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OPPORTUNITIES FOR GREENHOUSE GASES ABATEMENTS IN THE LEBANESE POWER AND TRANSPORT SECTORS

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Opportunities for Greenhouse Gases Abatements in the Lebanese Power and Transport Sectors

ABSTRACT

The accumulation of greenhouse gases in the atmosphere has led to an increase in the earth's average temperature, or global warming. Numerous reports and studies have clearly indicated that six of the warmest ten years on the records have been observed since 1990. Economic sectors based on energy conversion processes are regarded, worldwide, as the main contributors to global warming. This paper is aimed at presenting the contribution of the energy sector in Lebanon, namely the power and transportation sectors, to GHG emissions. Like in most developing nations, these two sectors are confirmed to be the main contributors to GHG emissions. The paper highlights technologies and policies being implemented globally for GHG abatement. It also focuses on presenting the feasible policy options and mitigation strategies that could be implemented in Lebanon and in other developing nations of similar social and economic structure, including the ESCWA region. The most economically feasible options are evaluated and implementation mechanisms are highlighted.

KEYWORDS: Electric power, transport, GHG emission, mitigation options, planning.

1. Introduction

The development of the United Nations Framework Convention on Climate Change (UNFCCC), entered into force in 1994, and the Intergovernmental Panel on Climate Change (IPCC), established in 1988, indicated a world-wide recognition that global warming imposes a major threat to the world's environment and economic development. Over 160 nations, including ESCWA member states, are currently committed to develop technologies, strategies and policies to reduce the GHG emissions and to stabilize their concentrations in the atmosphere.

In 1995, Lebanon ratified the "Framework Convention on Climate Change" aimed at stabilizing GHG concentrations in the atmosphere at levels that would prevent dangerous anthropogenic interference with the climate. Accordingly, a GHG inventory has been developed in accordance with the revised guidelines of the IPCC. The results obtained concerning the GHG emissions from various economic sectors, mainly electric power and transport, could be indicative to those expected from other countries with similar socio-economic structure. Based on these results (Chaaban and Chedid, 1999), the energy sector in Lebanon was found to contribute 85% of all carbon dioxide (CO_2) emissions. The energy consumption figures were quite contrasting. Whereas the consumption of electricity is relatively low and comparable to some developing nations, its car ownership rate is closer to those recorded in industrialized nations. This could be attributed to the civil disturbances that took place over a period of almost two decades. During this war, the infrastructure of the Lebanese electrical network suffered a great damage and this was reflected in a shortage in generating capacity and prolonged cut-off periods. On the other hand, the damage in the infrastructure of the transport sector has made people more dependent on personal vehicles for travel and business.

1.1 The Transport Sector

The transport sector of Lebanon constitutes a fleet of around 1.2 million registered vehicles, characterized as being relatively old and poorly maintained. It is estimated that over 70% of the vehicles are more than 15 years old (Chaaban, Kaysi and Chedid, 2000). 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. Figure 1 shows car ownership rates in various countries, both developed and developing. It should be noted that other nations have ownership rates much higher than shown figures such as Pakistan (145 persons/car), and Philippines (120). 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.

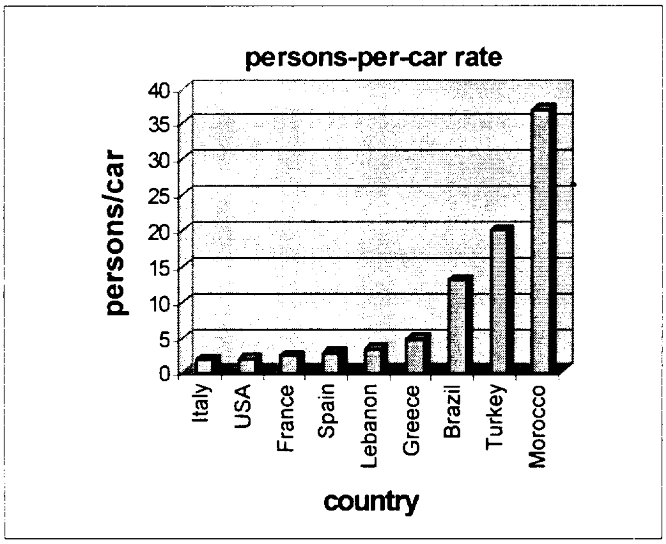

Fig.1: Car ownership rate in Lebanon compared to other nations.

