CLIMATE CHANGE VULNERABILITY AND ADAPTATION

ELECTRICITY

Lebanon's Second National Communication
Ministry of Environment/UNDP

2011

1. VULNERABILITY AND ADAPTATION OF THE ELECTRICITY SECTOR

1.1. VULNERABILITY ASSESSMENT

1.1.1. Background

Electricity in Lebanon is supplied through Electricité du Liban (EDL), an autonomous state-owned entity under the authority of the Ministry of Energy and Water (MoEW). EDL is responsible for the generation, transmission, and distribution of electrical energy in Lebanon (EDL, no date).

Access to Electricity:

Lebanon figures among the countries with high coverage of electric power in the region. Table 1-1 shows the access to electricity in some Middle East and North African countries for the year 2000. In 2002, access to electricity grew to be 96% in Lebanon (IEA, 2004) and it reached 99.9% in 2005 (IEA, 2006).

Table 1-1 Electrification rates in some Middle East and North African countries, 2002

COUNTRY	ELECTRIFICATION RATE (%)
Algeria	98.5
Bahrain	99.9
Egypt	97.7
Iran, Islamic Rep	99.2
Iraq	95.4
Jordan	95.5
Kuwait	100
Lebanon	96
Libyan Arab Jamahiriya	99.8
Morocco	77.4
Oman	9.6
Qatar	95.6
Saudi Arabia	98.4
Syrian Arab Rep	86.6
Tunisia	95
United Arab Emirates	97.4
Yemen	50.3

Source: IEA, 2004

Electricity Demand:

Demand figures are difficult to estimate for Lebanon, given that total production by existing power plants does not meet actual demand, therefore necessitating imports and self-generation to compensate for the deficit.

The peak electric load in Lebanon climbed from 1,666 MW in 2000 to 1,936 MW in 2004 (Figure 1-1). However, this figure does not account for the 33% self-generation mentioned below (World Bank, 2008). The actual load, when inflated by 33% to account for that component, is 2,575 MW.

In 2009, average demand was 2,000 - 2,100 MW, and the instantaneous peak load in summer was 2,450 (MoEW, 2010). If these figures are inflated to account for self-generation, this corresponds to an average demand of 2,660 – 2,793 MW, and a peak load of 3,258 MW.

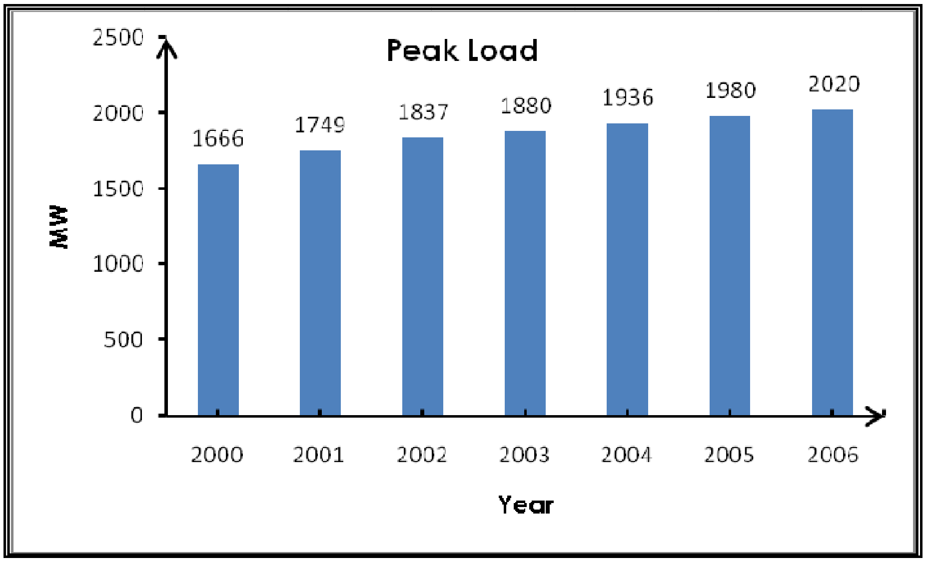

Figure 1-1 Electric Peak Load

Source: Organization of Arab Petroleum Exporting Countries (OAPEC).

Annual Statistical Reports 2001, 2002, 2003, 2004, 2005, 2006, 2007

Electric Energy Consumption:

An increase in electric energy consumption as well as in electricity demand met by EDL has been identified in the past years. The trend of electric energy consumption is represented in Figure 1-2: consumption reached 10,249 GWh in 2004 (OAPEC, 2005). If the 33% self-generation is taken into consideration, actual consumption reaches 13,631GWh, which is equivalent to around 3,177 kWh/ capita (based on a population size of 4.29 million in 2004, as reported in the Human Settlements and Infrastructure chapter, and according to CDR figures (2005)). This consumption figure is close to the World Bank's estimate of 13,200 GWh for 2006 (World Bank, 2008).

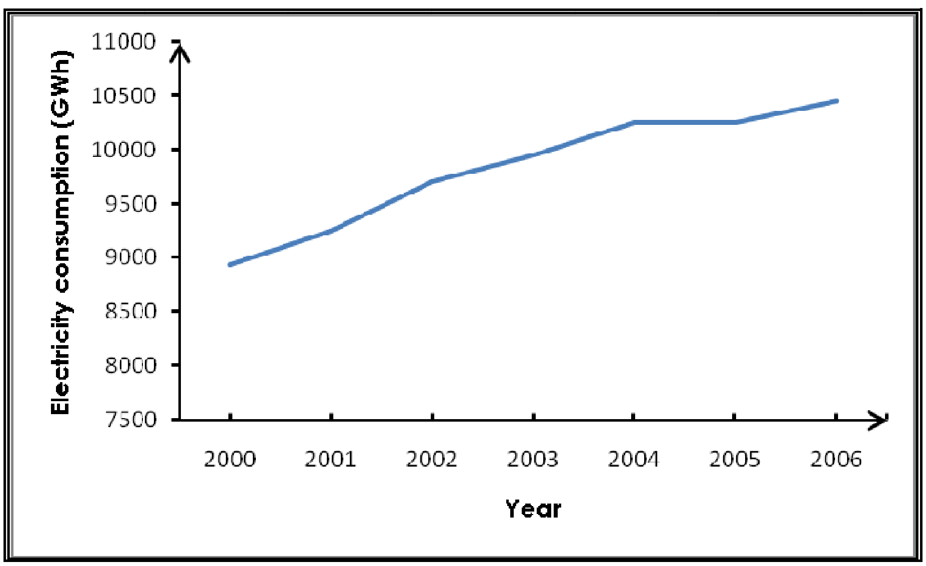

Figure 1-2 Electric Energy Consumption in Lebanon

Source: Organization of Arab Petroleum Exporting Countries (OAPEC).

Annual Statistical Reports 2001, 2002, 2003, 2004, 2005, 2006, 2007

Of the electricity consumed, private low-voltage consumers represent more than half of the demand in Lebanon.

Electricity Production:

Based on EDL's official annual statistics, electricity demand met by EDL grew from 7,839 GWh in 2000 to 10,124 GWh in 2005. This represents an increase of around 29.15% over that period. In 2004, electricity production reached 10,191 GWh. The trend of electricity production by EDL from 2000 to 2006 is represented in Figure 1-3.

