Climate Change

1 GENERAL INTRODUCTION

This report is a technical annex Lebanon's First National Communication to be submitted to the United Nations framework Convention on Climate Change (UNFCCC).

This report has been developed by two national teams of experts working under the climate change enabling activity, a project funded by the UNDP/GEF and implemented at the Ministry of Environment.

It comprises:

- A national greenhouse gas mitigation strategy which assesses and evaluates in details feasible options for GHG emission reduction in the following sectors:
  - Electricity Supply
  - Building sector, which includes two parts: the building equipment and the building envelops.
  - Industrial processes and energy use in industry.
  - Transportation sector
  - Forestry sector
  - Waste sector

- Assessment of the vulnerability of Lebanon's ecosystems to climate change resulting from an increase in global temperature. This assessment involves the following sectors:
  - Assessment of bioclimatic change
  - Water resources
  - Agriculture
  - Terrestrial ecosystems which comprise two parts: natural habitats and wild life
  - Coastal system which includes a physical component and marine ecosystem
  - Socioeconomic impact

2.THE ELECTRICITY SUPPLY SECTOR

2.1 INTRODUCTION

The electric power supply in Lebanon is a State monopoly by law. 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. 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. Such a program was launched by the Lebanese Council for Development and Reconstruction (CDR) in October 1993. The budget of this program is estimated at US$1.7 billion from national and foreign funding. 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. 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.
- A sufficient spinning reserve should be considered to provide continues 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.
- Major available and planned options depend on imported fuels.

2.2 THE BASELINE SCENARIO

The baseline scenario provides 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, and a long term plan extending from 2005 till 2040.

The supply system projections are closely linked to already announced government policy and priorities. In particular, the already announced policy 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.

Lebanons demand is divided into 2 parts:

1. Industrial.
2. Residential, commercial and others including schools, hospitals, governmental buildings, electricity needs for agriculture, and concessions.

The demand growth for the years 1994-1998 has been officially recorded by EDL; however, future demand on electricity is a function of income, prices, efficiency of energy conversion and government policy. In this study, 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. Hence, the following 3 scenarios, which are consistent with the projected economic growth of 3-6%, are proposed to accommodate possible demand growth. These are a low growth scenario: 4% annually, a medium growth scenario: 6% annually, and a high growth scenario: 8% annually. Table 1 shows the energy balance for the 4% demand growth rate. (The data provided in this Table may not tie very well with the data used by the building and industrial sectors. This is due to the energy loss, energy used in the power plants and electricity used in the agriculture which were not accounted for elsewhere.)

Table 1. 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

Shortages in electricity supply are to be expected at least until the year 2002 because of the unfinished works in the transmission network. Later, there is a need that every five years, necessary extra units are installed to satisfy the demand over the next five years (Table 2).

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

Table 2. 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

The percentage contribution of various fuels to electricity generation for the years 1994-2040 under the assumption of 4% demand growth rate is shown in Fig.1.

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Fig. 1. Percentage contribution of various fuels to electricity generation

The generation of electric energy in Lebanon is done mainly through thermal units operating on fuel and diesel oils and through very little of hydro power. In 1996, two combined cycle power plants were installed but they are expected to continue operating on diesel oil until 2005. At that time natural gas is expected to become available and the combined cycle units will fully operate on natural gas. However, because the future availability of natural gas is highly uncertain, the increase in demand will be satisfied in the baseline scenario by the continuous addition of thermal units operating on fuel oil.

Using projections on future demand and generation, the total emissions for the years 1994-2040 are calculated as shown in Table 3.

Table 3. 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

Transmission and distribution losses in Lebanon can be classified as technical and non-technical losses. Non-technical losses (very high in the last years reaching at some time 60%) result from theft of electricity through unauthorized connections and tempering with meter readings. Recently, 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, 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. Table 4 shows the environmental benefit that will take place if EDL succeeds in bringing its technical losses down to 10%.

Table 4. baseline scenario emissions reduction due to loss reduction

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

2.3 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. Between 2002-2005, the situation will depend on the availability of funds to install extra units of about 475MW. Later, there is a need that every five years, necessary extra units are installed to satisfy the demand over the next five years.
- 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 wer 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.

2.4 MITIGATION SCENARIOS

In this project, mitigation scenarios are developed under the following categories:

Category 1: Improving mix of supply through renewable energy
Category 2 : Fuel substitution through the use of natural gas.

To be consistent with the baseline scenarios, mitigation scenarios will have to ensure a 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.

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. 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 in accordance to the following categories: 1. All solar, 2. 50% solar, 50% wind, and 3. 70% solar, 30% wind.

As natural gas will be available starting 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. 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.

2.5 RESULTS AND CONCLUSIONS

The total CO_2 emissions associated with every scenario have been calculated and are summarized in Table 5.

Table 5 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. 2 below for the case of 4% growth rate and 10% discount rate.

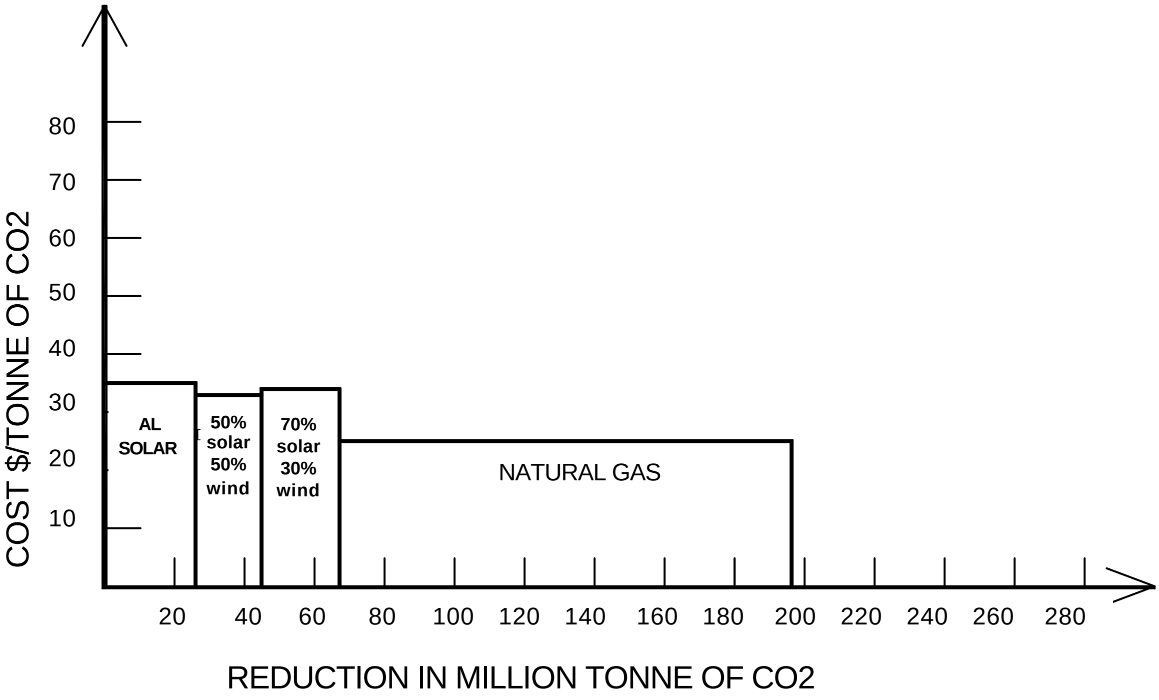


Fig. 2. The cost of one Ton CO_2 reduced: 4% growth rate

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. 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.

2.6 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.

Information Barriers

- 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.

Awareness Barriers

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

Economic and Financial Barriers

- 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.

3. BUILDING SECTOR

3.1 ELECTRICITY CONSUMPTION IN THE RESIDENTIAL AND COMMERCIAL SECTORS

The residential and commercial sectors consumed, in 1994, 30% of the final energy consumption which is 30 x 10^6 Gj, and in turn produced 1737 Gg of CO_2.

By analyzing the electricity structure and consumption for both residential and commercial sectors, we found out that the most consuming equipment which represent 80% of the total electricity consumption are :

- Electric heaters for space heating 31%
- Electric hot water for sanitary purposes : 22%
- Air conditioning : 13%
- Lighting : 8,5%
- Refrigerator : 6%

Since there are no specific policies for the management of demand in Lebanon, the energy efficiency in the residential and commercial sectors is slightly and slowly improved by the introduction of some efficient equipment due to the dynamic of the market but with different payback times, penetration rate and incremental costs.

Following the basic data for the base year 1994, we foresee an increase in demand in the electricity for the residential and commercial sectors at short term (year 2000), medium term (year 2015), and long term (year 2040) in case of:

A- no specific rational management of the demand side being adopted: business as usual “base case” .

B- mitigation policies: the options proposed are concerned with the development of solar domestic hot water systems, energy efficient refrigerators and compact fluorescent lamps .

Comparing the adopted different scenarios under the assumptions of GDP increase of 3% and 6% ,, we found out the following (See Table 6):

1) A reduction in the energy consumption around the year 2040 of at least 20% between “low base case” and low mitigation case” – GDP increase 3% - and consequently an equal reduction of CO_2 emissions.
2) A reduction in the energy consumption around the year 2040 of at least 25% between “high base case” and “high mitigation case” – GDP increase 6% - and consequently an equal reduction of CO_2 emission.

Table 6. Comparison of mitigation with base case scenarios.

Low case scenarios, 10^6 Gj	1994	2000	2005	2015	2040
Low base case	14.20	29.10	37.54	50.54	87.58
Low mitigation case	14.20	29.02	35.93	46.18	69.02
Energy consumption decrease	0.00	0.08	1.61	4.36	18.56
Approx. Co2 emission decrease (Gg)	0.00	4.88	98.21	265.96	1132.16
High case scenarios, 10^6 Gj	1994	2000	2005	2015	2040
High base case	14.20	31.70	42.27	65.28	195.41
High mitigation case	14.20	31.63	39.77	58.06	147.86
Energy consumption decrease	0.00	0.07	2.50	7.22	47.55
Approx. Co2 emission decrease (Gg)	0.00	4.27	152.50	440.42	2900.55

The two main barriers for the quick development of the previously mentioned options in Lebanon are:

1. The high prices of the equipment on the local market.
2. The relatively low cost of the electricity.

These two main barriers lead often to high payback times (8 years for the solar domestic hot water system, 15 years for the efficient refrigerator, etc..).

Consequently, steps to be adopted for accelerating the diffusion of options in question are:

At short and medium terms:

1) Adjustment of the electricity prices to reflect the real production cost.
2) Establishment of a quality control system such as certificates and labels of quality in order to better guide the consumer.
3) Training of technicians on energy saving issues and especially in the solar domestic hot water equipment.
4) Development of new customs policies and laws in favor of the performing equipment instead of the consuming one.
5) Awareness campaigns.

At long term:

1) Establishment of quality norms.
2) Development of local industries especially solar domestic hot water and efficient refrigerators.
3) Development of a loan system for credit sales on energy performing equipment at low rates for the industrials, contractors and consumers.
4) Establishment of regulations in the residential and commercial sectors for installing solar domestic hot water systems.
5) Integration in the energy pricing the notion of the “environmental cost”.

3.2 Residential, Commercial and Institutional Sector: Building Envelopes

3.2.1 Background

The energy consumed by the residential, commercial and institutional sector for space heating and cooling amounted to 13.77 x 10^6 GJ in 1994. As shown in Fig.3, this energy was derived from three sources: electricity, gas/diesel oil and wood. Where by the amount of electricity used corresponded to 27% of total country electricity-supply, and the amount of gas/diesel oil used corresponded to 15% of total country imports of gas/diesel oil.

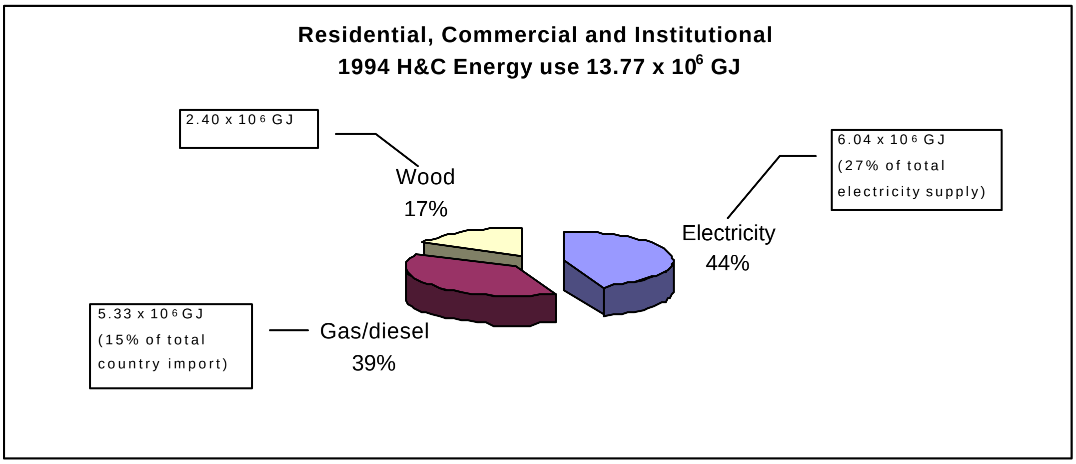


Fig.3: 1994 heating and cooling energy demand.

Building envelopes, and depending on their thermal characteristics play a key role in determining the amount of energy used for the provision of occupant thermal comfort. Although this is the case, the Lebanese building law has so far lacked any reference to the thermal performance of building envelopes.

Nevertheless there has been a recent governmental commissioning of a study concerned with the upgrading of the thermal performance of building envelopes in Lebanon. The specified upgrading suggestions are expected to bring about a 25% energy reduction on space heating and cooling needs.

This study, once approved, is intended to serve as a voluntary guideline only, given the numerous prevalent barriers that hinder its adoption and application. This in turn limits the possibilities of national energy reduction benefits, which are calculated to be 3.2% from total heating and cooling energy used between 1994 and 2040.

The current analysis takes this guideline as a point of departure, and assesses the potential national energy reduction that could be achieved as a result of a proposed barrier removal strategy, which will activate application rate and hence reduce the overall energy used for space heating and cooling.

3.2.2 Forecast

Based on a series of input data and assumptions, two baseline scenarios have been considered (Fig.4). The forecast results for the period 1994 – 2040 revealed the following:

- Under a low baseline scenario of 3% energy growth rate for space heating and cooling, the associated total energy consumption between 1994 and 2040 will be 1339 x 10^6 GJ, and will result in the emissions of 208 750 Gg of CO_2. Where as the yearly average energy demand will be 28.48 x 10^6 GJ/yr, and will result in the emission of 4 442 Gg of CO_2/yr.

- Under a high baseline scenario of 4% energy growth rate for space heating and cooling, the associated total energy consumption between 1994 and 2040 will be 1771 x 10^6 GJ, and will result in the emissions of 276 236 Gg of CO_2. Where as the yearly average energy demand will be 37.68 x 10^6 GJ/yr, and will result in the emission of 5877 Gg of CO_2/yr.

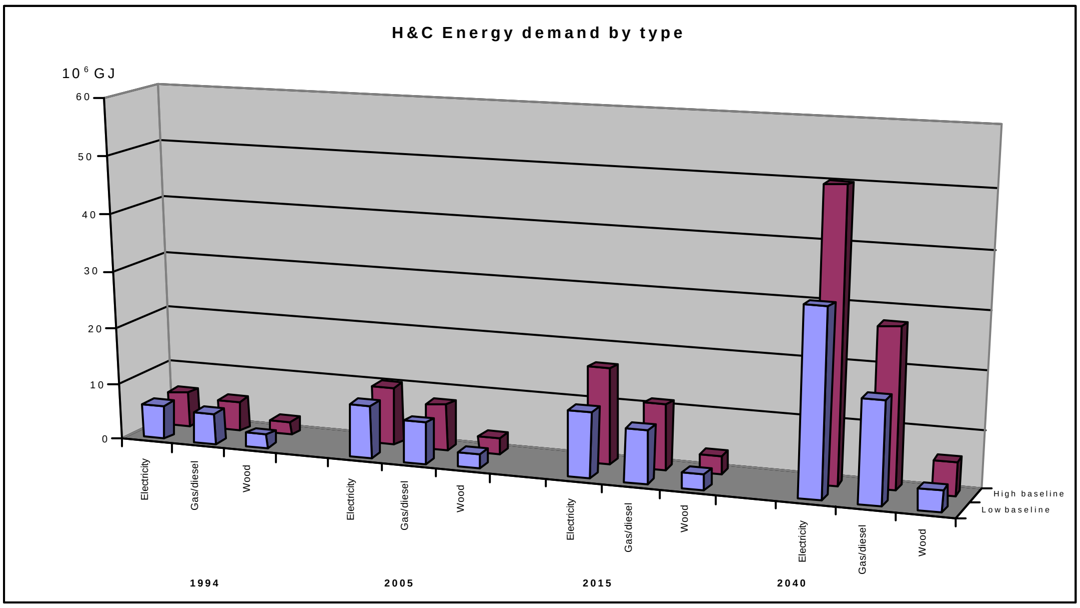


Fig.4: Forecast of heating and cooling energy demand by type.

