A4 TRANSPORT SECTOR

A4.1 INTRODUCTION

In the last two decades, transport issues have risen rapidly in local, national, and international agendas. This rise could be attributed to the dominant role that transport plays in everyday life due to the increasing amounts of energy used and to the environmental impacts of transport on local and global environment. Changes in travel behaviour and vehicle occupancy rates have influenced the rate of energy used over the last 2 decades. The main driver, however, for emission reductions remains the new developments in engine designs and technologies. Design parameters such as weight reduction, fuel injection, and improvements in lubricants, tires, and aerodynamics have led to significant reductions in fuel consumption and hence emissions. The transportation sector, world wide, still contributes around 70% of air pollution. The pollutants emitted from land, sea, and air transport include, among others, effluents such as carbon dioxide, hydrocarbons, and oxides of nitrogen that contribute to the greenhouse phenomenon.

Lebanon's transport constitutes a fleet of around 1.2 million registered vehicles and can be characterized as being relatively old and poorly maintained. On the other hand, and with a ratio of around 3 persons for every car, the car ownership rate in Lebanon is one of the highest in the world [4.1,4.2], see Table A4.1. This fleet is causing serious local air pollution problems especially in major cities and regions of permanent traffic congestion, in addition to the GHG emissions.

Table A4.1: Car Ownership Rate in Some Countries

Country	Philippines	China	Japan	USA	EU	Lebanon
Persons/car	124	250	2.5	1.25	5	3

Personal cars, trucks, and buses used inside the country can only use gasoline. A ban on the use of diesel has been enforced since the sixties. In 1994, only 5% of the drivers used unleaded fuel, and this rate increased to 6% in 1995, 8% in 1996, and to around 12% in 1997. Mitigation measures such as alternative fuels (natural gas) and catalytic converters are non-existing. Moreover, catalytic converters are still regarded as being luxury items and hence additional taxes are imposed on their import.

In this report, a description of different classes of the transport sector of Lebanon is provided and the projects that can be classified as base line scenarios are highlighted. The base line scenarios presented are based on these plans. Their impacts on fuel consumption, and hence GHG emission's reduction are also discussed.

A4.2 ANALYTICAL STRUCTURE FOR A MITIGATION ASSESSMENT

Analytical structure for mitigation assessment is based on the following methodology:

i- Comprehensive evaluation of national, social and economic development frameworks for climate change mitigation. The data in this evaluation process include:

- Base year statistics: Population: 3,725, 000
Household: 5/family
GDP growth: 8.5%
Inflation rate: 12%

ii- Baseline Scenarios: Short- term (till 2005) and long- term (till 2040) projections of CO_2 emissions from the transport sector, based on the bas year (1994) figures, will be considered taking into account official plans.
Common data are set as follows:
Population growth: 1.5%
GDP growth: 3 (low), 6 (high)
Inflation rate: 5, 10
Discount rate: 5, 10, and 15

iii- Mitigation Scenarios that include:
- Identification of mitigation options related to transport sector
- Assessment of the reduction potential and costs of the mitigation scenarios
- Integration of the costs with other measures and sectors

A4.3 Existing Conditions in Base Year

The Lebanese people, in 1994, were still in the early stages of recovery from long- term internal disturbances. All the country's economic sectors, including transportation, were badly hit by war. In what follows is a description of the state of the Lebanese transport sector in 1994 and the few years that followed.

A4.3.1- VEHICLE FLEET AND USAGE CHARACTERISTICS

Data about the vehicle fleet composition in Lebanon is not entirely reliable due to the lack of official sources of data. In particular, the number of vehicles taken out of circulation, and to some extent brought into circulation, during the war years, have not been accurately documented. Furthermore, most vehicle registration records are kept manually, making it difficult to update the status of the vehicles. Finally, the lack of a regular vehicle inspection program means that there is no annual milestone that allows authorities to check vehicles on a regular basis so that they may update existing records. These caveats must be kept in mind in interpreting the information provided here, which consists of the registered fleet composition, average age and kilometers driven per year, and the synthesized age distribution of Lebanese vehicles.

Table A4.2 indicates that the cumulative total of vehicles registered in Lebanon reached close to 1.4 million at the end of 1996. This is obviously a loose upper bound on the actual number of vehicles in circulation, for the above-noted reasons.

Table A4.2: Cumulative Number of Registered Vehicles

Vehicle Type	1994	1995	1996
Private Cars	1128710	1184648	1236890
Private Trucks and Pickups	89094	95300	101051
Private Buses	4481	4698	4927
Import/Export Trucks	6391	6449	6449
Special Purpose Trucks	385	107	341
Taxis (red plate)	10645	10690	10912

Public Transport Buses (red plate)	618	697	1153
Public Trucks (red plate)	3465	4120	6192
Tractors	3794	3780	4034
Construction Equipment	1361	1559	2276
Public + Emergency Vehicles + Misc.	230	1998	1983
Motorcycles	46075	52308	56569
Public Transport		163	163
Micro Buses		4000	
Total	1295249	1370517	1434936

However, registration data for newly acquired vehicles in at least the past five years should be reasonably accurate. Close to 64,000 vehicles were registered for the first time in 1996, of which approximately 53,000 were private cars. Close to 25% of the private cars registered in 1995 were new, and this proportion is likely to increase in the future with improvement in the economic situation and greater availability of financing alternatives, including credit facilities, for purchase of new cars.

The cumulative numbers of registered vehicles presented in Table A4.2 do not take into account the retirement and scrap page of old or destroyed vehicles. In order to estimate the number of vehicles actually circulating in Lebanon, a study by a major consulting firm (Dar Al-Handasah [4.3]) in Beirut was conducted. In this study it was estimated that the weighted average km/liter for the Lebanese vehicle fleet is 5.48, the weighted average km run per year is 16,800, and therefore the average annual consumption of fuel is 3,064 liters/vehicle. Using the annual total fuel consumption in Lebanon, the study concluded that the estimated number of vehicles circulating in Lebanon (end of 1994) was 1,050,000, compared to close to 1,300,000 registered vehicles (cumulative), yielding a cumulative scrap rate, at the end of 1994, of 19%. This figure includes all non-operative cars and cars damaged during the war.

The study also yielded estimates of the average age and kilometers driven by different types of vehicles in Lebanon, as shown in Table A4.3. The study also indicated that the average age of private passenger vehicles is close to 14 years, a fact that has significant implications in as far as potential vehicle replacement strategies are concerned.

