A1 THE ELECTRICITY SUPPLY SECTOR

A1.1 INTRODUCTION

Based on the results of the inventory of greenhouse gases [1] that was completed in 1998, the energy sector in Lebanon was found to contribute 85% of all CO_2 emissions and 96% of all SO_2 emissions. In addition, the consumption of both energy and electricity in Lebanon is relatively low compared with most industrialized countries but it is high compared with many developing countries of similar conditions. Tables A1-1 and A1-2 compare energy and electricity consumption in Lebanon with some other countries [2], [3]. Since Lebanon does not have basic heavy industries, the high electricity intensity suggests that there is low efficiency in both the generation and end-use.

Table A1-1. Per capita energy consumption

Country	Per capita GDP US$, 1991	Energy/ capita GJ/capita	Energy intensity MJ/US$ of GDP
Lebanon, 1992	1500	39.5	25
Iran	1995	48	24
Syria	1346	32	24
Turkey	1886	30	16
Chile	2105	21	10
Poland	1665	82	49
France	21113	92	4.5`
UK	12576	118	9

Table A1-2. Per capita electricity consumption

Country	Electricity Consumption MWh/Capita
Lebanon, 1992	1.2
Iran	1.4
Syria	1.25
Chile	1.6
Poland	2.6
Tunisia	0.6
Morocco	0.4
Egypt	0.8
France	6.5
UK	5

For this reason, developing mitigation scenarios for reducing GHG emissions in the electricity sector is of paramount importance to the country as such scenarios will certainly help decision makers in finding solutions to energy related problems which, in addition to their environmental benefits, may contribute to the improvement of economic and managerial aspects of the electricity sector in Lebanon.

The aim of this chapter is to describe both the baseline and mitigation scenarios of the electricity supply sector in Lebanon. The approach to be adopted in this analysis is a bottom-up one where the principle objective is to create a quantitative description of the technological structure of the electricity supply sector. It begins with an estimate of the demand, and from this foundation builds future scenarios using different combinations of technologies for energy demand and supply. Scenario analysis is one way of comparing alternative combinations of technological options to provide the same level of energy services [15]. This level of energy services must then be met through a combination of supply options capable of improving the overall system efficiency and reducing cost and emissions relative to the specified baseline supply resources. Therefore, it is essential to start the analysis by defining a baseline scenario based on official government plans and projections, and basic structure of the future economy. The mitigation scenarios will explore the merits of options not considered by the government to arrive at an optimal planning strategy that will lead to a generation expansion plan at minimum cost and minimum emissions.

A1.2 ELECTRIC POWER SECTOR OVERVIEW

The electric power supply in Lebanon is a State monopoly by law [16]. The public agency entrusted with electricity generation, transmission and distribution is the autonomous "Electricite Du Liban" (EDL) which is responsible to the Ministry of Hydraulic and Electric Resources. "L'Office National du Litany", an independent hydroelectric power authority, sells all of its generated electricity to EDL, and consequently is considered as part of the EDL system. The "Kadisha" electric company, although was an independent legal entity, has been placed under the authority of EDL and is currently considered as part of the EDL system.

Lebanon imports almost all needed resources to generate electricity (with the exception of very little contribution from the hydro power plants). These resources are fuel oil, diesel oil and natural gas in the future.

The power sector in Lebanon has been going since 1993 through a major rehabilitation program in order to cope with the consequences of 17 years of civil war. Major goals of such a program are:

- to repair and expand the existing network in order to remove the shortages in power supply
- to meet the forecasted increase in demand
- to improve the quality of power supply and
- to improve the efficiency of power supply.

During the war, the Lebanese electrical network suffered a great deal [5]. Underground cables and overhead lines were severely damaged or completely destroyed. All circuit and transformer protection devices for the MV and LV stations were malfunctioning, thereby rendering the circuits and transformers inaccessible. Regular service connections were damaged or removed, resulting in numerous illegal electrical connections. Many of the medium voltage cables were over 30 years old and have been weakened because of problems in the medium voltage protection system. In addition, some medium voltage feeders were subject to excessive voltage drops of up to 20%.

Many low-voltage feeders had unbalanced loads. In a number of transformer substations, the low-voltage protection systems were inoperative, with the result that equipment exceeded their short-circuit ratings. At best, this caused premature aging of the equipment and increased the risk of breakdowns.

Reconstruction of many components was done on an Ad Hoc basis, which badly affected the quality of finished works. Overall know-how among employees had deteriorated over time, and troubleshooting, involving, among others, non-standard customer connections, made it problematic to perform preventative maintenance. Technical losses were very high and non-technical losses reached 60% in some cases.

From 1974 until 1984, EDL continued its efforts to meet the increase in demand and therefore raised the capacity of the Zouk power plant as follow [4]:

- 1974 - 1975: 4 gas turbines each around 30 MW (total 120 MW).
- 1983 - 1984: 3 steam turbines 145 MW each (total 435 MW).
- 1987 additional steam turbine (Alsthon) 172 MW.

From 1987 to 1993, no major modifications in the Lebanese electrical network were observed. In addition to the technical problems attributed to the war activities, the demand continued to grow without an appropriate increase in the generation capacity. This caused the Lebanese Council for Development and Reconstruction (CDR) to come up in 1993 with a rehabilitation plan which was supposed to enable EDL to overcome the problems and shortages that took place during both the war and post war periods. The CDR plan is briefly detailed below [6,7,8,9].

A1.3 THE REHABILITATION PROGRAM OF THE ELECTRIC POWER SECTOR

The Lebanese Council for Development and Reconstruction (CDR), which is the body responsible for reconstruction investments, launched an emergency Power Sector Master Plan defined through a two-phase program for the years 1992-2002. The budget of this program is estimated at US$1.7 billion from national and foreign funding. The actual start of the rehabilitation program was in October 1993 where both rehabilitation and expansion of the existing network were attempted. Major activities included:

1. Power plant rehabilitation (US$ 120 million).
2. Transmission system rehabilitation (US$ 85 million).
3. Distribution system rehabilitation (US$ 35 million) according to the following 2 packages:

   - <u>Beirut & its suburb</u>:

     - Rehabilitation of 1100 distribution substations (Medium-Low Voltage).
     - Fixing new 84700 meters.
     - Fixing new 71 substations.

   - <u>Outside greater Beirut</u> :

     - Rehabilitation of 50% of the substations and installation of 65000 meters.

Also in 1994, a decision was taken to build 2 new combined cycles power plants each with a capacity of 415 MW (± 18%). Each power plant will have 2 gas units (145 MW each) and

1 steam unit (135 MW).

In 1995, the CDR and "GEC - Alsthom" signed an agreement to install 4 gas turbines in Baalbeck and Tyre (2 gas turbines in each with a total capacity of 150 MW). These turbines have been operated since 1996 on diesel oil.

In 1996, the preparation work on the future 225 kV high voltage transmission lines started. US$20.5 million were allocated to build 152 km of high voltage transmission line between Dayr Nbouh and Ksarah. US$65 million were reserved to build 7 substations (Medium Voltage) and 37.5 km of underground cables (to transmit energy from Baddaoui & Zahrani to Beirut). Later, additional overhead-lines, substations, and underground cables were added to the plan to result in total of 350km of overhead-lines, 10 substations and 60km of cables. Finally, the French Utility (EDF) started in that year a study on the new control center whose cost is estimated at around US$29 million.

At present, minor electricity rationing still occurs from time to time, especially in regions outside the Greater Beirut Area, but is expected to disappear after the completion of the rehabilitation of the transmission and distribution networks.

From the preliminary assessment and forecast of future electricity supply-demand balances, made on the basis of the prevailing rehabilitation and expansion program, the following observations can be made:

- Even with the rehabilitated facilities and all expansion capacities, the total production capacity would hardly cover the peak load estimates of the years 2000 onwards.
- A sufficient spinning reserve should be considered to provide continuos electricity supply capable of responding to preventive maintenance and unit failures needs.
- A gradual withdrawal of rehabilitated facilities has to be considered from the year 2000 onwards.
- Annual energy demand growth requires the installation of additional capacity from the year 2000 onwards. However, since the expansion of the transmission network will not be ready before 2002, it only makes sense then to install extra units starting 2002 onwards.

- Major available and planned options depend on imported fuels.
- Customer participation in shaping both the financial burdens of the sector and the electricity bill is completely non-existent.

A1.4 THE BASELINE SCENARIO

The baseline scenario will provide all the necessary information on activities that took place since 1994 (base line year) as well as the most likely developments that are planned for the future. Two plans have been distinguished:

- A short term plan extending from 1994 till 2005.
- A long term plan extending from 2005 till 2040.

All projections for future energy generation, demand increase and possible government actions have been made after consultation with officials from the Lebanese electric utility (EDL) [10] and in conformity with EDL published plan for the years 1996-2002 [9]. An important aspect of the baseline scenario is the uncertain environment in which it is being conducted. Elements of uncertainty include future fuel prices, discount rates, government policy with regard to renewable energy and advanced technology selection, demand increase, and electricity tariffs. In this work, 3 scenarios are suggested to only accommodate possible demand increase for the years 2005-2040. These are 4% (low growth), 6% (medium growth) and 8% (high growth). As for the years 1994-2004 the demand increase was made to follow the historical trend of decaying from 10% in 1994 to 4% in 2004 [11,12] according to the structure shown in Table A1-3. Other uncertain data will be taken care of while developing the mitigation scenarios.