The proposed mitigation strategy consists of increasing the penetration rate of guideline application for new buildings through appropriate national barrier removal activities and programs. Two mitigation scenarios are proposed:

- The first scenario assumes a 10% penetration rate from 2000 to 2005, a 30% penetration rate up to 2015, and a 70% penetration rate until 2040.

- The second scenario assumes a 20% penetration rate from 2000 to 2005, a 60% penetration rate up to 2015, and a 100% application until 2040.

As shown in Figs. 5 and 6, mitigation scenario 1 can achieve a 10% reduction in energy use for space heating and cooling between 1994 and 2040, and mitigation scenario 2 can achieve a 15% energy reduction.

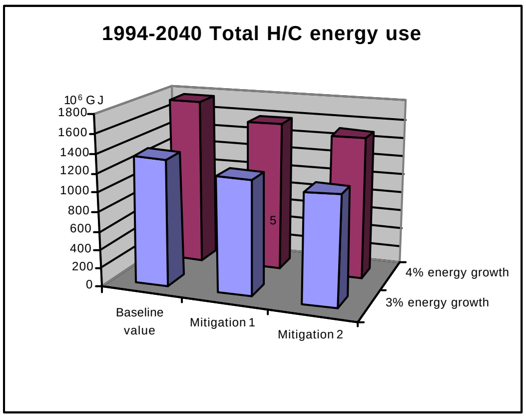


Fig.5: Total 1994 to 2040 energy use.

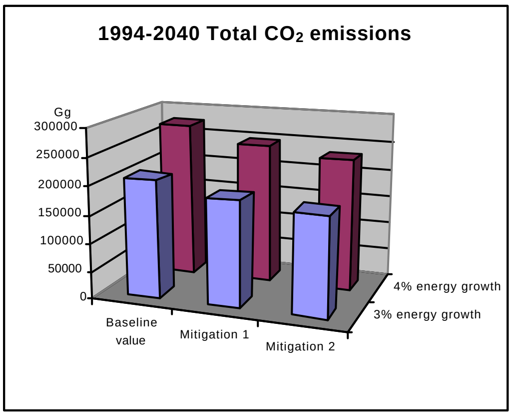


Fig.6: Total 1994 to 2040 CO_2 emissions

The cost benefit evaluation of mitigation scenarios 1 and 2 (calculated using the annualized cost concept) revealed the following: (Fig.7)

- For 3% energy growth rate, and 10% discount rate: Mitigation scenario 1 can save a total of 21 million tons of CO_2 at a cost of 106 US$/ton of CO_2 saved. Mitigation scenario 2 can save a total of 31 million tons of CO_2 at a cost of 112 US$/ton of CO_2 saved.

- For 4% energy growth rate, and 10% discount rate: Mitigation scenario 1 can save a total of 28 million tons of CO_2 at a cost of 80 US$/ton of CO_2 saved. Mitigation scenario 2 can save a total of 42 million tons of CO_2 at a cost of 85 US$/ton of CO_2 saved.

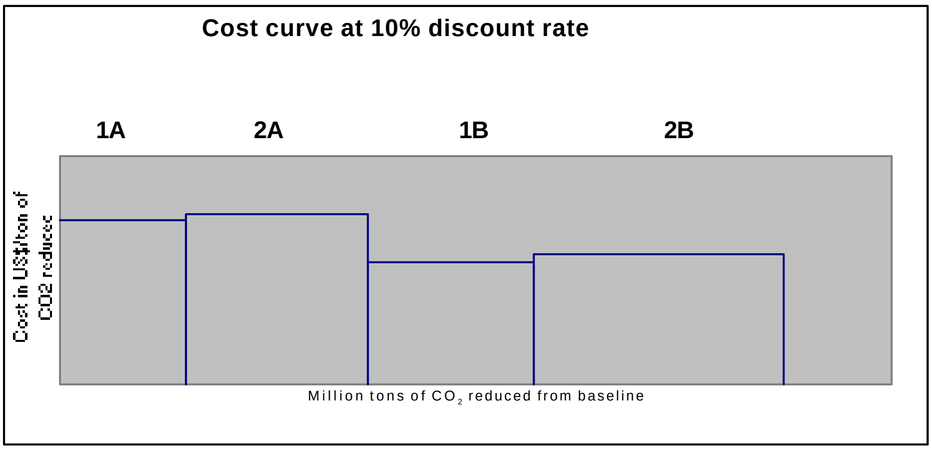


Fig.7: Cost curve for mitigation options 1 and 2 at 10% discount rate

1A: Mitigation scenario 1, energy growth rate 3%.
1B: Mitigation scenario 1, energy growth rate 4%.
2A: Mitigation scenario 2, energy growth rate 3%.
2B: Mitigation scenario 2, energy growth rate 4%.

3.2.3 Conclusions

In terms of energy conservation strategy, upgrading the thermal performance of building envelopes is a strategy whose impact is felt on a long-term basis. In this respect, mitigation scenario 2 revealed much higher CO_2 emissions reductions at minimal additional cost per ton of CO_2 saved.

3.2.4 Project proposals

The recently developed Thermal Building Guideline which aims at enhancing the thermal performance of building envelopes, and thus of reducing the energy consumed for space heating and cooling, faces numerous barriers that hinder its adoption and application. The main barriers are the following:

- ***Information and Know-how barrier:*** **Unfamiliarity with subject matter among professionals, policy makers and consumers; Uncertainty about the effectiveness of the new technology (Energy reduction versus new problems of construction details or space overheating)**
- ***Economic barrier:*** **Uncertainty with economic and environmental implications; Initial incremental cost of conservation measure.**
- ***Institutional barrier:*** **Lack of trained personnel; Lack of adequate verification mechanism.**

Consequently, there seems to be two main projects needed in this sector:

- **Capacity Building project** aimed at providing the needed foundation of supportive policy makers, informed consumers, skilled professionals, and trained personnel.
- **Market based program** aimed at overcoming the initial incremental cost and at activating market demand.

Recommendations for future work

- The analysis has been performed based on the assumption of 25% reduction on heating and cooling energy needs per building unit. A detailed simulation of study cases is needed for the various climatic zones in order to determine more accurately the potential of energy reduction.
- The specifications of the Thermal building guideline were recommended based on historical precedent in other countries. Further work is needed to update the specifications based on an economic cost-effective approach.
- The analysis has considered the potential of static building envelope conservation measures. A further multi-parameter assessment that looks at the overall potential of passive heating and cooling techniques for the Lebanese climate is needed.
- Assessment of the potential of microclimatic interventions such as increasing green cover along the coastal zone as a means of reducing the urban heat island effect, and thus reducing cooling energy needs.
- This analysis has assumed that both the residential and commercial uses will rely on partial heating and cooling. Further data refinement in terms of differentiating between residential and commercial energy uses and energy growth rates is needed.

- The analysis did not account for additional energy reductions due to the natural improvement of the efficiency of HVAC equipment.
- The cost-benefit assessment of this analysis looked at the national level; a further assessment of the consumer pay back period is needed.

4 INDUSTRIAL PROCESSES & ENERGY USE IN INDUSTRY

Greenhouse gas emissions in Lebanon mainly come from energy activities, which are responsible for 85% of all CO_2 emissions. The CO_2 emissions from energy use in manufacturing industries and construction represent 24% of the total emissions of the energy sector. Lebanese manufacturers' accounted for 39.15 million of gigajoules of fuel consumption for heat and power generation in 1994, including both fuel used directly and fuel burned remotely to generate electricity used in the sector. In addition to being processed by combustion, CO_2 is generated in calcining of carbonates in the manufacture of cement, iron and glass. Electricity, the most expensive form of energy, represented 25.87% of all fuel used for heat and power. Residual fuel oil and diesel, which are used mainly in direct combustion processes, represent 26.85 % and 26.55% of all energy use by industry, respectively. Manufacturing industries and construction, as have used 10.14 x 10^6 GJ (2816.6 GWh) of electricity in the base year of 1994.

Baseline scenarios at low and high economic growth rates for future energy use and CO_2 emissions are developed for the industrial sector in Lebanon. Scenarios relied on available data on major plants' outputs, and on reported amounts of fuels used by the industrial sector. Energy use in industry in Lebanon is projected in baseline scenarios that reflect technologies, activities and practices that are most likely to evolve from the base year 1994 to year 2040. Two baseline scenarios are created using a low economic growth rate (case BA) and a high economic growth rate (case CA). The scenarios are linked to the economic conditions in the country. The future projections of energy demand are shown in Table 7 for both scenarios. The low growth rate scenario shows that energy consumption will increase by the year 2005 by 28% over the current level, and will triple by the year 2040. This implies an average annual growth of 2.5% for the whole period in scenario BA. The high growth rate scenario shows that the energy consumption will increase by year 2005 by 70% over the current level and by 950% by year 2040. This implies an average annual growth of 5.94% for the whole period in scenario CA.

Table 7. Energy Demand: Fuel by Year, Industrial Sector (10^6 GJ) Scenario BA

Scenario BA	1994	2000	2005	2015	2040
ELECTRICITY	10.13	11.75	13.54	17.98	35.26
DIESEL/GAS OIL	10.39	11.79	13.12	16.31	28.74
RESIDUAL/FUELOIL	10.52	12.30	14.26	19.13	35.26
LPG/BOTTLED GAS	0.96	1.14	1.33	1.78	3.73
COAL BITUMINOUS	7.68	7.47	8.66	11.58	16.80
TOTAL	39.67	44.47	50.92	66.77	119.79
SCENARIO CA					
ELECTRICITY	10.13	13.96	18.57	32.84	128.14
DIESEL/GAS OIL	10.39	12.75	15.31	22.85	74.20
RESIDUAL/FUELOIL	10.52	14.62	19.56	34.85	118.58
LPG/BOTTLED GAS	0.96	1.36	1.82	3.26	13.98
COAL BITUMINOUS	7.68	8.88	11.88	21.00	42.00
TOTAL	39.67	51.56	67.14	114.80	376.91

All the fuel sources are linked properly to the Environmental Database in the LEAP program and the amount of GHG emissions and environmental effects are calculated for Lebanon. Table 8 presents the GHG emissions due to all industrial activities, including electricity use, for both scenarios BA and CA.

Table 8. Environmental Effects by Year: Physical Units (Gg), All Fuels Including Effect of Electricity Generation

	GHG TYPE	1994 (Gg)	2000 (Gg)	2005 (Gg)	2015 (Gg)	2040 (Gg)
Scenario BA (3%)						
	Carbon Dioxide (CO_2)	4,830	5,110	5,600	7,160	12,410
	Carbon Monoxide	8.81	6.64	5.51	7.23	13.82
	NMVOC	2.589	1.849	1.441	1.879	3.657
	Methane	0.04	.051	.061	.076	0.132
	Nitrogen Oxides NO_x's	837.93	976.56	1,078	1,342	2,374
	Sulfur Oxides	2.535	1.818	1.423	1.855	3.604
	Particulates	2.702	1.930	1.504	1.961	3.817
Scenario CA (6%)						
	Carbon Dioxide (CO_2)	4,830	5,890	7,400	1,217	39,190
	Carbon Monoxide	8.81	7.42	7.34	12.42	47.99
	NMVOC	2.589	2.05	1.91	3.26	12.85
	Methane	0.04	0.06	0.081	0.121	0.411
	Nitrogen Oxides NO_x's	837.93	1,056	1,262	1,894	6,200
	Sulfur Oxides	2.535	2.01	1.89	3.21	12.61
	Particulate	2.702	2.14	2	3.4	13.41

The mitigation scenarios for reducing CO_2 emissions are presented at the most likely discount rate of 10% for the two baseline scenarios BA and CA. The various single effect scenarios are given in Table 9. Most of the mitigation options for the industrial sector are concerned with improvement of energy efficiency either in electricity use for motors and lighting or in cleaner combustion processes in boilers and furnaces by fuel switching or replacement with efficient systems.

Table 9. List of Baseline and Mitigation Scenarios

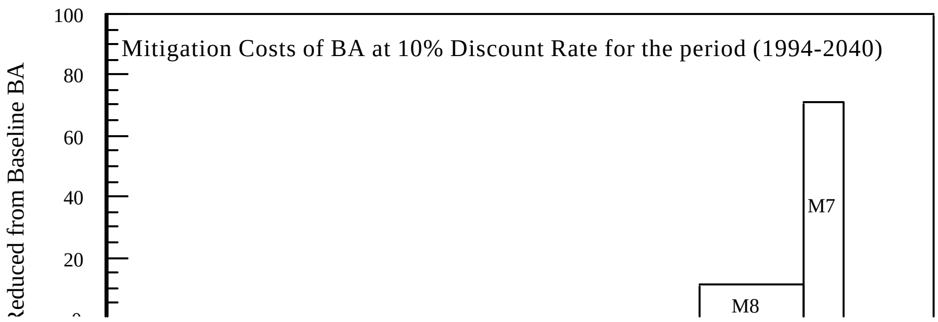
SCENARIO NO.	SCENARIO NAME	DESCRIPTION
	BA	Baseline (Growth Rate 3%)
	CA	Baseline (Growth Rate 6%)
1	C1	Cement 10% Reduction with Pre - Heat
2	C2	Cement 20% Reduction with Pre - Heat
3	M1A	Efficient Electric Motors Replace Old Motors
4	M1B	Efficient Electric Motors Replace New Standard Motors
5	M2	Advanced Lighting
6	M4	Efficient Boilers
7	M7	Bakeries Fuel Switching from Diesel to LPG
8	MB	Bakeries (Efficient Furnaces)
9	M8	Natural Gas Replace Fuel Oil
10	M9	Natural Gas Replace Diesel
11	CG	Co-generation

The environmental effects of various mitigation options can be clearly seen from the percentage of CO_2 reduction from the corresponding baseline scenarios and their transformation scenarios and the amount of CO_2 reduction for the year 2005 and the year 2040 as presented in Table 10.

The average emission reduction of CO_2 and the Levelized Cost of CO_2 Reduction (US$ / tonne of CO_2 reduced) CO_2, over the period 1994-2040, are calculated for the various mitigation options on the baseline scenarios BA and CA at the discount rate 10%. Figure 8 shows the discrete step cost curve of the cost in $/tonne of CO2 reduced from baseline BA versus the corresponding CO_2 emission reduction from baseline BA in Million tonnes over the study interval of 46 year (1994-2040) and at the discount rate of 10%. Figure 9 shows the discrete-step cost curve of the cost in $/tonne of CO_2 reduced from baseline CA versus the corresponding CO_2 emission reduction from baseline CA in Million tonnes over the study interval of 46 year (1994-2040) and at the discount rate of 10%. Mitigation options M1B, M1A and M2 that conserve in electricity use have a good cost-effectiveness prospects where the benefits in the long term exceed the implementation costs. Also the use of efficient boilers (M4) and co-generation (CG) are another negative cost options with substantial CO_2 emission reduction from both baseline scenarios BA and CA. Fuel switching in boilers and furnaces from fuel oil to LPG or natural gas has a substantial effect on reducing CO_2 emissions, but with a high cost because fuel oil is a cheaper than other forms of fuels like gasoil. Switching from diesel to natural gas or LPG had only marginal reductions of CO_2 with less cost per CO_2 emissions' reduction. Fuel switching from diesel to LPG in bakeries involved a very high cost compared with just using efficient diesel furnaces. When all single effect mitigation scenarios are implemented, the cumulative total reduction of CO2 from baseline scenario BA reaches about 126 Million tonnes while the total reduction of CO2 from baseline CA is estimated as 365 Million tonnes.