Table A4.3: Average Vehicle Age and Kilometers Traveled (1995)

Vehicle Type	Average Age (years)	Km/Year
Passenger vehicles	14	18000
Pickups	14	20000
Buses	18	35000
Goods vehicles	16	45000

Based on data obtained from the above-mentioned study as well as data obtained from a collaborative project between the American University of Beirut and MIT in the USA [4.4], a synthesized age distribution for the vehicle fleet in Lebanon was developed. A sample of the results in presented in Fig.A4.1. The distribution was developed taking into account the age distribution of vehicles at the time the studies were conducted as well as imports of new and old vehicles into Lebanon since that time.

This figure indicates that a significant proportion of cars is old, and that close to 70% of the private car fleet are manufactured in 1984 or even earlier.

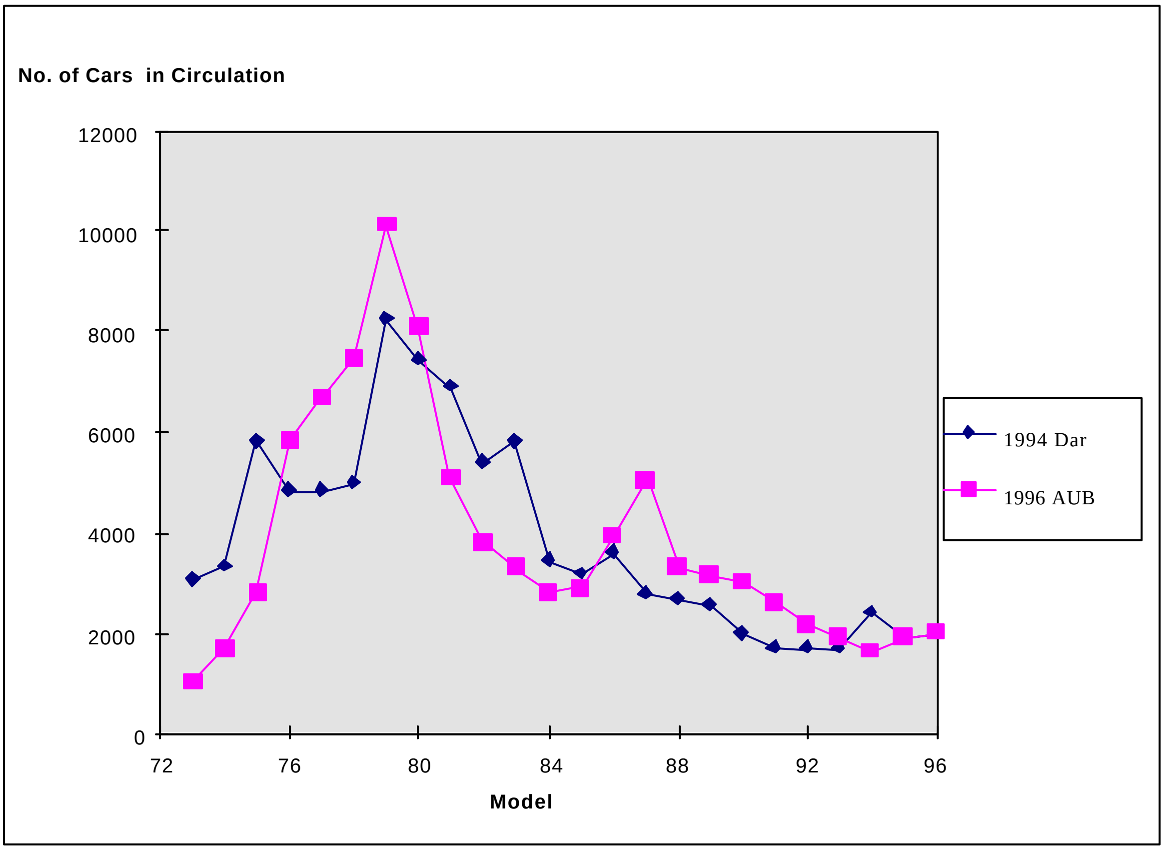

Fig.A4.1: A Synthesized Age Distribution of Lebanese Fleet.

A4.3.2 FUEL CONSUMPTION PATTERNS

The imports of transport fuels to Lebanon during the last four years (Ministry of Petroleum) are presented in Table A4.4. These figures give an indication to the increasing share of 98 octane and unleaded fuel of the local market and to the small increase in the total amount of fuel imported.

Table A4.4: Gasoline Imports (Mill. liters)

Gasoline Type	1993	1994	1995	1996	1997
Octane 92	1.383	1.392	1.175	0.9781	0.716
Octane 98	0.2364	0.3175	0.5607	0.7376	0.8525
Unleaded Gasoline	0.00946	0.0338	0.0824	0.1432	0.2134
Total	1.6293	1.6806	1.8184	1.859	1.782

A4.3.3 COLLECTIVE TRANSPORT

A4.3.3.1 Taxis and Service (Jitneys)

The number of for-hire vehicles and taxis, also known as red- plat vehicles, which could operate legally in Lebanon has undergone a significant change in 1994 with the passage of Law 384 of 4/11/94, according to the figures published by the Ministry of Transport, see Table A4.5.

Table A4.5: Number of Red Plates (licensed for hire)		
	Before Law 384	After Law 384
Shared Taxi	10,645	33,290
Bus	618	2,236
Minibus	-	4,000

A4.3.3.2 Bus Transport

Table A4.6 presents the evolution of the bus operations in the Greater Beirut Area (GBA) over the period 1994 to present. Two bus services are being offered, namely, by TCB (publicly owned and operated Transport Commun de Beyrouth) and by LCC (privately owned and operated Lebanese Commuting Company). The Table clearly indicates a significant improvement in the bus fleet size but a disproportionate increase in ridership. It also illustrates the fact that privately – owned service is more efficient in terms of the number of employees (331) in comparison to the publicly- owned one (1086 employees). Bus services outside GBA are generally restricted to inter- city lines operated by private companies.