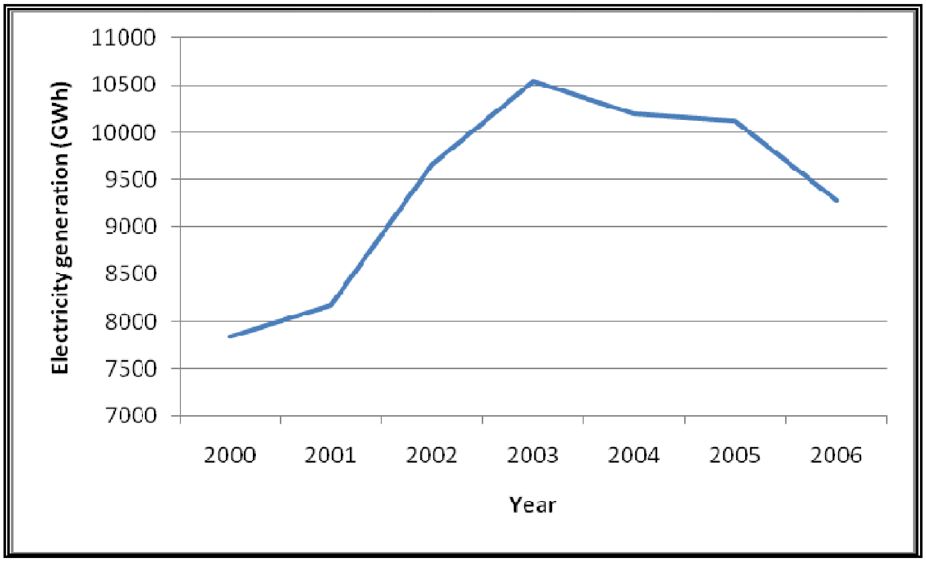

Figure 1-3 Electricity generation from 2000 to 2006

Source: EDL Official Annual Statistics 2000 to 2009

It is worth noting that the decrease in demand met by EDL in 2006 is partially explained by the destruction of the electricity infrastructure caused by the hostilities with Israel during the July-August 2006 war.

Electricity is produced through 6 major thermal power plants owned directly by EDL and one owned indirectly by the Establishment (the Hreysheh Concession); these are located in different areas of Lebanon. EDL also purchases a limited quantity of energy from the Litani River Authority, the Nahr Ibrahim, Al Bared, Safa and Hreysheh Qadisha concessions, all of which use small hydro-power plants with limited capabilities (EDL, no date).

Figure 1-4 shows the evolution of total installed capacity of power plants with time (OAPEC, 2001 to 2007). However, while public data shows that total available capacity amounts to 90% of installed capacity (Table 1-2), it is generally accepted that the available thermal power plant capacity currently varies from 1,600 to1,800 MW, i.e., around 70-80% of installed capacity (around 2,200 MW), due to the fact that many power plants are operating below their optimal efficiency. In 2009, installed capacity was 2,038 MW and available capacity 1,685 MW. (MoEW, 2010)

Most of Lebanon's thermal plants operate mainly as base or intermediate load plants (i.e., operating all the time at full available capacity) since supply capacity is insufficient to meet demand; with several scheduled and unscheduled outages (World Bank, 2008). The inability of EDL to meet the existing demand creates a deficit that has led to the import of electricity from Syria and private self-generation over the years in order to complement the existing supply and reduce suppressed demand.

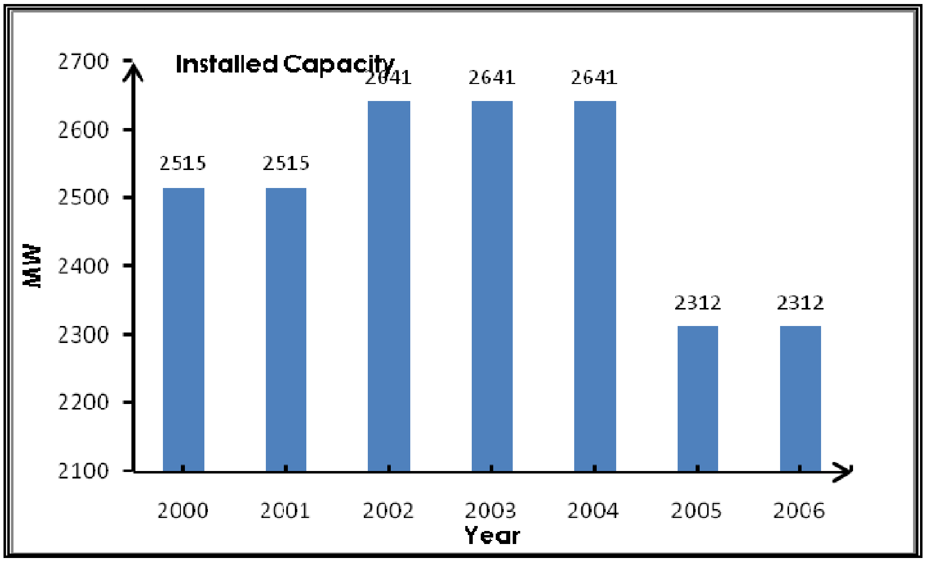

Figure 1-4 Total installed capacity of power plants in Lebanon (1998-2006)

Source: Organization of Arab Petroleum Exporting Countries (OAPEC).

Annual Statistical Reports 2001, 2002, 2003, 2004, 2005, 2006, 2007

Power Plants in Lebanon:

EDL operates 6 thermal power plants (Table 1-2), while the 7th power plant is owned by the Hreysheh Cconcession, and 5 hydropower plants.

Table 1-2 Total capacities and efficiency of thermal power plants in Lebanon

UNIT NAME	TOTAL INSTALLED CAPACITY (MW)	AVAILABLE CAPACITY (MW)	EFFICIENCY (%)
Zouk	607	520	38
Jiyeh	346	295	33
Tyre	70	70	38
Baalbeck	70	70	38
Zahrani	435	435	48
Deir-Ammar (Baddawi)	435	435	48
Hreisheh	75	NA	NA
Total capacity	2,038	1,770	

Source: EDL, no date and World Bank, 2008

Table 1-3 Installed capacity and annual energy of hydropower plants in Lebanon

UNIT NAME	INSTALLED CAPACITY (MW)	CAPACITY FACTOR (%)	ANNUAL ENERGY (GWH)
Litani	190	47	775
Al Bared	17	34	50
Safa	13	22	25
Nahr Ibrahim	33	35	100
Qadisha	21	41	75
Total capacity	274	43	1,025

Source: CDR, unpublished

Thermal capacity is divided into HFO-fired steam turbines at Zouk, Jiyeh and Hreysheh; diesel-fired Combined Cycle Gas Turbine (CCGT) at Beddawi and Zahrani; and diesel-fired Open Cycle Gas Turbine (OCGT) at Sour and Baalbeck.

A contract was signed in May 2009 between Lebanon and Egypt for the supply of natural gas to the Deir Amar plant in North Lebanon, which arrived in late October 2009, thus reducing demand for gas oil (MoF, 2010).

According to CDR's unpublished master plan for the electricity sector, the total Lebanese hydropower capacity amounts currently to 274 MW. However, the actual generation capacity is 190 MW (MoEW, 2010)70% of the hydropower generation comes from the Litani River Authority that manages three plants on the Qaraoun Lake: the dam confines a huge 220 Mm³ reservoir and the turbines deliver respectively 34 MW, 108 MW and 48 MW, amounting to a total capacity of 190 MW. The Bared and Nahr Ibrahim plants have an installed capacity of 17 and 33 MW respectively. All the hydropower units are between 40 and 70 years old, but they are not expected to be retired in the near future (CDR, unpublished).