Table A1-3. Demand growth rates

Year	Demand growth rate, %
1995	10
1996	9
1997	7
1998	5
1999	4
2000-2004	4
2005-2040	3 scenarios: 4, 6,8

The baseline scenario for the electricity supply sector includes projections of future energy demand and supply system structure. Energy demand can either be closely linked to macroeconomic activity projections or can be based on detailed inventories of electric energy consuming technologies. The supply system projections are closely linked to already announced government policy and priorities. In particular, the already announced policy [9,10,11] of the government on the following matters:

- Commitment to full restoration of the generation, transmission and distribution networks.
- Commitment to continuously increase the capacity in the future to meet the expected increase in demand.
- Selection of natural gas as the future fuel for electricity generation provided that necessary funds will become available.

A1.4.1 THE COMPUTER MODEL

In this work, the LEAP model [14] has been used. This is, essentially, an energy simulation model and not an energy optimization one. LEAP is used as a tool to determine the effects of changes in electricity supply and demand on the Lebanese electric power system in order to aid in planning for the future. Data on electricity generating units in the system, fuel prices, and the magnitude and nature of the load are entered interactively. The program determines, then, which units should be loaded at different levels of demand. The resulting output includes data on the degree that each of the plants is used, the amount of energy deficit (energy shortage) and information on environmental emissions. When building mitigation scenarios, LEAP provides data on both incremental cost and benefits of a scenario as compared to the base case.

LEAP needs the following data to operate:

1. **Demand**: peak demand, load curve
2. **Power plants**: capacity, fuel type, efficiency, plant factor and electric energy generation for the base year.
3. **Economic data**: lifetime of the project, fuel price, operation and maintenance costs, capital costs of new plants, and the discount and inflation rates.

LEAP uses a load-duration curve to model the demand (see section A1.4.2 on energy demand). The load duration curve plots the probability that a load will exceed a given level. The load curve that is used in this work is derived from 1974 EDL data because no measurement has been carried out since that time due to the war on one hand, and to other preferential activities during the rehabilitation period. As such, it will be assumed that the load duration curve has not changed in the following years because of the unchanged nature of demand. Details on electricity supply must also be entered into LEAP as described in section A1.4.3 on generation.

The general data used for this study are given in Appendix A.1.1.

A1.4.2 ELECTRIC ENERGY DEMAND

Electric energy demand typically varies considerably during the course of the day and the year. There are usually few hours of peak demand each day and several hours of low demand during the night. In addition, there is usually a season of relatively high demand, due to the seasonally driven end-uses such as air conditioning. The magnitude of the total demand in each hour of the year can be analyzed according to its frequency of occurrence. The cumulative frequency distribution of load levels is shown in the utility's load-duration curve. For the purpose of this analysis, Table A1-4 shows the data used to construct the Lebanese load-duration curve measured for 1974 [4].

Table A1-4. Data used for the construction of the load curve

Load, MW	Duration, Hours
20	8760
40	8760
60	8760
80	8760
100	8180
120	7160
140	6245
160	5290
180	4420
200	3515
220	2645
240	1850
260	1045
280	430
300	135
320	20
340	3

Lebanon’s demand is divided into 2 parts [4]:

1. Industrial.
2. Residential, commercial and others (including schools, hospitals, governmental buildings, electricity needs for agriculture, and concessions. The latter are private companies authorized by the government to buy electricity from EDL and sell to customers in certain towns of Lebanon). In what follows, this part of demand will be referred to as the residential demand.

In 1994, EDL produced 5000 GWH, 62% (3100 GWH) of which were consumed by the residential sector, 23% (1150 GWH) by the industrial sector and 15% (750 GWH, 400 GWH for use inside generation plants and 350 GWH as losses) for losses [2,4].

Also in 1994, the demand was around 6800 GWH. The EDL shortage is then calculated as follows:

(Load + Losses) -Generation = (6800+750)- 5000 =2550 GWH.

Out of these 2550 GWH, 35% (i.e 890 GWH) were due to the residential sector and 65 % (1660 GWH) were due to industry.

The demand growth for the years 1994-1998 has been officially recorded by EDL [4]; however, future demand on electricity is a function of income, prices, efficiency of energy conversion and government policy. In addition, the removal of illegal connections and improvement of bill collection are particularly influential in the Lebanese case. Since 1994, positive changes have occurred with reference to electricity pricing, bill collection and reduction of illegal connections, and these changes have been reflected in the decaying energy demand growth rates of the subsequent years. An additional major factor influencing the demand growth is the fact that major industries have recently shifted to their own electric generators to satisfy their energy needs. As for future demand forecast, the income effect will be given priority. In Lebanon, the income elasticity of demand for electric energy is estimated around 1.2 meaning that for every 1% increase in income, demand on electric energy rises by 1.2% [2]. The GDP variation for the years 1994-97 has been documented as shown in Table A1-5 [13]:

Table A1-5. GDP rates for 1994-97

Years	%
1994	8.5%
1995	7%
1996	6%
1997	4%

As can be seen, the GDP increase is decaying from 8.5% in 1994 to 4% in 1997. During these years, the demand increase on electric energy was also decaying from 10% in 1994 to 5% in 1998, and will decay further to 4% by 2004.

Although it is a normal practice to relate the increase in electricity demand with the economic growth of a nation, in Lebanon, such a procedure would not lead to an accurate forecast because the Lebanese economy does not rely mainly on productive sectors like industry, but rather on attracting investment from abroad, tourism and provision of services. These sectors depend mainly on the political stability in Lebanon and the region. For example, the GDP increase for the year 1997 was about 4% whereas the demand increase on electricity was estimated at 7%. In this study, therefore, the forecast of electricity demand growth for the years 1994-2004 was made to follow the GDP trend, but for the years 2005-2040 was based on the assumptions that by that time all the necessary infrastructure projects will be over and Lebanon will become a good place to attract foreign investments. In addition as basic services will become available, small industries, tourism and agriculture will be able to develop. Hence, for the long-range projections (2005-2040) the following 3 scenarios (which are consistent with the projected economic growth of 3-6%) are proposed to accommodate possible demand growth:

- Low growth rate: 4% annually.
- Medium growth rate: 6% annually.
- High growth rate: 8% annually.

Tables A1-6 & A1-8 show the projected industrial and residential loads for the years 1994-2040 under the growth rates of 4%, 6% and 8% respectively.

Table A1.6 Electrical Energy Demand (Gwh, 4% growth rate)

DEMAND	1994	2000	2005	2015	2040
RESIDENTIAL	3990	5980	7280	10780	28730
INDUSTRIAL	2810	4210	5120	7580	20200
TOTAL	6800	10190	12400	18360	48930

Table A1.7 Electrical Energy Demand (Gwh, 6% growth rate)

	1994	2000	2005	2015	2040
RESIDENTIAL	3990	5980	7280	13040	55950
INDUSTRIAL	2810	4210	5120	9170	39350
TOTAL	6800	10190	12400	22210	95310

Table 1.8 Electrical Energy Demand (Gwh, 8% growth rate)

	1994	2000	2005	2015	2040
RESIDENTIAL	3990	5980	7280	15720	107640
INDUSTRIAL	2810	4210	5120	11050	75700
TOTAL	6800	10190	12400	26770	183340

The demand growth is also graphically illustrated on Figures A1.1-A1.2 .

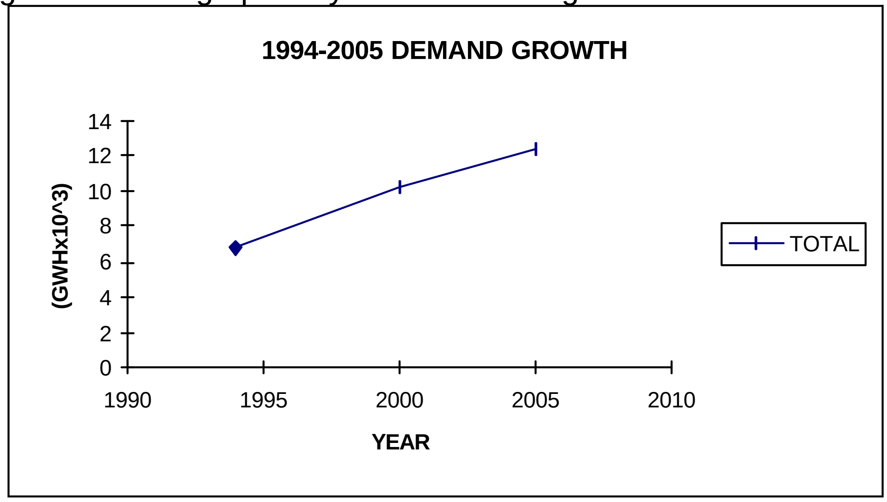


Fig. A1.1 Demand growth for 1994-2005

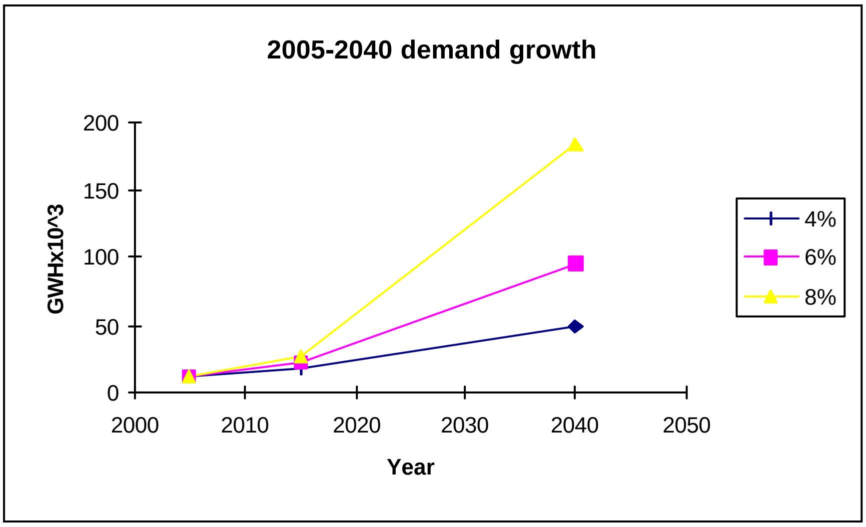


Fig. A1.2 Demand growth for years 2005-2040

A1.4.3 ELECTRICITY GENERATION

The Lebanese power plants can be grouped into 2 categories:

1- Hydraulic plants:

- Litani
- Nahr Ibrahim
- Bared
- Kadisha
- Safa

2- Thermal plants:

- Zouk
- Jieh
- Baalbeck
- Tyr
- Hrayche
- Beddaoui
- Zahrani

Power is generated at a medium voltage of 5 to 20 kV. For transmission efficiency, power is stepped up to 150 kV. Power transmission is performed over an integrated grid of aerial and underground 150 and 66 kV lines connected to the generating plants and to high voltage/medium voltage substations.

In 1994 and according to EDL [4,10] the thermal nominal capacity was around 1334 MW (90% fuel oil and 10% diesel) though the actual capacity was around 782 MW generating around 4367 GWH. This is mainly due to the damage caused during the war in addition to bad and unscheduled maintenance. The hydraulic capacity was 283 MW supplying energy of around 817 GWH.

In 1995 the actual thermal capacity was increased to 920 MW while the hydraulic capacity which was practically available dropped to the equivalent of 120 MW [9] (due to bad winter season). In addition, 292 GWH were imported from Syria [7].

In 1996 with the addition of Baalbeck and Tyr gas turbines (total of 150 MW) the thermal capacity reached around 1070 MW and the energy imported from Syria was 682.9 GWH [8].

The problem that appeared recently is that the major part of the combined cycle capacity can not be put in use because the transmission network is not ready yet to transmit the power to where it is needed. This has resulted in an ongoing rationing of electric energy in many regions in Lebanon. Only the Greater Beirut area was able to enjoy 24 hours a day of service. According to EDL, the transmission network will be ready by the year 2002 and therefore the combined cycle power plants will resume full service only at that date. An additional problem also appeared due to the unavailability of natural gas in Lebanon. As a consequence, the combined cycle power plants have been running so far on diesel oil, which renders their operation inefficient and does not demonstrate their environmental advantage. The problem of making natural gas available in the Lebanese market has been thoroughly discussed by the Lebanese government who have already negotiated this matter with the Syrian authorities and as a result natural gas is expected to be available starting 2005 [10]. In addition, to address the situation when Syria would not be capable of satisfying the whole Lebanese market, the USTDA (United States Trade and Development Agency) has sponsored a study to check the feasibility of importing gas from Europe and doing all the necessary treatment here in Lebanon to make it satisfy the required specifications.

In 1998 and despite the fact that 2 new power plants were completely built and ready to fully operate, the total capacity drawn from these plants was only around 300 MW. These 300MW are equally distributed among the North, South and Beirut (each 100 MW). The electric energy imported from Syria was around 1020 GWH. [10].

in 2002, Jieh units 1 and 2 (see Table A1.10), 60 MW each, and Zouk gas units (156MW) may be withdrawn from service. To ensure that the system is operating with no shortages, the LEAP simulation showed that 675MW are needed: partly to replace the units withdrawn from Jieh and Zouk and the remaining part to satisfy the expected increase in demand. Note that, at that time, the work on the transmission network is expected to be completed and so the Zahrani and Beddaoui power plants will be operating at full capacity on diesel oil.

In 2005, the natural gas will become available in the market and so the new power plants (Beddaoui and Zahrani) are expected to run on natural gas and operate at full capacity (830 MW). In addition, the energy imported from Syria will be 2050 GWH. [10].

For the Long-Range study 2005 - 2040, there is certainly a need to continuously install extra capacity in order to meet the increase in demand (at least 10% capacity reserve must always be ensured). For this reason, we are proposing that every 5 years a new capacity of thermal units operating on fuel oil (determined through LEAP simulation) be installed. This is because the issue of natural gas is still debatable and natural gas may not be available in the future. The additional capacity will guarantee operations with no shortage for the next 5 years. For example the capacity introduced in 2011 will guarantee no shortage in the system until 2015, and so on.

The units that are expected to be withdrawn from the system are:

- In 2010 Jieh units 3, 4 and 5 (65 MW each).
- In 2015 Zouk units and Hraiche (605 & 70 MW respectively).

To summarize, the characteristics of the generation system of 1994 are described in Table A1-9.

Table A1-9. Installed generation capacity for 1994

LOCATION AND TYPE	P-Total, MW
Zouk, Fuel oil	643
Zouk, Gas oil	166
Jieh, Fuel oil	347
Below all hydro	
Awali	109
Joun	48
Abdel-Al	34
Ibrahim 1	15
Ibrahim 2	12

Ibrahim 3	5
Bared 1	13
Bared	4
Safa	13

The Table above shows the units that are connected to EDL network [4]. However, there are other units connected to the Lebanese network. These are:

- 26.9Mw from hydro power plants
- 177.7MW from thermal power plants

Therefore the total hydro capacity is 283 MW and the total thermal capacity is 1334MW. The net total installed capacity for 1994 is 1617 MW.

The characteristics of electric energy generation for the years 1995-2040 are described in Table A1-10 below. In this table, the electricity import from Syria is assumed to be constant till 2040 on the basis that it is cheaper to feed the Bekaa region from this connection.

A1.4.4 BASELINE SCENARIO RESULTS

The above information was fed into LEAP software and the following results have been obtained for the short and long term planing horizons.

<u>4% -Growth Rate</u>

Table A1-11 shows the fuel supply inputs for electricity generation. As can be seen, the natural gas will not be available in the market before 2005, and the hydropower contribution will be decaying from 820 GWh in 1994 to 470 GWh for the year 2000 (due to bad winters and unscheduled maintenance). For later years hydropower contribution will not increase as no future investment for power plant expansion has been planned nor the resource contribution will improve. Also important to note that, although natural gas may become available around 2005, the contribution of fuel and diesel oil for electricity generation will continue to increase because it is unlikely to have sufficient natural gas that can satisfy the total demand. In this study, the merit of natural gas over fuel and diesel oils will be evaluated under a mitigation scenario.

Table A1-12 shows projected losses for the years 1994-2040. As mentioned previously a 15% loss rate has been adopted in this analysis.

Table A1.10 Generation characteristics for the baseline scenario. 1995-2040

Years	Capacity after rehabilitation	Units to be added	Units to be withdrawn	Import from Syria
1995	Thermal:920 MW Hydro: 120 MW			290 GWh
1996	Thermal:1070 MW Hydro: 120 MW	Gas turbine:150MW		682.9 GWh
1998		Combined cycle units: 300 MW out of 830MW operate on diesel oil		1020 GWh

2002		Zouk: 200 MW, fuel oil Jieh: 200 MW, fuel oil Additional 275 MW should be added in order to remove shortage until year 2005.	Jieh: 120 MW Zouk: 156 MW	2050 GWh
2003		Transmission network is complete. All combined cycle units operate on diesel oil.		
2005		Now the Combined cycle units operate on natural gas at full capacity: 830 MW		2050 GWh
2005-2040		Every five year add additional thermal capacity operating on fuel oil.		2050 GWh
2010			Jieh: 3x 65 MW	2050 GWh
2015			Zouk: 605 MW Hreiche: 70 MW	2050 GWh

Table A1.11 Fuel supply Inputs for electricity generation (Gwh)

	1994	2000	2005	2015	2040
ELECTRICITY (Import)	0	1020	2050	2050	2050
NATURAL GAS	0	0	9950	9950	9950
DIESEL/GAS OIL	1490	10450	4660	3300	1600
RESIDUAL/FUEL OIL	10760	13230	19380	39060	143200
HYDRO	820	470	470	470	470
TOTAL	13070	25170	36050	54830	157270

Table A1.12 Electric Losses (Gwh)

	1994	2000	2005	2015	2040
ELECTRICITY	750	1490	2190	3240	8630
TOTAL	750	1490	2190	3240	8630

Table A1-13 shows the energy balance for the years 1994-2040 under the assumptions made earlier in this analysis. It is clear that energy deficit will persist until 2001 and that EDL efforts to remove shortages will start show up from the year 2002 onwards (see Fig. A1.6) provided necessary funds will become available to install the extra generating units mentioned in Table A1.10.

Table A1.13 Energy Balance (GWh)

	94	2000	2005	2015	2040
Total Generation	5000	7570	12400	18360	48930
Total Demand	6800	10190	12400	18360	48930
EDL shortfall	2550	2630	0	0	0

The same calculations were repeated for growth rates of 6% and 8% and the corresponding results are given in Tables A1.14-A1.19

The percentage contribution of various fuels for electricity generation for the years 1994-2040 under all the proposed load growth rates are shown in Figures A1.3-A1.5 respectively.