Table A4.6: Bus Transport Characteristics			
	1994 TCB	1998 TCB	1998 LCC
Number of Lines	9	27	14
Number of Operable Buses	28	225	164
Estimated Daily Patronage	17,200	40,000	33,000
Fare (L.L.)*	250	250	500
Number of Employees		1086	331

* 1US$ = 1500 LL

A4.3.4 COMMITTED AND COMPLETED ROADWAY PROJECTS

Various government agencies in Lebanon have undertaken or committed to undertake projects in the transport sector over the past several years. Some of the major projects in the road sector include:

a) CDR (Council for Development and Reconstruction) - Rehabilitation and upgrading of roads and services in Greater Beirut Area (southern and northern suburbs).

b) CEGPVB (Conseil Executif de Grand Projets – Ville de Beyrouth) - Construction of several Penetrator Roads (including Ouzai-Jnah-UNESCO, Justice Palace-Aramouni and Achrafieh-Sin El-Fil)

c) CEGP (Conseil Executif de Grand Projets) - Completion of Coastal Expressway (Damour-Jieh and Chekka-Bohsas)

d) MPW (Ministry of Public Works) – Program for Maintenance and Rehabilitation of Lebanon Road Network

A4.3.5 ROADWAY PLANS AND PROJECTS UNDER CONSIDERATION

A4.3.5.1 The Beirut Urban Transport Project

The Beirut Urban Transport Project (BUTP), currently in the preparatory studies phase, is being sponsored by the World Bank. The primary development objective of the BUTP is to enhance the economic productivity of GBA by improving the operational and economic efficiency of its urban transport project. The main issues of concern can be grouped broadly into five main categories, namely: traffic management, network capacity, parking provision and control, public transport, and transport emissions.

In specific, the BUTP would comprise the following components:

a) Traffic Management Improvement Program which involves (i) capacity building in traffic management (ii) traffic signal and layout improvements for all significant intersections in the GBA (iii) equipping a Traffic Control Center (TCC) to be operated by the GBA Traffic Management Organization (TMO).

b) Parking Improvement Program to control parking along all main arteries and in selected zones and increase off-street parking in those zones

c) Corridor Improvement Program improves traffic flow along major corridors at entrances to Beirut by financing the construction of grade separations at 16 congested intersections.

A4.3.5.2 Peripherique and Northern Highway

This 32.5-km network comprises two major highways:

a) The Northern Highway, which will be a 2x3 viaduct connecting the Beirut Central District ("BCD") to the Kesrouan Interchange at the northern suburb of Zouk. Construction of the Northern Highway will start in 1999 and the BCD-Antelias section will be opened for traffic in the year 2000. The highway is expected be fully operational by the end of 2001.

b) The Beirut Peripherique, which will be a 2x3 ring road at grade around Beirut on the eastern edge of the suburbs, connecting Khaldeh to Antelias. Construction of the Peripherique will start in mid 1999 and the Zalka-Antelias section will be opened for traffic in the year 2001. The highway is expected be fully operational by mid 2002.

This $943.8 million project will be developed by a private company (ALTOROC), which will be awarded a BOT concession agreement for 35 years. The feasibility study and tender documents were under preparation in July 1998. More details about these projects are provided in Appendix A4.

A4.3.6 AIRPORT ACTIVITIES

Statistics from the Civil Aviation Board related to the number of flights and passengers and amount of freight in and out of the country are listed in Table A4.7. The rehabilitation and extension project is expected to be ready after few years, and it is expected that the airport then will be capable of serving around 6 million passengers annually.

Table A4.7: Airport Activities in 1994-1996.			
Year	**1994**	**1995**	**1996**
Flights in	9523	10238	10501
Flights out	9523	10240	10503
TOTAL	**19045**	**20478**	**21004**
Passengers in	717040	802353	818416
Passengers out	721258	809988	827063
Transit	51131	60317	69955
TOTAL	**1489429**	**1672658**	**1715434**
Freight (tons)	54007	49742	46505

A4.3.7 RAILWAY SYSTEM

Studies have been conducted for the rehabilitation and upgrading of the 170 km of railway along the coast from Tripoli to Tyr, taking into consideration a dual track system with electric traction. However, in light of the concerns raised about the potential impact of such an upgraded railway on the coastal area, consideration is being given to the possibility of looking at the feasibility of an alternative alignment.

A4.3.8 GOODS TRANSPORT

The Greater Beirut Transport Plan [4.5] identified the need for a logistics platform for the GBA. The study reached the conclusion that consolidation, break bulk, storage, and delivery of goods in the GBA are presently scattered and fragmented and recommended the gathering of these functions in proposed specialized areas outside the city. The study also identified several possible locations for such “logistics platforms”. Such organization would likely lead to an easing of the traffic congestion resulting from the current setup for goods transport in the GBA and would likely serve as a potential measure for mitigating the extent and impacts of transport emissions.

A4.4 BASELINE SCENARIO PROJECTION

A4.4.1 FUEL COST

Based on the historic trend of world fuel prices, and on the data obtained from Kuwait and Saudi Arabia, it expected that in the absence of any political or military events that might influence the world market the fuel prices will keep fluctuating around a price of about $16/barrel for crude oil. Although a great slump in oil prices took place by the end of 1998 during which prices reached $9/barrel, it will be assumed that this is momentary, and that prices will return to normal in the near future.

During the last decade, the prices of fuel used for transport in Lebanon have been increased due to additional taxation gradually imposed by the Government. It should be noted, however, that these increases had small impact on fuel consumption due to the lack of alternative means for transport and due to the fact the fuel is still cheap compared to other countries and compared to average income. Based on this, the fuel cost will be considered to have no impact in the baseline scenario.

A4.4.2 FUEL CONSUMPTION

Table A4.8 presents a breakdown of annual fuel consumption for different types of vehicles in Lebanon, based on the estimated number vehicles in each category, annual distance travelled, and fuel efficiency.

Table A4.8: Breakdown of Vehicle Types and their Consumption Rate in 1994

	Number of Vehicles	Annual Utilization	Fuel Efficiency	Annual Fuel Consumption	Total Annual Fuel Consumption
Category	1994	km/year	km/20 lit	lit/veh/year	(million lit)
Private Cars	914000	14000	130	2154	1654
Taxis and Microbuses	9000	28000	90	6222	47
Buses (private and public)	4000	35000	70	10000	34
Trucks and Other Vehicles	85000	45000	70	12857	918
Total (excluding motorcycles)	1012000	16811	124.4	3120	2652
*Reference: Dar Al-Handasah Report	1012000	16800	109.6	3064	3215

* These figures are used for comparison purposes

The statistics of imported fuel for transport indicate that the amount of fuel will be slightly dropping in the short term due to the following factors:

- i- The improvement in the status of the fleet due to the ban on import of cars older than 8 years imposed in 1995.
- ii- The modernization of road networks that led to a cut in the time spent in driving the car, mainly inside GBA.
- iii- The slow down in economic activities since 1996.