Table 10. Reduction of CO_2 Emissions (Gg) and their Percent Reduction of Mitigation Options from the Baseline Scenario BA for the years 2005 and 2040.

SCENARIO	ECONOMIC GROWTH 3%				ECONOMIC GROWTH 6%			
	% Red. From Baseline BA		Emission Reduction Gg		% Red. From Baseline CA		Emission Reduction Gg	
	2005	2040	2005	2040	2005	2040	2005	2040
Baseline	0	0	0	0	0	0	0	0
C1	1.93	1.6	108.21	200.89	1.99	1.26	147.1	492.53
C2	3.71	3.18	208	394	3.91	2.53	289.4	991.7
M1A	2.59	8.5	345.1	1055	2.61	9.45	192	3625
M1B	0.83	1.77	46.77	219.52	.84	1.92	62.14	754.3
M2	1.18	1.26	65.96	155.79	1.18	1.37	87	535
M4	2.64	10.29	147.9	1276.99	2.74	12.21	203	4783
M7	0.95	2.57	53	319	0.95	2.57	53	319
MB	0.95	2.4	53.14	298.3	0.95	2.4	53.14	298.3
M8	1.94	7.28	108.5	903	3.32	14.24	245.6	5582
M9	1.3	5.13	73.03	636.86	1.35	6.09	100.1	2385
CG	0.81	4.71	45.66	584.1	1	5.76	74	2258



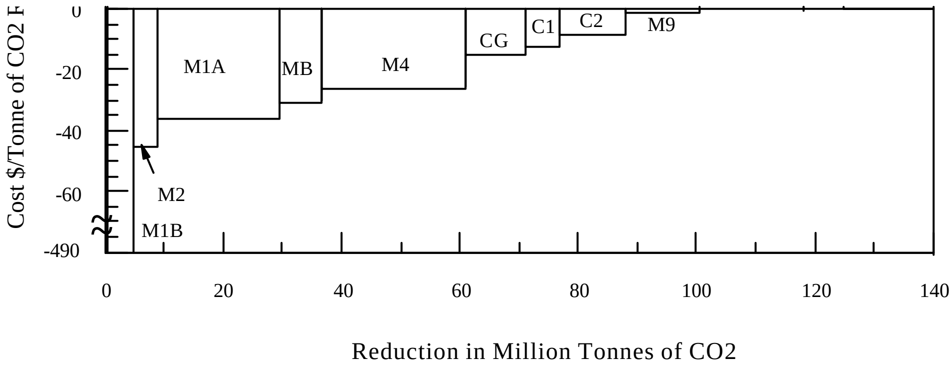


Figure 8 Cost in $/ton of CO2 reduced from baseline BA

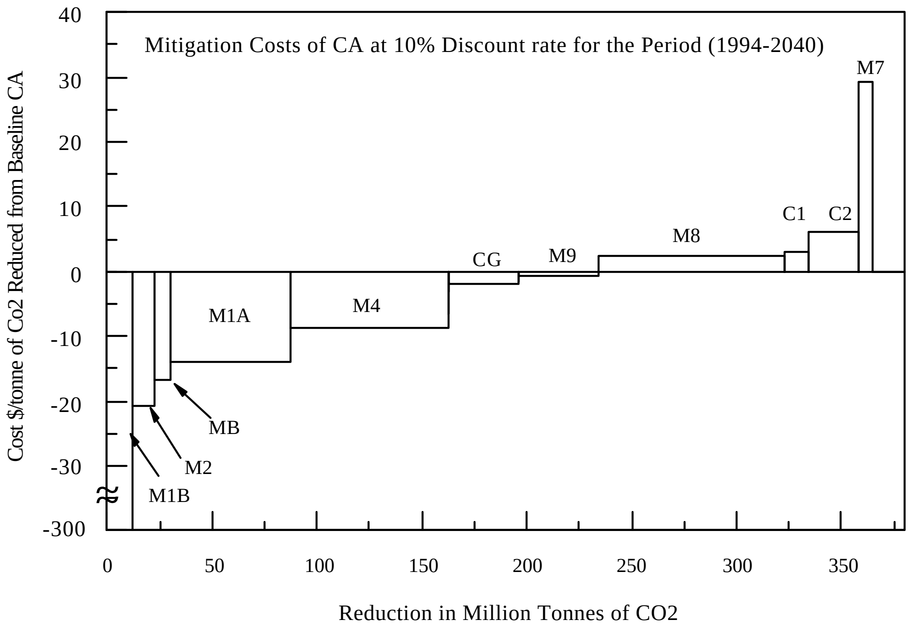


Figure 9 Cost in $/ton of CO2 reduced from baseline CA

4.1 Project Proposals for Industrial Sector:

4.1.1 Motor Drive System Improvement and Replacement M1A and M1B

Motor-driven systems are the backbone of industrial operations such as fluid handling and movement, and material processing and fabrication. These systems account for more than 70% of all electricity used by the industrial sector in Lebanon. Improvements in the efficiency of these electric motor systems can translate directly into enhanced productivity, competitiveness and environmental performance. Electric motors are generally regarded as very efficient, with first law efficiencies of order of 90%. Yet, in the aggregate, losses are considerable. In Lebanon, a large number of motor drive systems are relatively old, or second-hand. Replacing old motors with new ones represents a great opportunity for improving the system efficiency. But this has to go hand in hand with motor control improvements, particularly for variable frequency drives of induction motors, which can cut internal losses by a factor of 2, at least. In order to carry an accurate analysis, data should be available on the number of current motors in use by the industrial sector in Lebanon, their power rating, years of operation and efficiency. Such data were not available, so a few assumptions have to be made in order to arrive at a reasonable model for this mitigation option. Two scenarios for electric motor replacement are considered. The first scenario "M1A" considers replacement of old electric motors with new efficient ones. The second scenario "M1B" considers that the new standard motors added to the industry each year are replaced by new efficient motors.

The replacement of old electric motors by new energy efficient ones is proposed according to the following schedule: year 2000: 10 % of old motors is replaced by new ones, year 2005: 25% of old motors is replaced by new ones, year 2015: 50% of old motors is replaced by new ones, year 2040: 100% of old motors is replaced by new ones. The replacement of added new standard motors by efficient ones will be considered done for all new imported motors starting year 2000.

The average implementation current cost of the new energy-efficient motor is estimated as \$66/HP for the 20-50 HP range and \$61/HP for the 50-100 HP range. The motor rewind cost has an average value of \$16/HP, and the average standard motor cost is estimated as \$56/HP for the 20-50 HP range and \$61/HP for the 50-100 HP range. Industries in Lebanon use motors for periods of time that are far beyond the motor lifetime and rewind old motors once they breakdown. For the first motor scenario, the modified annualized life cycle cost is then based on the incremental cost of the new electric motor of which the motor rewind cost is subtracted rather than incremental cost between an energy efficient new motor and a standard base-case new motor. The calculated life cycle cost is then equal to \$50/HP for the 20-50 HP range and \$45/HP for the 50-100 HP range. In the second motor replacement scenario where the new standard motors are replaced by energy efficient ones, the modified annualized life cycle cost is then based on the incremental cost between an energy efficient new motor and a standard base-case new motor. The calculated life cycle cost difference is then equal to \$10/HP for the 20-50 HP range and \$12/HP for the 50-100 HP range. The energy savings are calculated based on 3600 hours of operation of the motors per year.

The proposed mitigation options costs and benefits for electric motors are shown in Table 11, where the cost in Million of real 1994 \$ is given over selected years and the discounted cost over the selected study period are presented. The expected carbon dioxide emission reductions over the study interval (1994-2040) are shown in Table 12.

Table 11: Electric Motor Improvement and Replacement Project Costs and Benefits

MITIGATION OPTION	Cost Million Real 1994 \$ (2000)	Cost Million Real 1994 \$ (2005)	Cost Million Real 1994 \$ (2015)	Cost Million Real 1994 \$ (2040)	Costs Discounted To 1994 \$ At 10% Dr (1994-2040)	Benefits Discounted To 1994 \$ At 10% Dr (1994-2040)	Benefit To Cost Ratio
Scenarios associated with low economic growth Baseline BA							
M1A Costs	0.26	1.04	2.91	12.75	12.42	84.51	6.8
M1B Costs	46.42	55.87	81.86	214.46	99.42	599.33	6.03
Scenarios associated with high economic growth Baseline CA							
M1A Costs	0.31	1.42	5.32	47.76	25.52	216.36	8.47
M1B Costs	55.15	76.6	149.5	803	168.91	1027	6.3

Table 12: Emission Reductions of Electric Motor Improvement and Replacement Project

Mitigation Option	CO_2 Reduction (Gg) (2000)	CO_2 Reduction (Gg) (2005)	CO_2 Reduction (Gg) (2015)	CO_2 Reduction (Gg) (2040)	Total CO_2 Reduction (Gg) (1994-2040)
Reductions from Baseline BA					
M1A	2.59	8.5	345.1	1055	20,633
M1B	29.45	46.77	79.39	219.52	4,640
Reductions from Baseline CA					
M1A	2.61	9.45	192	3625	57,822
M1B	33.95	62.14	134.56	754.34	12,512

4.1.2 Efficiency Improvement of Boilers and Furnaces by Replacement and Fuel Switching Options

The burning of fossil fuels in boilers, to raise high temperature and high-pressure steam that have been used for various heating and power generation processes, produces a problem source of carbon dioxide and other green house gases. Efforts to increase the efficiency of industrial processes should also focus on improving the efficiency of boilers and furnaces. Many industrial processes involve the use of direct thermal heating either from steam or using electricity directly. Examples vary from food processing industries, chemicals, plastics, glass and steel manufacturing. Conventional boilers used in industry are mostly operated using fuel oil followed by gas oil and a small percentage of LPG. Heating furnaces are also operated using fuel oil. Accurate data on age distribution and age-efficiency of boilers used in the industrial sector in Lebanon are not available. The current state of boiler equipment in industry is similar to that of electric motors, where the average age of boilers would easily exceed 20 to 30 years. In absence of an energy code for boiler-efficiency standards, engineering estimation and sizing of boilers to the respective application is not properly administered. The mitigation option of replacing old boilers in the industrial sector with cleaner and more efficient systems, these options are divided into two main categories. The first category considers only improvement in boiler efficiency where old boilers are replaced with new efficient ones operating on the same fuel type. The second category considers replacing inefficient industrial boilers with efficient ones that operate on a cleaner fuel such as LPG or natural gas.

- Replacement of old boilers by new energy efficient according to the following schedule:
  Year 2000: 10 % of old boilers is replaced by new ones.
  Year 2005: 25% of old boilers is replaced by new ones.
  Year 2015: 50% of old boilers is replaced by new ones.
  Year 2040: 100% of old boilers is replaced by new ones.

- Fuel switching from fuel oil and from diesel to natural gas and LPG is according to the following schedule for boilers and furnaces:
  Year 2000: 10 % of old boilers are replaced by new ones.
  Year 2005: 20% of old boilers is replaced by new ones.
  Year 2015: 40% of old boilers is replaced by new ones.
  Year 2040: 60% of old boilers is replaced by new ones.

The proposed mitigation options costs and benefits for boilers and furnaces are shown in

Table 13, where the cost in Million of real 1994 $ is given over selected years and the discounted cost over the selected study period are presented. The expected carbon dioxide emission reductions over the study interval (1994-2040) are shown in Table 14.

Table 13: Boilers and Furnaces Improvement and Replacement Project Costs and Benefits

MITIGATION OPTION	COST Million Real 1994 $ (2000)	COST Million Real 1994 $ (2005)	COST Million Real 1994 $ (2015)	COST Million Real 1994 $ (2040)	COSTS Discounted To 1994 $ AT 10% DR (1994-2040)	BENEFITS Discounted To 1994 $ AT 10% DR (1994-2040)	Benefit To Cost Ratio
Scenarios associated with low economic growth Baseline BA							
M4 Costs	0.2	0.8	2.41	9.76	9.87	84	8.5
MB Costs	.07	0.24	0.77	1.92	2.86	30	10.3
M8 Costs	.35	1.17	3.1	47	111.41	66	1.68
M9 Costs	1.14	3.73	12.5	30.24	69.38	75	1.09
Scenarios associated with high economic growth Baseline CA							
M4 Costs	0.24	1.09	4.41	36.56	20.25	173	8.54
MB Costs	.07	0.24	0.77	1.92	2.86	30	10.3
M8 Costs	.42	0.161	5.4	175	233.85	185	0.79
M9 Costs	0.6	2.06	8.3	64.67	144.95	151	1.04

Table 14: Boilers & Furnaces Improvement and Replacement Emission Reductions

MITIGATION OPTION	CO_2 Reduction (Gg) (2000)	CO_2 Reduction (Gg) (2005)	CO_2 Reduction (Gg) (2015)	CO_2 Reduction (Gg) (2040)	Total CO2 Reduction (Gg) (1994-2040)
Reductions from Baseline BA					
M4	40	150	400	1270	24473.84
MB	10	60	150	290	6913.8
M8	40	110	300	900	17552.22
M9	30	80	210	630	12416.32
Reductions from Baseline CA					
M4	40	210	740	4780	75265.66
MB	10	60	150	290	6912.88
M8	60	250	890	5580	88475.48
M9	20	100	390	380	37913.66

4.1.3 Cement Mitigation Option

The cement industry is the single largest source of Lebanese process CO_2 emissions and a major energy user. Energy related CO_2 emissions are of similar magnitude depending on the cement kiln technology. Of the process emissions, about 60% of the direct emissions are from calcination of lime stone and the other 40% are from combustion products of fossil fuels that directly or indirectly supply the energy for calcination. Grinding is the other major energy consumer in the manufacturer, which is usually a low efficiency process. According to the baseline scenario on cement demand, 38% of 1994-cement production is coming from an old technology while 62% of the production is already producing cement with retrofit and new plants.

The proposed mitigation option includes conservation and preheating in the pyroprocessing, which can save 10% in fuel energy, and include improvements in the grinding process, which is reported to have made small but significant gains through use of mill liners, grinding media and the use of more complex grinding circuits. Implementing such an improvement would save at least 5% of the electric energy use.

The proposed mitigation options costs and benefits for boilers and furnaces are shown in Table 15, where the cost in Million of real 1994 $ is given over selected years and the discounted cost over the selected study period are presented. The expected carbon dioxide emission reductions over the study interval (1994-2040) are shown in Table 16.

Table 15: Cement Production Improvement Project Costs and Benefits

MITIGATION OPTION	COST Million Real 1994 $ (2000)	COST Million Real 1994 $ (2005)	COST Million Real 1994 $ (2015)	COST Million Real 1994 $ (2040)	COSTS Discounted To 1994 $ AT 10% DR (1994-2040)	BENEFITS Discounted To 1994 $ AT 10% DR (1994-2040)	Benefit To Cost Ratio
Scenarios associated with low economic growth Baseline BA							
C2 Costs	.07	10.11	14.92	27.8	61.38	42.01	0.688
Scenarios associated with high economic growth Baseline CA							
C2 Costs	1.84	13.9	27.14	69.62	113.22	74	0.65

Table 16: Emission Reductions of Cement Production Improvement Project

MITIGATION OPTION	CO_2 Reduction (Gg) (2000)	CO_2 Reduction (Gg) (2005)	CO_2 Reduction (Gg) (2015)	CO_2 Reduction (Gg) (2040)	Total CO2 Reduction (Gg) (1994-2040)
Reductions from Baseline BA					
C2	20	210	270	390	11331.64
Reductions from Baseline CA					
C2	40	290	500	980	23626.98

4.2 RECOMMENDATIONS FOR FUTURE WORK

The mitigation efforts in industry should focus on long term support for energy efficiency measures and fuel switching in boilers and furnaces to cleaner types. A comprehensive energy audit for the industrial sector is a first step. Subsidy support should enable companies even those with limited financial resources to afford comprehensive efficiency measures, given the lack of resources to invest in new equipment by manufacturers. Policies should focus on increasing the speed with which technology is replaced. Standards for energy efficiency for equipment should be mandatory along with a mechanism for monitoring energy use and CO_2 emissions. More accurate data are needed to assess the industrial sector for each type of product or process. Training should be provided to managers and professionals to increases their awareness about GHG emissions and benefits associated with energy savings and measures taken to reduce these emissions.

