.2	70957.3	80054.0	91863.2
40-44	27832.0	38298.0	49717.3	58944.5	70399.6	79424.7
45-49	20242.0	27460.4	37796.0	49065.7	58220.1	69534.4
50-54	19622.0	19828.5	26908.9	37037.0	48136.4	57117.4
55-59	15820.0	19017.7	19227.7	26093.6	35976.2	46757.8
60-64	15213.0	15045.5	18102.0	18301.9	24907.4	34340.7
65-69	12823.0	13979.0	13846.8	16659.8	16931.7	23042.5
70-74	9391.0	11060.1	12091.3	11977.0	14545.5	14782.9
75+	11935.0	13266.4	15307.6	17146.5	18337.5	20969.6
TOTAL	785756.0	931821.1	1072634.0	1219170.0	1390762.0	1568281.0

MALES	1997	2002	2007	2012	2017	2022
0-4	143916.0	169746.2	166519.7	175079.2	202814.1	212380.8
5-9	126841.0	143386.1	169192.1	165976.1	174578.3	202233.9
10-14	99177.0	126536.3	143074.2	168824.0	165653.4	174238.8
15-19	87334.0	98811.3	126118.3	142601.6	168332.9	165171.5
20-24	77542.0	86806.8	98272.6	125430.8	141910.0	167516.4
25-29	65079.0	76982.7	86240.2	97631.2	124700.1	141083.3
30-34	54181.0	64587.2	76455.8	85649.9	97033.8	123937.1
35-39	41559.0	53701.7	64066.2	75839.0	85026.5	96327.6
40-44	27975.0	41054.2	53096.2	63343.7	75050.2	84142.1
45-49	21359.0	27431.2	40315.5	52140.8	62297.8	73811.0
50-54	16997.0	20657.3	26605.1	39101.3	50718.6	60598.5
55-59	12011.0	16070.3	19634.2	25287.4	37369.7	48472.5
60-64	12150.0	10992.0	14821.9	18108.9	23512.8	34747.2
65-69	9914.0	10642.6	9711.0	13094.6	16138.8	20954.8
70-74	7444.0	8111.9	8779.0	8010.5	10887.2	13418.2
75+	10865.0	10737.0	11240.9	11977.8	11855.4	13912.4
TOTAL	814344.0	966254.9	1114143.0	1268097.0	1447880.0	1632947.0
GRAND TOTAL	1600100.0	1898076.0	2186777.0	2487267.0	2838642.0	3201227.0

YEARLY RATES PER THOUSAND POPULATION

GFR=BIRTHS/FEM(15-44)	187.1	152.5	134.9	132.3	120.3
BIRTH RATE	38.9	32.5	29.9	30.2	27.9
DEATH RATE	4.7	4.2	4.1	3.8	3.9
NATURAL INCREASE	34.2	28.3	25.8	26.4	24.0
NET MIGRATION	000.0	000.0	000.0	000.0	000.0
POP INCREASE	34.2	28.3	25.8	26.4	24.0

APPENDIX 3.3

POPULATION PROJECTION SCENARIO 2, OUTPUT DATA FIVFIV SOFTWARE

POPULATION PROJECTION

FEMALES	1997	2002	2007	2012	2017	2022
0-4	136538.0	162366.7	159819.3	168666.0	196076.5	205765.5
5-9	120317.0	136556.9	162323.9	159784.5	168683.8	196021.1
10-14	93503.0	120595.5	136816.4	162543.9	160034.0	168921.1
15-19	81374.0	93792.1	120840.7	137031.6	162747.3	160241.5
20-24	71971.0	81608.9	94000.3	120973.9	137162.7	162815.1
25-29	60085.0	72171.1	81783.0	94129.8	121054.7	137191.8
30-34	50455.0	60276.3	72317.4	81886.5	94223.9	121042.0
35-39	38635.0	50612.1	60383.5	72352.6	81911.8	94182.6
40-44	27832.0	38764.7	50647.4	60335.5	72250.8	81734.8
45-49	20242.0	27926.0	38722.3	50449.3	60059.9	71828.7
50-54	19622.0	20292.5	27829.2	38408.7	49958.1	59386.6
55-59	15820.0	19479.2	20139.3	27447.6	37770.7	48989.3
60-64	15213.0	15502.8	18998.8	19627.1	26658.0	36511.7
65-69	12823.0	14428.7	14717.7	17935.2	18608.8	25113.3
70-74	9391.0	11496.7	12917.4	13167.4	16098.0	16686.2
75+	11935.0	13857.2	16538.1	19004.6	20836.7	24087.5
TOTAL	785756.0	939727.5	1088795.0	1243744.0	1424136.0	1610519.0