This drop, however, will not continue, and it is expected to have an annual increase since more km/day will be covered daily due to improved networks.

In the baseline scenario, and based on the above considerations, it will be assumed that the number of vehicles will have an annual increase of around 1.5%. This figure according to experts is consistent with the growth rate of the country. It is also expected that the full use of modern road networks, especially in GBA, will lead to demographic changes in which citizens will tend to live in the “cheaper” outskirts of Beirut thus leading to longer daily trips.

The ban on the import and use of diesel for transport, mainly for small and personal vehicles, is expected to remain in the base line scenario.

A4.4.2.1 Vehicle Stock analysis

The fleet condition is expected to improve since by year 2005, the average age of the vehicle fleet will drop to around 10-12 years compared to the 14- years average of 1994. This measure may, however, be compensated by worsening of technical status of the fleet in general. This may be attributed to the absence of any technical check up of the vehicles.

A4.4.2.2 Transport Management

Transport management at the within the Greater Beirut Area, and notably at the northern and southern entrances to the city, would eventually lead to some consumption reduction. Inside

Beirut, however, most of the measures are within the scope of traffic control (such as installing traffic lights) which would typically organize traffic flows rather than reduce traffic jams to any significant extent.

A4.4.2.3 Logistics Management

No actions or plans have been drafted to deal with freight movement. As a result, nothing can be classified as a baseline in the area of logistics management.

A4.5 SHORT AND LONG- TERM PROJECTIONS

A4.5.1 LAND TRANSPORT

The base line scenarios for land transport will be conducted taking into consideration the following factors:

i- The number of registered vehicles, as shown in Tables A4.2 and A4.8, will be adopted knowing that the latter table takes the 19% scrap rate into account. The short and long- term projections are as follows:

- Private cars: 1.5% annual increase throughout.
- 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.

Table A4.9 Fuel Consumption Trends (mill. Liters)					
Fuel	1994	2000	2005	2015	2040
Gasoline	2020	2510	2570	3070	4780
Jetfuel	612	1210	1710	1790	1970
Diesel	1200	1410	1330	1470	1880

ii- The annual distance travelled is expected to increase for private cars since the modernization of road networks is expected to lead to demographic changes. These changes are due to the expected tendency of people to move to the “cheaper” outskirts of major cities. As a result the annual distance travelled by private cars will increase to 16000 Km by 2005, and to 18000 Km by 2040. Distance travelled by other categories will remain the same as in Table A4.8.

iii- Due to the modernization of the car fleet caused by the ban on import of cars older than 8 years, it is expected that the consumption rate for all vehicles will drop by 10% by year 2005. The projection, in the base line scenario, of the demand in the transportation sector for the gasoline, diesel, and jet fuel is shown in Table A4.9 and the equivalent energy content is illustrated in Fig.A4.2. Finally, Table A4.10 shows the expected consumption rates of various types of vehicles.

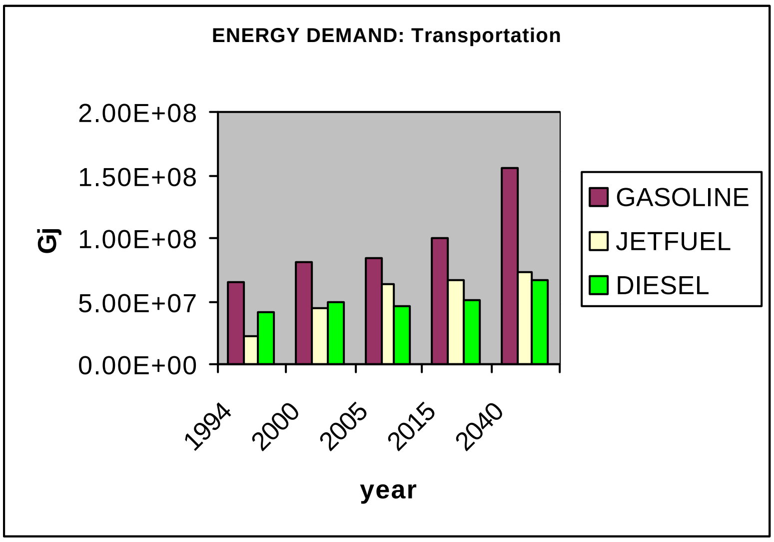

Fig.A4.2: Transport fuel projection in the base line scenario.

TableA 4.10: Consumption rates in the base line projection.					
Vehicle Type	Consumption Rate (km/liter)				
	1994	2000	2005	2015	2040
CARS & JEEPS	6.500145	6.460954	7.222469	7.409435	7.222402
TAXIS & MICROBUSES	5.625153	4.500123	5.000139	5.000139	5.000139
BIG BUSES	2.800031	2.800031	3.111146	3.111146	3.111146
TRUCKS & OTHERS	3.500038	3.500038	3.888928	3.888928	3.888928

A4.5.2 AIRPORT ACTIVITIES

The rehabilitation and extension project of Beirut International Airport (BIA) is expected to be ready early in the next century (estimated at 2006), and it is expected that the airport then will be capable of serving around 6 million passengers annually. In the baseline scenario, it is assumed that by 2005, the number of passengers will be around 5 million, and in 2040 it will run with full capacity of 7 million passengers.

In addition to passenger travel, BIA is expected to serve increasing levels of cargo and freight. Trans-Mediterranean Airways (TMA) will be the operator of the Cargo Village Project at BIA. The Project shall include a facility within an area of 21,000 m^2, with a capacity to handle 240,000 tons per year. Plans are being developed to use BIA as a center for delivery and distribution of air cargo, served by feeder activity. This is in accordance with the general trend in aviation business nowadays of developing hubs to avoid costly stops en route.

A4.5.3 SEAPORT AND MARINAS ACTIVITIES

In the base year inventory, and based on consultation with local authorities, it was assumed that in Lebanon, fuel consumed for sea transport is restricted to that used by local marinas and sports clubs. In the base line 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. The new marinas include the Antelias-Dbaye' marina (700 boats) and the West Marina in the Beirut Central District, which is of comparable size. Therefore, it will be assumed that the number of marinas, and eventually number of boats operated from these marinas, will increase four times by 2005, and further by two times in 2040.