Moreover, the lack of a regular vehicle inspection and maintenance 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, and ensure vehicles compliance with emission standards and limits.

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. Figure 2 shows the energy fuel demand as projected till year 2040. It is 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.

By the end of 2000, it has been reported that around 18% of motor vehicles use unleaded fuel. Moreover, catalytic converters are still regarded as being luxury items and hence additional taxes are imposed on their import. The country has been suffering over the past three years from excessive emissions due to the uncontrolled use of low- quality diesel for small passenger taxi vehicles.

The Lebanese Parliament has recently approved a new set of regulations aimed at banning diesel fuel as a transport fuel, and gradual shift towards unleaded fuel. The new bill also calls for re-instating the annual inspection and maintenance program as a tool for reducing fuel consumption, and hence emissions from transport.

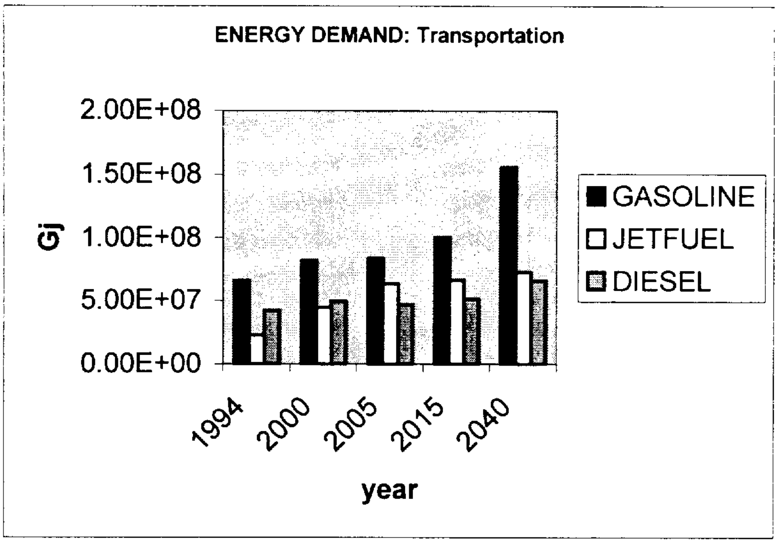

Fig.2: Transport fuel projection in the base line scenario.

1.2 The Electric Power Sector

The electricity supply sector 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 Energy and Water (MEW). EDL currently has over 1,050,000 subscribers and provides around 85% of total electricity demand whereas private generators supply the remaining 15% (Abi Said and Baroudi, 2001). Consuming sectors are domestic (48%), industrial (23%) public sectors (12%), and concessions and losses constituted 17 % (GHG inventory, 1997).

The Council for Development and Reconstruction (CDR) launched an emergency Power Sector Master Plan defined through a two-phase program for the years 1992-2002. The spending in this program exceeded the equivalent of 2 billion US$ in 2000 from national and foreign funding. Major activities included (Bank of Lebanon, 1998) power plant rehabilitation, transmission network rehabilitation, and distribution system rehabilitation.

By year 2000, two new combined cycles power plants each with a capacity of around 440 MW have been commissioned. These plants, however, have not been put in full operation due to the shortage of the transmission and distribution network. The rehabilitation program enabled EDL to expand its generation capabilities from about 600 MW in 1992 to 2000 MW in 2000, but electricity rationing is still unavoidable especially outside GBA. Table 1 shows the generation capacity projection till year 2040.

Table 1 Generation capacity required for the years 2000-2040.