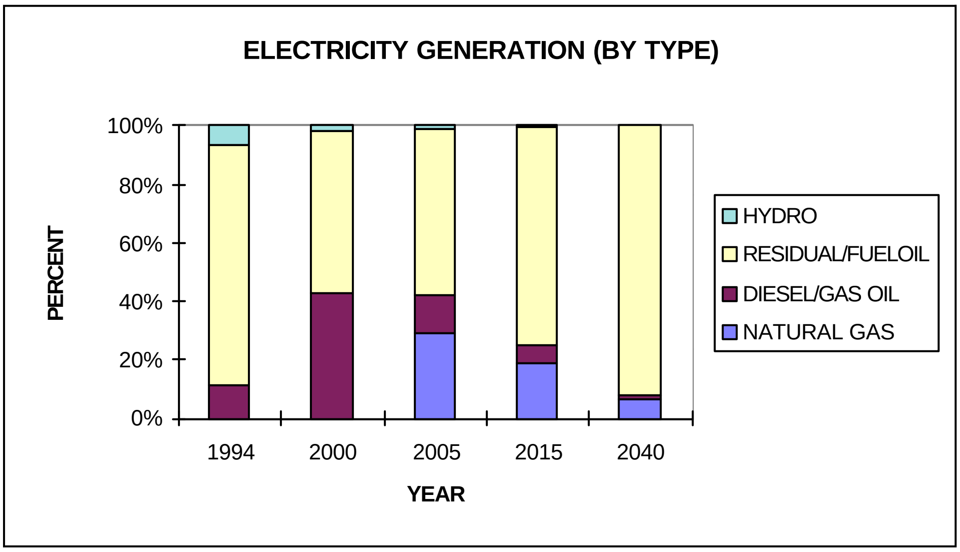


Fig. A1.3 Percentage contribution of various fuels to electricity generation

<u>6% -Growth Rate</u>

Table A1.14 Fuel supply Inputs for electricity generation (Gwh)

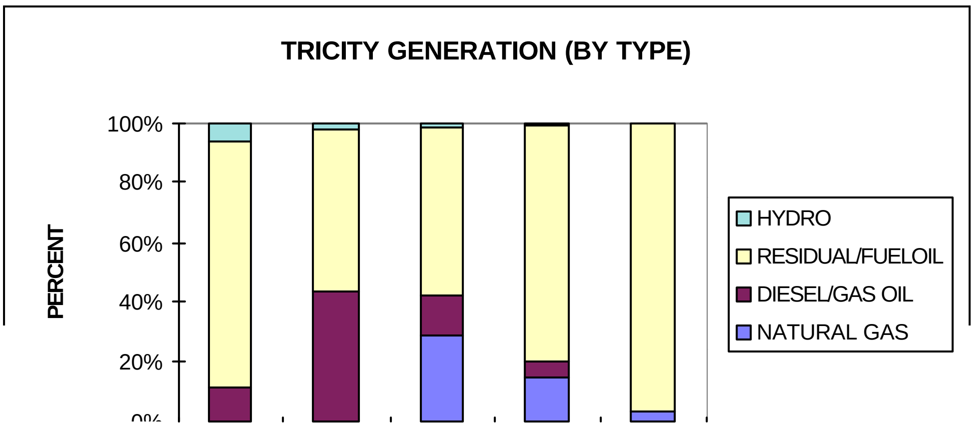
	1994	2000	2005	2015	2040
ELECTRICITY(Import)	0	1020	2050	2050	2050
NATURAL GAS	0	0	9950	9950	9950
DIESEL/GAS OIL	1490	10450	4660	3060	1600
RESIDUAL/FUELOIL	10760	13230	19380	52190	299080
HYDRO	820	470	470	470	470
TOTAL	13070	25170	36050	67730	3131600

Table A1.15 Electric Losses (Gwh)

	1994	2000	2005	2015	2040
ELECTRICITY	750	1490	2190	3920	16820
TOTAL	750	1490	2190	3920	16820

Table A1.16 Energy Balance (Gwh)

	94	2000	2005	2015	2040
Total Generation	5000	7570	12400	22210	95310
Total Demand	6800	10190	12400	22210	95310
EDL shortfall	2550	2630	0	0	0



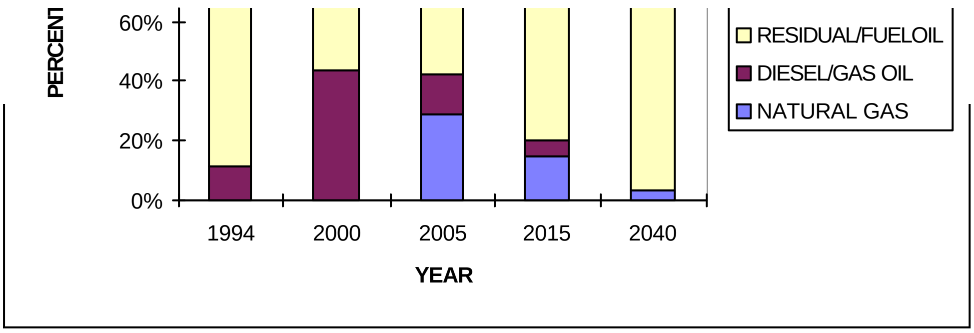


Fig. A1.4 Percentage contribution of various fuels to electricity generation

8% -Growth Rate

Table A1.17 Fuel supply Inputs for electricity generation (Gwh)

	1994	2000	2005	2015	2040
ELECTRICITY (Import)	0	1020	2050	2050	2050
NATURAL GAS	0	0	9950	9950	9950
DIESEL/GAS OIL	1490	10450	4660	3190	1770
RESIDUAL/FUELOIL	10760	13230	19380	67430	594840
HYDRO	820	470	470	470	470
TOTAL	13070	25170	36050	83100	609080

Table A1.18 Electric Losses (Gwh)

	1994	2000	2005	2015	2040
ELECTRICITY	750	1490	2190	4720	32350
TOTAL	750	1490	2190	4720	32350

Table A1.19 Energy Balance (Gwh)

	94	2000	2005	2015	2040
Total Generation	5000	7570	12400	26770	183340
Total Demand	6800	10190	12400	26770	183340
EDL shortfall	2550	2630	0	0	0

The electric energy shortages for the years 1994-2005 are shown in Figure A1.6 This Figure does not show any value for the years 2006-2040 because we assumed that the capacity expansion will take care of the demand completely and so no shortages will occur between 2006-2040.

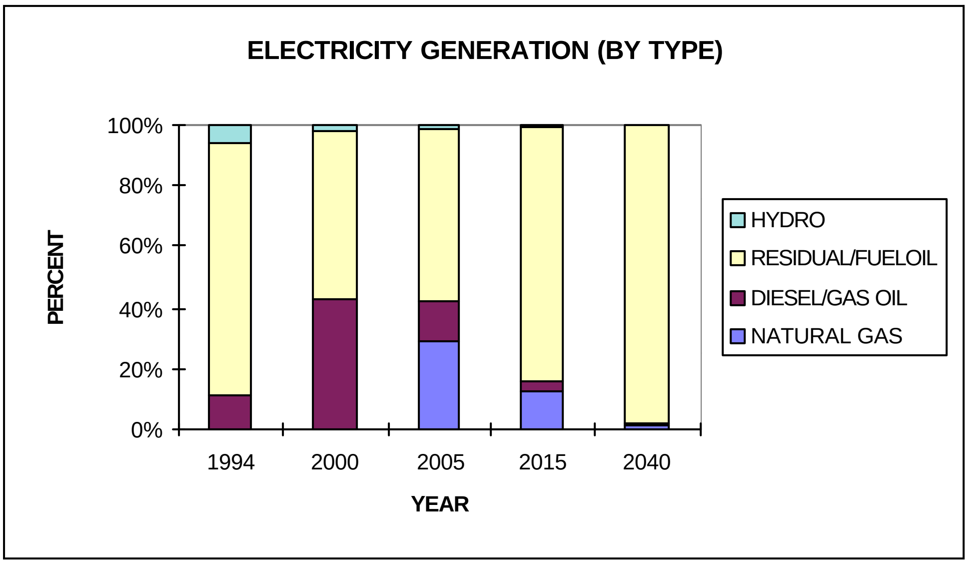


Fig. A1.5 Percentage contribution of various fuels to electricity generation

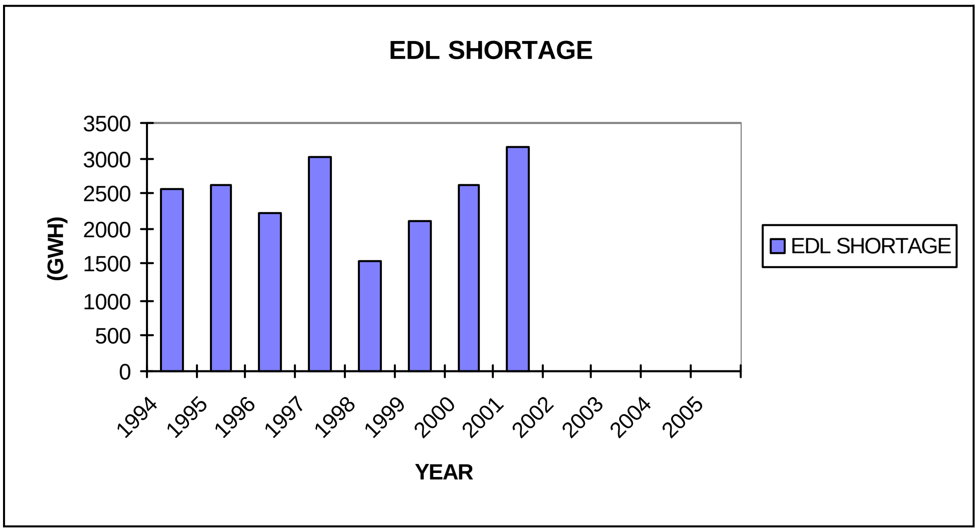


Fig. A1.6 Electricity shortages for the years 1994-2005

Complete details about the baseline scenario in terms of yearly demand, total yearly generation, and itemized yearly generation for all proposed growth rates can be found in Appendix A1.2

A1.4.5 ENVIRONMENTAL ANALYSIS

EDL is committed to minimizing and eliminating, as far as possible, negative environmental impacts associated with the supply of electrical energy to its customers [9]. For this purpose the power system expansion program will incorporate environment-friendly technologies for the power generation, and the transmission systems' design will carefully attend environmental issues. As a consequence, the environmental management plan based on the environmental assessment completed in early 1996 for both the new power plants at Beddaoui and Zahrani, and the transmission system, is being adopted.