Self-Generation:

Even though the electrification is very high in Lebanon (99%), self-generation plays a large role in electricity supply and demand, as already mentioned. Power outages are a daily occurrence in Lebanon and in some regions of the country the quality of electricity supply is particularly poor. No new power generation capacity has been added since the two combined cycle plants were installed in the 1990s. This has led to a massive investment by low-voltage consumers (households and commerce) and industry in back-up arrangements.

The reason for this is the inability of EDL to meet demand effectively due to insufficient generation capacity, high levels of lost electricity and poor load management. Hence, 33% of total electricity demand in 2003-2004 was met through self-generation, as estimated by the World Bank (2004), in addition to suppressed demand that is reported to be around 8.8%. Figure 1-5 shows estimated consumption figures for 2006, where self-generation accounts for 33.6% of total consumption, and suppressed demand for 5.3%. Self-generation was reported to increase between 1998 and 2006, and is inflating consumers' electricity bills up to 25% for the sake of "security of supply" (World Bank, 2008).

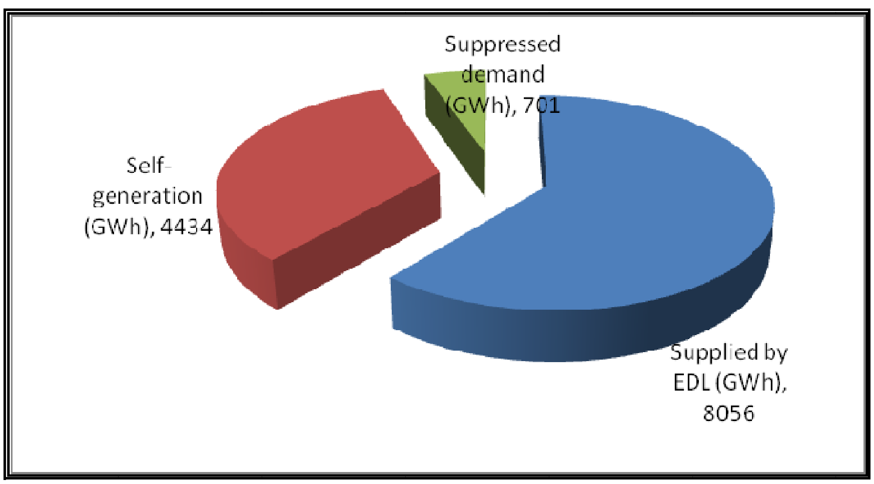

Figure 1-5. Estimated total consumption of electricity in 2006

Source: World Bank, 2008

Imports:

Electricity has also been imported from Syria for over a decade in order to compensate for the shortfall in production. More than 8,000 MWh have been imported since 1998, and the monthly imports usually depend on the availability of surplus in Syria (Byblos Bank, 2010). Table 1-4 shows the annual import figures from 2000 to 2009, as per EDL's official annual statistics. The maximum import capacity from Syria is 300 MW. In 2006, Lebanon imported up to 200 MW at a price of approximately 12 US¢/kWh (World Bank, 2008), which is cheaper than the cost of electricity generation.

In 2009, electricity started being purchased from Egypt in addition to Syria. Purchases from both countries constituted 7.5% of the total energy production (MoEW, 2010).

Table 1-4 Electricity Imports from Syria throughout the years

YEAR	IMPORTS (GWH)
2000	1,397
2001	1,263
2002	532
2003	-
2004	216
2005	455
2006	929
2007	972
2008	561
2009	1,116*

* 589 GWh from Syria and 527 GWh from Egypt

Source: EDL Official Annual Statistics 2000 to 2009.

Losses:

Of the electricity supplied by EDL, a significant portion is lost either due to technical losses in the network or due to theft. Technical losses are reported to be in the order of 15% in 2007, according to EDL. Non-technical losses – which essentially comprise non-billed consumption of electricity through illegal connections on the distribution network) – are reported to be about 18% in 2007. This 18% of non-billed electricity translates into US$150 million in lost revenue per year for EDL and is partly explained by a weak billing system within EDL, but also by political interference in the operation of the utility. Over the years, EDL has sought to reduce its non-technical losses, and a decline of about 3% was achieved during 2004-05. As a result of these two types of losses, over 30% of produced electricity is not billed (World Bank, 2008).

Achieving technical losses better aligned with international best practice (8-10% for some of the world's best performing electricity utilities) is a necessity to improve the technical, financial and governance performance of the sector. For instance, a reduction in technical losses from the current 15% to 10% would free up about 100 MW of capacity, avoiding investment in the equivalent amount (a saving of about US$80- US$100 million in avoided investment cost) and enabling this amount of already generated electricity to be billed to consumers rather than being lost in the network.

Costs and Deficits

The Lebanese electricity sector is at the heart of a deep crisis. The sector is unable to supply the reliable electricity needed by homes, offices and industry. It is a massive drain on government finances, crowding out more valuable expenditures on education, infrastructure, social protection, and health, and putting macroeconomic stability at risk. The state of the sector has reached a critical stage, with a massive drain on public resources (estimated at 4% of GDP for 2007 and 4.3% of GDP in 2009), significant revenue loss for industry and commerce, and exorbitant spending on back-up generation by the general population.

Since no new power generation capacity has been added since the 1990s, consumers and industry rely heavily on back-up arrangements. This form of energy security is estimated to cost the population at least an additional 25% in spending on electricity per month. The poor electricity service provided by the public sector is costing the Government massive amounts in the form of generalized subsidies required to cover fuel oil and gas oil bills due to low levels of revenues caused by the fact that tariffs are set far below cost recovery (as well as an inefficient tariff structure), low billings and collections, in addition to other technical reasons. With the huge increases in international oil prices in recent years, the lack of tariff adjustment since 1996 (when the oil price was US$21/barrel) has become a clear and present problem and one that is closely linked to being able to address the fiscal drain of the sector (World Bank, 2008).

Moreover, despite the abundance of natural gas in the region, gas-oil (diesel) continued to be used in two major power plants designed to use natural gas, as well as in the gas turbines designed as peaking plants but used as base load plants due to insufficient capacity to serve demand, until the end of 2009 when natural gas arrived from Egypt via Jordan and Syria. The high O&M cost of all power plants due to insufficient regular maintenance and spare parts, as well as high technical losses, result in very high production costs. Indeed, Lebanon's electricity tariff level is high by regional standards and in relation to service quality, but too low to cover EDL's costs. As a result of the continued service un-reliability, any tariff increase is likely to be met by protest by consumers and a significant decline in the billing and collections (World Bank, 2008).

Given the mismatch between its inlays and outlays, EDL relies considerably on Government transfers, aimed primarily at covering the deficit – rather than investment activities – through contributing to the repayment of fuel oil and gas oil bills. The Government's financial support to the electricity company dates back to the civil war – although back then the frequency and structure of transfers was not systematic, as is currently the case (Figure 1-6). The substantial increase in recent years reflects the rise in international oil prices, coupled with growing demand for oil. In 2008, transfers reached LBP 2,430 billion (US$ 1.6 billion), which translates roughly to US$ 400 per person per year. If total expenditures are taken into account, transfers to EDL constitute the third largest public expenditure item, after interest payments and personnel cost (MoF, 2010).