Year	2002	2005	2010	2020	2030	2040
Capacity [MW]	2450	3100	3870	5887	8900	11355

Traditional electricity planning has sought to expand supply resources to meet anticipated demand growth with very high reliability, and to minimize the cost of this expansion. These criteria, aided until recently by improving economies of scale in electric generation, led to a nearly universal strategy of rapid capacity expansion and promotion of demand growth. This is what actually happened in Lebanon until 1974. In addition to the general culture of overusing electricity, during the war years electric energy was cheap, and the majority of population did not actually pay for it. This resulted in a large electric energy consumption per capita (2.0 kWh/capita), which when coupled to the fact that Lebanon does not have basic heavy industries, it strictly suggests that there is low efficiency in both the generation and end-use. A project to import Syrian gas through pipelines from Homs has been recently initiated.

According to the natural gas agreement, the Syrian government will guarantee a continuous supply of 3 million m^3/day. The pipeline cost is estimated at around $ 200 million, to be covered in collaboration with the private sector.

Table 2 shows typical emissions from power plants using different types of fuel. The reduction in CO_2 emissions that could be achieved by shifting to natural gas is quite evident.

Table 2: Typical emission from power plants [g/kWh] (source: EPRI)

Fuel type	CO	CO_2	SO_2	NO_x	VOC
Natural gas	0.2	490	0.004	1.5	0.025
Fuel oil	0.19	781	5.1	1.5	0.05
Coal	0.11	1060	5.5	2.4	0.01

A major limitation to long- term planning is the expected size of investments, where there is a fear that the government may not be capable of handling further expenditures. As a result, it is important that existing plants and transmission networks be used efficiently. Despite the huge rehabilitation program of the electric power sector, Lebanon has made little investments in the areas of energy conservation and load management, system optimization and loss reduction, and diversification of supply and renewable energy.

2. Mitigation Technologies

There exists a wide scope of established technologies, policies, and measures aimed at reducing GHG emissions from various sectors. The major options for electric power and transport sectors, as reported in the IPCC Technical Paper I (Watson et al., 1996), will be highlighted.

2.1. Transport Sector

2.1.1. Technologies for Reducing GHG Emissions in the Transport Sector

Transport systems technologies are evolving rapidly. Although these advances have focused on enhancing performance and safety, a number of technological and mitigation options are proven to be cost-effective in many countries. The cost-effectiveness of these technical options may vary depending on availability of resources, institutional capacity and technology, as well as on local and regional market conditions.

a. Energy-efficiency Improvements

There is a world- wide 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. Moreover, new sets of legislation have been imposed in many industrial nations aimed at setting fuel economy standards. It is expected that cost-effective savings in 2020 might amount to 10-25% of projected energy use, with price increases in the range $500-1500 per vehicle. Larger savings in energy are possible at higher cost, but these would not be cost-effective. 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.

b. Alternative Energy Sources

Studies have indicated that alternative fuels and renewable energy sources have the potential to reduce GHG emissions from vehicle by 80% or more. New technologies such as electric and hybrid electric vehicles (HEV) with high- energy efficiency offer significant drop in fuel consumption and hence in GHG emission rate. Widespread use of alternative fuels depends on overcoming various barriers, including the costs of shifting to new vehicle types, fuel production and distribution technology, concerns about safety and toxicity, and possible performance problems in some climates. Fossil fuel alternatives to gasoline, namely liquefied petroleum gas (LPG), compressed natural gas (CNG), can offer 10-30% emission reductions, and are already cost-effective for small urban buses and delivery vans. 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.

c. Infrastructure and System Changes

Transport systems volumes and infrastructure can affect the distance travel on daily basis. These factors are usually designed predominantly for objectives other than GHG mitigation. Traffic and fleet management systems have the potential to achieve energy savings on the order of 10% or more in urban areas. Modal shifts from road to rail may result in energy savings of 0-50%, often resulting in commensurate or greater GHG emission reductions, especially where trains are powered by electricity from non-fossil fuel sources. The cost-effectiveness and practicality of freight transport by rail varies widely among regions and commodities.

2.1.2. Measures for Reducing GHG Emissions in the Transport Sector

The most economically feasible measure to mitigate GHG emissions from transport systems is by removing the subsidies that exist in some countries for road transport, and by introducing pricing mechanisms that reflect the full social and environmental cost of transport.
Long-term management of GHG emissions from motor vehicles is likely to depend on implementing strategies that include fuel economy standards, fuel taxes, incentives for alternative fuels, measures to reduce vehicle use, and investing in research and development (R&D) related to vehicle and transport system technology and planning. Many of these measures might be justified wholly or partly by objectives other than GHG mitigation.