MALES	1997	2002	2007	2012	2017	2022
0-4	143916.0	170615.8	168337.4	177656.3	206289.3	216483.5
5-9	126841.0	143854.0	170526.8	168255.9	177616.2	206167.3
10-14	99177.0	127004.5	144009.3	170624.1	168397.0	177739.1
15-19	87334.0	99279.2	127052.9	144001.6	170595.8	168375.2
20-24	77542.0	87274.1	99205.5	126827.8	143770.8	170236.0
25-29	65079.0	77449.8	87171.7	99025.1	126556.4	143400.7
30-34	54181.0	65054.1	77386.8	87042.2	98886.5	126249.3
35-39	41559.0	54168.4	64996.2	77229.4	86875.7	98633.9
40-44	27975.0	41520.1	54023.7	64729.4	76892.4	86438.4
45-49	21359.0	27895.4	41237.6	53516.2	64125.5	76087.6
50-54	16997.0	21118.3	27517.0	40457.3	52518.8	62838.7
55-59	12011.0	16526.3	20529.5	26611.3	39124.0	50651.4
60-64	12150.0	11440.9	15693.0	19385.2	25196.1	36830.7
65-69	9914.0	11082.3	10549.0	14305.6	17719.5	22898.2
70-74	7444.0	8538.0	9569.3	9129.5	12323.3	15161.8
75+	10865.0	11316.0	12419.7	13719.5	14127.9	16682.5
TOTAL	814344.0	974137.4	1130226.0	1292517.0	1481016.0	1674874.0
GRAND TOTAL	1600100.0	1913865.0	2219020.0	2536260.0	2905151.0	3285393.0

YEARLY RATES PER THOUSAND POPULATION

GFR=BIRTHS/FEM(15-44)	187.1	152.5	134.9	132.2	120.2
BIRTH RATE	38.8	32.4	29.7	30.1	27.7
DEATH RATE	4.7	4.3	4.3	4.0	4.1
NATURAL INCREASE	34.1	28.1	25.5	26.1	23.6
NET MIGRATION	1.7	1.5	1.3	1.1	1.0
POP INCREASE	35.8	29.6	26.7	27.2	24.6

APPENDIX 3.4

POPULATION PROJECTION SCENARIO 3, OUTPUT DATA FIVFIV SOFTWARE

POPULATION PROJECTION

FEMALES	1997	2002	2007	2012	2017	2022
0-4	136538.0	162366.7	163983.3	177563.0	207519.7	216557.0
5-9	120317.0	136556.9	164975.9	166587.4	178649.3	207433.7
10-14	93503.0	120595.5	139470.6	167846.1	167920.6	178873.0
15-19	81374.0	93792.1	123494.5	142334.7	169133.8	168115.3
20-24	71971.0	81608.9	96652.8	126272.9	143545.1	169185.9
25-29	60085.0	72171.1	84434.5	99424.3	127428.8	143553.8
30-34	50455.0	60276.3	74967.7	87176.4	100588.9	127390.7
35-39	38635.0	50612.1	63031.8	77635.4	88264.0	100513.2
40-44	27832.0	38764.7	53292.3	65606.2	78581.5	88037.1
45-49	20242.0	27926.0	41361.2	55698.4	66352.8	78081.6
50-54	19622.0	20292.5	30458.8	43624.1	56191.2	65560.4
55-59	15820.0	19479.2	22755.3	32613.6	43914.8	55043.9
60-64	15213.0	15502.8	21591.1	24709.4	32657.9	42376.5
65-69	12823.0	14428.7	17268.2	22871.4	24363.4	30664.0
70-74	9391.0	11496.7	15394.3	17850.3	21432.1	21710.5
75+	11935.0	13857.2	19892.9	25983.9	29541.6	32813.2
TOTAL	785756.0	939727.5	1133025.0	1333797.0	1536085.0	1725910.0