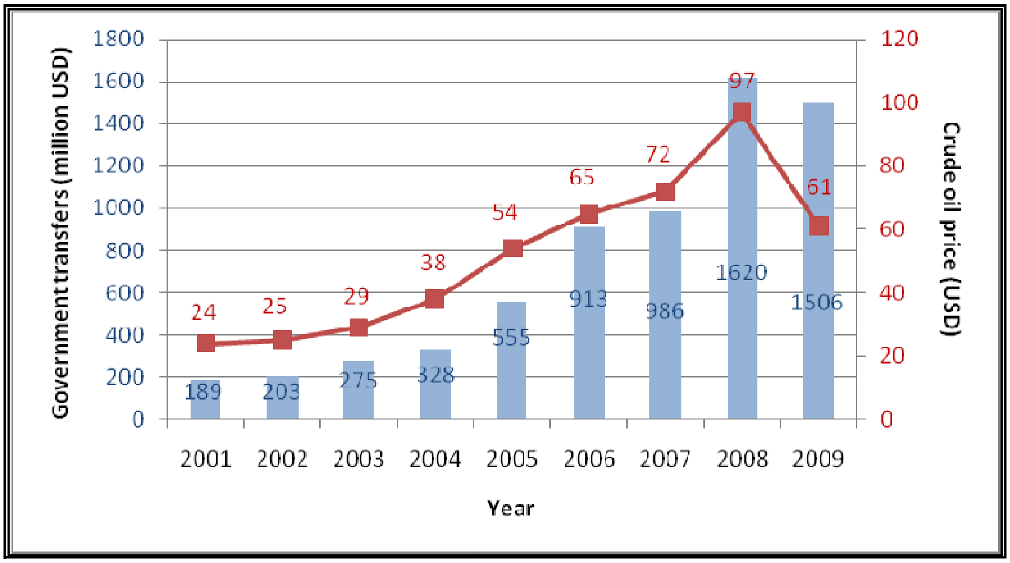

Figure 1-6 Transfers to EDL and crude oil prices (2001-2009)

Source: MoF, 2010

1.1.2. *Methodology*

1.1.2.1. *Scope of Assessment*

Unit of Study

The main aspects of vulnerability this chapter focuses on are the following:

- Increased pressure on the energy production system as a result of:
  - Increased cooling demand during summer, in addition to the increase in demand driven by natural and economic growth;
  - Increase in oil/gas prices, which will drive the cost of energy production higher, leading to a reduction of GDP growth; and
  - Potential disruption of some energy production units, notably those using water resources (e.g., hydroelectric power plants), as a result of reduced precipitation.
- Increased pressure on the power supply chain as a result of increased demand, and possibly storm surges.

Spatial Frame

The assessment covers the entire country, since cooling and heating demands, hydropower generation, and power supply cover the whole territory.

Time Frame

The assessment covers summer and winter seasons, covering cooling and heating demand depending on season, as well as the availability of water resources, solar radiation and wind throughout the year for renewable energy production.

The assessment extends from 2004 (baseline year) until 2030.

1.1.2.2. *Climatic Factors*

The climatic factors of importance for the electricity sector are:

- Temperature and relative humidity, which affect cooling and heating demand;
- Precipitation, which affects hydropower generating potential;
- Wind speed and cloud cover which determine the feasibility and capacity of power generation from renewable energy (wind and solar); and
- Storm frequency and intensity which might affect electricity infrastructure.

1.1.2.3. *Methods of Assessment*

The expected increase in temperature was used to calculate the increased energy demand in summer as a result of increase in temperature, using the following equation:

$Q = R * A * (T_{outside} - T_{inside})$, where: Q = Quantity of energy;

A = Area;

R = Transmission Coefficient;

$T_{outside}$ = Outside Temperature

T_{Inside} = Inside Temperature

If the outside temperature increases by X°C, the new quantity of total energy needed for cooling is calculated as follows:

$$Q_1 = R * A * ((T_{outside} + X) - T_{inside}$$

The quantity of energy needed to eliminate this increase in temperature, and accordingly to compensate for the added cooling load would be:

$$Q_1 - Q = [R * A * ((T_{outside} + X) - T_{inside})] - [R * A * (T_{outside} - T_{inside}$$

$$Q_1 - Q = R * A * X$$

The corresponding increase in energy consumption is calculated as follows:

$$Percent \quad increase \quad (\%) = 100 \times (Q_1 - Q) / Q = 100 * [X / (T_{outside} - T_{inside})]$$

In order to calculate equivalent $KW_{electrical}$ from a $KW_{cooling}$ demand, we need to use a value for the COP (coefficient of performance), which is calculated as follows (or found on any cooling compressor's datasheet):

$$COP = kW_{cooling} / kW_{electrical}$$

Using the COP, the electrical energy consumption that would be increased due to the rise in temperature can be calculated:

% increase in electrical energy consumption = $100 * [X / (COP * (T_{outside} - T_{inside}))]$

In order to calculate the estimation of the increase in the electrical energy demand due to rise in temperature, temperature variations are used as reported in Table 1-5.

Table 1-5 Temperature Variation over one year

MONTH	AVERAGE $T_{OUTSIDE}$* (°C)	T_{INSIDE} (°C)
January	13.6	22
February	14.0	22
March	15.9	22

MONTH	AVERAGE $T_{OUTSIDE}$* (°C)	T_{INSIDE} (°C)
April	19.0	22
May	22.7	22
June	25.9	22
July	28.1	22
August	28.7	22
September	27.1	22
October	24.0	22
November	19.4	22
December	15.3	22

* Ministry of Public Works and Transport, 1971

Assuming that the average COP is 2.8 (based on expert judgment), Table 1-6 shows the annual increase in cooling consumption for the range of 1 – 3 ^{0}C increase in temperature (by 2040). No projections were made for the 5 ^{0}C increase in temperature by 2080-2098 since it is difficult to predict energy demand by then.

Table 1-6 Annual increase in cooling consumption for a 1-3°C increase in temperature

INCREASE IN TEMPERATURE	ANNUAL INCREASE IN ELECTRICAL COOLING CONSUMPTION
Increase 1°C	9.04%
Increase 1.5°C	13.56%
Increase 2°C	18.08%
Increase 2.5°C	27.76%
Increase 3°C	28.55%

The increase in demand from natural and economic growth from 2004 to 2030 was estimated using expert judgment (as described in Section 1.1.3) in the absence of data on activity level, energy intensity, etc. to make a disaggregated end-use oriented demand analysis and projections using the Long-range Energy Alternatives Planning system (LEAP). The additional growth in energy consumption resulting from increased cooling demand in summer was calculated for the same period as described above and superimposed on the business-as-usual scenario. These estimates were entered on the Long-range Energy Alternatives Planning system (LEAP) just to draw a curve on the growth in consumption under the baseline scenario and the two warming scenarios (+1°C and +3°C).

LEAP is a scenario-based energy-environment modeling tool. Its scenarios are based on comprehensive accounting of how energy is consumed, converted and produced in a given region or economy under a range of alternative assumptions on population, economic development, technology, price and so on. LEAP serves several purposes: as a database, it provides a comprehensive system for maintaining energy information; as a forecasting tool, it enables to make projections of energy supply and demand over a long-term planning horizon; as a policy analysis tool, it simulates and assesses the effects - physical, economic, and environmental - of alternative energy programs, investments, and actions (SEI, 2006).

The software was used for modeling purposes in the mitigation section (Electricity chapter), based on the MoEW's plan and expert judgment of missing values.