A comprehensive Environmental Impact Assessment and related report were completed in 1996. The review included the two new power plants as well as the new 220 kV transmission system - lines, substations, and cables. The mitigation plan adopted by EDL for the new transmission system provides for the following key actions. At construction stage:

(a) Payment of adequate compensation for rights-of-way, tower and substation sites, including for crops and woodlands.

(b) Line alignment designed to minimize interference with agricultural land.

(c) Tower heights reduced whenever possible, especially in mountainous areas.

(d) Maximum use of existing roads and village tracks for access to tower/substation sites.

(e) Use of existing rights-of-way, wherever possible.

(f) Re-vegetation of new access roads and tower sites after construction.

(g) Procedures for contractors to follow in case of archaeological finds.

During the operational phase, key actions will include:

- Routine inspections for erosion control at tower sites and steep slopes.

- Selective hand clearance of vegetation along rights-of-way and at substation sites.

The major pollutants emitted from the power plants are sulfur and carbon dioxides. Carbon monoxide and nitrogen oxides will also be calculated.

The Zouk power plant began to use, as of 01/01/96, heavy fuel oil with 1% maximum sulfur content in accordance with the Governmental decision relative to the reduction of sulfur emissions. The percentage composition of fuels used for electricity generation is given in Table A1-20, and the emission factors are given in Appendix A1.1..

Table A1-20. Fuel Composition (in percent)

	FUEL OIL	DIESEL/GAS OIL	NATURAL GAS
Carbon	84.4	86.5	73.4
Nitrogen	2	0.59	0
Sulfur	1	0.4	0

The LEAP results concerning environmental emissions from the electricity supply sector for the years 1994-2040 under the 4%, 6% and 8% growth rates are given in Tables A1-21-A1-23.

Table A1.21 Environmental Emissions (Gg) , 4%

	1994	2000	2005	2015	2040
CARBON DIOXIDE	2855	3511	7014	13110	40300
CARBON MONOXIDE	0.588	0..72	2.202	3.47	9.07
NITROGEN OXIDES	7.89	9.07	20.83	36.94	112.4
SULFUR OXIDES	37.43	46	67.43	136.18	498.34

Table A1.22 Environmental Emissions (Gg) , 6%

	1994	2000	2005	2015	2040
CARBON DIOXIDE	2855	3511	7014	16540	81680
CARBON MONOXIDE	0.588	0..72	2.202	4.180	17.6
NITROGEN OXIDES	7.89	9.07	20.83	46.44	226.67
SULFUR OXIDES	37.43	46	67.43	181.85	1040.66

Table A1.23 Environmental Emissions (Gg) , 8%

	1994	2000	2005	2015	2040
CARBON DIOXIDE	2855	3511	7014	20600	160230
CARBON MONOXIDE	0.588	0..72	2.202	5.01	33.78
NITROGEN OXIDES	7.89	9.07	20.83	57.7	443.57
SULFUR OXIDES	37.43	46	67.43	235.8	2070

It is clear from the above Tables that carbon dioxide, carbon monoxide, nitrogen oxides and sulfur oxides emissions will increase from 1994 to 2005 as in this period the available major technologies will still operate on fuel and diesel oil. Although natural gas will be introduced in 2005 and so the 2 new power plants at Beddaoui and Zahrani will start operating on natural gas, the emissions for the years 2005- 2040 will increase due to the fact that the demand will increase and so more energy will be produced to meet that demand. The production of such energy will still mainly depend on fuel and diesel oils.

The total emissions that will result from the baseline scenario for the years 1994-2040 are given in Table A1-24 below.

Table A1.24 Total emissions for 2005-2040 (Gg)

	1994-2004	2005-2040		
		4%	6%	8%
Carbon Dioxide	39644	741450	1200870	1952920
Carbon Monoxide	8.76	180	275	430
Nitrogen	117	2074	3343	5421
Sulfur	557	8459	14492	24362

From the above table, one can conclude that the average yearly emissions for the years 1994-2040 is as follows:

Table A1.25 Average yearly emissions for 1994-2040, Gg

Demand growth rate	4%	6%	8%
Carbon Dioxide	16980	26968	43317
Carbon Monoxide	4	6	10
Nitrogen	48	75	120
Sulfur	196	327	542

A1.4.5.1 ENVIRONMENTAL IMPACT OF LOSS REDUCTION

As mentioned earlier, transmission and distribution losses in Lebanon can be classified as technical and non-technical losses. Non-technical losses result from theft of electricity through unauthorized connections and tempering with meter readings. Non-technical losses were very high in the last years reaching at some time 60%. Recently, with many government efforts to eliminate illegal connections and enhance the bill collection process, these losses have been reduced significantly and will continue to reduce in the future. In this analysis, such losses were not considered.

Technical losses, on the other hand, refer to energy that is dissipated through the various elements of the transmission and distribution system (transformers, feeders, etc.). These losses were estimated at 15% in the baseline scenario, and it is assumed that after the rehabilitation is over and normal operation goes back to the system, losses can be significantly reduce. Along the ongoing rehabilitation program, large investments are expected to be spent on the building of a modern control center that will house state of the art energy management systems, which together with other projects related to modernization and upgrading of the network will contribute to loss reduction in the coming years. As such, loss reduction will not be considered as a mitigation scenario but rather a usual EDL practice. Table A1.26 shows the environmental benefit that will take place if EDL succeeds in bringing its technical losses down to 10%.

Table A1.26 Baseline scenario emissions reduction due to loss reduction

Losses (%)	Growth (%)	Discount rate (%)	Average yearly emissions reduction, Gg/year			
			CO2	CO	NOX	SOX
10	4	5	624	0.13	1.7	8
10	4	10	624	0.13	1.7	8
10	4	15	624	0.13	1.7	8
10	6	5	1028	0.21	2.8	13.5
10	6	10	1028	0.21	2.8	13.5
10	6	15	1028	0.21	2.8	13.5
10	8	5	1758	0.36	4.9	23
10	8	10	1758	0.36	4.9	23
10	8	15	1758	0.36	4.9	23

A1.5 CONCLUDING REMARKS- BASELINE SCENARIO

From the baseline scenario of the electricity supply sector in Lebanon, the following conclusions can be drawn based on the results obtained:

- Shortages in electricity supply are to be expected at least until the year 2002. This is mainly due to the unfinished works in the transmission network. After 2002, the situation will depend on the availability of funds to install extra units of about 475MW and to ensure that every five years, necessary extra units are installed to satisfy the demand over the next five years.

- In order to help the economic growth in the country between the years 1999-2002, the government must do something to be able to meet the demand on energy with no shortages. The baseline scenario did not suggest anything in this regard, as there have been no announced government plans. Had the transmission network been finished, the government could have been able to supply additional electric energy based on the added contribution of the new combined cycle power plants which, in this case, will operate on diesel oil.

- Under the assumed demand growth of 4% and technical losses of 15%, the supply of electricity with no shortages will require the following additional yearly capacity:

Table A1.27. Required yearly expansion of generation capacity

Years	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	2036-2040
Capacity, MW	130	154	181	222	271	332	491

Taking into consideration that the cost of a thermal power plant is around US$1000000/MW, then, without considering the cost of transmission and distribution, a yearly expenditures of about US$130 million will be required between 2006-2010, US$154 million between 2011-2015, US$181 million between 2016-2020 and so on. Such yearly expenditures will impose a heavy burden on the Lebanese economy in the future. Certainly, much higher expenditures are awaited if demand growth rates happened to be 6% or 8%.

The impact of technical loss reduction on baseline scenario capacity expansion is shown in Table A1.28.

Table A1.28. Required yearly expansion of generation capacity for 10% losses.

Years	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	2036-2040
Capacity, MW	95	130	160	200	225	280	422

As seen, it is proposed that thermal units are added every five years according to the simulation results shown in the tables above.

- The contribution of hydro power stations is on the decrease as there are no government plans neither to increase the capacity of the existing plants nor to build new hydro power plants. Also, the water resources in Lebanon are not expected to contribute more in the future.

- Natural gas will not be available in the market before 2005. Therefore, the new combined cycle's power plants will continue to operate on diesel oil. A matter that defies their purpose as clean and efficient technologies. The reason for this fact is that natural gas is not available in Lebanon and the construction of pipes that will bring it from Syria has not been finished yet.