For technologies where natural gas is to be used, the government must insure uninterrupted supply.

Although the proposed mitigation projects suggest a substantial reduction in CO_2 emissions associated with manufacturing activities, it would require a strong, well-designed policy package involving a political will.

5. TRANSPORTATION SECTOR

5.1 INTRODUCTION

The transportation sector, world wide, still contributes around 70% of air pollution. The pollutants include, amongst others, carbon dioxide, hydrocarbons, and oxides of nitrogen that contribute to the greenhouse phenomenon.

Lebanon’s transportation sector constitutes a fleet of over one million registered vehicles and can be characterized as being relatively old and poorly maintained. Moreover, the car ownership rate in Lebanon (3 persons for every car) is amongst the highest in the world. In the baseline and mitigation assessment, the data used in the comprehensive evaluation of national, social and economic development frameworks for climate change mitigation process included base year statistics as well as common data for short- and long- term projections.

5.2 BASE YEAR CONDITIONS

Its poor status and the lack of a regular vehicle inspection could characterize the Lebanese transport sector in 1994. The cumulative total of vehicles registered in Lebanon reached close to 1.4 million at the end of 1996, however, the actual number may not exceed 1 million vehicles. The average age of private vehicles is around 14 years.

The number of red- plat vehicles has undergone a significant change from around 10 thousand vehicles in 1994 up to around 32 thousands. Two bus services are operated, one publicly owned and one privately owned, the latter being more efficient. This sector has witnessed a significant improvement in the bus fleet size but with a disproportionate increase in ridership.

In the railways division, studies have been conducted for the rehabilitation and upgrading of the 170 km of railway along the coast. However, in light of the concerns raised about the potential impact of such an upgraded railway on the coastal area, the feasibility of an alternative alignment is being considered.

5.3 BASELINE SCENARIO PROJECTION

Fuel prices are expected to keep fluctuating around $16/barrel for crude oil. In Lebanon, prices of fuel used for transport have been increased due to additional taxation. These increases, however, had a small impact on fuel consumption due to the lack of alternative means for transport and due to low fuel prices compared to other countries and compared to the average income.

Statistics on imported fuel for transport indicate that the amount of fuel will be slightly dropping in the short term due to the improvement in the status of the fleet caused by the ban on import of cars older than 8 years.

In the baseline scenario, it is assumed that the number of vehicles will have an annual increase of around 1.5%. The fleet condition is expected to improve so that by year 2005, the average age of the fleet will drop to around 10-12 years compared to the 14-years average of 1994. Transport management would eventually lead to some consumption reduction. Inside GBA, however, most of the measures are within the scope of traffic control rather than traffic jams reduction.

In providing short- and long- term projections, the following factors are taken into consideration:

- Private cars: 1.5% annual growth.
- Taxis and microbuses: 30,000 by 1997 and an annual increase of 1% for later years.
- Buses: 4000 by 1996, and 1% increase from then on.
- Trucks and others: 96000 by 1996, and 1% annual increase from then on.

The annual distance travelled is expected to increase to 16000 Km by 2005, and to 18000 Km by 2040. Moreover, the consumption rate for all vehicles is expected to drop by 10% by year 2005 due to the drop the fleet's average age. The projection of the demand for gasoline, diesel, and jet fuel is shown in Fig.10.

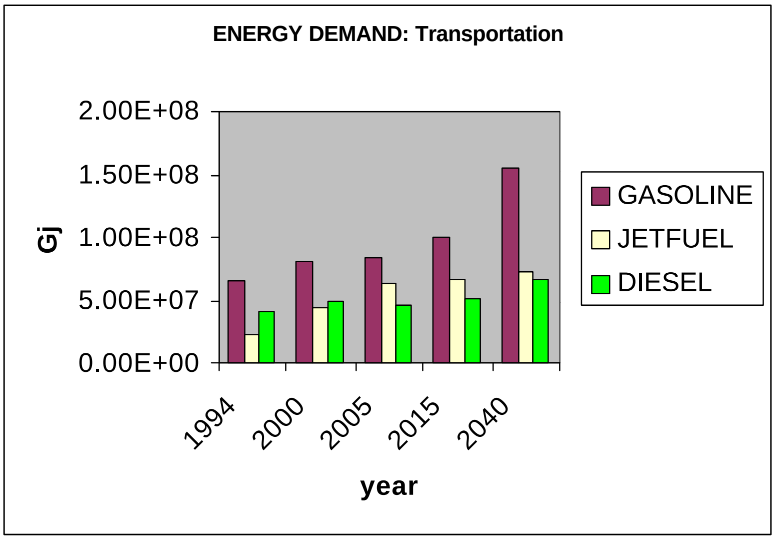


Fig.10 Transport fuel projection in the base line scenario.

The rehabilitation and extension project of Beirut International Airport would increase the capacity to around 6 million passengers annually. Plans are being developed to use the airport as a center for delivery and distribution of air cargo, served by feeder activity. For seaport and marinas activities, it is assumed that fuel consumed for sea transport is restricted to that used by local marinas and sports clubs. In the baseline scenario and in the absence of any statistics or plans, the data are set taking into consideration the new marina projects being planned and built along the Lebanese coast.

Table 17. Transport data					
	Number of Vehicles				
Device	1994	2000	2005	2015	2040
CARS & JEEPS	914000	999000	1077000	1249000	1813000
TAXIS & MICROBUSES	9000	30909	32486	35884	46019
BIG BUSES	4000	4566	4799	5301	6798
TRUCKS & OTHERS	85000	99846	104939	115918	148657
	Number of boats				
SMALL BOATS	280	738	1200	1440	2400
	Number of Flights				
PASSANGER JETPLANES	19450	38878	61220	63791	70220
FREIGHT JETPLANES	1500	2517	4000	4200	4700

Table 18: Consumption rates in the base line projection

Vehicle Type	Consumption (Gj/vehicle) = (Gj/veh/km) *(km)				
	1994	2000	2005	2015	2040
CARS & JEEPS	70.065	75.525	72.066	74.638	81.075
TAXIS & MICROBUSES	202.409	202.409	182.168	182.168	182.168
BIG BUSES	369.750	369.750	332.775	332.775	332.775
TRUCKS & OTHERS	475.393	475.393	427.854	427.854	427.854
ELEC-GASO-VEH.	35.032	37.762	36.033	37.319	40.537
ELEC.TRAINS	12600	12600	12600	12600	12600
	Consumption (Gj /flight)				
P-JETPLANES	1080	1080	972	972	972
F-JETPLANES	1080	1080	972	972	972
	Consumption (Gj / boat)				
SMALL BOATS	36.975	36.975	33.278	33.278	33.278

A summary of the data used for the baseline scenario is shown in Table 17. Table 18 presents the consumption rate of various elements of the transportation sector.

5.4 CONCLUDING REMARKS ON BASELINE CONDITIONS

Gasoline will still be the major source of fuel for the transport sector and consequently, transport sector in Lebanon will still be regarded as the major source of greenhouse gases, namely carbon dioxide. The annual distance traveled would increase from 14000 km in 1994 only to 18000 km by 2040. The increase in the number of cars in accordance with the population growth would lead to a fleet size of 1.8 vehicles in 2040, compared to 0.914 million in 1994. The Lebanese fleet will be modernized to a certain extent, leading to consumption and emission reductions. The overall result is almost a doubling in the amount of GHG emitted, from around 4160 tons of CO_2 in 1994 up to 9150 tons in 2040. Buses used for private and public transport will increase due to Government intention, in the foreseeable future, to implement public transport in the entire country.

5.5 MITIGATION MEASURES

The transportation sector's emissions of GHG are in general related to the fuel type and its emission rate, the vehicle's technical status and its fuel consumption rate, and the distance traveled and time needed for every trip.

Therefore, the corresponding mitigation options are switching to fuel with lower emission rates, improving the technical status of the fleet, and improving the system's efficiency. Analysis and cost effectiveness for the mitigation options have been conducted for discount rates of 5, 10, and 15%.

5.5.1 Switching to Fuel with Lower Emission Rates

A major breakthrough has been recently reported in the development of hybrid electric vehicles (HEV) with a consumption rate almost 60% of that of equivalent conventional fuel-driven cars with a unit price almost 25% higher than the equivalent petrol- driven vehicle. In this aspect, two mitigation scenarios have been developed based on the spread of HEV in local fleet. The first scenario considers that by year 2015, HEV would constitute 1% of the local fleet, and this number is expected to double by year 2040. In the second scenario, a car registration fees waiver is considered leading to an HEV share increase between 5% and10% in 2015 and double that value by 2040. The 10% boundary is to be considered since it gives more optimistic figures in terms of emission reductions.

5.5.2. Shift to Travel Modes with Lower Emissions

Measures applicable within this context include promoting public transport and freight railway systems. It is estimated that in 1994 there were 1.5 million motorized daily person trips in the GBA, subdivided among the various travel modes; private car (71%), taxi-service (17%), and buses (12%).

The number of motorized daily person trips in the GBA is expected to grow to 5 million by the year 2015. This significant growth in trip-making levels will not be matched by a similar growth in other parts of the country. To cope with this tremendous increase, two scenarios are considered. Scenario A, taken as base case, focuses on mass transport, and includes a significant heavy mass transit component, namely rail. Scenario B represents a continuation of existing trends, and focuses on the intense use of the private auto through further development of the road network.

Adopting an aggressive mass transport scheme in GBA as in Scenario A results in a 67% modal share for small vehicles in 2015, almost a 20% reduction from the base case. Since almost one-half of the national small vehicles fleet operates in the GBA, the 20% reduction will translate into a 10% reduction in automobile-related trip making at the national level. In this case, it was considered that the annual growth rate for private autos will drop from 1.5% to 1% (2000-2004), and to 0.7% for the year 2005 and beyond. These rates would result in a car fleet in 2015 that is 10% less than the base case. However, the rising speed from 18 km/hr to 22 km/hr in GBA is translated into an increase in fuel efficiency by about 30 km/20 liters.

Lebanon, being a car- importing country has no direct control on the design of vehicles, but can set specifications and requirements on imported cars. A more realistic measure is to encourage the import of new cars to reduce the average age of the fleet leading to higher efficiencies and lower emissions.

5.6. MITIGATION SCENARIOS- COMPARATIVE ANALYSIS

The 3 scenarios adopted for the transportation sector are:

- Hybrid electric vehicles, referred to as HEV. In this scenario, and due to the absence of any incentives, it is expected that by year 2015 hybrid vehicles would constitute only 1% of the local fleet.
- Hybrid electric vehicles with incentive, referred to as HEV II. In this scenario, a car registration waiver, estimated at 10% of the car cost, is offered by the government. As a result, it is expected that by year 2015 hybrid vehicles would constitute 10% of the local fleet.
- Trains for freight services, referred to as ET. The cost of this mitigation scenario is considered to be the difference in total investment between scenarios A and B of the ET.

Table 19. Cost Comparison of the 3 Different Scenarios (Mill. $)

Scenario	Discount	Benefits	Costs	NPV	B/C	Levelized Cost (1994 $/ton)		
	Rate	1994	1994	1994	Ratio	CO2	CO	N0x
HEV	5	975	990	-5.4	0.9848	40	120	3100
	10	261	265	-4	0.987	30	190	4880
	15	90.6	92.4	-1.8	0.988	20	100	2600
HEV II	5	9970	9840	130	1.01	-86.58	-420	-10800
	10	2666	2629	37	1.01	-28.4	-136	-3550
	15	930	918	12	1.01	-26.8	-130	-3350
ET	5	12160	2890	9270	4.21	-390	-1860	-48380
	10	3063.48	981.3	2082.18	3.12	-300	-1450	-37720
	15	1045.92	438.96	606.97	2.38	-130	-600	-15620

The benefits- to- costs ratio (B/C) expresses the measure's feasibility. HEV deployment, with financial incentive, would lead to significant GHG reduction and savings in the long run. The 10% waiver in terms of registration fees would eventually lead to 4.67% drop in fuel consumption in 2015, and to around 10% drop by 2040.

The use of mass transit is the ultimate mitigation option. It leads to a relatively high benefit/cost ratio that varies from 2.4 up to 4.21 depending on the national discount rate.

Fig.11. Emission reduction and cost of applied scenarios.

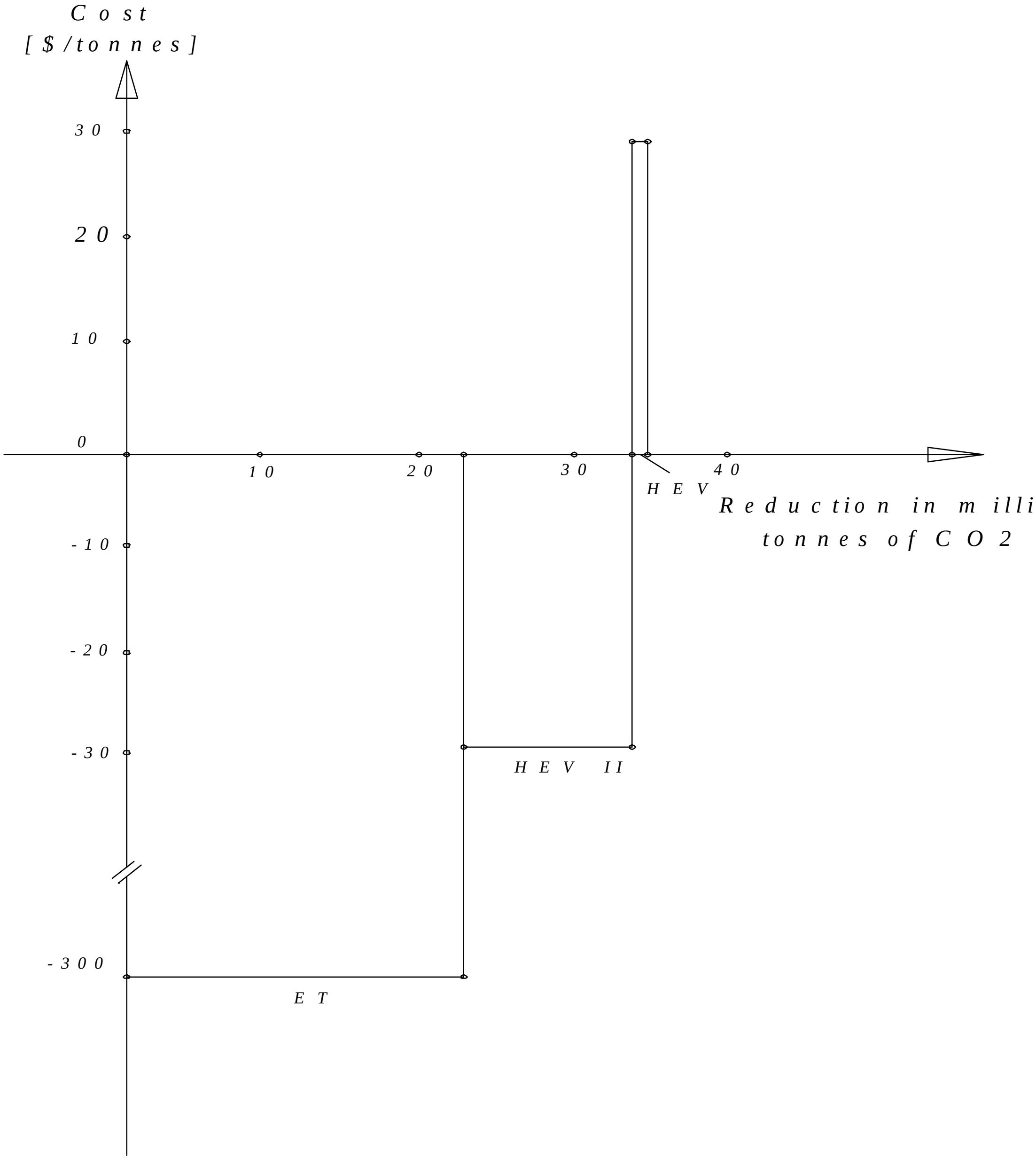


Fig.11 shows the reduction of carbon dioxide achieved by each of the three scenarios for discount rate of 10%. The negative cost values indicate that the corresponding scenario is profitable in the long run.