Moreover, results of the water vulnerability assessment were used to assess the potential impact on hydropower generating capacity, given the Government plan to build over 20 dams and hydropower plants along major rivers throughout the country in the long term, coupled with the expected decline in precipitations (rainfall and snowfall).

Finally, the assessment of the sector's overall vulnerability to climate change was conducted based on:

- Developing two baseline socio-economic scenarios that show and characterize the current and the possible future variation in the demographic, socio-economic and technological driving forces in the country.
- Developing a climate change scenario to indicate how climatic and climate related factors could possibly change.
- Identifying vulnerable hotspots to climate change based on their social and biophysical exposure, their sensitivity and their adaptive capacity to climate change. This identification was based on professional judgment and literature review.
- Setting out indicators to study the sensitivity, adaptive capacity and vulnerability of vulnerable hotspots under socio-economic and climate change scenarios.
- Determining the likely climate change impacts through a literature review and further analysis.

1.1.2.4. Data Sources and gaps

The main sources of data used in this assessment were Electricité du Liban (EDL), CDR, OAPEC (Organization of Arab Petroleum Exporting Countries), and the World Bank's "Electricity Sector Public Expenditure Review". Data on demand, supply, power generation, etc. were taken from EDL figures when available.

Data gaps relating to the energy sector in Lebanon prevented the use of the Long-range Energy Alternatives Planning system (LEAP) in conducting a disaggregated end-use oriented demand analysis with projections. These and other gaps include:

- Data on energy consuming devices at the household level and corresponding energy consumption;
- Breakdown of demand and consumption figures into industrial, residential, commercial, etc.;
- Lack of transparency and proper record keeping, and little data accessibility (demand, supply, capacity and efficiency of power plants, etc.);
- Accurate figures on the proportion of electricity self-generation.

1.1.2.5. Assumptions and Limitations

As mentioned above, data gaps inhibited the use of LEAP in conducting a disaggregated end-use oriented demand analysis with relevant projections.

As for the figures on cooling consumption, they were calculated using an equation relating temperature increase to the increase in energy demand. These equations comprise variables that are not documented for Lebanon and thus relied on expert judgment, with associated uncertainties and limitations. Moreover, actual figures depend on factors such as construction materials, the building envelope, etc., that vary across buildings.

Similarly, the percent energy consumption by sector and percent of cooling consumption by sector (that were used to calculate the increase in demand from increasing temperature) also relied on expert judgment in the absence of documented values for Lebanon.

1.1.3. Scenarios

1.1.3.1. Socio-economic scenarios

The National Physical Master Plan for the Lebanese Territories (NPMPLT) projections (CDR, 2005) put Lebanon's energy demand in 2030 at 4,200 MW, that is around 800 W per person, based on the following evolution of consumption per capita, including the needs for industrial and other economic activities (Table 1-7):

Table 1-7 Forecasted increase in per capita energy consumption by 2030

PERIOD	PERCENT INCREASE IN CONSUMPTION/ CAPITA
2002-2015	3%
2015-2025	2%
2025-2030	1%

Source: CDR, 2005

The addition of 3,000 MW by 2030 was planned in order to meet this projected increase and taking into account the closure of the Zouk power plant by 2010.

However, current projections give a higher estimate of increase in demand, and recent government plans consider the rehabilitation of the Zouk and Jiyeh plants rather than their retirement. Therefore, expert judgment was used to correct for these differences in plans and estimates: a 4 - 5% yearly increase in demand was assumed until 2020, followed by a 2 – 3% increase from 2020 until 2030, knowing that in middle income countries, demand for electricity grows at a factor above the GDP growth, as reported by the World Bank (2008). Based on a peak load of 2,575 MW in 2004 including self-generation, these rates yield a projected demand of around 4,820 – 7,555 MW by 2030. These figures are in line with the World Bank's projection of demand by 2015 of 4,000 MW, necessitating an additional 1,500 MW from EDL and self-generation by that date (World Bank, 2008).

In terms of energy consumption, projections using the same growth rates give a range of 25,530 – 40,000 GWh by 2030, based on 13,631 GWh in 2004.

The lower and higher boundaries of the growth range can be assumed to correspond to scenarios A and B (defined below).

The CDR defined, in the NPMPLT, different challenges that Lebanon faces today and ones that it might face in the future (CDR, 2005). According to those challenges, two possible scenarios were proposed for the development of the energy sector by the year 2030. These two scenarios are detailed below.

Scenario A	
▪ Growing integration of international trade, Lebanese production of exchangeable products would not be significantly developed. ▪ Less balanced economic development ▪ GDP grows at an annual average rate of 4.2%[1] ▪ Low population growth – Population will grow, however at a decreasing rate – average of 0.35%[2] between 2010 and 2030 ▪ Total urbanized area will slightly increase ▪ The migration balance[3] between 2001 and 2030 will be around (-27,000) persons yearly ▪ Same standard of living.	Under Scenario A, energy consumption per capita and total demand will not increase significantly as a result of slow population growth and stable standard of living. Since total urbanized area will not increase much, the distribution network will not be under pressure for coverage expansion. With limited affluence but also limited need for expansion (supply and distribution), the power sector and energy security will not really be at a disadvantage. The higher level of environmental awareness will lead to increased interest in the development of renewable energy sources.
Scenario B	
▪ Growing integration of international trade, local production could better resist the competition induced by imported products ▪ Balanced economic development ▪ Considerable GDP growth: GDP is assumed to grow at an annual average rate of 8.6%[4] between 2010 and 2030 ▪ High population growth: Population will grow at a modest increasing rate with an average of 0.96%[5] between 2010 and 2030 ▪ Total urbanized area will increase with population: growth of 284 km^2 of urbanized areas ▪ The migration balance between 2001 and 2030 will be around (-6,000) persons per year ▪ Better standards of living: ~ 2.4 times higher.	Under Scenario B, high population growth and GDP growth combined with higher standards of living will have a double edge impact on both energy consumption per capita and total energy demand, which are expected to increase considerably. Additionally, the increase in urbanized area will put additional pressure on the power distribution system that will require expansion. In spite of the relative affluence and more balanced economic development that will enable EDL to cope with this increase in demand and area to be served to a large extent, energy security will still be threatened.

1 This is an average of the actual GDP growth rate, at constant 1990 prices, between 2000 and 2004 (IMF, 2009).

2 This an average of the population growth rate in a **low fertility scenario** as projected in the World Population Prospects: The 2008 Revision (UN, 2009).

3 The migration balance is defined as the difference between the number of persons having entered the territory and the number of persons having left the territory in the course of the year, independent of nationality (INSEE, 2010).

4 An assumption, whereby the annual average GDP growth rate would grow by double the IMF-projected average annual growth rate of 4.3%, for the period between 2010 and 2014 (IMF, 2009).

5 This an average of the population growth rate in a **high fertility scenario** as projected in the World Population Prospects: The 2008 Revision (UN, 2009).

Plans

Successive governments have suggested numerous master plans for the electricity sector throughout the years. However, none of these plans and strategies has been implemented so far. The current Government proposed in June 2010 a policy paper for ensuring 24-hour supply, improving security and reducing costs and losses in the electricity sector by 2014. The proposed plan tackles the addition of generation capacity to cover the existing gap, the required reserve margin, as well as the necessary improvement in transmission and distribution infrastructure. The plan, detailed in the electricity mitigation chapter, mainly consists of:

Infrastructure

GENERATION

The generation policy targets a total installed capacity of 4,000 MW by 2014 and 5,000 MW thereafter to meet a load of 2,500 MW (recorded in summer 2009), 500 MW of demand not currently supplied (i.e., self-generation), future demand corresponding to an annual load growth of 7%, and around 15% of peak load reserve. The additions will be in the form of capacity additions (mainly from gas and renewables), rehabilitation and maintenance of existing plants, rental and purchase.

