3. Greenhouse Gas Mitigation Analysis

The purpose of this chapter is to provide an analysis of the measures to reduce GHG emissions and enhance carbon sinks in Lebanon. The analysis is based on 2 types of scenarios: the baseline scenarios and the mitigation scenarios.

The baseline scenarios are constructed based on the current sectoral plans, policies and projected trends. Baseline scenarios are different from the business-as-usual scenario since the government of Lebanon has committed itself to long-term plans which introduce major changes to the existing structure of the economy. Some of these changes may be considered as a baseline scenario, such as in the energy sector while some plans are considered as a mitigation scenario such as the national waste management plan that still needs time for its execution. The choice of baseline scenario is achieved through a thorough consultation process with all stakeholders and sectoral decision makers. The data used are derived from periodical reports, national and international studies and literature review. The GHG abatement analysis is made for 20 years, i.e. till the year 2030. The projection of trends uses 2004 as the base year and project forecasts the values to 2030, taking into account demographic, social, and economical assumptions available in official documentation. When faced with major lack of data, projections are developed in close cooperation with the relevant institutions to determine the most appropriate political and economical development of a specific sector.

The mitigation scenarios are proposed plans and projects that have a potential for sectoral emission reduction or sink enhancing. Mitigation options are selected and analyzed according to their direct and indirect economic impact, consistency with national development goals, economical feasibility, and compatibility with implementation policies, sustainability and other specific criteria. Various methods and tools are used to evaluate each mitigation option in terms of technological and economical implications. It should be noted that due to major lack of data, most of the values used in the analysis are based on international applications and studies.

3.1. Energy Sector

3.1.1. Electricity

Electricity in Lebanon is supplied through Electricité du Liban (EDL) that is responsible for the generation, transmission, and distribution of electrical energy in Lebanon. The sector has faced many challenges and difficulties, mainly the inability of meeting demand over the last few decades, as well as a considerable budget deficit necessitating continuous government transfers (reaching USD 328 million, equivalent to 1.5% of GDP in 2004). Electricity generation is the main emitter in Lebanon, with 5,773 Gg CO_2 eq. in 2000 or 31% of total emissions in 2000.

3.1.1.1. Baseline scenario

A number of plans and strategies for the electricity sector have been formulated to date, as different governments with different political inspirations and views have changed former plans. However, no plan has been implemented, and the gap between demand and supply has kept increasing as a result of the increasing demand, leading to an increase in rationing year after year. Table 3-1 presents the main components of the Ministry of Energy and Water’s (MoEW) latest policy paper for the electricity sector released in June 2010, endorsed by the Council of Ministers, which, if implemented with the necessary additional investments for capacity expansion until 2030, will have very significant influence in keeping up with growing demand (MoEW, 2010).

3.1.1.2. Projected Emissions

The energy sector releases mainly CO_2 emissions from fuel combustion. Figure 3-1 illustrates the breakdown of the total installed capacity of power plants in Lebanon under the baseline scenario using Long-range Energy Alternative Planning system (LEAP). LEAP is a scenario-based energy-environment modeling tool. Its scenarios are based on comprehensive accounting of how energy is consumed, converted and produced in a given region or economy under a range of alternative assumptions on population, economic development, technology, price and so on. LEAP serves several purposes: as a database, it provides a comprehensive system for maintaining energy information; as a forecasting tool, it enables to make projections of energy supply and demand over a long-term planning horizon; as a policy analysis tool, it simulates and assesses the effects - physical, economic,