- When some thermal units are retired, the replacement will be done with units operating on fuel oil because, first natural gas will not be available before 2005, and second natural gas as a potential fuel is unlikely to satisfy the market in the foreseeable future.

As far as the GHG emissions we saw that carbon dioxide is expected to increase from 2855 Gg in 1994 to 40300 Gg, 81680 Gg and 160230 Gg in 2040 for the 4%, 6% and 8% scenarios respectively. Carbon monoxide emissions are expected to increase from 0.6Gg in 1994 to 9.07Gg, 17.6Gg and 33.78Gg in 2040 for the 4%, 6% and 8% scenarios respectively. Nitrogen oxides emissions are expected to increase from 7.89Gg in 1994 to 112.4Gg, 226.67Gg and 443.57Gg in 2040 for the 4%, 6% and 8% scenarios respectively. Finally sulfur emissions are expected to increase from 37.43Gg in 1994 to 498.34Gg, 1040.66Gg and 2070Gg in 2040 for the 4%, 6% and 8% scenarios respectively

A1.6 MITIGATION SCENARIOS

Traditional electricity planning has sought to expand supply resources to meet anticipated demand growth with very high reliability, and to minimize the cost of this expansion. These criteria, aided until recently by improving economies of scale in electric generation, led to a nearly universal strategy of rapid capacity expansion and promotion of demand growth [17]. This is what actually happened in Lebanon until 1974. In addition to the general culture of overusing electricity, during the war (1975-1990) energy was cheap as many people did not actually pay for it. This resulted in a large electric energy consumption per capita with almost no consideration of the necessity of rationalizing energy use. More recently, several factors have put pressure on decision-makers to redefine the whole planning process. Among these factors are the huge investments spent on the rehabilitation program, the continuing efforts for EDL restructuring, the continuous increase in load, the necessity to expand further the system in the near future, and the restrictions on environmental quality.

Modern utility planning is evolving toward Integrated Resource Planning (IRP) [17] where a broader range of technological options, including technologies for energy efficiency and load control on the demand side, are integrated. In addition, some non-traditional options such as decentralized and non-utility generating sources are brought into the mix of potential resources. IRP also means integrating a broader range of cost components including environmental costs, into the evaluation and selection of potential technical resources.

The expected results of the market changes must bring about more favorable economic environment for the development and application of efficient end-use technologies and cleaner and less centralized supply technologies, including renewable energy sources. The difficulty with implementing such changes in a market economy is that the value of environmental quality is not traded in the market, and that the benefits of energy efficient technologies are not fully captured by the market because of various market and institutional barriers. Therefore, planning and regulations will have to be used to address these problems to move the market toward cleaner and more efficient energy technology. Higher electricity prices are often needed to implement the IRP plans, but price measures are not a sufficient solution in a market with no competition and incomplete information.

Although, the trend in Lebanon is favoring privatization of the electric power sector, and so the mandatory use of IRP and DSM is expected to decline as more planning functions will be left to the forces of the deregulated market, there are still several ways in which the principle of IRP will continue to be relevant in a deregulated environment. For example, competitive supply firms can use IRP principles to satisfy customer needs for efficiency and low prices, to comply with environmental restrictions and to optimize supply and demand-side investments and returns. However, it is believed that in Lebanon and many other developing countries, the state and or/monopoly utilities will continue to play a central role or at least a planning function will remain in place. In such a case, public authorities can use the IRP principles to design programs to encourage end-use efficiency and environmental protection.

The planning of the electricity supply sector in Lebanon must take into consideration several factors [5]. Namely, the limits on available resources and uncertainty about the future. A major limitation, is the future size of investments? Lebanon has already spent more than US$1.7 billion on the rehabilitation and expansion of its electrical network and this has imposed a major economical burden on the whole economy. Therefore, there is a fear that the government may not be capable of handling further expenditures. As a result, it is important that existing plants be used wisely and that transmission be efficient. Also, any future plans for construction of newer power plants must recognize that capital may be available slowly such that construction will not be able to take place at once. Such an assumption is used to construct future scenarios by assuming that system expansion will occur every five years as the need arises.

Incomplete information about both the operations of the power system and the demand is another reality in Lebanon. There is a great deal of information about the power system before 1975, but currently, tremendous efforts are needed to develop a complete database on all aspects of electric energy generation, distribution and use.

Despite the huge rehabilitation program of the electric power sector, Lebanon has made little investments in the following areas:

- energy conservation and load management
- system optimization and loss reduction
- diversification of supply and renewable energy
- fuel substitution.

In this project, mitigation scenarios that will focus on the last two issues will be considered. Namely, mitigation scenarios will be developed under two categories:

Category 1: Improving mix of supply through renewable energy

Category 2 : Fuel substitution through the use of natural gas.

In both categories, scenarios will have to ensure an additional 10% capacity reserve from combined cycle units operating on natural gas. This reserve will be used to facilitate scheduled maintenance, repair and to make up for unit failures. (10% was selected because the largest unit currently available is 182 MW representing less than 10% of capacity. In practice, we would suggest a capacity of around 15% as a suitable reserve).

Under category 1, scenarios will be developed to account for the use of solar and wind energy in Lebanon. A justification for such scenarios arises from the fact that the current contribution of renewable energy is less than 1% and is mainly through the installation of domestic solar hot water systems. Additionally, it has been confirmed through field measurements that Lebanon has very good solar resources estimated as follow [18]:

Table A1-29. Average monthly solar insolation, KWh/m^2 /day.

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
H, coast	2.4	3.2	4.1	5.5	6.6	7.3	7.0	6.3	5.3	4.0	2.9	2.3
H, interior	2.4	3.4	4.4	5.9	7.2	8.5		7.7	6.5	4.7	3.3	2.4

As to wind resources, there are no real measurements to properly evaluate the wind energy potential in Lebanon, but preliminary studies as well as old field measurement suggest that wind speeds of 5-6 m/s exist in many regions for a period of time ranging from 3 to 7 months. Finally, it has been reported, worldwide, that renewable energy technologies have become commercially available technologies at competitive costs for many applications (wind electric energy is being generated in many places at about 7-9c/kWh and solar electricity is being generated at 14-28c/kWh from thermal power stations and at 35-50c/kWh from photovoltaic units.

Although officials at EDL have expressed their support to renewable energy (in particular for solar energy), it would be difficult to drastically change the situation into one favoring a significant penetration of renewable on both the generation and demand sides. In addition, it has been clear from recent years that the contribution of existing hydropower stations is on the decrease and that no official plans have been announced for building any new hydro power stations. Since renewable energy is unlikely to significantly penetrate the market in the near future, it will be assumed that only 5% of the generated capacity can be satisfied by renewable energy until the year 2010 and that 10% penetration can be maintained between 2010 and 2040 as indicated in Table A1-29.

On the other hand, since both the intensity and the availability of solar energy are higher than those of wind energy, the current study assumes that the 5% and later 10% penetration rates will be achieved through the following scenarios:

- All solar
- 50% solar, 50% wind
- 70% solar, 30% wind

As natural gas will be available around 2005, category 2 will consider it, from 2005 till 2040, as a substitution fuel to replace the fuel oil which was heavily relied on in the baseline scenario. Fuel substitution can be done for both existing and new power plants. It is achievable for existing plants but with high retrofit costs. The cost of retrofitting a power unit may, in some cases, be even higher than that for installing a new power unit, while a fuel alternative plan for new power plants is easier and economic to accomplish, added to that is the fact that the Lebanese government has already announced its position in adopting natural gas as a major fuel for the future. For this, it is worth mentioning that the move to build new lines of natural gas in the very near future in order to import from Syria 3, 6 and 10 million m^3 of gas, supports the opinion that combined cycle power plants operating on natural gas represent the technology option for the future since the current load requires only 3 millions m^3 of gas.

Natural gas in combined-cycle power plants has the highest conversion efficiencies of all fossil fuels. Presently 46% in the short term and 55% in the longer term. Additionally, natural gas has the lowest CO_2 emissions per unit of energy of all fossil fuels at about 187 g/kWh, compared to fuel oil with about 259 g/kWh and diesel oil at about 272 g/kWh (see Appendix A1.1) [20].

Full-cost pricing of energy services

The literature on full-cost pricing of electric energy production is controversial. No consensus exists on how to monetize the external costs of energy production and use. If external costs were to be added on top of the current cost of electricity than a different picture will appear where some unwanted expensive technologies may become widely acceptable. An example to this situation is the wind energy, which will become cheaper than energy from fossil fuel once the external cost is added. External costs include those costs usually not reflected in market prices in the absence of policies. Examples include morbidity, mortality, environmental damage and the like. Because such a practice is absent in Lebanon and is unlikely to be implemented in the near future, the proposed mitigation scenarios will be evaluated without taking into consideration the external (environmental) cost.

Other possible mitigation scenarios

In addition to what was presented above, CO_2 control strategies for the electric sector may include one or more of the following options [20]: Demand-Side Management (DSM), carbon tax, CO_2 emission standard, fuel alternatives, and CO_2 capture technologies.