Table A4.11: 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
ELEC-GASO-VEH.	0	0	0	0	0
ELECTRIC TRAINS	0	0	0	0	0
	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
	Distance Traveled (1000 km)				
Road Devices	1994	2000	2005	2015	2040
CARS & JEEPS	14	15.091	16	16.571	18
TAXIS & MICROBUSES	28	28	28	28	28
BIG BUSES	35	35	35	35	35
TRUCKS & OTHERS	45	45	45	45	45
ELEC-GASO-VEH.	14	15.091	16	16.571	18
ELEC.TRAINS	90	90	90	90	90

Table A4.12: 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 A4.11. Tables A4.12 and A4.13 represent the consumption and emission rates respectively. The consumption figures of Table A4.12 are calculated in GJ based on the estimate of the annual fuel consumption in liters/vehicle/year presented in Table A4.8 and in km/l as presented in Table A4.10.

Table A4.13: Environmental Effects- Emissions (Kg)					
Types of Effluents	1994	2000	2005	2015	2040
CARBON DIOXIDE, NON-BIOGENIC	4.08E+09	5.6E+09	6.2E+09	6.9E+09	9.15E+09
CARBON MONOXIDE, TOTAL	3.645E+08	4.3E+08	4.43E+08	5.25E+10	8.25E+10
HYDROCARBONS, TOTAL	3019.679	7960.15	1087	13975.44	21739.57
HYDROCARBONS, METHANE	1402582.5	1670835	1720558	2029692	3099701
NITROGEN OXIDES, TOTAL	4.24E+07	5.25E+07	5.45E+07	0.61E+07	0.82E+07
SULFUR OXIDES, TOTAL	905.801	2388.023	3260.901	4192.632	6521.871
PARTICULATES, TOTAL	41439.52	142317.2	134619.1	148703.2	190701.7

A4.6 Mitigation Measures

A4.6.1 INTRODUCTION

There is a worldwide trend toward improving the energy conversion efficiency in the transportation sector. Technical design parameters such as lighter bodies, improved tiers designs, aerodynamics, automatic transmissions, and improved engine designs have reportedly led to around 50% reduction in fuel consumption [4.6]. Moreover, new sets of legislation have been imposed in many industrial nations aimed at setting fuel economy standards. In the USA, the Corporate Average Fuel Economy (CAFE) program has been set and car manufacturers that failed to meet the minimum prescribed fuel average were fined in proportion to their shortfall. Similar approaches were followed in other countries such as France, UK, Italy, and Canada. This trend has been paralleled, however, by a sharp increase in the number of cars used, the lengths of distances traveled, and consequently the amount of fuel consumed. Therefore, fuel economy is not enough, and further measures such as volume of travel have to be examined to achieve reductions in GHG emissions to the level set by IPCC.

The transportation sector is a sub-sector of the energy sector, and therefore there is a significant overlap between the two sectors. Due to this overlap, emissions assessment and incremental costs of mitigation options in the transportation sector may be accounted for in other sectors. For example, wide spread use of electric vehicles will reduce GHG emissions from transport. This option, however, will lead to increased emissions from the power sector if fossil fuels will be burnt to generate the required electric power, and therefore should be accounted for as part of the power sector emissions.

A4.6.2 CLASSES OF MITIGATION OPTIONS

Emissions of GHG from the transportation sector are in general related to the following factors:

- The fuel type and its emission rate.
- The technical status of the vehicle and its fuel consumption rate.
- The distance traveled and time needed for every trip.

Based on these factors, the corresponding mitigation options are generally classified into three major categories as follows:

- Switch to fuel with lower emission rates
- Improve the technical status of the fleet
- Improve system efficiency

Each of these mitigation options will be elaborated based on local and international practices. Mitigation scenarios applicable for Lebanon will be conducted using the Long-range Energy Alternatives Planning (LEAP) package for GHG emissions. Other mitigation options related to advances in research and development and manufacturing processes are also highlighted. Analysis and cost effectiveness for the mitigation options have been conducted for discount rates of 5, 10, and 15%.

A4.6.3 SWITCH TO FUEL WITH LOWER EMISSION RATES

Fossil fuels, in general, have limited potential for GHG emissions reduction. There exist, however, a wide variety of alternative fuels with lower emission rates such as ethanol, natural gas and biogases. Measures in this prospect could be taken to encourage the import of these fuels and import of cars to use them. Abundant natural gas provides a feasible alternative since its technology is established and already applied in marketed cars. Recent reports [4.7] have indicated that natural gas has a CO_2 emission rate 20% less than conventional petrol.

A4.6.3.1 Electric Vehicles

Switching to electric vehicles can be regarded as a mitigation option only if the electricity used for charging the batteries is generated from a clean energy source such as hydropower, or eventually renewable energy resources. Use of electricity generated from natural gas for batteries charging could lead to around 30% reduction in GHG emissions. Batteries are still expensive and currently electric cars cost almost twice as much as petrol-driven ones. Modern lead-acid batteries have recently shown improved energy density, but their energy per unit mass is still low thus limiting the drive- per- charge range to less than 100 km. Moreover, batteries are still vulnerable to climatic conditions such as excessive heat.

These limitations will most likely make electric vehicles a less attractive option related to conventional vehicles at least in the near future and therefore will not be considered amongst the proposed mitigation scenarios.

A4.6.3.2 Hybrid Electric Vehicles

A major breakthrough has been recently reported in the development of hybrid electric vehicles (HEV) with high- energy efficiency and a much lower GHG emission rate. HEV's are defined as vehicles in which propulsion energy is made available from two or more on-board energy storage and supply systems. HEV generally uses electric power when starting or driving slowly, whereas during normal driving conditions, the fuel engine is used to provide power to drive the wheels and to charge the batteries simultaneously. Regenerative braking converts the kinetic energy of braking into electricity to charge the batteries. HEV could have a consumption rate almost 60% of that of equivalent conventional fuel-driven cars [4.8], see Table A4.14. The unit price of HEV is almost 25% more than the equivalent petrol- driven vehicle [4.9]. This new technology has been implemented in several countries with quite satisfactory results as long as GHG reduction is concerned. Therefore it has been considered for mitigation options.