Table 3-1 Main components of MoEW policy

Infrastructure
- Target of total installed capacity of 4,000 MW by 2014 and 5,000 MW thereafter to meet a load of 2,500 MW (summer 2009), the 500 MW of demand currently supplied by self generation, and future demand corresponding to an annual load growth of 7%, and 15% of peak load reserve.
- Possibility of renting 250 MW (barges, small generators or imports) between 2010 and 2013
- Rapid increase of the installed capacity by 600-700 MW using CCGT (400 MW) and/or Reciprocating Engines using diesel starting 2011 and over a period of 3 years
- Rehabilitating, maintaining, replacing, or upgrading existing plants to increase their overall capacity by about 245 MW
- Increasing installed capacity by 1,500 MW immediately and 1,000 MW after 2014 using the modality of Independent Power Producer (IPP) in collaboration with the private sector. Increasing the share of hydropower production between 2012 and 2015 Introducing wind power via the private sector by building wind farms (60-100 MW) between 2011and 2013.
- Use "waste to energy" or geothermal energy if possible to add a capacity of 15-25 MW between 2013 and 2014
- Removing bottlenecks, reducing transmission losses, completing a control facility to ensure adequate connection between power plants and load centers together with high reliability and stability at the lowest cost
- Improving the distribution services in 2010 and equalize respectively the supply and collection between regions
- Subcontract company for the upgrade/ rehabilitation of the distribution system
- Developing a center able to monitor automatic meter reading, perform remote connection/ disconnection of supply and demand management functions between 2012 and 2014
- Introducing new services, payment facilities and new tariff structures and mechanisms
- Developing a Distribution Management Center (DMC) to be implemented between 2012 and 2014
Supply and Demand
- 2/3 of the fuel mix is based on natural gas with multiple sources of supply
- More than 12% of the fuel mix to be supplied by renewable energy sources
- Developing an infrastructure plan to supply and distribute natural gas
- Completing a prefeasibility study and construct a Liquefied Natural Gas (LNG) marine terminal in Selaata or Zahrani between 2011 and 2013
- Building a gas pipeline along the coast to feed all power plants between 2011 and 2013
- Completing a wind atlas for Lebanon and launch IPP wind farms with the private sector
- Starting a prefeasibility study on Photovoltaic (PV) farms
- Encouraging initiative of waste to energy
- Save a minimum of 5% of the total demand from demand side management and energy efficiency
- Adopting the Energy Conservation law, institutionalizing the Lebanese Center for Energy Conservation (LCEC) and launching a national plan for energy conservation
- Widely spreading the use of Compact Fluorescent Lamp (CFL)
- Increasing the penetration of Solar Water Heaters (SWH) and devising innovative financing schemes
- Encouraging the use of energy saving public lighting
- Setting up the National Energy Efficiency and Renewable Energy Account (NEEREA) and developing the ESCO (Energy Service Company) business
- Gradually increasing tariff in conjunction with improvements in the electric service provision
- Implementing Time of Use (TOU) tariffs in conjunction with the implementation of Automatic Meter Reading (AMR) schemes
Legal Framework
- Developing rules and laws that promote the largest penetration of "Green Buildings (GB)" and "Energy Efficiency (EE)"
- Comply and respect international norms and standards in the energy efficiency, environmental and public safety domains
- Increasing the human resource capacity of EDL
- Updating the legal due diligence needed to corporatize EDL as per the three functions of generation, transmission and distribution
- Using Service Providers, independent power production, Operation & Maintenance (O&M) contracts
- Initiating the process of revising Law 462 with concerned parties
- Beginning with the current legal status of EDL governed by Decree 4517
- Adopting a Law for the new power plants and encouraging all kinds of Public Private Partnership to facilitate the transition and ensure proper continuity between current and future legal status

Source: MoEW, 2010

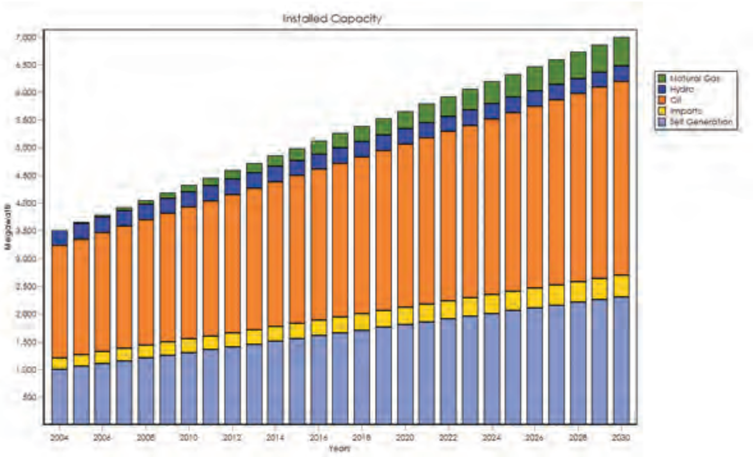

Figure 3-1 Breakdown of total installed capacity under the baseline scenario

and environmental - of alternative energy programs, investments, and actions (SEI, 2006).