Governments can adopt some of these measures individually or combined. For example, fuel economy standards and incentives can result in a lower driving cost, hence more traffic, unless implemented in conjunction with fuel taxes, road pricing, or other measures to discourage driving. Effective measures also include implementing computerized traffic control; parking restrictions and charges; use of tolls, road pricing and vehicle access restrictions.

2.2 Electric Power Sector

2.2.1 Technologies for Reducing GHG Emissions in the Electric Power Sector

Technologies to reduce GHG emissions include established as well as new concepts such as improved conversion efficiency of fossil fuels, switching to low-carbon fossil fuels, switching to renewable sources of energy and switching to nuclear energy. Each of these options has its unique characteristics that determine cost-effectiveness, as well as social and political acceptability.

a. Energy Efficiency Improvement

Modern technologies offer better conversion efficiencies from chemical energy (fossil fuels) to electric energy. For example, the efficiency of power production can be increased from the present world average of about 30% to more than 60% in the longer term. Also, the use of combined heat and power production (CHP) offers a significant increase, up to 80—90%, which is much higher than separate electricity and heat production. The economics of CHP are closely linked to the availability or development of district heating and cooling networks and sufficient demand densities.

b. Switching to Low-carbon Fossil Fuels

Switching to fuels with a lower carbon-to-hydrogen ratio, such as from coal to oil or natural gas, and from oil to natural gas, can lead to significant reduction in GHG emissions. Natural gas has the lowest CO_2, emissions per unit of energy of all fossil fuels, at about 15 kg C/GJ, compared to oil with about 20 kg C/GJ and coal with about 25 kg C/GJ.

Switching from coal to natural gas, and accounting for the conversion efficiency of natural gas, which is generally higher than that of coal, reduces the overall emissions reduction by up to 50%. A wider shift to natural gas, however, would lead to changes in policy issues regarding transport and distribution. Moreover, a wider use of natural gas could lead to additional leakages of CH_4, the main component of natural gas.

c. Switching to Renewable Energy Sources

Technological advances are leading to drastic declines in costs of renewable sources. In the longer term, renewable resources, with low or zero- GHG emissions, can meet a major part of the world's demand for electric power.

i. Hydropower

Hydropower is one of the oldest and most established forms of energy resources used even for electric power generation. The GHG emissions reduction potential depends on which fossil fuel hydropower replaces, and the capital cost involved. The investment costs for hydro projects in 70 developing countries for the 1990s suggest that, on average, the cost of new hydroelectricity delivered to final use is 7.8cent/kWh.

Hydro power plants, however, have direct and indirect environmental and social impacts, such as water diversion, reservoir and infrastructure preparation, or disturbing aquatic ecosystems, with adverse human health impacts. Social consequences include the relocation of people as well as a boom and bust effect on the local economy.

ii. Solar Energy

Photovoltaic (PV) cells, that offer direct conversion of sunlight to electricity and heat, is yet to be competitive as a stand-alone power source remote from electric utility grids. Per unit generation costs are still in the range of 20—33cent/kWh. However, the cost of PV systems is expected to drop significantly through further R&D. Although PV devices emit no pollution in normal operation, some systems involve the use of toxic materials, which can pose risks in manufacture, use and disposal.

Solar thermal-electric systems have the long-term potential to provide a significant fraction of the world's electricity and energy needs. This technology generates high-temperature heat, thus may realize conversion efficiencies of about 30%. In addition to electricity production, solar thermal systems can provide heat for water and space heating which normally constitute around 30% of the electricity bill of a typical household.

iii. Wind

Intermittent wind power on a large grid can contribute an estimated 15—20% of annual electricity production without special arrangements for storage, backup and load management. In a fossil-dominated utility system, the mitigation effect of wind technologies corresponds to the reduction in fossil fuel use. The present stock average cost of energy from wind power is approximately l0cent/kWh, although the range is wide. Costs could be significantly lower for large wind farms. Countries with large numbers of operating wind turbines sometimes experience public resistance to such factors as the noise of turbines, the visual impact on the landscape and the disturbance of wildlife.