Table A4.14: Fuel Consumption Rates		
Driving mode	*Standard 1500 cc fuel car*	*HEV*
City driving	7.6 l/100 km	4.9 l/100 km
Highway driving	6.5 l/100 km	4.4

The base line scenario for transport in 2015 and 2040 did not account for the hybrid electric vehicles (HEV), that may lead to significant fuel consumption and hence GHG emissions reduction as indicated in Table A4.14.

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, an incentive is introduced by the government in which car registration fees, averaged at around 10% of the estimated car cost, would be waived. Based on consultation with car dealers in the country, it is expected that such incentive would lead 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 emissions reductions.

Other feasible alternatives with great potential to reduce GHG emissions are different biomass- derived gases. Ethanol is derived by fermenting sources of cellulosic nature such as wood, wood wastes, and agricultural and municipal solid wastes into alcohol and other products. It has been reported recently that ethanol can reduce CO_2 emissions by around 90% [4.6].

A4.6.3.3 Diesel Fuel

Diesel engines have been regarded in the past as inferior to gasoline engines. This was attributed mainly to the higher smoke emissions, noisier operation, and slower acceleration rates. Advances in engines' technology, mainly in fuel injection and combustion chamber design, have improved the performance of diesel engines, and consequently made them more competitive to the gasoline ones. Diesel engines are more environment- friendly in some aspects such as carbon monoxide, oxides of nitrogen, and hydrocarbons emissions. Also, the energy content of diesel fuel is higher than that of gasoline by about 15%. On the other hand, diesel fuel has higher carbon content and more Btu per unit volume. As a result, expert studies have indicated that the using diesel would lead to an overall reduction in energy consumption and CO_2 emissions in the range of 1% only, [4.6]. Diesel fuel would still be an attractive alternative for personal travel since its cost in Lebanon currently is almost 60% that of gasoline, and is expected to keep the same level in the long run. The wide-spread use of diesel fuel should, however, be accompanied by a strict tail pipe smoke and emissions control. Smoke control is conducted by means of muffler/filter that has to be replaced after a certain period of time or distance traveled.

A4.6.4 IMPROVE THE TECHNICAL STATUS OF THE FLEET

Options to improve the vehicle design are applicable in the production stage of the vehicle. These include improving the aerodynamics, reduce vehicle weight, reduce engine size and improve the combustion efficiency. 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. Modern vehicles have significantly lower emissions rates than older ones, but are still not clean enough. Moreover, they become more polluting if not maintained properly. Re- instating the inspection and maintenance program can be the starting point in a set of measures to reduce GHG emissions. Technical status of cars should be annually checked through tail pipe inspection to make sure that emissions are within set standards and that the engine status in satisfactory. Similar checks should be conducted on the quality of the fuel.

A4.6.5 SHIFT TO TRAVEL MODES WITH LOWER EMISSIONS

Measures applicable within this context include promoting public transport and freight railway systems. Public transport has a great potential if sufficient campaigns and incentives are created. Subsidies to public transport would lead to a reduction in fares compared to personal travel, mainly for longer-distance trips. Other options include promoting walking and cycling. Fuel taxes are proven useful measure with two objectives: an increase in fuel price would lead to wider spread of economic vehicles, and incentive for people to use their cars in a more moderate manner. This would eventually lead to a reduction in the length, rather than the frequency of trips.

The Greater Beirut Area (GBA) Transportation Study [4.10] was conducted in 1994 and developed long-term forecasts of travel needs that extend to the year 2015. This study provides useful guidelines with respect to potential modal shifts towards mass transport that could occur in the GBA and in the whole country.

The study estimated that in 1994 there were 1.5 million motorized daily person trips in the GBA, subdivide among the various travel modes as follows:

- Private car: 71%
- Taxi-service: 17%
- Buses: 12%

This Study predicted that the number of motorized daily person trips in the GBA would grow to 5 million by the year 2015. This significant growth in trip-making levels in the GBA is not expected to be matched by a similar growth in other parts of the country. Moreover, higher vehicle occupancy rates are expected in the year 2015 (as explained below). As such, The relative growth in motorized person-trips in the GBA between 1994 and 2015 exceeds the relative *nationwide* growth in vehicle-kms for the same period, as indicated in Table A4.9. Also, trips' length inside GBA is much less than the national average.

To cope with this tremendous growth in travel expected for the GBA, the Study considered two scenarios, as described below.

Scenario A - This scenario focuses on mass transport, and includes a significant heavy mass transit component, namely rail.

Scenario B – This scenario would represent a continuation of existing trends, and focuses on the intense use of the private auto through further development of the road network.

The Study considered the cost requirements and the implications of the two scenarios and a third "proposed" scenario on various characteristics of urban travel in the GBA. A summary of this comparison is provided in Table A4.15.

Table A4.15: Long-term Passenger Transport Scenarios for the Greater Beirut Area		
	Scenario A	Scenario B
Investment in Roads (mill. US$)	4850	5650
Investment in Railway-Metro Network (mill. US$)	3160	540
Investment in Bus Network (mill. US$)	70	320
Total Investment (mill. US$)	8080	6510
Average Speed for AM Peak in GBA (km/hr)	22	18
Average Trip Duration (minutes)	34	40
Mass Transit Market Share in GBA	33%	16%

The base case under this scenario reflects Scenario B of Table A4.15 in which case it is considered that there will be a continuation of existing trends, reflecting an intense use of the private auto through further development of the road network. The mitigation scenario reflects Scenario A of Table A4.15 that focuses on mass transport, and includes a significant heavy mass transit component by means of railway systems. The basic parameters involved in the mitigation scenario are discussed below.

Adopting an aggressive mass transport scheme in the GBA as in Scenario A results in a 67% modal share for small vehicles (private autos and taxis) in 2015, almost a 20% reduction from the base case (84% in Scenario B). Since almost one-half of the national small vehicles fleet operates in the GBA [4.10], and based on the modal use shares in other parts of the country holding steady, the 20% reduction in modal share of small vehicles for the GBA is expected to translate into a 10% reduction in automobile-related trip making at the national level. To formulate the inputs to the mitigation scenario, 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, consistent with the 10% nationwide reduction in trips by small vehicles between 1994 and 2015.

The increase in speed on the GBA from 18 km/hr to 22 km/hr is translated into an increase in fuel efficiency by about 30 km/20 liters [4.11]. This increase in fuel efficiency is considered to reflect emission reductions due to the increase in speed.