TRANSMISSION

The transmission policy will focus on removing bottlenecks, reducing transmission losses, completing a control facility to ensure adequate connection between power plants and load centers together with high reliability and stability at the lowest cost.

DISTRIBUTION

The distribution sector policy consists of implementing a transitional and realistic program with the participation of the private sector based on the existing legal framework, and aiming at investing in planning, constructing, operating and maintaining the distribution activities including metering, billing and collection through modern and smart systems.

Supply and demand

FUEL SOURCING

The fuel sourcing policy is based on diversity and security where 2/3 of the fuel mix is based on natural gas with multiple sources of supply; more than 12% of the fuel mix comes from renewable energies; and the remaining from other sources of fuel while selecting technologies that work on both natural gas and fuel oil.

Renewable energy

The main goal is to reinforce all public, private and individual initiatives to adopt the utilization of renewable energies so as to reach 12% of electric and thermal supply (hydro, wind, waste to energy, solar).

DEMAND SIDE MANAGEMENT / ENERGY EFFICIENCY

The policy commits to the preparation and spreading of the culture for proper electricity use and the adoption of national programs focused on demand side management in order to save a minimum of 5% of the total demand. This will promote effective energy use, peak shaving, load shifting and demand growth control.

TARIFFS

The policy will gradually restructure and increase the existing tariff to eliminate the financial deficit in the electricity sector and establish a balanced budget for EDL on one hand, and reduce the financial burden on citizens caused by the utilization of costly private generators on the other hand.

Legal Framework

NORMS AND STANDARDS

The policy aims at setting norms and standards for the provision of electric services that are safe, equitable and fair with the best quality and lowest cost.

CORPORATIZATION OF EDL

The success of this policy necessitates the "revitalization" of EDL because it is the core entity of the sector. This entails providing the financial, administrative and human resource flexibility needed to cope with the rapid and vital changes.

LEGAL STATUS

This component covers:

- Initiating the process of revising and amending Law 462 with concerned parties.
- Beginning with the current legal status of EDL governed by Decree 4517 in order to avoid delays in the execution of the strategy.
- Adopting a Law for the new power plants with all possible technologies and encouraging all kinds of Public Private Partnership to facilitate the transition and ensure proper continuity between current and future legal status.

1.1.3.2. Climatic Scenarios

The following table summarizes the projections of the climatic factors of relevance to the Energy sector for the Mediterranean region and for Lebanon as they figure in the IPCC Fourth Assessment Report and the EEWRC Climate simulations respectively.

Table 1-8 Projected change in climatic factors of significance to the electricity sector

CLIMATE FACTOR	PROJECTIONS FOR THE MEDITERRANEAN REGION[1]	PROJECTIONS FOR LEBANON[2]
Temperature	The annual mean warming from the period 1980-1999 to 2080 -2099 varies from 2.2°C to 5.1°C. The warming in the Mediterranean area is likely to be largest in summer.	Increases in Tmax are projected to be between 1°C on the coast of Lebanon and 2°C inland by 2040, and between 3°C on the coast and 5°C inland by 2090.
Precipitation	The annual area-mean change from the period 1980 -1999 to 2080- 2099 varies from –4% to –27% in the Mediterranean region.	Rainfall reduction is projected to be between -10 and -20% by 2040, and between -25% and -50% by 2090.
Relative humidity	-	Annual average relative humidity changes will be very small by 2040, but reductions up to 10% in the eastern part are projected for the 2080s.
Wind speed	The northward shift in cyclone activity tends to reduce windiness in the Mediterranean area.	Less than ±0.3 m/s change for 2025-2044 and 2080-2098.
Cloud cover	-	Decrease by about 5% inland.
Storm frequency and intensity	Conflicting predictions: Extreme phenomena such as storms and violent winds expected to increase over the Mediterranean basin, even though this increase is less certain than those of temperature and aridity (Tourre et al., 2008). Weakening of the storm track over the Mediterranean, related to a large scale hemispheric change (Bengtsson et al., 2005); northward shift in cyclone activity tends to reduce windiness in the Mediterranean area[1].	-

Sources:

1 Christensen et al., 2007.

1.1.4. *Vulnerability Assessment*

1.1.4.1. *Sensitivity to Climate Factors*

Electricity demand is sensitive to fluctuations in ambient temperature, through a reduction of peak load in winter (as a result of reduced heating demand), and an increase in peak load in summer (as a result of higher cooling requirements). This drives the peak load up during summer, putting pressure on the electricity generation and supply system that already suffers from prevailing shortages and rationing. Oil prices also depend on the increasing global demand. Similarly, hydropower generation is sensitive to any forecasted decrease in precipitation, as are wind and solar power generation to potential changes in wind speed and cloud cover. However, climate simulations for Lebanon predict insignificant changes in wind speed and a slight decrease in cloud cover (especially inland), which act in favor of these renewable energy sources.

1.1.4.2. *Adaptive Capacity*

The adaptive capacity of the power sector is generally moderate to low as a result of the already existing shortages and rationing, the slow expansion in power generation capacity with time in spite of rising demand, and the deficit in EDL's budget. Adaptive capacity will be lower under scenario B because of the expected higher increase in population size and living standards, which will drive demand up at a high pace. However, the more balanced development and higher economic growth might improve adaptive capacity by increasing EDL's ability to formulate and implement plans to develop renewable energy, increase power production and eliminate rationing. This would also enhance adaptive capacity with respect to rising oil prices that would be lower under scenario B unless renewable energy is developed.

As for hydropower generation, given the projected number of planned dams and lakes and associated hydropower plants, adaptive capacity is low, especially under scenario A with its limited economic growth.

1.1.4.3. Vulnerability Assessment results

Table 1-9 was used to identify vulnerable systems in the energy sector based on both their sensitivity to climate change and their adaptive capacity. Energy demand, power production and supply chain, as well as hydropower generation were rated as having moderate to high vulnerability; while wind power generation has a low vulnerability based on the forecasted minimal change in wind speed; and the potential for solar energy production is expected to increase given the expected slight decrease in cloud cover inland.

Regarding supply, vulnerability to storms was not considered significant, especially that increased storm frequency and intensity might decrease over the Mediterranean basin, and damage to electricity infrastructure from weather is uncommon or insignificant in Lebanon.

Table 1-9 Identification of vulnerable systems

SYSTEM	SENSITIVITY	ADAPTIVE CAPACITY		OVERALL VULNERABILITY	
Energy demand	High due to increasing cooling demand with hotter weather	Scenario A	Moderate	Scenario A	High
		Scenario B	Low	Scenario B	High
Power production	High due to the need to keep up with increasing cooling demand	Scenario A	Moderate	Scenario A	High
		Scenario B	Moderate	Scenario B	High
Power supply chain	Moderate due to the difficulty of meeting increasing demand and the low efficiency of power plants and transmission lines	Scenario A	Moderate	Scenario A	Moderate
		Scenario B	Low	Scenario B	High
Oil prices	Moderate due to the global increase in demand that will become worse with increasing cooling demand	Scenario A	Low	Scenario A	High
		Scenario B	Moderate	Scenario B	Moderate
Hydropower generation	Moderate due to the forecasted decrease in precipitation and increase in evapotranspiration	Scenario A	Low	Scenario A	High
		Scenario B	Moderate	Scenario B	Moderate
Wind power generation	Low due to the forecasted insignificant change in wind speed	Scenario A	Moderate	Scenario A	Low
		Scenario B	High	Scenario B	Low
Solar power generation	None due to the forecasted slight decrease in cloud cover	Scenario A	-	Scenario A	None
		Scenario B	-	Scenario B	None

1.1.5. *Impact Assessment*

1.1.5.1. *Selected Impact Indicators*

Table 1-10 lists the indicators selected for the assessment of the impacts of climate change on the electricity sector in Lebanon, together with their relevance.