In air transport, realistic ideas include changes to promote and accelerate the deployment of fuel- efficient technologies in aircraft. The relevant costs are, however, still very difficult to estimate.

5.7 CONCLUDING REMARKS

Mitigation scenarios are conducted for measures that are applicable in Lebanon. The new vehicle technology of hybrid electric vehicle (HEV) with much lower GHG emission rate could have a consumption rate almost 60% of that of equivalent conventional fuel-driven car but with a unit price almost 25% more. Two scenarios with and without financial incentives have been developed. In the second scenario, car registration waiver is introduced by the government, and this is expected to increase the share of HEV to 10% of the imported cars by 2015 and again by twice this value by 2040. This scenario would lead to emission reduction rate is around 10% and would be profitable in the long run due to savings in fuel consumption.

Measures to shift towards travel modes with lower emissions include promoting public transport and freight railway systems. Rail freight systems have the greatest benefit- to-cost ratio and the greatest relative emissions reduction compared to the HEV options. Deployment of rail systems for freight is the most promising alternative in term of consumption and emissions reduction. Adopting a rail system of six lines results in a 67% modal share for small vehicles in 2015. This reduction is expected to translate into a 10% reduction in automobile-related trip making at the national level. The increase in speed on the GBA from 18 km/hr to 22 km/hr is translated into an increase in fuel efficiency and consumption rate close to 30 km/20 liters.

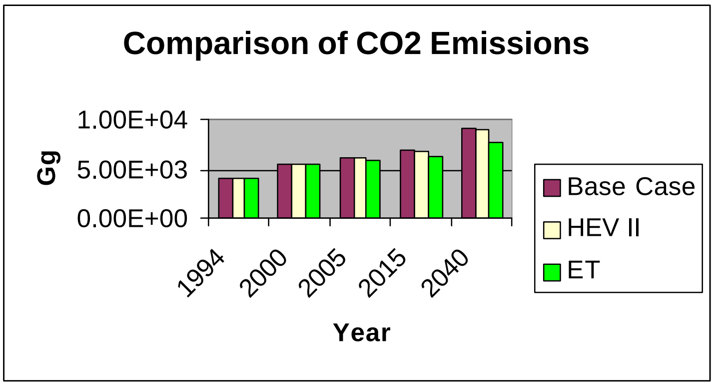


Fig.12 Comparison of CO_2 emissions

A comparison of the CO_2 emissions in the base line, the HEV with incentive, and the electric trains scenarios are illustrated in Fig. 12.

6. FORESTRY

6.1 INTRODUCTION

The forestry sector in Lebanon provides opportunities for mitigating climate change through:

1. Reducing emissions of GHG by maintaining existing carbon sinks through conservation and protection of forests; and improvement of management practices.

2. Sequestering carbon by expanding forest cover and increasing carbon storage in forest, soils and in long-term products.

The Lebanese government's forestry orientations aim at the conservation of the environment and bio-diversity, the protection of soil and water and the provision of social services through:

- Protection and conservation of natural forests and improvement of forest management.
- Expansion of the forest area from 75,000 hectares to 200,000 hectares as a low target and up to 282,000 hectares as a high target through reforestation, agro-forestry, and urban forestry.

Table 20 shows the land use pattern in Lebanon in year 1994 (base year) and the most likely trends (Baseline scenario) in land use change in years 2000, 2005, 2015 and 2040 respectively.

Table 20. Land use pattern, Baseline scenario (Area x 1000 hectares)

2040	2015	2005	2000	1994[1]		
					Forest land:	1
93	54	39	32	32	> 40% crown cover	
20	34	39	43	43	10 - 40% crown cover	
22	47	57	60	60	< 10% crown cover: Woodlands	
147	147	147	147	147	***Range lands***	
282	282	282	282	282	Sub-total	
(36)	(20)	(12)	(6)		Protected land[2]	2
253	293	308	316	316	Grass land (pasture)	3
360	320	305	297	297	Crop land	4
126	126	126	126	126	Other	5
1021	1021	1021	1021	1021	Total	

[1]Sources: Bio-diversity Country Study (1996) and agriculture census (1998), Ministry of

agriculture. Trends of land change are based on officials and experts' estimation since no official statistics are available.

[2]For the record, this area is already included in forestland.

6.2 MITIGATION SCENARIOS

The approach used in this study consists of:

1. Identification of Mitigation options significant to Lebanon;
2. Assessment of the current and future land area available for restraining emissions and for carbon sequestration;
3. Determination of the land area and wood production scenarios;
4. Estimation of the emission reduction and the carbon sequestration per unit area of forests for each mitigation option;
5. Estimation of the total and unit costs and benefits of each option;
6. Evaluation of the cost-effectiveness of mitigation options.

In addition to the changes already taking place in the baseline scenario in the field of forest protection and management as well as in reforestation, more intensive management/protection and more expansion of forest area are foreseen. In particular,

1) In the first mitigation scenario; all the forests will become dense (crown cover more than 40%) and the total forest area will increase up to 200,000ha it means additional 87,000ha versus the baseline scenario.

2) In the second mitigation scenario the total forest area will reach the amount of 282,000ha that means an additional 82,000ha will be reforested versus the first mitigation scenario.

6.2.1 Forest protection and management

The total carbon pool sequestered by forest protection is:

- In the Baseline scenario: t.c: 14,587,500
- In the Mitigation scenario: t.c: 20,175,000, and
- The incremental carbon sequestered: t.c: 5,587,000

The protection of 75,000 ha of natural forest from the year 2000 up to 2040 will produce the results shown in Table 21: (Discount rate used is 10%)

Table 21. Cost-effectiveness indicators

Incremental C. sequestered		Equivalent Co_2 reduced		Total cost
Total t.c	Initial cost $/t.c	t. Co_2	Cost $/t. Co_2	In $
5,587,500	0.403	20,450,250	0.110	2,251,726

6.2.2 Expansion of carbon sinks by reforestation

To expand the stock of carbon in biomass, soil, and wood products, it was assumed that carbon will need to be stored in perpetuity and so the amount of stored carbon on a given area needs to be estimated over an infinite number of rotations. Thus the options will be based on:

- the amount of reforested area taken as 125,000 ha (first scenario) and 207,000ha (second scenario) and
- the length of the rotation age taken as 75, 100 and 125 years in each scenario

The C. pool for each scenario is summarized in Table 22 below:

Table 22. Total C. pool reforestation

Reforested Area / ha	Rotation Age / years	Mitigation C. pool t.c	Incremental C. sequestered t.c
125,000	75	23,529,750	19,439,750
–	100	29,337,000	25,242,000
–	125	32,213,850	31,118,850
207,000	75	42,123,250	38,028,250
–	100	43,404,000	49,303,000
–	125	64,819,950	60,724,950

For a rotation age of 100 years and a discount rate of 10% the results will be as shown in Table 23.

Table 23. Cost-effectiveness indicators

Reforested	**Incremental C. sequestered**		Co_2 reduced		Total co
Area / ha	t.c	Initial cost	t. Co_2	$ / t.. Co_2	In $
125,000	25,242,000	19.7	92,385,720	5.38	497,267,
207,000	49,303,000	10.10	180,448,980	2.76	497,960,

6.3 STRATEGY / RECOMMANDATIONS

The main polices that aiming at maintaining carbon stocks and expand carbon sinks should include the following:

Forest protection and conservation policies

To preserve existing forests in a sustainable fashion, the following measures have to be taken:

- Undertaking a new-forest inventory and mapping (the first one was done in 1966) including a descriptive structure and composition of forests stands.
- Developing forest management systems that improve the long-term productivity and ecological integrity of the forests.
- Developing sound methods of fighting fire, insects, and diseases.

Reforestation

- Long rotation periods adapted to species' characteristics will increase carbon stock periods and reduce the cost per reforested unit area as well as the cost of the carbon sequestered.
- Quality of wood produced should permit its use for long life products; thus more carbon will be stored away. Quality of wood depends on forest species and management systems.
- Research on species and seeds provenance and on appropriate techniques for harvesting and regeneration of forests.

Other measures

- Amendment of the forest laws to allow various parties to participate in implementing reforestation programs and forest management plans.
- A comprehensive land use planning and zoning through which appropriate land is spread for agriculture, forestry and pasture.
- Grazing, in forests and reforested lands should be managed to avoid damages that goats and sheep could cause to regeneration of old forest stands or to the growth and development of young forest and new reforested lands. Serious prejudices will affect any forestry development plan if the grazing problems are not solved.

7. WASTE MANAGEMENT

7.1 INTRODUCTION

Waste management covers two major activities namely land disposal of solid waste; and wastewater treatment (domestic, commercial, and industrial). Depending of the method of waste disposal and the wastewater treatment technology, these two activities can result in greenhouse gas (GHG) emissions which include primarily methane (CH_4), carbon dioxide (CO_2); and nitrous oxide (N_2O). In order to estimate the amount of GHG emissions from the waste sector in Lebanon, estimation of the following parameters were first made:

- Population;
- Method of solid waste disposal;
- Solid waste composition; and
- Solid waste generation rates.
- Method of wastewater treatment;
- Wastewater characteristics; and
- Wastewater generation rates.

For mitigation purposes, a baseline scenario was established with respect to the projected status of facilities for solid waste disposal and wastewater treatment that are expected to come in operation at a certain year. In this report, the years 1994, 2005, 2015 and 2040 were selected as short term and long term baseline scenarios. GHG emissions from waste management in Lebanon associated with these years were estimated (Fig. 13). Mitigation measures were then discussed and the economics of implementing the most suitable and feasible measures in the context of the Lebanese situation are presented. The revised default methodology developed by the Intergovernmental Panel on Climate Change (IPCC) was followed in order to estimate emissions from solid waste disposal on land.

Note that at this stage, the assumptions adopted in this report would result in no methane emissions from wastewater treatment because of the trend of using aerobic treatment processes. The validity of these assumptions must be continuously checked when updating inventory and mitigation reports for GHG emissions depending on treatment systems that may come into operation.

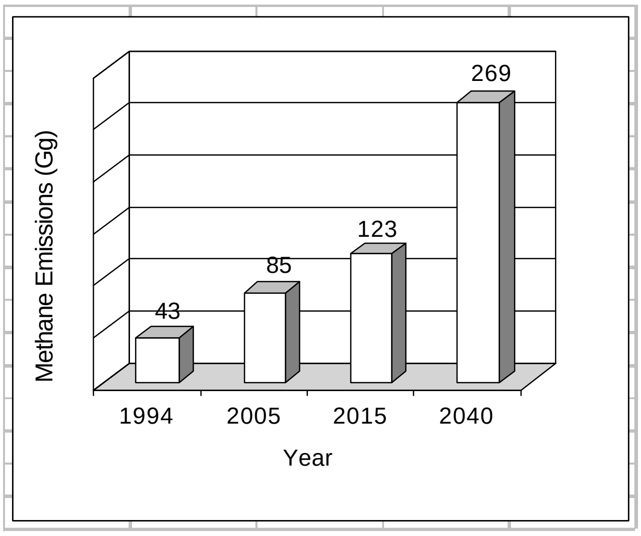


Fig.13. Methane emissions from waste management in Lebanon

7.2 MITIGATION OF METHANE EMISSIONS

The Lebanon Context

In Lebanon, the historic background of solid waste management consisted primarily of waste disposal in large open dumps. The current and future government policy on solid waste management advocates an integrated waste management system of recycling, composting and landfilling. Incineration was completely phased out due to public pressure that emanated from the adverse impacts of operating two old incinerators. The current policy did not succeed to date. In fact, the market for recyclable materials has been very weak. The target for recyclables was set at 10 percent but did not achieve more than 1 percent. The experience with composting was not successful either. The one year experience was plagued with operational problems: system overload, odor generation, and a low quality compost product. As a result, the majority of compost material was disposed of in landfills. Efforts continue to improve processing and composting facilities. For the years of the baseline scenario, four possible solid waste management alternatives were considered.

Alternative 1.

Continue with the current waste management policy (recycling, composting, landfilling) until it succeeds. To date, this appears to be one alternative that is adopted by the government at some locations. Under this alternative, a great part of degradable organics are removed from the waste stream that may reach a landfill thus reducing the economic incentive for the installation of gas recovery systems since the amount of methane that can be produced would not cover the cost of gas recovery. The best remaining mitigation measure under this alternative would be methane gas flaring which again, on and by itself, does not present any rate of return on investment. As such, unless the government requires and enforces gas flaring, methane emissions will be completely released into the atmosphere and no reduction in GHG emissions from the waste sector would be expected.

Alternative 2.

Modify the current waste management policy and adopt complete landfilling of municipal solid waste. This is a second alternative that the government has adopted at many locations for the baseline years. The probability of occurrence of this alternative will increase if the recycling and composting policy continues to fail. Under this alternative, no degradable organics are removed from the waste stream that may reach a landfill thus increasing the economic incentive for the installation of gas recovery systems since the total amount of methane that can be produced would be available for recovery and energy production. While flaring is a mitigation option under this alternative, gas recovery may provide a favorable option even if the government does not adopt a policy to reduce GHG emissions.

Alternative 3.

Modify the current waste management policy and adopt complete landfilling of municipal solid waste with separation of food waste at the source. This alternative can be partially accomplished by requiring kitchen grinders but it requires significant public participation and government enforcement which decreases the probability of its occurrence. Similar to alternative 1, under this alternative, a great part of degradable organics are removed from the waste stream that may reach a landfill thus reducing the economic incentive for the installation of gas recovery systems since the amount of methane that can be produced would not cover the cost of gas recovery. The best remaining mitigation measure under this alternative would be methane gas flaring which again, on and by itself, does not present any rate of return on investment. As such, unless the government requires and enforces gas flaring, methane emissions will be completely released into the atmosphere and no reduction in GHG emissions from the waste sector would be expected.

Alternative 4.

Modify the current waste management policy and adopt complete incineration of municipal solid waste. This is the third likely alternative that the government may adopt. The probability of occurrence of this alternative is slim because of higher costs lack of technical expertise, and public pressure. Under this alternative however, methane emissions can be eliminated or minimized.

Economy of Alternatives

In Lebanon, an economic assessment study was conducted to evaluate the cost of three waste management options (composting, incineration and landfilling) that are planned for several Lebanese cities. Fig. 14 depicts the associated cost with the three options clearly favoring the landfilling option.

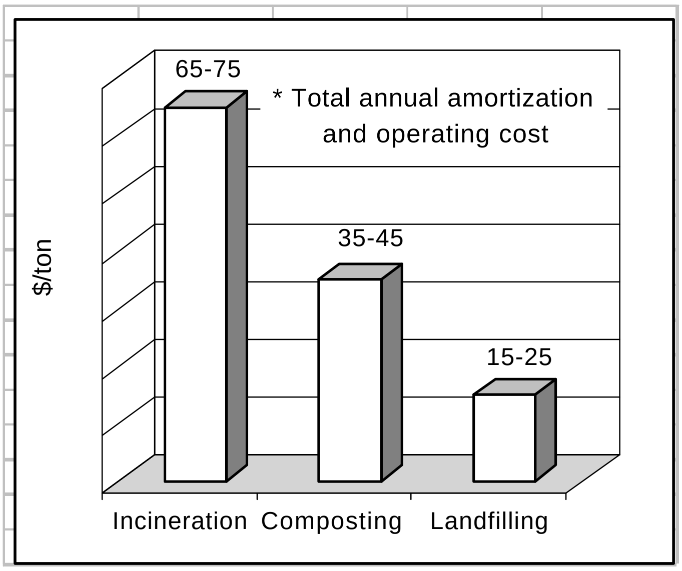


Fig.14 Economy of waste management options

Feasibility of Emission Reduction in Lebanon

Gas recovery projects for energy use require relatively large landfills that accept adequate quantities of waste with high biodegradable organic fraction. The trend in Lebanon is towards constructing such landfills (i.e. Naameh and Zahle landfills). Emission reduction at such landfills can reach 90 percent of total methane emissions depending on the efficiency of the gas collection system. While gas flaring does not provide economic incentives for landfill operators and can only be imposed through government regulations, gas recovery may be economically beneficial irrespective of government intervention. Therefore, further economic assessment was conducted in terms of the potential benefits from gas recovery.