iv. Biomass

Potential biomass energy supplies include municipal solid waste, industrial and agricultural residues, existing forests, and energy plantations. Costs of biomass energy depend on local conditions, such as land and biomass waste availability and production technology.
The mitigation cost range for biomass-derived energy forms such as electricity, heat, biogas or transportation fuels not only depends on the biomass production cost but also on the economics of the specific fuel conversion technologies. At present, advanced biomass conversion technologies as well as biomass plantations do require further R&D to become competitive.

v. Geothermal and Ocean Energy

The cost of electricity generation from geothermal resources is around 4cent/kWh. Direct use of geothermal water occurs in about 40 countries. Various emissions are associated with geothermal energy, including CO_2, hydrogen sulphide and mercury. Advanced technologies, however, are almost closed-loop and have very low emissions.

d. Decarbonisation of Flue Gases and Fuels, and CO_2 Storage

The removal and storage of CO_2 from fossil fuel power plant stack gases is feasible, but reduces the conversion efficiency and significantly increases the production cost of electricity. Because of its costs and the need to develop the technology, this option has only limited opportunities for near- and medium-term application

e. Switching to Nuclear Energy

Nuclear energy, with generation cost in the range of 2.5 – 6 cents/kWh, is used in many nations to cover base load electricity generation if generally acceptable responses can be found to concerns such as reactor safety, radioactive-waste transport and disposal, and nuclear proliferation. Moreover, the wide spread use of nuclear power is restricted by international treaties on strategic materials.

2.2.2 Measures for Reducing GHG Emissions in the Electric Power Sector

a. Market-based Programmes

In a competitive market, and under an emission tax or tradable quota scheme, it is anticipated that emitters would reduce emissions up to the point where the marginal cost of control equals the emission tax rate or the equilibrium price of an emission quota. Market- based programmes include:

i. Phasing Out Permanent Subsidies

Conventional energy technologies benefit from direct subsidies of more than $300 billion per year worldwide. These subsidies provide incorrect market signals to producers and consumers alike, and may lead to energy prices below actual cost. Subsidies to old technologies do create artificial market barriers to the entry of new more- environment- friendly technologies. Subsidies could still be as measures to support the market entry of GHG mitigating options such as renewable energy and/or clean technologies.

ii. Full-cost Pricing of Energy Services

The concept of monetizing external (social) costs of energy production and use is quite controversial. External costs include those costs usually not reflected in market prices in the absence of policies such as morbidity, mortality, environmental damage, or the potential adverse consequences of the impacts of climate change. The inclusion of energy externalities would improve the competitiveness of low-emission energy technologies.

iii. Tradable Emission Permits

This measure, that includes setting emission quotas and issuing tradable emission permits, is proven to be a success in many developed countries. At the international level, fulfilment of quotas can enhance activities implemented jointly, which could simultaneously bring technology and finance to less developed nations.

iv. Financing Assistance

Capital shortage, especially in the developing countries, is a major barrier to the implementation of GHG mitigation options. If a project has lower life-cycle costs and emissions but higher capital requirements, it may not attract the necessary finance. In addition, energy supply technologies compete with other development needs for limited capital.

v. Regulatory Measures

The conventional approach to environmental policy in many countries has used uniform standards and direct government expenditures on projects that are designed to improve the environment. The trend is that polluters undertake pollution abatement activities; alternatively, the government itself expends resources on environmental quality. The disadvantage, however, is that the costs incurred are often unknown and can be higher than market-based instruments.

b. Voluntary Agreements

Voluntary agreements generally refer to actions undertaken in the participants' self-interest and endorsed by a government with the objective of reducing GHG emissions. The agreements can take on many different forms at both national and international levels, and can include target-and performance-based agreements.

c. Infrastructural Measures

i. Removal of Institutional Barriers

The removal of institutional barriers can attract private-sector interest in advanced renewable technologies. Regulatory reform and deregulation have allowed small and independent power producers access to the grid and improved their competitiveness. In the case of adoption of advanced renewable technologies, these measures can reduce GHG emissions.