GHG emissions for the year 2004 amount to around 7,261 Gg of CO_2 eq., which is lower than the value obtained in the GHG inventory. This can be attributed to differences in the approach used in the IPCC guidelines and in LEAP, differences in the efficiencies of power generation, and differences in emission and conversion factors. Projected emissions are expected to reach 32,569 Gg CO_2 eq. by 2030 under the baseline scenario, including self-generation (Figure 3-2). The emissions from the electricity imports from neighboring countries are not reported as they do not account for national emissions.

3.1.1.3. Mitigation scenarios

Mitigation scenario 1: Implementation of MoEW's latest policy paper for the electricity sector, in addition to capacity expansion (around 3,500 MW between 2015 and 2030 based on the 2/3 natural gas fuel mix, in addition to 11.4% of renewable energy by 2030) **post-2015 to keep up with demand.**

Mitigation scenario 2: Implementation of MoEW's policy paper but with a full switch of oil-fired power plants to natural gas by 2030, an increase in the penetration rate of renewable energy technologies (17% by 2030) and no electricity imports.

The data and assumptions for these scenarios are summarized in Table 3-2 and the breakdown of total installed capacity of power plants is illustrated in Figure 3-3 and Figure 3-4.

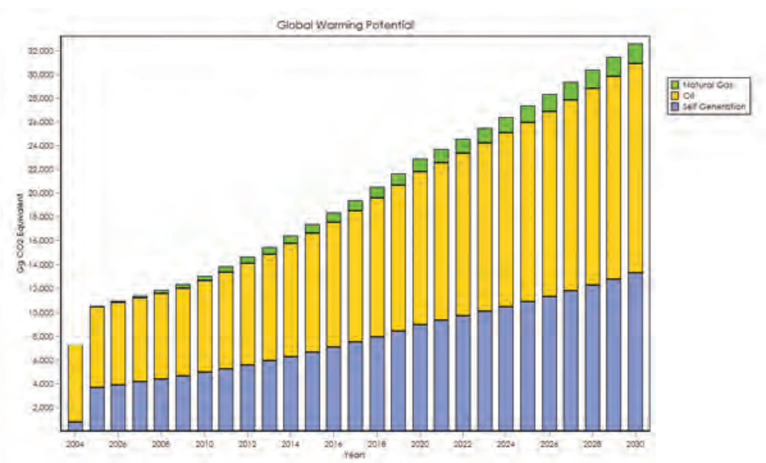

Figure 3-2 GHG emissions from the electricity sector under the baseline scenario

Table 3-2 Data and assumptions for Mitigation scenario

	Exogenous capacity (MW)	
	Mitigation Scenario 1	Mitigation Scenario 2
Oil	2004: 2,038 2014: 2,538 2030: 1,230	2004: 2038 2014: 2538 2030: 0
Diesel	2004: 0 2014: 300 2030: 0	2004: 0 2014: 300 2020: 0
NG	2004: 0 2014: 1,617.5 2030: 4,690	2004: 0 2014: 1617.5 2030: 5,850
Hydro	2004: 274 2015: 310 2030: 400	2004: 274 2015: 310 2030: 600
Wind	2004: 0 2015: 80 2030: 253.8 (8% growth as of 2016)	2004: 0 2015: 80 2030: 334.2 (10% growth as of 2016)
Solar	2004: 0.5 2015: 0.5 2030: 81.4 (5% growth between 2021 and 2030)	2004: 0.5 2015: 0.5 2030: 129.7 (10% growth between 2021 and 2030)
MSW	2004: 0 2015: 20 2030: 63.4 (8% growth as of 2016)	2004: 0 2015: 20 2030: 129.7 (10% growth as of 2021)
Imports	2004: 200 2011: 300 2030: 300	2004: 200 2011: 300 2030: 0
Self-Generation	2004: 1,000 2015: 0 2030: 0	2004: 1,000 2015: 0 2030: 0
Total in 2030	7,019 MW (11.4% renewable)	7,044 MW (17% renewable)