MALES	1997	2002	2007	2012	2017	2022
0-4	143916.0	170615.8	172654.7	186959.2	218301.2	227837.8
5-9	126841.0	143854.0	173178.7	175211.0	187984.7	218144.8
10-14	99177.0	127004.5	146662.7	175923.6	176431.2	188087.4
15-19	87334.0	99279.2	129704.8	149298.0	176972.0	176386.0
20-24	77542.0	87274.1	101854.5	132114.2	150132.6	176581.3
25-29	65079.0	77449.8	89819.3	104304.4	132902.6	149725.5
30-34	54181.0	65054.1	80033.9	92318.8	105223.9	132556.7
35-39	41559.0	54168.4	67641.8	82500.7	93203.7	104925.1
40-44	27975.0	41520.1	56665.0	69986.4	83197.0	92700.6
45-49	21359.0	27895.4	43869.9	58742.3	70380.4	82288.1
50-54	16997.0	21118.3	30133.2	45626.6	58681.2	68923.0
55-59	12011.0	16526.3	23120.0	31688.4	45133.9	56540.8
60-64	12150.0	11440.9	18246.1	24327.5	30972.3	42418.9
65-69	9914.0	11082.3	13050.5	19062.6	23158.4	28046.0
70-74	7444.0	8538.0	11993.0	13616.6	17280.0	19683.8
75+	10865.0	11316.0	15711.1	20410.7	22118.6	24306.4
TOTAL	814344.0	974137.4	1174339.0	1382091.0	1592074.0	1789152.0
GRAND TOTAL	1600100.0	1913865.0	2307365.0	2715889.0	3128159.0	3515062.0

YEARLY RATES PER THOUSAND POPULATION

GFR=BIRTHS/FEM(15-44)	187.1	152.5	134.8	132.1	120.0
BIRTH RATE	38.8	32.4	29.4	29.6	27.2
DEATH RATE	4.7	4.5	4.8	4.7	4.8
NATURAL INCREASE	34.1	27.9	24.6	24.8	22.4
NET MIGRATION	1.7	9.5	8.0	3.4	.9
POP INCREASE	35.8	37.4	32.6	28.3	23.3