ii. Energy System Planning

Traditionally, the domain of energy sector industries has been the production and sale of kWhe, litres of gasoline, or tonnes of coal. The focus was on matching the growth in demand by expanding the supply, rather than on adopting efficient ways to meet the growing and widening demand for energy services. Modern regulatory commissions require power industries to adopt a wider business concept that includes the provision of energy services rather than the sale of energy units. In this aspect, end-use efficiency and technologies become an integral part of the energy industry capital allocation process.

iii. Local and Regional Environment Measures

Energy supply and end use lead to a number of local and regional environmental impacts. Policies and measures for mitigating these impacts can affect and interact with policies for mitigating climate change. For example, more efficient conversion and end use of energy brings multiple benefits as it reduces environmental impacts on all scales.

In addition to the above- mentioned options, innovations based on R&D in the energy sector are a prerequisite for meeting the most ambitious GHG mitigation objectives and significantly lowering the costs of many technology options below present levels.

3. Mitigation Measures Assessment

3.1. Transport Sector

Efforts have been focused recently on the problem of transport in Lebanon and its impacts on the environment. Several studies have been conducted in an attempt to identify the most feasible solutions. In what follows is the description of the mitigation measures regarded as most economically and socially feasible.

a. Improving the Technical Status of the Fleet

Emissions of GHG from transport are in general related to many factors including fuel type, the technical status of the vehicle and its fuel consumption rate, and the distance travelled and time needed for every trip. 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 efficient short-term measure is to encourage the import of new cars so as to reduce the average age of the fleet.

Moreover, re-instating the inspection and maintenance program is expected to significantly improve the overall condition of the fleet, leading to GHG emission reduction in the range of 10-15%. Quality of imported transport fuels has to be controlled as well.

b. Urban Traffic Management

One of the major problems associated with urban transport is the heavy traffic that occurs in most urbanized regions in Lebanon, especially in Greater Beirut Area (GBA). This leads to very significant delays and prolonged trips duration. Studies have shown that the average speed on 75% of GBA streets is less than 20 km/hr (Helou, 1999). This corresponds to an average delay of travel time of around 70%, and an equivalent average of excessive emissions including GHG. The major reasons are the lack of modern traffic and parking management components in GBA. Also the reliance on public transport is very low. Based on these studies, it is expected that improving traffic management systems and providing an efficient and reliable public transport system would lead to emission reductions in the range of 40-50%.

c. Shift to Fuels with Less Emissions

Options in this category generally include alternative fuels and technologies such as using electric propulsion. These are regarded as medium- and long- term options. A major breakthrough, however, has been reported in the development of hybrid electric vehicles (HEV) with high- energy efficiency and a much lower GHG emission rate. HEV's employ propulsion energy system that constitutes 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 (Reizeman, 1998), see Table 3. The unit price of HEV is almost 25% more than the equivalent petrol- driven vehicle. This new technology has been implemented in several countries with quite satisfactory results as long as GHG reduction is concerned.

Table 3: 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

Other options under this category include using mass transport to match the ever-increasing travel needs. A study (TEAM 1995) has developed long-term forecasts of travel needs that extend to the year 2015. It 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 the 1.5 million daily-motorized trips of 1994, in the GBA, would increase to 5 million by the year 2015. To cope with this tremendous growth in travel two scenarios have been considered: The first one, Scenario A, focuses on mass transport, and includes a significant heavy mass transit component, namely rail. The second, scenario B, is a continuation of existing trends, and focuses on the intense use of the private vehicles through further development of the road network. Table 4 shows the estimated cost and the implications of the two scenarios on various characteristics of urban travel in the GBA.

Table 4: Long-term passenger transport scenarios for GBA.

Tasks	Scenario A	Scenario B
Investment in roads (mill. $)	4850	5650
Investment in railway-metro network (mill. $)	3160	540
Investment in bus network (mill. $)	70	320
Total investment (mill. $)	8080	6510
Average speed for AM peak (km/hr)	22	18
Average trip duration (minutes)	34	40
Mass transport market share	33%	16%

The base case under this scenario reflects Scenario B of Table 4. 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). 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 litres (DOT, 1993). This increase in fuel efficiency is considered to reflect emission reductions with the increase in speed.