As outlined in Scenario A [4.10], the backbone of the mass transit system is based on heavy rail technology and consists of six lines. At full implementation, the system would require about 30 trains (of four units each), with each train covering approximately 90,000 km/year. The trains will be powered by electric power using a third-rail system. At an average energy consumption of 1×10^6 Joules per passenger-km [4.12], the consumption of each train is approximately 140×10^6 Joules per km.

A4.6.6 MITIGATION SCENARIOS- COMPARATIVE ANALYSIS

Table A4.16 gives a comparative summary of the impacts of the 3 scenarios adopted for the transportation sector. These 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. This difference totals \$1.57 billion, and is phased in over a period of 10 years (2005 to 2015).

Table A4.16: Cost Comparison of the 3 Different Scenarios (Mill. \$)

Scenario	Discount Rate	Benefits 1994	Costs 1994	NPV 1994	B/C Ratio	Levelized Cost (1994 \$/ton) 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 figures as shown in Table A4.16 represent the savings that result from implementing the relevant mitigation option, whereas the Costs figures show the additional cost resulting from the mitigation option. The benefits- to- costs ratio (B/C) gives a clear indication of the feasibility of the measure. Regardless of the social costs of pollution, a mitigation option with B/C ratio greater than one is regarded as feasible and profitable.

HEV deployment, when accompanied by financial incentive, would lead to significant GHG reduction. It should be noted that in this scenario, the impact of HEVs’ cost on the community has not changed. The 10% waver in terms of registration fees would eventually lead to 4.67% drop in fuel consumption in 2015, and 10% drop by 2040, as shown in Table A4.17.

Table A4.17:Difference in Energy Demand from BA (Mill. GJ)

Scenario	Fuel	2005	2015	2040
HEV	Gasoline	0	-0.23	-0.5
HEV II	Gasoline	0	-2.67	-5.14
ET	Gasoline	-6.04	-10.39	-26.81
	Electricity	0.08	0.82	1.05
	Total	-5.96	-9.57	-25.76

The use of mass transit, namely electric trains for freight services are found to be the ultimate mitigation option. It leads a relatively high benefit/cost ratio that varies from 2.4 up to 4.21 depending on the national discount rate. Moreover, electrically- driven trains have the highest reduction rate and, with positive NPV, would be profitable to the community in the long run, see Table A4.18. Fig.A4.3 shows a comparison of the amount of reduction and cost of each of the three scenarios at a discount rate of 10%.

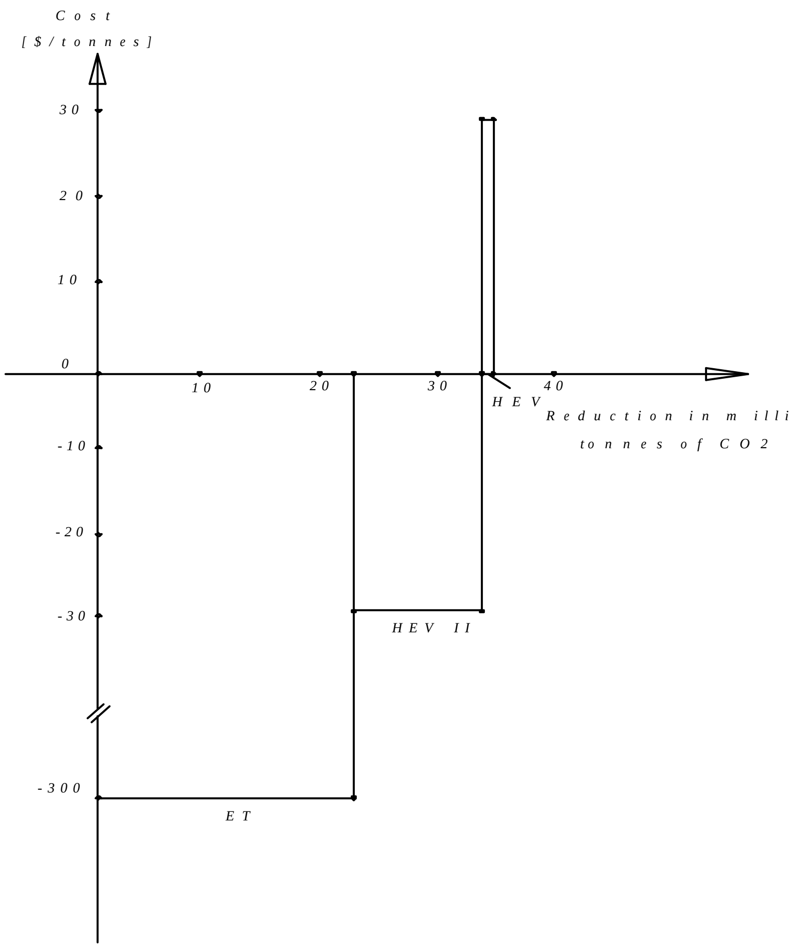

Fig.A4.3: Cost and emission reduction for the 3 scenarios

Table A4.18: Reduction in Emissions					
Scenario	Effluent	unit	2005	2015	2040
HEV	CO2	Gg	0	-11.57	-26.28
	CO	Gg	0	-2.68	-5.08
	HC	10^-3Gg	0	-8.22	-20.3
	N0x	10^-3Gg	0	-90.76	-213.85
HEV II	CO2	Gg	0	-122.33	-261.97
	CO	Gg	0	-25.08	-55.98
	HC	10^-3Gg	0	-88.29	-191
	N0x	10^-3Gg	0	-0.98	-2.27
ET	CO2	10^3Gg	-0.33	-0.37	-0.87
	CO	Gg	-33.69	-66.15	-112.82
	HC	Gg	-0.25	-0.37	-0.99
	N0x	Gg	-3.06	-4.58	-11.22

A4.6.7 IMPROVE SYSTEM EFFICIENCY

Improving system efficiency can be provided by a set of measures including:

- Improving traffic flow by implementing computerized signal timing
- Increasing vehicle occupancy rate by ride sharing
- Reducing the distance traveled by urban planning that would decentralize the locations of businesses and services and make it closer and easier to reach.

A4.6.8 CHANGES IN AIR TRANSPORT

There is a continuous development in the aviation technologies that is expected to lead to GHG emissions reduction. Some of these are still in the research and development stages. Realistic ideas are the changes made to promote and accelerate the deployment of fuel-efficient technologies in aircrafts. These changes could lead to a reduction of fuel burnt per seat of around 40% by 2015 [4.13]. This would be achieved by improving the propulsion system operation (25%), and the aerodynamics and reducing body weight (15%) of the planes. These developments, when realized and acquired by the national airlines, would lead in the long run to significant reductions in GHG emissions. The relevant costs are, however, still very difficult to estimate and are beyond the scope of this report and therefore is not included as one of the scenarios.