APPENDIX 3.5

LATION PROJECTION SCENARIO 4 , OUTPUT DATA FIVFIV SOFTWARE

ULATION PROJECTION

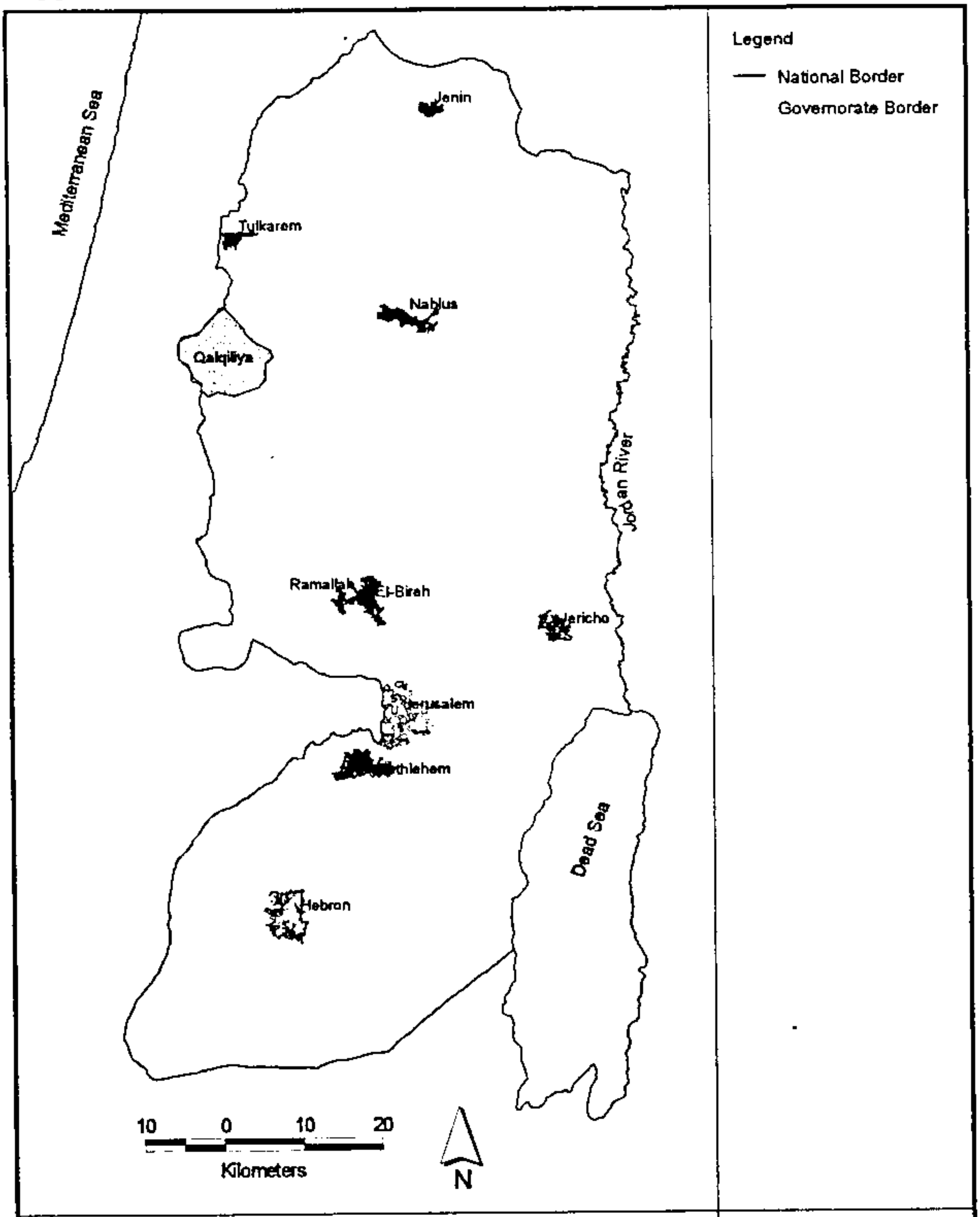
FEMALES	1997	2002	2007	2012	2017	2022
0-4	136538.0	162366.7	173780.8	198497.1	241937.3	254252.5
5-9	120317.0	136556.9	171216.1	182594.4	207329.6	244412.2
10-14	93503.0	120595.5	145715.8	180322.0	191712.8	210168.5
15-19	81374.0	93792.1	129738.7	154812.6	189395.4	194522.8
20-24	71971.0	81608.9	102894.2	138741.1	163795.2	192050.7
25-29	60085.0	72171.1	90673.2	111881.9	147657.1	166391.1
30-34	50455.0	60276.3	81203.8	99623.5	120794.1	150189.7
35-39	38635.0	50612.1	69263.1	90065.5	108435.2	123258.4
40-44	27832.0	38764.7	59515.7	78007.8	98695.8	110695.6
45-49	20242.0	27926.0	47570.2	68049.3	86366.4	100588.6
50-54	19622.0	20292.5	36646.0	55895.7	76046.6	87826.0
55-59	15820.0	19479.2	28910.6	44768.6	63535.6	76948.9
60-64	15213.0	15502.8	27690.6	36667.9	51895.4	63701.2
65-69	12823.0	14428.7	23269.2	34485.9	42946.6	51018.0
70-74	9391.0	11496.7	21222.3	28869.0	38889.4	40423.0
75+	11935.0	13857.2	27786.5	42405.9	56687.1	64046.2
TOTAL	785756.0	939727.5	1237097.0	1545688.0	1886120.0	2130493.0