> The backbone of the proposed 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.

Table 5 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 HEV's would constitute 1% of the local fleet.
- Hybrid electric vehicles with incentive, referred to as HEV II. In this scenario, a car registration waiver, the Government offers 10% of the car cost. As a result, it is expected that by year 2015 hybrid vehicles would constitute 10% of the local fleet.
- Electric 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.

Table 5: Cost comparison of the 3 different scenarios (Mill. $)

Scenario	Discount	Benefits	Costs	B/C	Levelized Cost (1994 $/ton)		
	Rate	1994	1994	Ratio	CO_2	CO	$N0_x$
HEV	5	975	990	0.9848	40	120	3100
	10	261	265	0.987	30	190	4880
	15	90.6	92.4	0.988	20	100	2600
HEV II	5	9970	9840	1.01	-86.58	-420	-10800
	10	2666	2629	1.01	-28.4	-136	-3550
	15	930	918	1.01	-26.8	-130	-3350
ET	5	12160	2890	4.21	-390	-1860	-48380
	10	3063	981	3.12	-300	-1450	-37720
	15	1046	439	2.38	-130	-600	-15620

The Benefits figures as shown in Table 5 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.

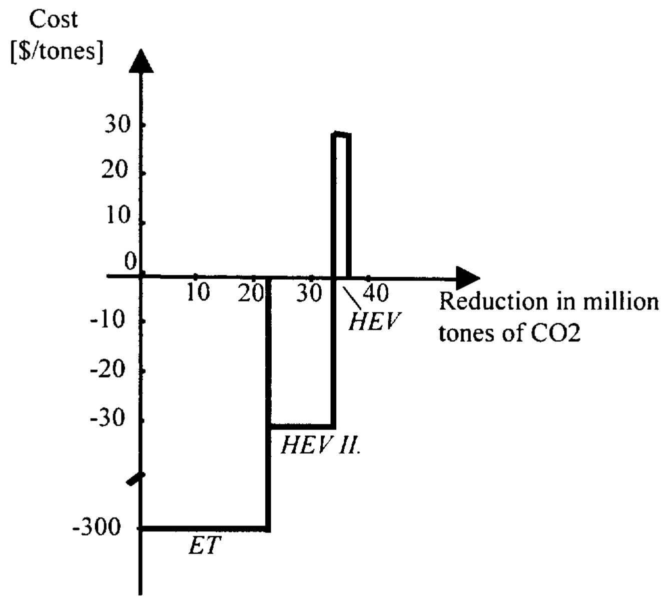

Fig.3: Cost and emission reduction for the 3 scenarios

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. Figure 3 shows a comparison of the amount of reduction and cost of each of the three scenarios.

3.2. Electric Power Sector

a. Improving the System Efficiency

It has been stated that typical losses in the Lebanese mount up to almost 17% of the generated power. This could be attributed mainly to the current technical status of the network that still relies on old technologies. It is estimated that upgrading the transmission and distribution networks would drop the losses to the internationally accepted level of around 7%. This leads to GHG emissions reduction of around 10%. One methodology is through increasing the HV transmission level to 220 or even 400 kV.

b. Reliance on Renewable Energy Resources

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, it is expected to gain ground as a competitive energy resource once the new gas networks between several regional countries including Lebanon are materialized.

Table 6: 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

Table 6 shows the projected CO_2 emissions from the power sector as estimated using scenarios based on deployment of renewable energy resources and natural gas. Figure 4 shows a comparison of the amount of reduction and cost of each of the examined scenarios.