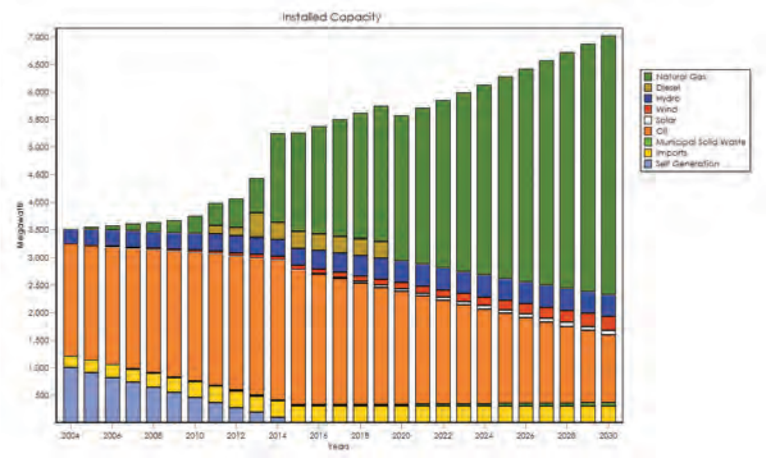

Figure 3-3 Breakdown of total installed capacity under mitigation scenario 1

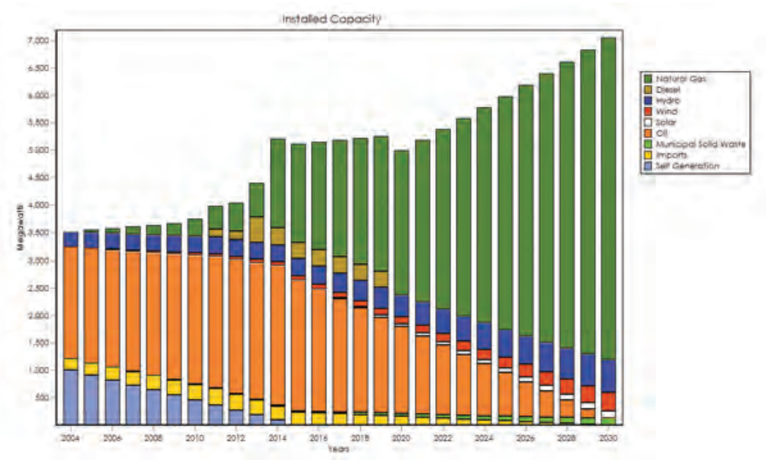

Figure 3-4 Breakdown of total installed capacity under mitigation scenario 2

3.1.1.4. Emissions reduction and costs of mitigation scenarios

Mitigation scenario 1: The cumulative reduction in GHG emissions from mitigation scenario 1 adds up to 177,912 Gg of CO_2 eq. between 2011 and 2030, or a 33% reduction from 2004. The emissions reduction in 2030 is around 41.6%, as in Figure 3-5.

The cost of implementation of mitigation scenario 1 is estimated at USD 8.14 billion, which includes the implementation cost of MoEW's plan (USD 4.87 billion). The additional investments amount to USD 3.27 billion, assuming that all added CCGT capacity consist of new power plants rather than conversion of old oil-fired power plants and that the investment is made at once in 2016 and not gradually (Table 3-3). The resulting unit cost of emissions reduction from mitigation scenario 1 is USD 42.9/tCO_2 eq. Discounted unit costs are calculated at 10% and 15% discount rates (Table 3-3 and Table 3-4).