Table 1-10 Selected indicators for the assessment of climate change impacts on vulnerable systems

VULNERABLE SYSTEM	INDICATOR	RELEVANCE
Energy demand	Cooling demand	Cooling demand in summer increases with rising temperatures (Tmax).
	Heating demand	Heating demand in winter decreases with rising Tmin.
	Peak demand	Peak demand rises when cooling and/or heating demand rises.
	Energy intensity	Energy intensity increases with rising temperatures.
Power production	Total production (installed capacity) needed (MW)	The needed installed capacity increases when demand increases (from increased cooling demand).
Power supply chain	Daily hours of rationing	The number of hours increases if supply cannot keep up with increasing energy demand.
	Available capacity (MW) needed	The needed available capacity increases with increasing demand (that results from increased cooling demand)
Oil prices	Electricity production cost (US$)	Production cost increases with increasing oil prices.
Hydropower generation	Percent share of electricity production from hydropower	The percent share decreases with decreasing precipitations.

1.1.5.2. *Impacts due to Non-Climatic Factors*

The increasing population size and standards of living lead to higher energy consumption, which puts pressure on the power generation and supply system. This applies especially under scenario B, which is characterized by a high increase in population size and consumption rates. However, the higher economic growth under this scenario could offset this impact through the higher ability to expand power generation capacity compared to scenario A.

The same factors on a global scale will lead to a rise in oil prices, especially under scenario B. Finally, hydropower generation projects would multiply at a higher pace under scenario B given the higher economic growth and financial capacity.

1.1.5.3. *Impacts from Climatic Factors*

The forecasted rise in ambient temperatures would lead to higher cooling demand in summer, pushing the peak load up in addition to the increase resulting from the natural growth in population and consumption rates. This would in turn put pressure on the power production and supply system to meet the additional increase in demand; and consequently drive the cost of power production up.

As for the forecasted reduction in precipitation, it would limit the hydropower generation potential, which would jeopardize the government's plans to increase this capacity. Thus there might be a need to reconsider these plans.

1.1.5.4. *Summary of Impact Assessment:*

In addition to the increase in consumption resulting from population growth and increased per capita energy consumption, the additional increase in consumption due to temperature increase forecasted by 2044 (1-2°C) was estimated. Figure 1-7 below shows this increase in energy consumption (GWh) for the period 2004- 2030 based on 3 scenarios (the climate change scenarios being conservative):

- The baseline scenario;
- The climate change scenario characterized by a 1°C increase in temperature by 2044; and
- The climate change scenario characterized by a 3°C increase in temperature by 2044 (the actual increase falls between 1°C and 3°C).

The increased energy consumption due to the added cooling load was found by estimating (based on available data and expert judgment) the overall current percentage of cooling energy consumption for each sector in Lebanon (Residential, Commercial, Industrial, Agricultural, Public.,…) in order to find the overall total percent share of the cooling load energy consumption for all sectors in Lebanon out of total consumption. These are shown in Table 1-11. The additional energy consumption resulting from the added cooling load was then added to the baseline consumption forecast (Figure 1-7). It should be noted that the 2004 consumption figure was used as a starting point, with the growth figures mentioned in Section 1.1.3.1 (Baseline Scenario).

Table 1-11 Percent share of cooling consumption out of total consumption

SECTOR	% ENERGY CONSUMPTION BY SECTOR (A)	% COOLING OUT OF SECTOR'S OVERALL CONSUMPTION (B)	% COOLING LOAD OUT OF TOTAL CONSUMPTION BY ALL SECTORS (A*B)
Industrial	20%	10%	2%
Residential	40%	20%	8%
Public	15%	20%	3%
Agricultural	5%	5%	0%
Commercial	20%	35%	7%
TOTAL	100%		20%

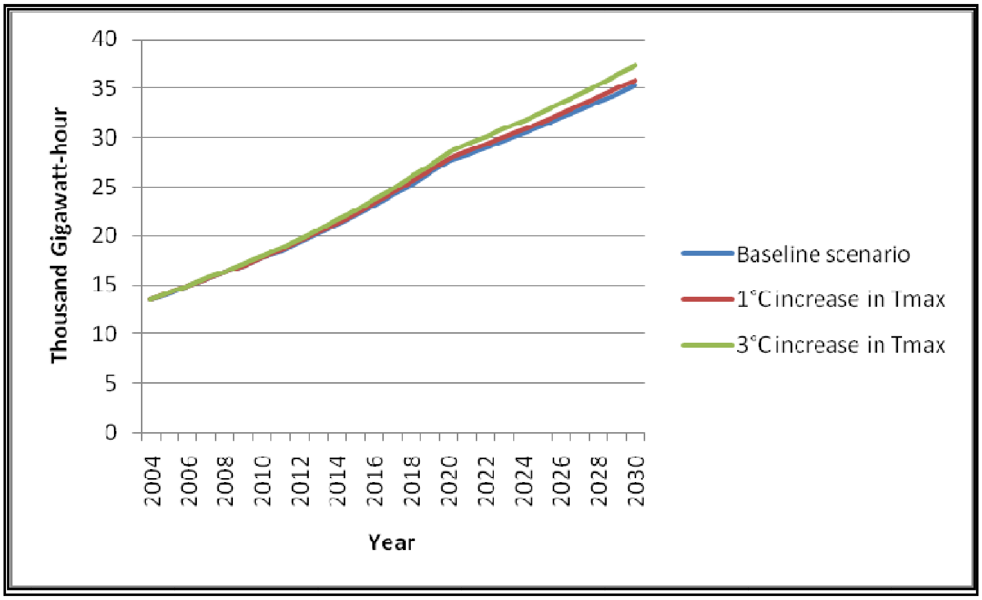

Figure 1-7 Forecasted increase in energy consumption resulting from a 1°C to 3°C increase in ambient temperature

This 1-3°C increase will incur an additional 635 GWh to 2,047 GWh on energy consumption. Given that cooling consumption constitutes 20% of total energy consumption, and that temperature increases of 1°C to 3°C lead to 9.04% and 28.55% increase in cooling consumption respectively, the increase in total consumption resulting from increased cooling consumption will be 1.8% for a 1°C increase in temperature, and 5.8% for a 3°C increase in temperature. Thus, this range of temperature increase necessitates a 1.8% to 5.8% expansion of installed capacity in addition to the planned additions; otherwise rationing of power supply will be unavoidable. Based on a forecasted demand of around 4,820 – 7,555 MW by 2030, the needed expansion in installed capacity would range between 87 and 438 MW. The demand increase will surely be higher under Scenario B with the high population increase and improvement in standards of living that will bring about an increase in per capita energy consumption regardless of climate change. The needed power generation capacity will therefore be higher under scenario B.