DSM strategies consider initiatives aiming to change the shape of the load curve, or the total area under the curve, or can be a combination of both goals. Classical DSM strategies include:

- Peak clipping
- Valley-Filling
- Load shifting
- Strategic load conservation

In the Lebanese context, it is believed that the load can be decreased by 10% without any loss of comfort. As to capacity reduction, we also believe that through proper peak clipping techniques supported by peak shifting policies, a 10% reduction in the planned capacity can be achieved to satisfy the expected energy demand. It is important at this stage to mention that there are many other techniques that can be implemented under DSM programs to address the following issues:

- *Better utilization of installed/planned capacities*. Increased availability and load factors should be placed into the position of target values of electricity planning, correspondingly reducing fixed capital costs. In order to act upon these parameters, the passive adaptation of supply to demand and the artificial separation into two different entities is to be abolished. An active role by the suppliers is to be taken in order to achieve a better match of demand patterns to supply characteristics.

- *Increase of flexibility and differentiation of the supply system*. In order to cope with insecurities in power supply system, higher flexibility and differentiation of the pattern of electricity supply (by sources of energy, sizes, plant types, operators, etc.) is to be aimed at. This process is to be anticipated and regulated.

- *Higher degree of efficiency of electricity generation, distribution and use*. Improvement of efficiencies at all levels of the electricity chain reducing primary energy without loss of quality, comfort and security of supply to final electricity users should be a prime target of sector policy. For this purpose the invisible relationship between supply and demand and their costs involved has to be made transparent.

- *Promotion of distribution management systems techniques and control technologies*

- *Motivation of active involvement of customers in energy conservation*

However, due to the limitation of this study, some of the DSM options will be tested in the section that deals with the building sector of this project. More profound DSM analyses are better left to future detailed studies on the Lebanese system.

The employment of a tax policy and CO_2 emission standard are regulations but not the actual means, which lead to CO_2 emission reduction. The carbon tax and CO_2 emission standard if determined by the government will depend on other CO_2 mitigation options and they may lead to politically undesirable consequences and, therefore, will not be considered in this study. Also CO_2 capture technologies are feasible but reduce the conversion efficiency and significantly increase the production cost of electricity. Another approach to decarbonization uses fossil fuel as a feedstock to make hydrogen-rich fuels. Because of its cost and the need to develop the technology further, such options will not be recommended at this stage.

A1.6.1 RESULTS AND CONCLUSIONS- MITIGATION SCENARIOS

Both the mitigation scenarios and the corresponding LEAP results are summarized in Tables A1-30-A1-31 for categories I and II respectively. Details of the yearly results are given in Appendix A1.3. In examining these results, the following explanations should be considered:

1. To be consistent with the baseline scenarios, all the scenarios in the two categories envisage a 10% capacity reserve.

2. The cost is actually the incremental cost of a proposed scenario over that of the baseline one.

3. The contribution of renewable energy to electricity generation is considered as 5% of total capacity till 2010 and will be maintained at 10% between 2011-2040. Additionally, it is the solar thermal technology that is being considered in this analysis.

The total CO_2 emissions associated with every scenario have been calculated and are summarized in Table A1-32.

Table A1.32 Total CO_2 emissions from all categories for 1994-2040

Years	1994-2004	2005-2040		
scenario	Demand growth➩	4%	6%	8%
Baseline	39644	741450	1200870	1952920
Ren. (All Solar)	39644	711498	1150002	1865044
Ren.(50%S-50%W)	39644	719886	1164186	1889560
Ren.(70%S-30%W)	39644	716538	1158498	1879732
Natural Gas	39644	624738	949878	1476280

As can be seen, from emissions point of view, the best policy is to adopt natural gas with the corresponding combined cycle technology. The last scenario provides emission reduction of 14.95%, 20.24% and 23.92% as compared with the baseline scenario for demand growth of 4%, 6% and 8% respectively.

The costs of one Ton of CO_2 reduced from various scenarios compared to the baseline one are shown in Fig. A1.7-A1.9 below for the cases of 4%, 6% and 8% demand growth rate respectively. These Figures were plot for one discount rate 10%. Plots for other dicount rates can be similarly prepared using the data in Tables A1.30 and A1.31.

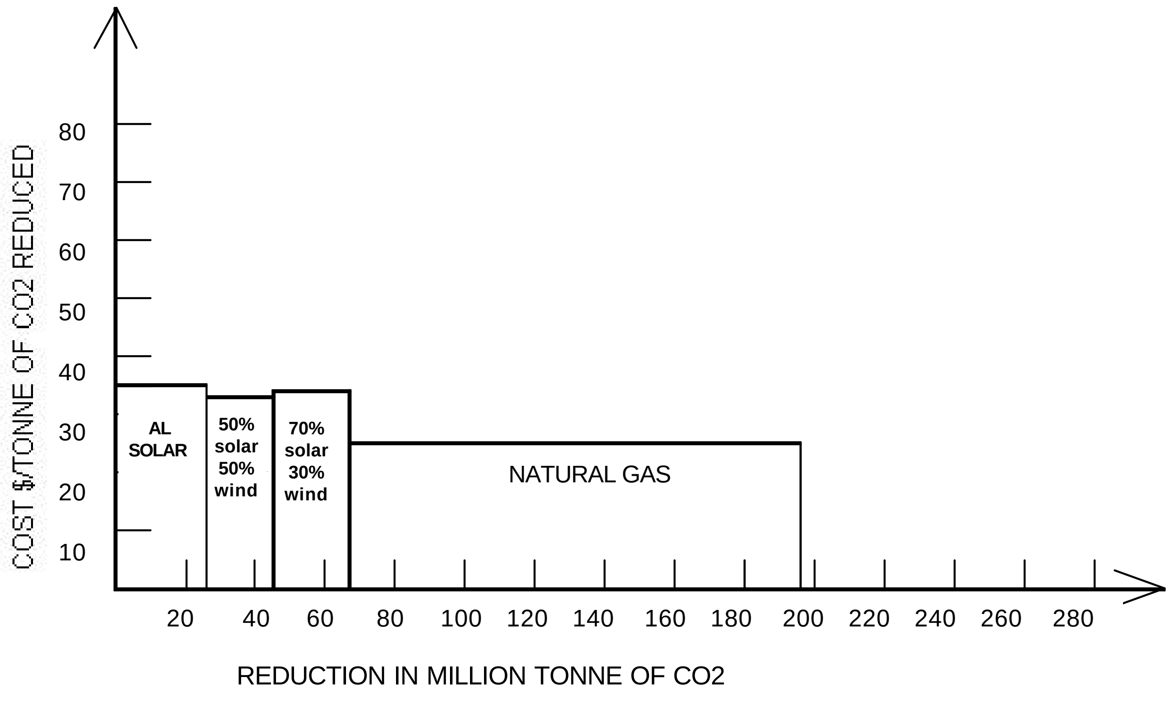
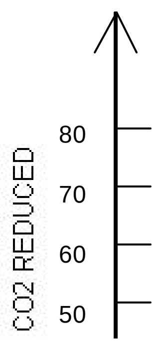