Mitigation scenario 2: The cumulative reduction in GHG emissions from mitigation scenario 2 adds up to 204,768.3 Gg of CO_2 eq. between 2011 and 2030, or a 38% reduction from 2004, which is higher than scenario 1. Emissions reduction reaches 43.6% in 2030.

The total cost of mitigation scenario 2 is around USD 11.0 billion, with the cost of additional investment being USD 6.12 billion, as shown Table 3-3. The resulting unit cost of emission reduction is USD 57.6/tCO_2 eq., which is higher than scenario 1 since a greater fraction of existing installed capacity (oil-fired) has to be replaced by CCGT and renewable technologies.

A comparison of scenarios 1 and 2 reveals that scenario 2 reduces GHG emissions by 26,856 Gg more than scenario 1, or 7.5% more between 2004 and 2030.

It should be noted that these figures are not meant to be compared merely for scenario selection purposes, and the two scenarios were mainly considered to illustrate the

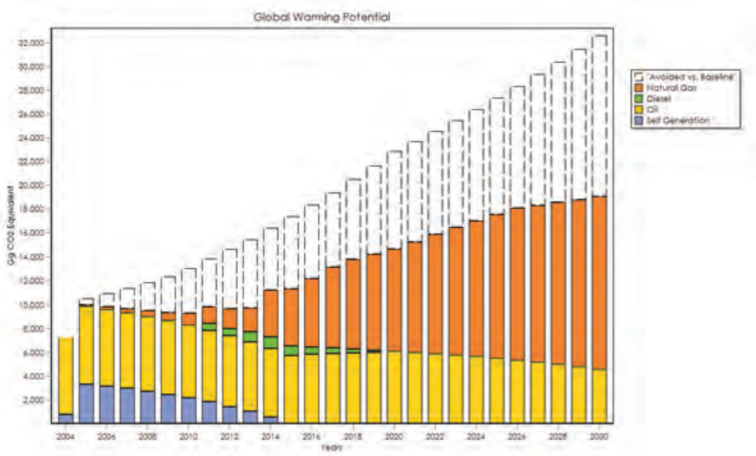

Figure 3-5 GHG emissions and avoided emissions under mitigation scenario 1

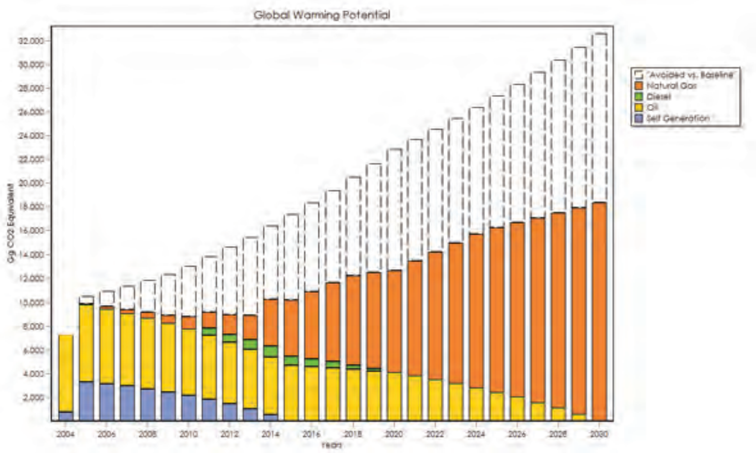

Figure 3-6 GHG emissions and avoided emissions under mitigation scenario 2

Table 3-3 Cost of installed capacity expansion needed in addition to MoEW's plan

Technology	Cost/MW (USD million)	Mitigation scenario 1		Mitigation scenario 2	
		Capacity to be added (MW)	Total Cost (USD million)	Capacity to be added (MW)	Total Cost (USD million)
CCGT	1.00	2,072	2,000	3,232.5	3,200
Hydropower	5.80	90	522	290	1,700
Wind	1.95	173.8	339	254.2	496
Solar	4.00*	80.9	324	129.2	517
Waste to energy	1.90	43.4	82.5	109.7	208
Total	-	2,460.1	3,270	4,015.6	6,120

* Expert opinion. Cost figures for the other technologies are taken from MoEW, 2010.