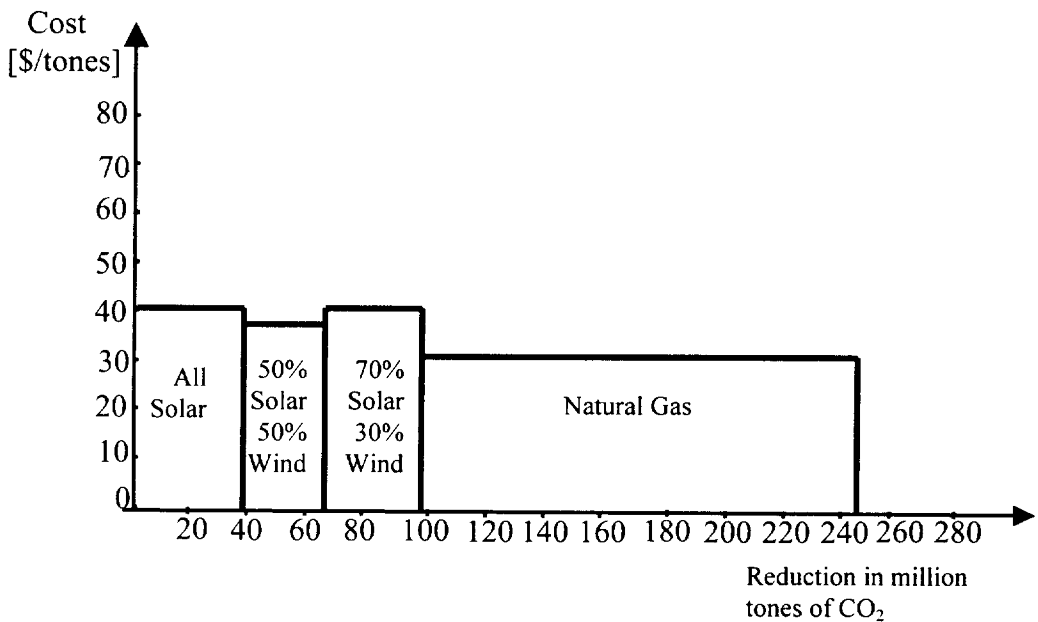

Fig. 4. Cost and emission reduction in the power sector.

4. Conclusions- Recommendations

Based on the results obtained, the following recommendations are suggested for mitigating GHG in the transport and electricity supply sectors.

4.1. In the Transport Sector

a. Improving the technical status of the fleet through:
   i. Financial incentives for new efficenct technologies.
   ii. New legislations for fuel and vehicles imports.
   iii. Re- instating technical inspection and maintenance program.

b. Upgrading the traffic management system through:
   i. Modernizing the traffic systems in urbanized areas.
   ii. Providing parking policy.
   iii. Modernizing urban planning and building codes regulations.

c. Increasing the reliance on mass transport through:
   i. The development of rail system for goods and passengers transport.
   ii. Improving the current public transport system.
   iii. Development of traffic restriction zones in the city centre.
   iv. Appropriate road taxation system.

Financial incentives are proven to be a very effective tool. One example (success story) is the recent introduction of incremental cost of transport fuel based on which unleaded fuel became cheaper by 10% than leaded. As a result, the share of unleaded has increased from around 15% up to 50% of the market.

4.2. In the Electric Power sector:

a. Shift towards less polluting fuels and technologies through:
   i. The deployment of natural gas as the main fuel for power generation.
   ii. The deployment of combined- cycle plants.
   iii. Upgrading the existing plants with modern more efficient generating units.
   iv. Upgrading the transmission and distribution networks so as to reduce technical losses.
   v. Controlling the quality of imported fuels.

b. Promotion of renewable energy resources through:
   i. Providing financial incentives for their deployment.
   ii. The removal of various institutional and technical barriers.
   iii. Imposing social costs to improve renewable energy competitiveness.
   iv. Increasing public awareness and acceptance.

With regard to the energy sector in general, efforts should be focused on addressing several barriers. These are: The information barriers that are reflected in the shortage of knowledge concerning modern clean and more efficient technologies. Shortage of data on patterns of end-use energy consumption in all sectors of the economy prevents practical evaluation of the energy market. Also there is a shortage of documentation and awareness regarding the economic, environmental and social implications of existing technologies and trends. Finally, the economic and financial barriers due to the lack of dedicated financing programs or special incentives to promote clean and renewable energy systems have to be tackled through appropriate planning and financing.

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