Fig. A1.7. The cost of one Ton CO_2 reduced: 4% growth rate



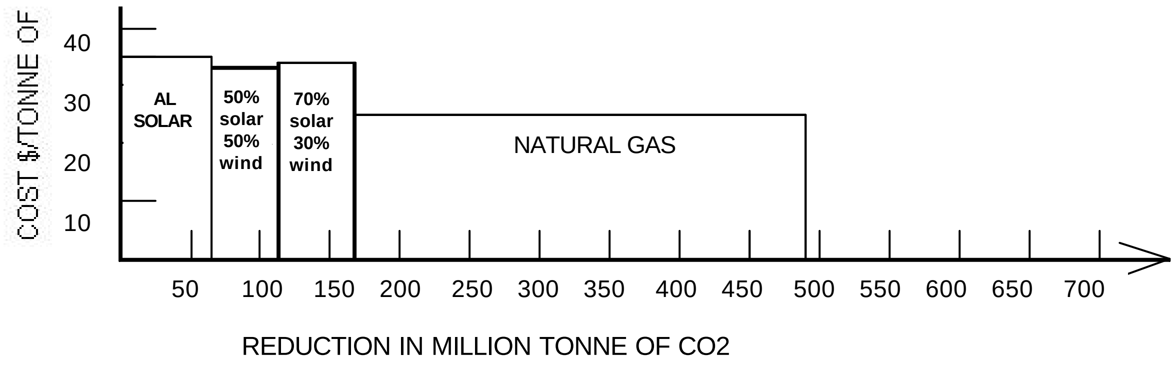


Fig. A1.8. The cost of one Ton CO_2 reduced: 6% growth rate

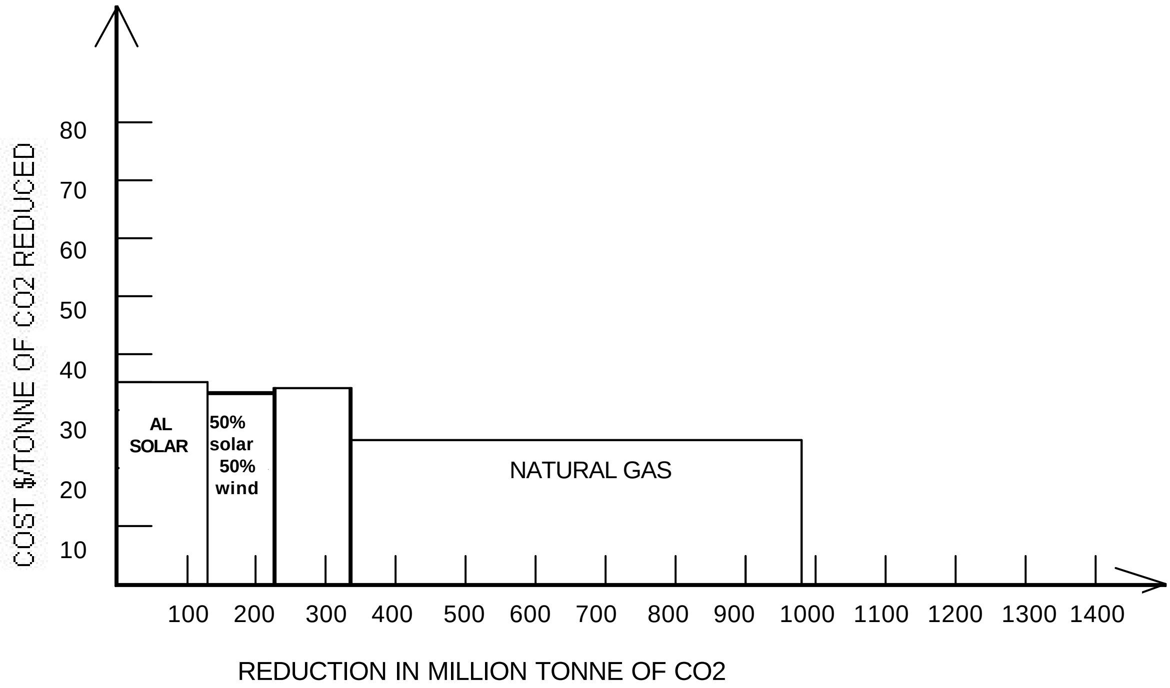


Fig. A1.9. The cost of one Ton CO_2 reduced: 8% growth rate

Based on the results obtained, the best strategy to be suggested for mitigating GHG in the electricity supply sector is the following:

1st. On the level of technology and fuel selection.

1. The choice of natural gas as future fuel is highly recommended
2. The choice of combined cycle power plants as the preferred technology is also highly recommended

1st. On the policy level.

1. Due to their environmental benefits, the promotion of renewable energy technologies is recommended and should be given priority when these technologies become economically competitive. However, the large penetration of renewable energy into the Lebanese system is unlikely to happen in the near future due to many institutional and

technical barriers, which must be addressed carefully and overcome in future projects.

2. The reduction of losses to 10% positively contributes to GHG mitigation in Lebanon. The achievement of such a goal requires no recommendation, as it should be a normal EDL practice.

3. 10% capacity reserve or even more should also be a normal practice at EDL, as the consequences of future electricity shortages will considerably harm the Lebanese economy.

4. Mitigation options have all been evaluated without consideration of the external environmental cost associated with energy generation.The use of external cost in future economic calculations of electricity is obviously recommended as the addition of such a cost will encourage the use of environmentally friendly technologies and resources by making them economically competitive with traditional sources of energy. However, care must be taken to insure that a high price of electricity does not negatively affect the economy nor it imposes heavy burden on citizens whose incomes are cut by inflation year after year.

A1.6.2 PROJECT PROPOSALS AND RECOMMENDATIONS

The two options that have been identified for the electricity supply sector in Lebanon are solar and wind energy generating units, and combined cycle plants operating on natural gas. As for natural gas, the unavailability of such a resource in Lebanon is currently being addressed. The Lebanese government has already negotiated the issue of natural gas with the Syrian authorities and as a result natural gas is expected to be available around 2005. In addition, to address the situation when Syria would not be capable of satisfying the whole Lebanese market, the USTDA (United States Trade and Development Agency) has sponsored a study to check the feasibility of importing gas from Europe and doing all the necessary treatment here in Lebanon to make it satisfy the required specifications. Additional feasibility studies have to be conducted in this area.

With regard to renewable energy, a lot of work has to be done to drastically change the situation into one favoring a significant penetration of renewable on both the generation and demand sides. The following are the barriers that the project should address at present.

<u>Information Barriers</u>

- Lack of accurate wind and solar resource assessment. Shortage of data on patterns of end-use energy consumption in all sectors of the economy prevents practical evaluation of supply-side and demand-side management programs based on solar and wind energy.
- Lack of documentation regarding the economic, environmental and social implications of existing supply-side energy technology.

<u>Awareness Barriers</u>

- Decision makers are not familiar with the social, environmental and economic benefits, resulting from the introduction of renewable energy.

<u>Economic and Financial Barriers</u>

- There are no dedicated financing schemes or special incentives to promote renewable energy systems especially that such systems have very high capital investment costs.

Institutional Barriers

- No policy that favors renewable energy, nor there are laws that permit private electricity generation in the country.

Capacity Barriers

- There are very few people who are familiar with the installation, operation and control of solar and wind energy systems.

Table A1.30 Mitigation scenarios for category I

Scenario: Cat.I: Renewable Energy					Without environmental cost					Average emission reduction, Gg/year		
Scenario Number	Type	Growth (%)	Interest (%)	Benefit (Million $)	Cost (Million $)	NPV (Million $)	B/C	$/Ton of CO2 reduced	CO2	CO	NOX	SOX
1	All solar	4	5	1456	2436	-980	178.98	63.6	832	0.17	2.3	10.9
2	All solar	4	10	695	1548	-853	127.26	40.4	832	0.17	2.3	10.9
3	All solar	4	15	392	1121	-729	94.56	29.3	832	0.17	2.3	10.9
4	All solar	6	5	2329	3882	-1553	174.14	59.7	1413	0.29	3.9	18.5
5	All solar	6	10	1044	2251	-1207	126.61	34.6	1413	0.29	3.9	18.5
6	All solar	6	15	558	1513	-955	97.16	23.3	1413	0.29	3.9	18.5
7	All solar	8	5	3762	6873	-3111	156.12	61.2	2441	0.5	6.7	32
8	All solar	8	10	1588	3672	-2084	113.56	32.7	2441	0.5	6.7	32
9	All solar	8	15	802	2291	-1489	89.04	20.4	2441	0.5	6.7	32
10	S.50%-W50%	4	5	1186	1710	-524	184.8	62.05	599	0.12	1.7	8
11	S.50%-W50%	4	10	575	1074	-499	133.15	38.9	599	0.12	1.7	8
12	S.50%-W50%	4	15	327	772	-445	99.74	28.02	599	0.12	1.7	8
13	S.50%-W50%	6	5	1894	2696	-802	181.75	57.5	1019	0.21	2.8	13.5
14	S.50%-W50%	6	10	864	1541	-677	134.33	32.8	1019	0.21	2.8	13.5
15	S.50%-W50%	6	15	465	1024	-559	104.49	21.8	1019	0.21	2.8	13.5
16	S.50%-W50%	8	5	3070	4645	-1575	167.06	57.37	1760	0.36	4.9	23.2
17	S.50%-W50%	8	10	1323	2457	-1134	122.91	30.3	1760	0.36	4.9	23.2
18	S.50%-W50%	8	15	676	1523	-847	97.18	18.8	1760	0.36	4.9	23.2
19	S.70%-W30%	4	5	1294	2003	-709	181.73	62.9	692	0.14	1.9	9
20	S.70%-W30%	4	10	623	1265	-642	130.43	39.7	692	0.14	1.9	9
21	S.70%-W30%	4	15	354	912	-558	97.59	28.6	692	0.14	1.9	9
22	S.70%-W30%	6	5	1962	3185	-1223	177.08	58.8	1177	0.24	3.3	15.5
23	S.70%-	6	10	898	1816	-918	131.06	33.5	1177	0.24	3.3	15.5

23	S.70%-W30%	6	10	898	1816	-918	131.06	33.5	1177	0.24	3.3	15.5
24	S.70%-W30%	6	15	489	1212	-723	101.49	22.4	1177	0.24	3.3	15.5
25	S.70%-W30%	8	5	3346	5536	-2190	161.67	59.2	2033	0.42	5.6	26.7
26	S.70%-W30%	8	10	1428	2943	-1515	118.25	31.5	2033	0.42	5.6	26.7
27	S.70%-W30%	8	15	726	1831	-1105	92.85	19.6	2033	0.42	5.6	26.7

Table A1.31 Mitigation scenarios for Category II.

Scenario Cat.II : Fuel substitution using natural gas				Without environmental cost					Average emission reduction, Gg/year			
	Type	Growth (%)	Interest (%)	Benefit (Million $)	Cost (Million $)	NPV (Million $)	B/C	$/Ton of CO2 reduced	CO2	CO	NOX	SOX
28	Natural Gas	4	5	11000	10320	680	1.06	69.2	3242	-0.93	5.79	93
29	Natural Gas	4	10	4655	4207	448	1.11	28.2	3242	-0.93	5.79	93
30	Natural Gas	4	15	2350	2058	292	1.14	13.8	3242	-0.93	5.79	93
31	Natural Gas	6	5	21400	20020	1380	1.07	62.4	6972	-1.98	12.47	200
32	Natural Gas	6	10	8823	7955	868	1.11	24.8	6972	-1.98	12.47	200
33	Natural Gas	6	15	4336	3790	546	1.14	11.8	6972	-1.98	12.47	200
34	Natural Gas	8	5	37460	34930	2530	1.07	57.3	13240	-3.8	23.76	382
35	Natural Gas	8	10	14990	13460	1530	1.11	22.1	13240	-3.8	23.76	382
36	Natural Gas	8	15	7155	6228	927	1.15	10.2	13240	-3.8	23.76	382

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