Table 3-4 Discounted total cost and unit cost at different discount rates

Discount rate	Mitigation scenario 1		Mitigation scenario 2	
	Discounted total cost (USD billion)	Discount unit cost (USD/tCO_2 eq.)	Discounted total cost (USD billion)	Discount unit cost (USD/tCO_2 eq.)
10%	6.94	41.08	8.68	44.59
15%	6.53	38.63	7.92	40.69

extent of emissions reduction possible and associated costs. It is expected that the greater the shift to cleaner technologies, the cost is greater, as indicated in scenario 2. The more funds can be secured, the greater the possible investment to increase the proportion of clean fuels (natural gas and renewable) in power generation – as in scenario 2 – and thus reduce GHG emissions.

3.1.1.5. Mitigation Strategy

The mitigation strategy consists mainly of implementing the elements elaborated in the policy paper for the Electricity Sector (MoEW, 2010), which addresses the problem in a comprehensive, integrated manner.

Regarding the diversification of fuel supply and the proposed expansion of CCGT capacity to generate most of the capacity needed, LNG can offer important relief in the medium to longer term by (Poten and Partners, 2009) by significantly reducing generation cost.

Two options were advocated for the supply of natural gas to the power plants:

- A gas pipeline along the coast between Baddawi and Tyre advocated in the MoEW policy paper to feed all power plants falling along that coastal strip. This option would be expensive (Poten and Partners, 2009), in addition to the fact that gas volumes coming to Baddawi would not suffice.

- A permanently moored offshore Floating Storage and Regasification Unit (FSRU) with ship to ship LNG transfer, linked to the coast by a subsea gas pipeline in the case of the Zahrani power plant (Poten and Partners, 2009).

With an FSRU, LNG solution at Zahrani would result in USD 75 – 80 million/ year total saving, an Internal Rate of Return (IRR) of more than 90%, and investment payback in one or two years. Expanding Zahrani can be a good proposition in the longer term, given LNG's comparable life cycle generation costs to coal without the environmental drawbacks.

In the current surplus market conditions, Lebanon could secure long term prices of around USD 7/million BTU (assuming oil prices of around USD 65/barrel). However, EDL might not qualify as a creditworthy LNG buyer, which might require additional government guarantee and potentially a World Bank partial-risk guarantee from the supplier.

A site-specific feasibility study to determine the feasibility of such a project is needed, followed by a Front End Engineering and Design (FEED) study. Another important pre-requisite for such a project is the finalization of a gas/LNG import law to clarify the regulatory and fiscal regimes governing the import terminal and the various participants including EDL, terminal developer and LNG supplier. Finally, a long term LNG supply procurement strategy needs to be developed and finalized (Poten and Partners, 2009).

3.1.2. Manufacturing Industries and Construction

The manufacturing industries and construction sector covers private self-generation of electricity which accounts for around 33% of the total electricity generation. Total emissions from this sector reached 2,838.06 Gg of CO_2 eq. in 2000. Since a significant amount of private generation is derived from manufacturing industries, this chapter addresses measures to increase the efficiency of power generation in the industrial sector, especially in cement industries which constitute one of the major energy intensive industries in the country.

3.1.2.1. Mitigation scenarios and costs

Mitigation scenario 1: Waste heat recovery and utilization for power generation in cement plants

The objectives of this option are to meet the electrical supply needs of cement plants and to reduce GHG emissions through the recovery and use of waste heat from the rotating kiln of the cement clinker production line. Additionally, this option has the potential to significantly reduce harmful emissions (including SO_x, NO_x and floating particles), and thus improve the local environment.

Based on figures of heat recovery and utilization reported in UNFCCC 2007, 2008a, 2008b, and 2009, the following assumptions (Table 3-5) are considered concerning the case of Lebanon and the results are presented in Table 3-6 and Table 3-7.