A4.7 CONCLUSIONS

From the above baseline scenarios, the following conclusions can be drawn:

Gasoline will still be the major source of fuel for the transport sector. Alternative fuels with lower polluting impacts such as natural gas are yet to be included in official planning. Consequently, transport sector in Lebanon will still be regarded as the major source of greenhouse gases, namely carbon dioxide. Although the annual distance traveled would increase from 14000 km in 1994 only to 18000 km, 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 rehabilitation and modernization of road networks will, in the short run, lead to a certain reduction in fuel consumption. It is expected, however, that in the long run, the impact will be reversed. The Lebanese fleet will be modernized to a certain extent, and this would lead 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.

The modernization and extension of the airport in Lebanon will eventually lead to significant increase consumption in jet fuels since it is expected that the airport will be able to serve annually around 6 million passengers compared to around 1.5 million passengers in 1994. Buses used for private and public transport will increase due to the intention of the Government to implement public transport in the whole country in the foreseeable future.
The construction of new tourist resorts with marinas among the Lebanese cost will lead to an increase in the share of emissions from boat fuels. This share, however, will still be very small compared to road and air transport. Railways will still be non- existing as a mean for transportation in Lebanon.

In the mitigation options, cost- effective and near cost- effective measures to reduce GHG emissions have been highlighted. Mitigation scenarios are conducted for measures that are applicable in Lebanon. Most of the emissions reduction comes from small and light-duty vehicles that form the vast majority of the fleet. Switching to electric vehicles can be effective only if the electricity used for charging the batteries is generated from a clean energy source such as hydropower, or eventually renewable energy resources. Use of electricity generated from natural gas for batteries charging could lead to around 30% reduction in GHG emissions. Batteries are still expensive and currently electric cars cost almost twice as much as petrol- driven ones and the drive- per- charge range is still less than 100 km. These limitations still make electric vehicles a less attractive option related to conventional vehicles for wide- spread use.

Another new vehicle technology is the hybrid electric vehicle (HEV) with high- energy efficiency and a much lower GHG emission rate. HEV 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 have been developed. The first lacks any governmental incentives and assumes merely a 1% share for HEV of imported vehicles by year 2015, and double this value by 2040. In the second scenario, car registration waver is to be 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.

Advances in diesel fuel and engines' technologies made diesel cars more competitive to the gasoline ones. Diesel engines, with higher energy content, are more environment-friendly in some aspects such as carbon monoxide, oxides of nitrogen, and hydrocarbons emissions. On the other hand, diesel fuel has higher carbon content and more Btu per unit volume. As a result, the overall reduction in energy consumption and CO_2 emissions would not reach 1%. Diesel fuel would still be an attractive alternative for personal travel since its cost is almost 60% that of gasoline. Their use should, however, be accompanied by a strict tail pipe smoke and emissions control.

Other feasible alternatives with great potential to reduce GHG emissions are different biomass- derived gases. It has been reported recently that ethanol can reduce CO_2 emissions by around 90%. This technology, however, is still in the stages of research and development in car- manufacturing nations and hence its pricing is still very difficult to set. Similar analysis would apply to options to improve the vehicle design such the aerodynamics, reduce vehicle weight, reduce engine size and improve the combustion efficiency.

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. Subsidies to public transport would lead to a reduction in fares compared to personal travel, mainly for longer-distance trips. 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 (private autos and taxis) 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.

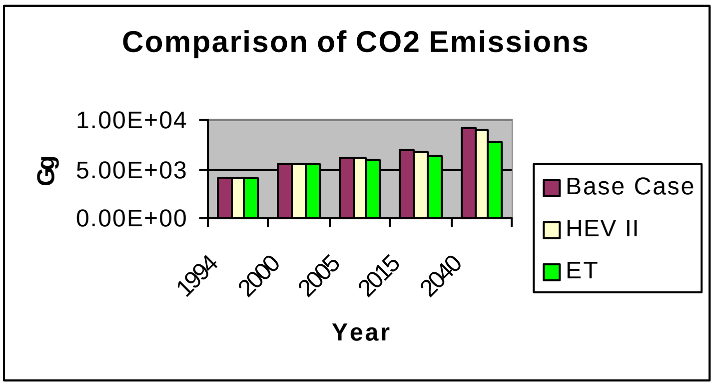

Fig.A4.4: Comparison of CO_2 emissions.

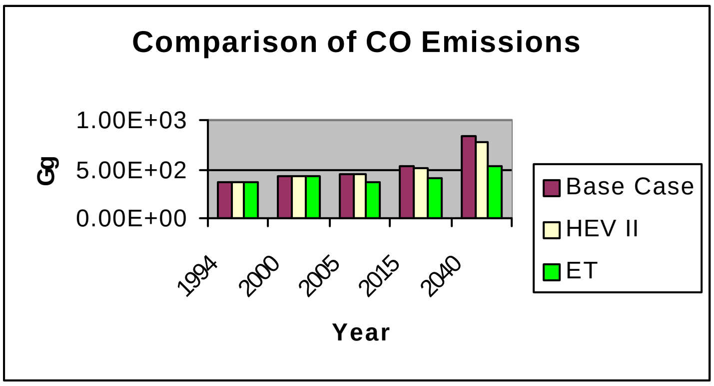

Fig.A4.5: Comparison of CO emissions.

A comparison of the CO_2 and CO emissions in the base line, the HEV with incentive, and the electric trains scenarios are illustrated in Figures A4.4 and A4.5, respectively.

Measures for improving system efficiency are highlighted. These include improving traffic flow by implementing computerized signal timing, increasing vehicle occupancy rate by ride sharing, and reducing trips lengths via decentralization.

Development in the aviation technologies, worldwide, is expected to lead to better energy conversion efficiency. These developments, when realized, would lead to significant reductions in GHG emissions in countries that would acquire these new generations of planes, including Lebanon.

Technologies used in aviation as well as in other transport sectors have a great potential for reducing GHG emissions. Their impact may, however, take some time before it is felt. Meanwhile, new policies and legislation have to be set to provide incentives for shifting towards technologies and measures that would eventually lead to GHG reduction in the country.

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