On the other hand, the global increase in energy demand, coupled with the gradual depletion of oil reserves, is expected to lead to an increase in oil prices, which will drive the cost of energy production higher. The production cost will be higher under Scenario B owing to the higher increase in demand compared to Scenario A.

At the same time, the forecasted 10 to 20% decrease in precipitation by 2040, together with the increase in temperature, leading to higher evapotranspiration, will eventually lead to a decrease in river flows, which will decrease the hydropower generation potential. The availability of hydropower plants is also expected to decrease given the forecasted shortening of the winter season and the increase in the length of drought periods. By the end of the century, the reduction in precipitation will be higher in magnitude (28 to 49%), coupled with higher evapotranspiration rates from temperature increase, and thus the hydropower generation potential will drop further. The initial increase in the share of hydropower generation out of total power generation will be higher under scenario B that is characterized by higher affluence and economic growth, but will then probably decline due to the expected decrease in precipitation and higher water demand.

As for the governmental plans to invest in wind energy, they might not be affected since a change in wind speed of less than ±0.3 m/s is forecasted by 2025-2044 and throughout 2080-2098. Similarly, the potential for solar energy might be positively affected, especially inland, where a 5% decrease in cloud cover is forecasted by the end of the century. The investment in these renewable energy sources will be higher under scenario B.

These impacts are illustrated in Table 1-12 through the use of the indicators identified above for each system. The impacts of climate change are generally higher under Scenario B as compared to Scenario A.

Table 1-12 Impacts of climate change on specific indicators

VULNERABLE HOTSPOTS	INDICATORS	CHANGE IN INDICATORS UNDER NON-CLIMATIC (BUSINESS-AS-USUAL) SCENARIOS		CHANGE IN CLIMATIC FACTORS	CHANGE IN INDICATORS UNDER THE CLIMATE CHANGE SCENARIO	OVERALL CHANGE IN INDICATORS	
Energy demand	Cooling demand Heating demand Peak demand Energy intensity (TOE)	Scenario A	Moderate increase Slight increase Moderate increase Moderate increase	Increase in Tmin and Tmax (between 1°C on the coast and 2°C inland by 2040; and between 3°C on the coast and 5°C inland by 2090) Little change in RH by 2040; 10% decrease by 2098.	Slight increase Slight decrease Moderate increase Moderate increase	Scenario A	Moderate increase No change Moderate increase Moderate increase
		Scenario B	High increase Moderate increase High increase High increase			Scenario B	High increase Slight increase High increase High increase
Power production	Total production (installed capacity) needed (MW)	Scenario A	Moderate increase		Moderate increase	Scenario A	Moderate increase
		Scenario B	High increase			Scenario B	High increase
Power supply chain	Daily hours of rationing Available capacity (MW) needed	Scenario A	Moderate decrease Moderate increase		Slight increase Moderate increase	Scenario A	Slight decrease Moderate increase
		Scenario B	High decrease High increase			Scenario B	Moderate decrease High increase
Oil prices	Electricity production cost (US$)	Scenario A	Moderate increase		Moderate increase	Scenario A	Moderate increase
		Scenario B	High increase			Scenario B	High increase
Hydropower generation	Percent share of electricity production from hydropower	Scenario A	Slight increase	Decrease in precipitation Increase in temperature	Slight decrease	Scenario A	No change

VULNERABLE HOTSPOTS	INDICATORS	CHANGE IN INDICATORS UNDER NON-CLIMATIC (BUSINESS-AS-USUAL) SCENARIOS		CHANGE IN CLIMATIC FACTORS	CHANGE IN INDICATORS UNDER THE CLIMATE CHANGE SCENARIO	OVERALL CHANGE IN INDICATORS	
		Scenario B	Moderate increase			Scenario B	Slight increase

1.2. ADAPTATION MEASURES

Adaptation to the potential adverse impacts of climate change on the power sector in Lebanon first entails ensuring a 24-hour supply of electricity, as well as accounting for the expected additional generation capacity needed to meet the increasing cooling demand. Additional measures to be taken include: 1) reducing the deficit brought about by the sector; 2) reducing dependence on foreign oil for power generation, in order to enhance energy security and reduce costs with time. Therefore, adaptation efforts should mainly be directed at implementing the Policy Paper for the Electricity sector launched by the MoEW in June 2010, which provides an integrated solution for the sector by 2014. In this context, adaptation and mitigation efforts converge and complement each other. The reader can refer to the Electricity Mitigation chapter for a detailed presentation of MoEW's plan and an analysis of mitigation measures and the relevant strategy.

Table 1-13 and below summarize the adaptation action plan for the Electricity sector.

Table 1-13 Adaptation action plan

IMPACT	PROPOSED ADAPTATION STRATEGY	ACTIVITIES	RESPONSIBILITY	PRIORITY (ST/ MT/ LT)	INDICATIVE BUDGET (USD)	SOURCES OF FINANCING/ IMPLEMENTATION PARTNERS
Increase in energy demand	Adopt a strategy to meet the increase in demand	Implementation of MoEW's Policy Paper for the Electricity sector, including: Addition of installed generation capacity to meet baseline demand *and* cater for increased demand due to climate change, estimated between 87 and 438 MW (Section 1.1.5.3) Diversification of the fuel mix so as to increase the proportion of renewables to 12% and natural gas to 67% progressively. Implementation of a DSM (Demand Side Management) program that includes tariff adjustments, development and enforcement of standards for home appliances (especially air conditioning devices), and promotion of awareness to reduce demand at all society levels. Adoption of the Energy Conservation Law Corporatization/restructuring of EDL and enhancing its overall resources and capabilities, through the amendment of Law 462. Modification of tariff schemes to reflect the current global oil prices and to include some sorts of KVA/KW demand penalties. In addition to the following	EDL MoEW LCEC	ST-MT	Cost of additional capacity needed as a result of increased cooling demand (87 – 438 MW) is estimated between 68 and 347 million USD (estimations based on calculations by Prayas Energy Group based on "database search and analysis conducted by the World Resource Institute using 'Capital Data Project Ware'"- Prayas Energy Group, 2001)) Cost of implementing MoEW's Policy Paper for the Electricity sector in all its aspects: USD 4.87 billion.	MoEW budget The Arab Fund (AFESD) EU WB Kuwait (KFAED) EIB

IMPACT	PROPOSED ADAPTATION STRATEGY	ACTIVITIES	RESPONSIBILITY	PRIORITY (ST/ MT/ LT)	INDICATIVE BUDGET (USD)	SOURCES OF FINANCING/ IMPLEMENTATION PARTNERS
		measures: Securing a supply of natural gas to Lebanese power plants as a pre-requisite to fuel switching. Development and implementation over a mid/long term period of a smart grid system Implementation of the Lebanese Thermal Standards for buildings as a mandatory law. Implementation of AMR (Automatic Meter Reading) Systems Building a subsidy scheme for energy efficiency (EE), renewable energy (RE) and Green Building (GB) projects or products Provision of a special financing scheme for EE/RE/GB projects Modification of legislation to allow feed in tariffs for individual RE Power Producers. Engagement of the private sector. Enhancement of LCEC's role				

1.3. RECOMMENDATIONS FOR FURTHER WORK

The following recommendations can be made for further work in the electricity sector:

- Improvement of EDL's databases regarding electricity demand, production and consumption; percent share of generation from different technologies; and increased accessibility and centralization of such databases.
- Studies on the distribution of demand and consumption by sector.
- Research on renewable energy technologies and their feasibility in Lebanon, as well as their impact on power consumption.

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