Mitigation option 2: Partial substitution of fossil fuels with alternative fuels or less carbon intensive fuels

Since the majority of the industries in Lebanon use fossil fuel sources for their production processes and operations (petroleum coke, diesel oil and residual fuel oil), a main option to reduce the related CO_2 emissions is to reduce the carbon content of the fuel by using fossil fuel types

Table 3-5 Assumptions considered for the case of Lebanon

Parameter	Value
Average Gg CO_2 eq. reduced/Gg of cement produced	0.033
Average amount of electricity generated (MWh/ year)	97,817
Capital Cost per MWh of electricity generated (USD/MWh)	10.98
Expected operational lifetime of the project (years)	20
Operational cost	20% of investment cost
Growth rate in clinker production under scenario A	2%
Growth rate in clinker production under scenario B	4%

Table 3-6 Results of mitigation option 1 under scenario A and scenario B for selected years

Year	2010	2020	2030
Scenario A			
Production of Cement (tonnes)	4,666,602	5,688,562	6,934,325
Amount of electricity generated (MWh/year)	168,835	205,809	250,881
Amount of CO_2 eq. reduced (Gg CO_2 eq.)	155	189	230
Scenario B			
Production of Cement (tonnes)	5,243,240	7,761,277	11,488,585
Amount of electricity generated (MWh/year)	189,698	280,799	415,652
Amount of CO_2 eq. reduced (Gg CO_2 eq.)	174	258	381

Table 3-7 Breakdown of the cost of mitigation option 1 under scenario A and scenario B for the period 2010-2030

	Investment Cost (USD million)	Operational Cost (USD)	Total Cost (USD million)	Total Discounted Cost (10%) (USD million)	Cost (USD/Gg CO_2eq.)	Total Discounted Cost (15%) (USD million)	Cost (USD/Gg CO_2 eq.)
Scenario A	1,854	370,909	2.22	2,658	693	2,537	661
Scenario B	2,083	416,741	2,50	3,624	672	3,288	610

Table 3-8 CO_2 emissions per type of fuel

Fuel Type	Net calorific value (TJ/Gg)	Effective CO_2 emission factor (Gg/TJ)	CO_2 Emissions per Gg of fuel (g CO_2/g of fuel)
Fuels already in use			
Petroleum Coke	32.5	0.097	3.152
Residual fuel oil	40.4	0.077	3.126
Diesel oil	43	0.074	3.182
Alternative Fuels			
Natural Gas	48	0.0561	2.692
Municipal waste	10 - 11.6	0.0917 - 0.1	0.971 - 1.16

Source: IPCC, 2006

with a lower CO_2 emission factor on a net calorific value basis (tCO_2/GJ) such as natural gas (Table 3-8).

Another option is the application of waste-derived alternative fuels such as wastes originating from fossil sources or biomass residues. In considering using waste-derived fuels in cement industries specifically, a number of issues should be considered such as energy efficiency of waste combustion in cement kilns, fuel quality, generation of trace elements and heavy metals and production of secondary waste (Hendriks et al., 2004).

3.1.3. Transportation

In comparison with developed nations, Lebanon has a larger percentage of older vehicles, which probably leads to a proportionately higher percentage of emissions released into the atmosphere per vehicle-kilometer or vehicle-hour of congestion than in developed countries. The transport sector accounts for 19.5% of Lebanon's GHG emission (3,976 Gg of CO_2 eq.), and around 98.5% of total CO emissions. This section focuses on land transport of passengers, which is the largest contributor to GHG transport emissions in Lebanon.

3.1.3.1. Baseline scenario

The main existing transport legislation relevant to the mitigation of GHG emissions comprises:

- Decree 6603 (4/4/1995) that defines standards for operating diesel trucks and buses, as well as the implementation of a monitoring plan and permissible levels of exhaust fumes and exhaust quality (particularly for CO, NO_x, hydrocarbons and TSP).

- Decision 9, issued by the Council of Ministers on 5/4/2000, which calls for the reform and re-organization of the Land Public Transport Sector in Lebanon and the reduction of the number of public transport vehicles from 39,761 to 27,061 vehicles.