MALES	1997	2002	2007	2012	2017	2022
0-4	143916.0	170615.8	182812.8	208848.4	254313.6	267431.0
5-9	126841.0	143854.0	179418.5	191575.8	217612.6	256706.7
10-14	99177.0	127004.5	152905.9	188393.0	200569.1	220311.4
15-19	87334.0	99279.2	135944.5	161760.3	197206.3	203106.1
20-24	77542.0	87274.1	108087.4	144552.8	170328.0	199367.3
25-29	65079.0	77449.8	96048.9	116726.3	153058.5	172451.7
30-34	54181.0	65054.1	86262.5	104734.4	125358.4	155237.4
35-39	41559.0	54168.4	73866.6	94903.9	113313.0	127559.6
40-44	27975.0	41520.1	62879.8	82355.8	103243.0	115243.1
45-49	21359.0	27895.4	50063.7	71039.0	90293.5	104637.4
50-54	16997.0	21118.3	36289.1	57789.7	78348.5	90913.0
55-59	12011.0	16526.3	29215.2	43634.7	64397.9	77934.5
60-64	12150.0	11440.9	24253.3	35956.5	49618.6	62894.0
65-69	9914.0	11082.3	18936.3	30255.6	40909.7	47175.5
70-74	7444.0	8538.0	17695.8	24174.5	33740.2	36875.1
75+	10865.0	11316.0	23455.5	36154.7	47429.6	52314.9
TOTAL	814344.0	974137.4	1278136.0	1592855.0	1939741.0	2190159.0
RAND TOTAL	1600100.0	1913865.0	2515233.0	3138544.0	3825860.0	4320652.0

YEARLY RATES PER THOUSAND POPULATION

FR=BIRTHS/FEM(15-44)	187.1	152.4	134.7	131.8	119.4
IRTH RATE	38.8	32.2	28.9	28.5	25.9
EATH RATE	4.7	4.8	5.9	6.2	6.5
ATURAL INCREASE	34.1	27.4	23.0	22.3	19.4
ET MIGRATION	1.7	27.3	21.3	17.3	4.9
OP INCREASE	35.8	54.6	44.3	39.6	24.3

Appendix 4.1



Basemap of West Bank
National and District Borders

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APPENDIX 4.2

PRELE Model Description

The PRELE model is a linear programming model destined to planification studies of mixed generation and transmission systems. The studies may be of factibility or pre-factibility, depending about the planner requirements.

The system that may be studies composed of generation units, either hydroelectric or thermal, transmission lines or generation or demand nodes. The model system must be able to operate under various circumstances, called the status of the system, for example in presence of Unisia or circuits in transmission lines unavailability's or under low inflow circumstance en hydro reservoirs or during the low inflow periods of the year.

The main objective of the model is the computation of an economically optimal plan of investment in generation units and transmission lines so that the total discounted cost of the system would me minimal, The computation takes into account the various circumstances or states operation, each one pondered by its occurrence probability, to which the system will be confronted to supply the energy and power demand. A simulation of the generation and transmission system also introduced in the optimization process, permits to carry out the optimization by taking into account a realistic economic operation of each generation unit and a coherent utilization of the transmission lines of the modeled system.

The model proved its efficiency to solve problems related to the development of national systems or systems with several countries or regions interconnected. The model enables the planner to compute the benefits associated to investment projects through the comparison of the results of the system simulation under various scenario assumptions.

The definition of the system relies on five concepts: the system nodes, the generation units, the transmission lines, the loads (demand and energy) and the system states.

The problem to be solved by PRELE model may be defined as follows:

To determine the investments in generation and transmission capacities that, taking into account the system states, are able to supply the demand and that minimize the total system discounted cost, and that comply with the constraints of capacity of generating units and transmission links.

The linear programming is the solution method for this problem. Linear programming allows finding out a minimum of the objective function; here the total system discounted cost, while complying with the set of constraints and restrictions of the system.