7.3 ECONOMICS OF LANDFILL GAS RECOVERY

The economic appraisal of any landfill gas exploitation project requires the scrutiny of the overall process of sanitary landfilling. In this analysis, collection and disposal fees are assumed to be incurred irrespective of the gas recovery system. Only the costs associated with the gas recovery system are considered for the purpose of economic assessment of methane emission reduction. These include 1) capital cost for gas extraction, conversion, and the end-use equipment that need to be installed; 2) maintenance and operation (OM) costs; and 3) income from the sale of landfill gas. Factors relevant to this issue such as tariffs and other indirect revenues (environmental savings) are not included in this analysis.

7.4Economics of Selected Mitigation Alternatives

As indicated earlier, the two basic alternatives that are likely to occur in Lebanon

and that were considered in the economic assessment include 1) landfilling and 2) composting and landfilling. Both alternatives have two options for emission reduction: a) gas recovery and flaring or b) gas recovery and utilization thus leading to a total of four possibilities as follows:

1.a Landfilling with gas recovery and flaring (LF+F)
1.b Landfilling with gas recovery and utilization (LF+U)
2.a Composting and landfilling with gas recovery and flaring (C+LF+F)
2.b Composting and landfilling with gas recovery and utilization (C+LF+U)

The cost of methane emission reduction for the four options was calculated. For this purpose, the quantity of methane emissions reduced over the lifetime of the facility was determined. The cost of emissions reduction is reported on the basis of of cost per ton of methane reduced. Results are also expressed in terms of cost of equivalent CO_2 reduction. Comparison of alternatives was conducted using the following criteria:

- Operations & maintenance costs=10 % of gas flaring/utilization capital cost
- Revenues = 30 percent of gas utilization capital cost (Sales would constitute 38% if sold at the current average price of $0.065/kW-hr)
- Discount rate = 10 percent

Based on these criteria the composting and landfilling with gas recovery and utilization ranked first among selected mitigation options. The remaining three alternatives were relatively similar (Fig. 15).

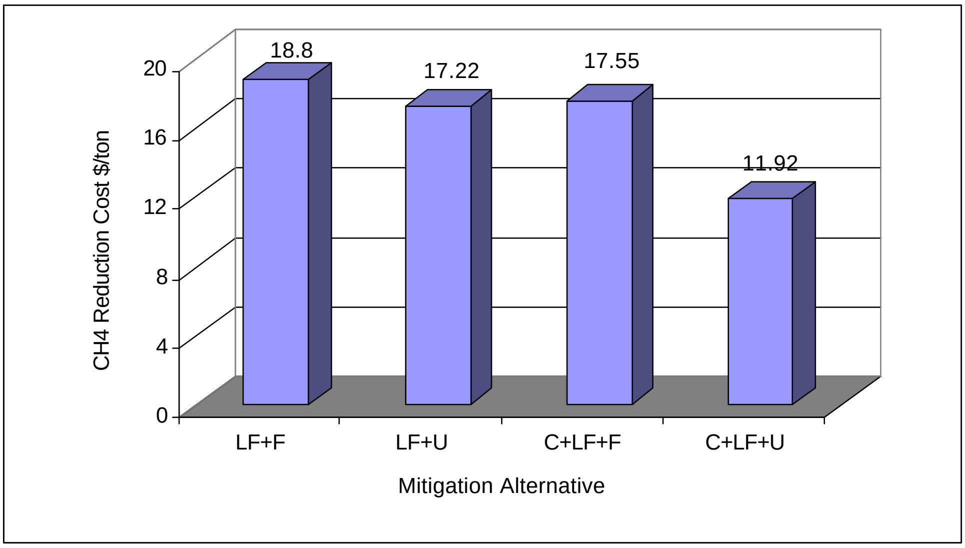


Fig. 15. Comparison of selected mitigation alternatives

Methane Emission Reduction

Emission reduction of The amount of methane and equivalent carbon dioxide (at 90% reduction rate) over the lifetime of the facility was conducted. The amount of methane reduction for the years (2000, 2005, 2015, and 2040) are depicted in Fig. 16.

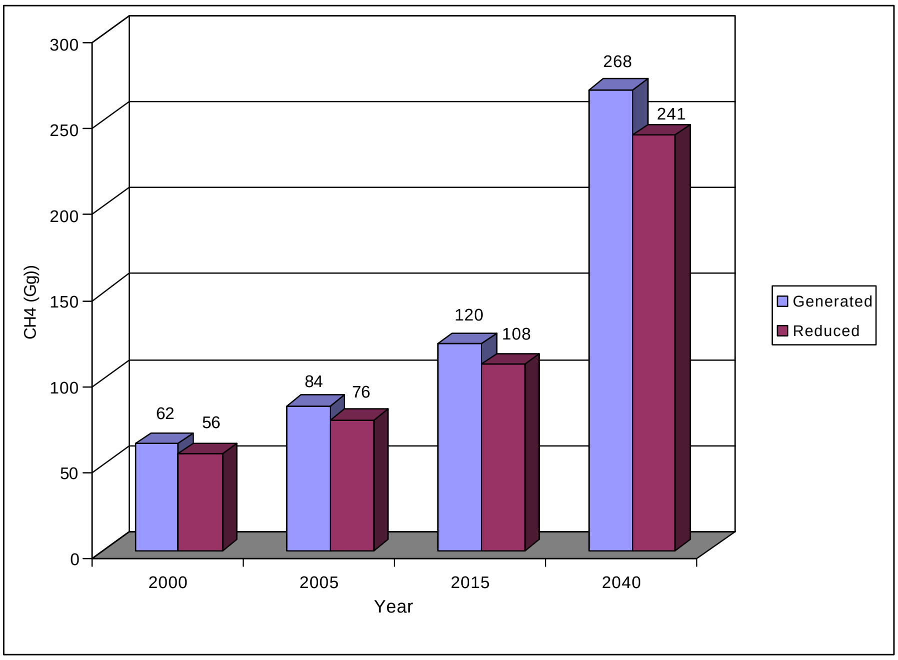


Fig. 16. Methane generation and reduction

8. GENERAL CONCLUSION

This study has focused on two major issues: i) description and evaluation of sectoral baseline scenarios, and ii) development of mitigation measures for all sectors concerned. The sectors that have been studied are:

- Electricity supply,
- Electricity consumption in the residential and commercial sectors, building envelop,
- Industrial,
- Transport sector,
- Waste and
- Forestry

A summary plot of cost per Ton of CO_2 saved for selected mitigation options is shown in Fig 17. Details on each of these options were discussed in due paragraphs above.

The study has revealed the following important conclusions:

- Although some ongoing/planned government plans are useful for mitigating GHG in Lebanon, there is a lot to be done in order to have a comprehensive strategy that can lead to a substantial GHG emissions reduction for the years 1994-2040.

- Despite the fact that some mitigation scenarios are expensive to achieve, others have high benefit to cost ratio. Some others are win-win scenarios and therefore, they do not require extra investments to achieve considerable GHG emissions reduction.

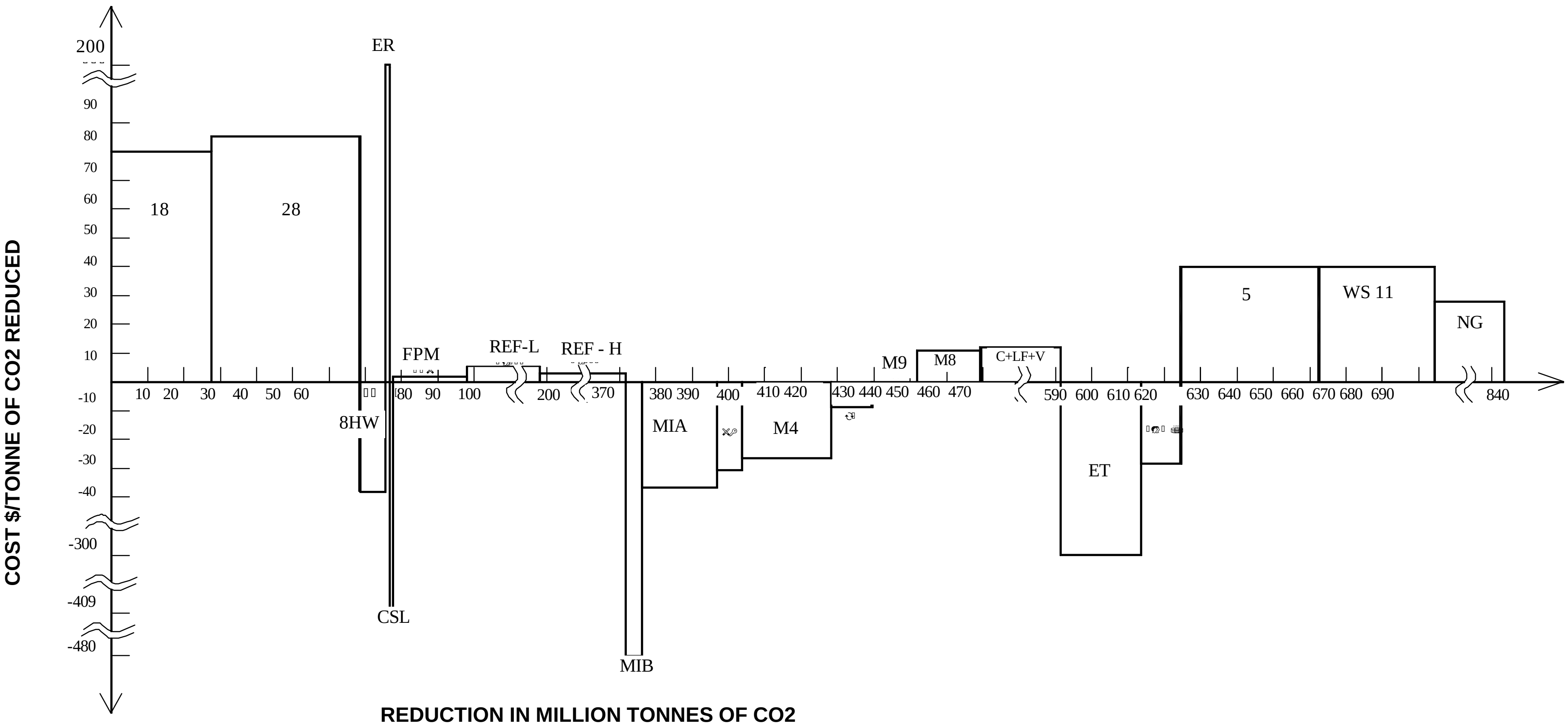
- Most of the identified mitigation scenarios have important economic return on the national level beside their positive impacts on the environment.

- In the absence of an integrated economic plan linked to an environmental agenda, the identified mitigation scenarios together with the sectoral baseline scenarios make an important document for the government of Lebanon which can use them to develop national plans that are environmentally friendly and economically viable for the country.

Finally, the study has identified some concrete projects useful for reducing GHG emissions, and has set some recommendations for future work. Good efforts are needed to further elaborate these proposals, bring them to the attention of government officials and convert them into real projects

Climate Change

Figure 17



9 ASSESSMENT OF BIOCLIMATIC CHANGE AND VULNERABILITY (LEBANON CASE STUDY)

9.1 GOALS OF ASSESSMENT

The general target is to identify, under the predicted modifications in CO_2 levels and according to the IPCC-proposed climate change scenarios, the changes that would occur in the Lebanese climate. This study points out the probable modifications of the current bioclimatic levels, as changes in the principal climatic factors (*e.g.* precipitation, temperature…) reflect directly upon the distribution of those levels. It is possible, then, to outline the different bioclimatic vulnerability levels with or without the doubling, by year 2100, of the 1990-atmospheric concentration of CO_2.

9.2. SCOPE OF WORK

Our investigations cover the whole Lebanese territory. This is due to the fact that variations in the meso and microclimatic conditions exist all across the country and influence, to a great degree, the distribution, the structure and the species composition of the Lebanese terrestrial ecosystems.

As for the time frames, we settled for the following:

- Baseline scenario: taking into consideration that a 30-year average of meteorological observations is necessary the most appropriate, and available, time-serie was: 1940-1970.
- Climatic change scenario: according to the General Circulation Model and scenario that we adopted (*i.e.* HadCM2 / HHGGax) years 2020, 2050 and 2080 were chosen instead of the IPCC-proposed milestone years 2015, 2050 and 2100.

9.3. METHODS AND UNCERTAINTIES

The parameters that characterise the climate are numerous: precipitation, temperature, atmospheric humidity, winds, intensity and length of the drought period, potential evapotranspiration etc…

While conducting this study we were bound by a number of restrictions, namely:

- the very restricted number of synoptic climatic stations that produced complete thirty-year series of data,
- many of the remote stations were provided only by pluviometers,
- lack of time to undertake statistical calculations in order to fill the gaps in the actual data and,
- most of all, the unavailability of specific software and models specialised in the manipulation of such data.

In order to build up the different bioclimatic scenarios that reflect the predicted changes, we had to draw first the baseline scenario. The most recent study of the Lebanese climate identifies six bioclimatic levels (Abi-Saleh, B. *Etude phytosociologique, phytodynamique et écologique des peuplements sylvatiques du Liban.* Thèse Univ. Droit. Econ. Sc. Aix-Marseille III. 1978; 184p.) Based on the same principles, each of the different stations was given a code according to the bioclimatic level in which it is located. Expert judgement was used in the case of stations that had only precipitation values, based upon analogue approach and taking into consideration relief and geographical parameters.

By gathering all the stations located in the same level, we managed to create the map of the bioclimatic levels. This map is considered to reflect the current Lebanese climate situation and the assumed fluctuations in absence of global warming. The chosen model / scenario for the Lebanese case study for Vulnerability Assessment to Climate Change is HadCM2 / HHGGax, according to which CO_2 emissions will continue to increase with an annual rate of 1%, leading to a doubling of the 1990 CO_2 level by the year 2060.

After identifying Lebanon's position according to the grid defined by this model we applied, for each station, the predicted modifications in precipitation and temperature values.

The same methodology and data analysis as for the bioclimatic assessment in the baseline scenario was then applied. Consequently, we came up with the maps relative to the bioclimatic levels that would be observed under these new climate conditions.

Respective area percentage of the Lebanese territory, covered by each of the identified bioclimatic levels, in each of the above-mentioned maps, is shown in the table hereafter:

Bioclimatic level	**Baseline scenario**	**Climate change scenario**		
		Year 2020	**Year 2050**	**Year 2080**
Extreme arid	—	—	—	2.762
Arid	4.856	4.919	4.920	13.270
Semi-arid	19.321	23.838	23.871	15.223
Subhumid	45.166	49.575	50.652	60.757
Humid	25.903	19.728	19.442	7.470
Perhumid	4.522	1.765	1.115	0.518
Oromediterranean	0.232	0.175	—	—

9.4. VULNERABILITY ASSESSMENT

The assessment of bioclimatic vulnerability must take into account the interaction between all the climatic factors that contribute to the definition of the climate and the bioclimatic levels. In our case, *i.e.* the Mediterranean climate, the evaluation of the degree of vulnerability can be based on the study of the two principal *limiting factors: period of drought* and *risk of frost*. The vulnerability to climatic modifications becomes greater when these factors increase in value or in intensity.

However, some precautions are to be taken while doing this analysis. For every bioclimatic level, the different climatic parameters are included into bracket values. Due to a decrease in precipitation amounts, a given zone could become included in a “drier” level; however, its degree of vulnerability would remain unchanged if the observed decrease does not exceed the lower limit of the corresponding level.

At this point of the study we can say that the most bioclimatic vulnerable zones are the levels that are the most humid and cold ones, the areas that lay under severe drought conditions and also the regions where a “climatic warming” would occur within the high altitudinal ranges, *i.e.* > 1500 m.

On the other hand, a medium degree of vulnerability can be given to the areas submitted to changes that will induce their crossing to the closest level, especially in the medium altitudinal ranges, *i.e.* from 500 m up to 1000 -1500 m.

All other areas would be classified under a low vulnerability degree, particularly where no changes in the distribution of the bioclimatic levels have occurred. The chronology of these changes is shown on the enclosed map.

9.5. CONCLUSION

As a result of this study, we can make the following comments:

- The predicted changes in climatic prameters, *i.e.* decrease in precipitation amounts combined with an increase in temperature values, reflect clearly on the spatial distribution of the bioclimatic levels.
- The decrease in area coverage, for a given bioclimatic level, is frequently accompanied by a fragmentation of the initial area. On the other hand, an increase in such coverage results in joining separate regions under one geographic and bioclimatic zone.
- Another relevant fact consists in the individualisation, in year 2080, of a new bioclimatic level EXTREME ARID, characterized by a twelve-month period of drought, and in the disappearing of the OROMEDITERRANEAN level along milestone-years 2050 and 2080.
- Variations are also observed through the latitudinal and longitudinal shifting of the boundaries of these bioclimatic levels.

10 WATER RESOURCES

10.1 GOALS

Lying in the semi arid-sub humid eastern Mediterranean zone sensitive to climate change, Lebanon is witnessing a higher frequency of droughts and episodic torrential rain signifying its apparent trend towards more aridity. Water mismanagement is leading to increase wastage and, coupled with increasing demand, is making securing the needed water a problem.

The study tries to investigate the impacts of climate change on the water budget, and vulnerability of representative hydro-systems and the community. It identifies adaptation measures for proper management through a variety of technical, administrative and policy options.

10.2 SCOPE

The exposure units used to reflect the vulnerability of the water sector are surface water, ground water and the drought affected community. These are exposed in both coastal and inner Lebanon through a time frame defined by on-going trends, as well as the years 2015, 2050 and 2080 as benchmarks for climate change.

10.3 METHODS AND UNCERTAINTIES

Different approaches are followed including analogues to learn from past or similar conditions; field surveys where data are missing or where new techniques are applied; expert judgment is sought in many instances because reliable and documented data in Lebanon are not easily available; modeling is also used as some data are predictive in nature, and future projections are a must in a theme as uncertain as climate change inherently is. Indeed, there are uncertainties in all the above methods because data in Lebanon and the scope of scientific research are quite lacking. This is why evaluations are done for the predictive capabilities of the mentioned methods. Thus, sensitivity analysis, scientific feasibility and data needs are employed for valuation and a summary matrix gives the overall picture of appropriateness of the methodology. This leads to establish a set of useful data on precipitation trends, evapo-transpiration as an indicator of desertification, stressed community, depletion of water sources, soil moisture, water quality, water supply-demand (balance), green-cover and soil removal, and an idea about management.

10.4 VULNERABILITY AND IMPACT ASSESSMENT

This is where first the climate change scenario is introduced and then impacts are analyzed. To be meaningful, the expected future has to be compared to the present. Thus, existing conditions and plans in terms of water supply and demand (total and sectoral) are shown as a baseline to the year 2015 (where some studies believe the demand will double), and projected further to 2050 and 2080. It clearly shows a water deficit building up anywhere between 140 MCM to 800 MCM annually. Then, with climate change impact reflected by less expected precipitation, it only means that the above deficit could become worse, i.e. possibly between 250- maybe more than 800 MCM annually (Fig. 18). This is further linked to the possible effects of sea level, as seawater intrusion will impact the quality of coastal fresh water. Yet, indications are given that if certain measures are taken starting now, the above negative picture could be reduced.

10.5 ADAPTATION MEASURES

These are identified at three levels as the impacts are expected to affect the whole social structure: the strategic, the population and the individual levels. A total of 34 options are given falling under 4 opportunities: prevention, sharing, changing, and control technology. The options are further recommended, after being screened with respect to their priorities, into 3 phases: the immediate within the year 2001, the medium term within 2005, and the long term within the year 2010 (see attached list).

11- AGRICULTURE

EXECUTIVE SUMMARY

11.1 GOALS

The expected increasing in the mean annual temperature up to 4.1°C during the coming Century, accompanied by a doubling of CO_2 concentration and a shortage rainfall, will deeply affect the Lebanese agriculture. Some crops will be displaced to higher altitudinal elevation, while others, more tolerating varieties will take place instead of older ones. Furthermore, a possible change in the planting dates and in the irrigation practices in term of timing and quantity will take place. These changes necessitate an appropriate technical, financial and legislative measure to be taken.

The goal of impact evaluation is to provide means of early awareness of the problem by the decision makers on both central and regional levels.

11.2 SCOPE

The exposure unit used to reflect the vulnerability of the Lebanese agriculture to climate change are 4 typical plants growing in different agroclimatic zones: citrus in coastal thermo-Mediterranean zone, olive in EU-Mediterranean zone, apple in oro-Mediterranean zone, and sugar beet in the internal subarid zone. Others large planted crop such as grapes or potatoes were excluding in spite their economic importance because of their adaptability and flexibility to grow in different agroclimatic zones, that can mask the yield variability due to climate change.

11.3 METHODS AND UNCERTAINTIES

The methods followed to evaluate the climate change's impact are analogs and expert judgments. The analogic with warmer climatic condition was used to predict the future expected yield, growth and pathological state of these selected crop. Missing data or delay in its updating was substituted by expert judgment. More objective methodological approach such as modeling was not used due to reasons beyond our control.

Based on previous studies, some interpolations were made to predict land use changes during the coming 2020, 2050 and 2080 years.

11.4 VULNERABILITY AND IMPACT ASSESSMENT

According to a population growth rate of 1.5%, the coastal lands known as thermo-Mediterranean zone, will be by the 2080 year entirely covered by construction and relevant infrastructure.

The demographic pressure accompanied by climate change tolerates the geographical dislocation of citrus, olive and apple plantation to a new, higher areas. This situation necessitate terraces building, soil reclamation, damps construction, artesian wells digging and plantation of new, more adapted crop varieties. The mountainous characteristic of the Lebanese territory, known by the climatic phenomenon named "the altitudinal zonation", (which indicates, that the temperature decreases by half degree with each 100m elevation above sea level), can be used to overcome the negative thermal impact on cited above three crops.

As for sugar beet, it tolerates the temperature increasing, the soil salinity and the doubling of CO_2 concentration. These physiological characteristics can encourage the government on keeping the currently adapted subsidization policy.

11.5 ADAPTATION MEASURES

To combat with climate change impact, some recommendations were provided to be adopted on governmental, private sector and individual levels. These measures are: decrease of population growth rate, sustainable and economic water use, soil fertility conservation by land reclamation, low regulation to mitigate the disintegration of estate ownership, advanced agriculture technique use and governmental subsidence policy for social reasons.

12 TERRESTRIAL ECOSYSTEMS, NATURAL HABITATS AND WILDLIFE

12.1. GOALS OF THE ASSESSMENT

The main goals of this study are to identify terrestrial species and ecosystems that may be particularly sensitive to climate change, assessing the degree of vulnerability to climate change and the main aspects that may be impacted. These are spatial distribution, determined by vegetation and bioclimatic zones, species composition and community structure. This assessment includes an overview of the status of the species that are endemic, endangered, under the threat of extinction, and/or at the edge of their geographic distribution. Scenarios for baseline tendencies and climate change impacts are constructed for natural areas and wildlife and adaptation measures are accordingly proposed.

12.2. SCOPE OF ASSESSMENT

The exposure units in this study are basically natural habitats and wildlife species. The natural areas considered are those that are representative of major types of ecosystems in addition to categories of particular or special interest. The latter include wetlands, islands and sandy beaches. Study areas are chosen as the ones identified as the most vulnerable under the baseline and climatic change scenarios.

The time frame for baseline scenario and for climate-change scenario milestone-years is the one that has been defined for the assessment of the bioclimatic changes and vulnerability.

The general data bioclimatic, habitat distribution and vegetation maps. Further data is required from other sectors in order to conduct a more comprehensive analysis of our sector.

12.3. METHODS, MAJOR ASSUMPTIONS AND UNCERTAINTIES

Simulation models as a means of constructing baseline and climate change impact scenarios were not used due the limitations of the available data. The methods used were mostly based on empirical-statistical methods, analogues and expert judgment. However, the use of GIS tools for drawing and overlaying different maps (Bioclimatic zones, vegetation zones and ecosystems/natural habitats) facilitated the judgment in identifying the most vulnerable areas.

Protected areas were examined in terms of their latitude and altitude ranges, their presence in various bioclimatic and vegetation zones, their species composition, especially the presence of sensitive species and the vulnerability to sea level rise. Lists of various animal and plant species were compiled detailing, whenever available, their current status i.e. endemic, rare, endangered and presence at the edge of their geographic distribution (e.g. southernmost).

12.4 CLIMATE CHANGE VULNERABILITY IMPACT ASSESSEMENT:

The main baseline disturbances that are currently affecting natural habitats are:

a. Chaotic urbanization at the expense of forests and woodlands.
b. Pollution of various sources, air, water and soil.
c. Fires that seem to be increasing in frequency with the lengthening of the dry season.
d. Changes in the water table due to excessive water exploitation for domestic and agricultural use.
e. Quarrying activity which is also affecting the water table.
f. Overgrazing.
g. Fragmentation by one or more of the above factors.

Any intensive or extensive increase in any of these factors will lead to a degradation of the natural habitats that will be further exasperated by climatic changes.

The expected changes in the distribution of vegetation communities may lead to the disappearance of certain vegetation associations and their replacement by others. For example, a forest may regress into a shrubland or even grassland depending on the intensity of the modification.

Two forests in protected areas, namely Horj Ehden in the North and Arz Al-Shouf in the Barouk Mountain are characterized by great floral diversity of herbaceous and arborescent plants containing many endemic, rare and endangered species some of which are at the southernmost edge of their distribution. The distribution of *Cedrus libani libani which* normally falls within the precipitation range of 500-1300 mm with mean winter temperatures between –2 and –5^{o}C may become increasingly under stress with the upward shift in bioclimatic zones. For a 3^{o}C temperature increase, for example, an upward shift in vegetation belts of around 545m would be expected. Climatic factors, however, are not the only factors that may affect the success of cedars but there is a clear preference for humid atmospheres and moist well-drained soil.

According to the climatic scenario used here, there may be a 300m upward shift in the year 2020, 486m in 2050 and more than 700 meters in the year 2080. This would push the tree line in the year 2080 in both reserves to around 2500m. Considerable stress will begin to be felt as early as the year 2020. This makes both protected areas highly vulnerable. Furthermore, the rate of change may be faster than the species ability to adapt. Mountain vegetation as found in the two above-mentioned reserves may face considerable threat of serious decline and even disappearance.

Other factors, however, such as the increased water efficiency due to CO_2 increase may enhance its ability to withstand the new drought conditions. It is also uncertain to what extent and how soon there may be a change in soil characteristics affecting the vegetation.

In the main wetland area in Lebanon, the Ammiq ephemeral marshes intensive water pumping for the irrigation of several cultivated lands in the surrounding areas has reduced the area and shortened its seasonal span. It is expected that, in the absence of climate change and due to the lack of management plans, these marshes will be affected by:

- Change in land use in the surrounding areas, where more land will be reclaimed for cultivation,
- Increased water demand for the irrigation of these and other nearby cultivated lands.

The effect of climate change on the marshes may take two forms:

1. Spatial: leading to reduction in the total area of the marshes
2. Temporal: shortening of the duration in which the marshes exist during each year. This may mean, for example, that there may be no marshland left for the birds in their autumn return migration.

It is estimated that the total area of the marshes may undergo a decline at the rate of about 6% per year. At this rate, without climate change, the marshes may practically disappear in less than two decades and without climate change. This will be obviously exasperated under climate change.

Rivers and Riparian habitats would be vulnerable to precipitation changes. Some pass through more than one bioclimatic zone. Their fragility has increased during last 20 years by reduced water supply, reduced precipitation., population increase, excessive exploitation of water resources, pollution, quarrying, agricultural side-effects including soil erosion, pesticides and fertilizer runoff. Due to climate change, the reduced flow and increased water temperature (which is uncertain in magnitude) may lead to a reduction in the riparian (riverbank) vegetation. Altitudinal and latitudinal shifts in these zones may influence the pattern of vegetation

The Tyr sandy beach, the only remaining significant sand dune habitat in Lebanon for many plants and animals that are unable to thrive except on sandy substrates. The main pressures on the sandy beach in the foreseeable future, without climate change, are land reclamation and tourist development. Increased population density and the demand for more agricultural land will place more pressure on the whole zone. It is considered to be highly vulnerable to sea level rise and is classified as “critical”. This implies high vulnerability to erosion and flooding. The establishment of a nature reserve in the Ras El-Ain area may not be enough to protect sufficient sandy areas. There is a risk that the sandy beach narrow or even disappear with its indigenous fauna and flora.

The Palm Islands Nature Reserve, composed of three islets, will be subjected to inundation under a climate-change scenario.

The main problems facing the Lebanese wildlife today are the same as those listed above for natural areas. Populations of many species may be subjected to extirpation (local extinction) due to the great fragmentation affecting their habitats. This fragmentation is likely to continue and perhaps accelerate due to increased urbanization.

The species most vulnerable to climate change may be those that are endemic, endangered, at the edge of their geographic distribution, mountain, coastal and those which may be replaced by potential competitors from other zones. Some such species have been named in this report as facing decline or extinction.

In Lebanon, the known endangered forest tree species are found in degraded, heavily grazed areas. The extent to which they face threat is directly related to the continuing human pressures through felling and grazing. No study has quantified these two aspects. Under climate change, some areas of distribution may shift bioclimatically putting more stresses on these species.

12.5.ADAPTATION

Adaptations that may reduce the climate change impact may include the following:

1. Natural adaptation where the vegetation and wildlife may acclimatize where the climate change being still within their tolerance range. Some may adapt (in the evolutionary sense) if containing enough genetic diversity. T
2. Natural adaptation may have to be assisted by exploring and cultivating certain drought-tolerant ecotypes. It may be also be enhanced by reducing habitat fragmentation and thus allowing the natural genetic variation to lead to suitable adaptations.
3. Habitat fragmentation can be reduced by establishing corridors and connections between the isolated habitat types.
4. Intensive studies on species and ecosystems have to be devoted to assess the degree of vulnerability an to discern the above aspects.
5. Water use and change in land use have to be rationalized to protect wetlands and riparian habitats.
6. The area and the number of protected areas need to be expanded to include more of the sensitive habitat types and/or more vegetation and bioclimatic zones.
7. Buffer zones need to be established around protected areas to reduce the human impacts and those of climate change.
8. Adaptation measures have to be adopted within the next two decades.
9. Because of the international importance of some protected area it may be possible to seek international assistance especially in schemes such as “debt swapping” which involves trading foreign debts for financing the establishment and maintenance of protected areas and nature reserves.

13 THE COASTAL SYSTEM

A. THE PHYSICAL COMPONENT

13A.1. GOALS

Coastal erosion is a widespread phenomenon along the Mediterranean shorelines, especially those where human interference has been continuous for thousands of years like Lebanon. Coastal land subsidence, the frequently severe climatic regime and low-lying shoreline segments mean a high rate of coastal deterioration, notably with the expected Relative Rise in Sea Level (RRSL) resultant from climate change. The vulnerability of the coastal community and the quality of coastal fresh water are serious issues affecting more than 70% of Lebanon's population.

Accordingly, this study aims to assess the impacts of climate change on the physical aspects of the coastal system, and vulnerability of components affecting the quality of life of the coastal community. It identifies adaptation measures for proper management through a variety of technical, administrative and policy options.

13A.2. SCOPE

The exposure units used to reflect the vulnerability of the coastal physical component are the coastal stretch, the community and coastal water. They are exposed at different fragile coastal segments along Lebanon's shoreline through a time frame defined by on-going trends, as well as the years 2015 (like water resource of Chapter 2), 2050 and 2080 the benchmark years of climate change.

13A.3. METHODS AND UNCERTAINTIES

Different approaches are followed including analogues to learn from past or similar conditions; field surveys where data are missing or where new techniques are applied; and modeling because some data are predictive in nature and there is an obvious need in themes related to climate change to resort to future projections. Indeed, there are uncertainties in all the above methods because data in Lebanon and the scope of scientific research are quite lacking. This is why evaluations are done for the predictive capabilities of the mentioned methods. Thus, sensitivity analysis, scientific feasibility and data needs are employed for valuation and a summary matrix gives the overall picture of appropriateness of the methodology. This leads to establish a set of useful data on coastal storms and their impacts especially on the community, physical parameters of the shoreline as they are crucial indicators for calculating land loss using the famous Bruun Rule, estimates of rates of annual RRSL, study cases of coastal erosion, climatic modeling, and the status of the shoreline including its geoidal elevation, therefore, where it is at most risk.

13A.4. VULNERABILITY AND IMPACT ASSESSMENT

This is where first the climate change scenario is introduced and then impacts are analyzed. To be meaningful, the expected future has to be compared to the present. Current estimates and calculations show a RRSL of about 4mm, and land loss varying between 7 and 16mm. The coastal stretch was classified into three categories: very critical, critical and less critical. Thus, existing conditions and plans in terms of expected incurred economic losses due to an increase in coastal flooding and resource deterioration are shown as a baseline to the year 2015 (this is in line with the water sector-see Chapter2- as water is a vulnerable unit), and projected further to 2050 and 2080. It shows an estimated financial annual losses between $55-60 million. Then, with climate change impact reflected by a higher level of the sea, it means that low-lying areas are flooded more and financial losses could increase to $75 million annually (Fig. 19).

13A.5. ADAPTATION MEASURES

These are identified at three levels as the impacts are expected to affect the whole social structure: the strategic, the population and the individual levels. A total of 33 options are given falling under 4 opportunities: prevention, sharing, changing, and control technology. The options are further recommended, after being screened with respect to their priorities, into 3 phases: the immediate within the year 2001, the medium term within 2005, and the long term within the year 2010 (see attached list).

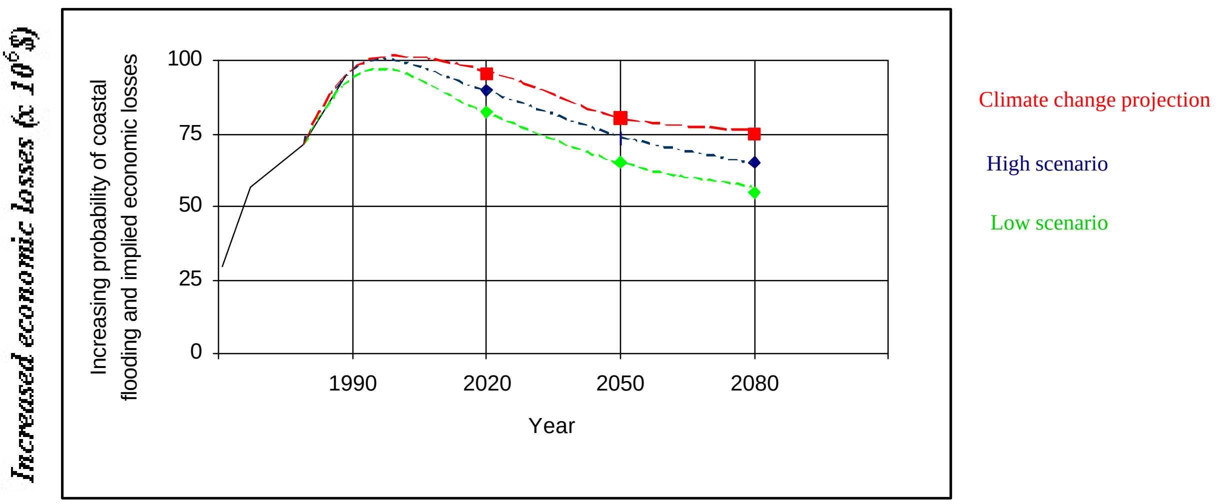


Fig. 19. Climate change projection, probability of coastal flooding and implied increase in financial losses

Proposal concepts on selected themes relating to the physical component of the coastal system

Theme	Justification	**Methodology, Workplan and Duration**	**Budget $**
4. Assessing environmental indicators at "very critical" low-lying shorelines in Lebanon for coastal protection	Heavy financial losses will be incurred as studies have indicated an estimated 4mm of coastal land subsidence, a land loss varying between 7 & 16mm annually, and the presence of low-lying shorelines. With expected relative rise in sea level due to climate change, those losses will increase	Phase I: 1-2 months • Documentation • Preparation • Pilot area • Stake holders Phase II: 8-10 months • Shoreline parameters • Defining climate coastal regime • Defining human interference • Geoenvironmental stresses • Satellite-borne data Phase III: 6-8 months • Monitoring parameters-indicators • Data analysis including GIS • Defining control mechanisms • Protection measures Phase IV: 4-6 months • Projected limits and constraints • Optimum protection parameters • Feedback testing • Reporting & dissemination	85000
5 Effects of sea level rise on salt-water intrusion along selected coastal segments	As sea water is expected to rise, and because the land is karstic and/or fractured with sea water intrusion occurring, this intrusion will increase and affect further the quality of coastal fresh groundwater	Phase I: 1-2 months • Documentation • Preparation • Pilot area • Stake holders Phase II: 10-12 months • Geological delineation • Hydrological regime • Human interference and water use • Relative rise in sea level Phase III: 8-10 months • Monitoring coastal regime • Monitoring groundwater • Data analysis including	145000

		GIS • Defining intrusion boundaries Phase IV: 4-6 months • Model construction • Model validation • Reporting & dissemination	

Climate Change

B- ASSESSING CLIMATE CHANGE IMPACTS AND ADAPTATION ON MARINE ECOSYSTEMS

13B.1 GOALS AND OBJECTIVES

Sea-level rise and water temperature increasing due to climatic changes are expected to have a pronounced impact on the offshore marine ecosystems on low-lying coast all over the world. The coastal area in Lebanon is expected to be affected by sea level rise (partly enondation of terrasses and erosion, changes of coastal ecosystems and loss of land and productivity) which will necessarily induce loss of urban areas and socioeconomic changes over the whole Lebanese coastal zone. Fishery ressources will also be affected directly or indirectly due to declining and ultimate disappearance of coastal biotops or ecosystems.

13B.2 SCOPE

The Exposure unit is the Marine Ecosystems in coastal zones which we can divide into two parts:

- Benthic:
    - sandy coast
    - rocky coast
- Pelagic: -plankton: primary production,..
    - nekton: fisheries,...
    -

By global warming, the former will be affected particularly by sea level rise and the later by water temperature increasing.

The study area is a natural region situated in the central part of Lebanese coast: **Jounieh bay** and another one in **Batroun Bay**.

The timeframe for impact studies is at different intervals 2020 and subsequently at 30 years intervals for the period 2050 to 2080. Normal climatic period from 1940 to 1970.

The availability of data on climatic and hydrographic parameters is not consistant and is a limitation in this study; hence, the collection of new data is an important element.The major data required for the exposure units are:Meteorological data (trend of annual atmospheric temperature and precipitationl), Hydrologic data (Water surface temperature , Salinity and Relative Rise in Sea level (RRSL),Topographic maps, preferably with at least-3m contour intervals,Bathymetric maps, particularly of the nearshore areas (less than 10m of water)

Historical records indicative of previous sand of sea level will be important to study benthic ecosystem especially submerged marine terrasses.

13B.3 SOME REMARKS SHOULD BE DONE CONCERNING AVAILABLE DATA

1- Data available were collected during special projects in speciel places and times and it were stopped with the end of project. This is true for water temperature, salinity, planktonic populations wich will be directly affected by atmospheric temperature increasing. No regular data available for a long period to help to put a trend line.

2- Data of fishs product, which also can be affected by water temperature rise, are availables only in FAO reports wich were given by the Ministery of Agriculture (Bureau de pêche) and are approximately the same every year and are not exact because a large quantity of fish are directely buy by fishermen to the consumers without any indication to the Ministery; also fish collected by amateurs and illegal methods are not mentionned there.

3- Data on benthic populations especially in the intertidal zones, which will be directely affected by sea level rise and will be a good indicater, are very scarce.

For all these reasons we did a choice for some parameters trying to estimate the effect of climate change:Water temperature, Phytoplanktonic populations, Total product of fish and total product of Clupeidae.

These parameters were choosen because phytoplankton populations constitute the autotrophic primary producers in the pelagic food chains in marine waters and it is well known that their annual cycle is affected by many physical features that affect nutrient levels; these include fronts characterized by large horizontal gradients in variable such as **temperature.** Concerning the third parameters, Clupeidae which are very sensitive to temperatures change and are represented in our country by sardines *(Alosa fallax, Sardinella aurita, S. maderensis and Sprattus sprattus* which are planktivores and so directely affected by these populations.In Lebanese coastal waters, *Sardinella* are the most important pelagic fish and they play an important role in the local fishing ; abundant in spring and early summer in inshore waters.

13B.4 VULNERABILITY IMPACT ASSESSEMENT

The increasing of water temperature is based on the increasing of air temperature after GCM. In Jounieh Bay,for exemple, in January, actual water T° is17.79°C, in 2020 the projection of water temperature is 19.02°C and 19.59°C in 2050 and 20.67°C in 2080 and so on in every month. In Batroun Bay, Basing in a sketch map of Lebanon's coastline showing geoidal elevation (G.E.) and geographic distribution of risk potential areas, we conclud that the region of Batroun bay is situated in the category of *less critical* zone (geoidal elevation > 2.5m) and G.E. is 3.8m in this region .Terrasses, which are partially submerged and partially immerged, will be gradually immerged. Algae will receive different qualitative and quantitatve leight and this will affect their distributionand in consequence the distribution of fauna.

Concerning pelagic ecosystem, phytoplankton populations in Jounieh bay , species responsible for bloom at late winter and at the beginining of spring like *skeletonema costatum, Nitzschia* spp., *Leptocylindrus danicus* and *L. minimus* and others could start earlier, because features of temperate marine planktonic ecosystems are not only sensitive to annual variations in weather, but also any trends that might result from greenhouse warming or other factors that affect the climate system and both density and timing of spring blooms will be altered in some regions. Also, the taxonomic compositions of the phyto- and zooplankton may change influenced by the change of ocean structure .

Clupeidae which is very sensitive to the gradient of temperature will reproduce also earlier in our country. Concerning species, maybe thermophile species will increase in density replacing the biota of others species prefering cooler waters.

In case of increasing water temperature we can expecte: advance in spawanning for these species, abundance for other species of clupeidae such as *Sardina* and finally the abundance of thermophilic species and decreasing of xerophilic species.

13B.5 Recommendation

The following conclusion and recommendations can be drawn:

1. Coastal systems in the country are under high potential threat from development and urgently need a coastal mangement for a sustainable development

2. Most data concerning coastal zone are not sufficient.

3. Appropriate programms and selected marine enviromental factors should start properly on a regular basis and for a long term to help the determination of trend of climate change.

4. Studies concerning ecosystems should focusing on the studies of species not only groups or families.

5. Importance of coordination between research Centers working in environmental programms to collect the maximum of data and maximum of parameters.

14- SOCIO-ECONOMIC IMPACT

14.1 THE PROBLEM

Given economic regional disparities, the climate change impact will vary widely among regions. Under served remote areas and suburbs, will suffer more. Consequences on economy and human health will be assessed.

14.2 EXPOSURE UNIT

The whole Lebanese population, stressing at times on the most vulnerable groups in the under served areas (remote agricultural regions and poor suburbs).

14.3 UNCERTAINTIES AND METHODS

Major causes of uncertainties are lack of data, transitional state of economy with rapid dynamic changes, regional peace process hesitations and international trade accords. In addition, it is difficult to use analogues and modeling; thus the field survey and expert judgment will compensate partially theses uncertainties.

14.4 VULNERABILITY TO CLIMATE CHANGE

Baseline and projection without climate change: Income Disparities induce a strong rural-urban migration and a high rate of urbanization (87% in 1994 and 93% in 2015). Annual population growth rate is decreasing steadily.

The Lebanese economy is a liberal economy dominated by the service sector. The share of industry in the GDP is 19%, and whose of agriculture 7%. The imbalance is corrected by invisible earning (tourism, overseas Lebanese remittances…). Post war reconstruction implies high expenditures leading to a budget deficit. Nevertheless GDP continue to increase reaching 4800$ per capita in 1998. Unemployment rate is only 14% despite more than 1 million foreing workers. Economy will continue to rely on services and invisible earnings. This general view masks the severity of the problem in the agricultural remote areas where the low income and unemployment will lead to migration.

Tourism assured 20% of GDP before 1975. This sector is able to regain importance and consequently to contribute to the development of some regions, some other economical sectors and employment.

Coastal activities show very limited fisheries and an over urbanization. Average annual losses du to natural events are 35 millions dollars in 1983, particularly in the low-laying coastline settlements.

Water problems affect agriculture and health by mean of quantity or quality. The deficit will remain in 2021 even if adequate measures are taken. Quality of water is also a matter of concern (contamination of aquifers and networks by sewage, salt intrusion secondary to over pumping, fertilizers, and lack of treatment and filtering, old network…)

Agriculture represents now 10% of GDP, 7.8% of labor force, 12% of population and 19% of exportation but Lebanon still import 80 % of foods. Already in bad shape, agriculture will continue to decline and is going to be less and less competitive, even on the local market. Despite its slight share in economy, it will hit severely the rural areas, mainly du to the fact that they are not able to shift towards other activities because of unskilled labor. This will lead to more poverty, more exodus to the poor suburbs of the big cities.

In the same way health services are unequally distributed with consequent disparities in the unsatisfied basic needs index and unemployment, which are the highest in the peripheral areas and the suburbs of Beirut. Vicious circle of poverty is closed with high household size (6,5 to 7), low income and unskilled young people. The cost of health care is one of the highest in the world. It is insured mainly by the private sector and reached 11.8% of the GDP in 1995. The preventive component is very weak. Disparities are evident. Most vulnerable groups to diseases are infants, children, elderly, malnourished and non-immunized. Three categories of diseases are relevant: Water borne diseases (diarrhea, typhoid and hepatitis-A are a real problem), Vector borne diseases (conditions of outbreak of Malaria are still present), Acute respiratory illness which is one of the most causes of infant mortality.
In addition to vaccination annual campaign, MOH launched recently a program to prevent and treat diarrhea and respiratory illness.

Water shortage, pollution and poverty will lead to an increase in these diseases.

14.5.CLIMATE CHANGE IMPACT

Some sectors are more vulnerable such as agriculture and human health. Fishery is already very limited, and coastal activities will witness doubling of the losses in 2020 unless deliberate adaptation is applied.

Impact on tourism is variable: ski season will be shorter, sandy beaches will be eroded and inundated without great economical effect. Estival activities in the mountains will increase. Thus, Developing tourism may balance losses in other sectors.

Agriculture will know high cost production leading to lack of competitiveness. Despite a limited impact on economy as a whole, rural population will highly suffer.

Human health will be affected in the same under served areas by climate change. All above-mentioned diseases will find a favorable physical and sociological medium. Increase in temperature and humidity will allow anopheles to breed and Malaria parasite to mature. Diminishing of precipitation will increase air pollution and consequent respiratory effects mainly in the suburbs of Beirut. Adaptative and preventive measures are very important.

The whole economy is weakly vulnerable, because it doesn’t rely in agriculture and coastal activities, there is no big natural catastrophe, presence of many geoclimatic regions and alternative sectors. The profile of Lebanese economy is thus closer to U.S.A. one (1% of loss) than to India (4.6 %). Meanwhile, it is mandatory to consider disparities among regions.

14.6.ADAPTATION

Prevention measures	Alternative measures
BEHAVIORAL	
Reduction of household size Acceptance of vaccination and other preventive measures.	Rural exodus Improvement of tourism products Lebanese Diaspora tendency to return sporadically or permanently to Lebanon
DECISIONAL	
Focused health services for less advantaged and vulnerable groups Easier accessibility to primary health care Extend medical insurance all over the country Enhance vaccination and other preventive programs Health education Epidemiological surveillance	World class tourism promotion Preparing tourism workforce Strategic economical choice Stimulate productive economic activities Sustained development policy for rural regions with alternative productive sectors. Integrated rural development