- Law 341(6/08/2001) that lays the legal framework for reducing air pollution from the transport sector and encouraging the use of cleaner sources of fuel. Specifically, the law bans the import of minivans operating on diesel engines, as well as old and new diesel engines for private passenger cars and minivans. The law empowered the GoL to retrieve 10,000 public license plates operating on diesel.

Numerous transport studies and policies and legislative texts are available, but little has been effectively implemented to date, leaving the sector in a chaotic situation. Table 3-9 presents a number of formulated and on-going projects and studies which, if implemented will have very significant influence in enhancing the sustainability of the transport system and reducing GHG emissions.

3.1.3.2. Projected growth in the vehicle fleet

The projected demographic growth in Lebanon from a total population of 4.29 million to around 5.2 million over the coming 25 years would inevitably be translated into growing demands for the various urban services, including transport. The vehicle population is expected to grow to 1,400,000 in 2015 (MoE, 2005). Moreover, it is estimated that, in 25 years, the vehicle fleet as well as the average number of daily motorized trips per person will both grow by almost 60%.

Given the relatively affordable car prices, available credit facilities, and the lack of a reliable and efficient public transport system, it is expected that the current trend would remain constant in the coming years under the baseline scenario; i.e., the share of passenger-trips traveled by private vehicles would keep increasing until it reaches 90% in 2030. The share of passenger-trips traveled by buses would remain constant, while that for vans would decline. Buses are assumed to operate on diesel, and vans on gasoline as mandated by law 341/2001. Fuel types and associated energy intensity would remain unchanged for all modes of passenger transport.

3.1.3.3. Mitigation scenarios

Mitigation scenario 1: Revitalization of the Public Transport System

This option consists of creating an efficient and reliable public transport system, whereby the distribution of passenger-trips traveled by bus and car would be reversed (more than half of person trips to be traveled by bus). This will entail the introduction of 637 buses countrywide with 507 buses in GBA, 85 in Tripoli, and 45 to serve intercity (between Mohafaza centers). The total non-recurring investment in vehicles, infrastructure, terminals, depots, etc., is estimated at USD 400 million (based on unpublished data from the MoPWT). The GBA public transport will require an annual subsidy of USD 100

Table 3-9 Summary of formulated and on-going projects and studies relevant to the transport sector

Study/ Project	Status and comments
Urban Transport Development Plan (UTDP) for the city of Beirut Funded jointly by the World Bank and the Republic of Lebanon, and implemented by the CDR	The corridor improvement component has been suffering serious impediments and delays attributed to slow expropriation procedures on the Government side. Around 60% of this component has been implemented
Revitalization of the Public Transport and Freight Transport Industries Launched by the MoPWT	The background assessment for this study has been launched
Restructuring of the Directorate General for Land & and Marine Transport Launched by the MoPWT	No implementation to date
The Road User Charges Study	No concrete action has been taken to date in order to establish neither a Road Fund nor a Transport Fund, and the study is now outdated, especially with the unexpected rise in oil prices
The Proposed National Transport Policy Prepared by the DGLMT and submitted to the Government of Lebanon in 2002	No concrete implementation to date
The National Physical Master Plan for the Lebanese Territories (NPMPLT)	Although the MPMPLT was endorsed by the Council of Ministers in 2009, no application decrees were issued for its application into land use, urban planning, or development schemes and projects
The Beirut Suburban Mass Transit Corridor Study	This project is also not considered financially viable by the government due to the costs it entails and to the present loss of the rail right-of-way by urban encroachment on the existing track in many locations
Setting up of the Traffic Management Organization (TMO)	The TMO was created by Decree No.11244 dated October 25, 2003, but has had an administrative rather than a more technical traffic management role, which has held the TMO from fulfilling the actual objectives and tasks it was created for. The current TMO needs restructuring – including hiring traffic experts
Regulation of the Public Transport Industry in Lebanon Carried out by the MoPWT-DGLMT (2002)	No concrete implementation to date

Source: MoE, 2005

million, which is modest compared to what is currently paid to employees as transport allowance. This cost should be considered starting 2011, with an additional USD 200 million in 2020 for the renewal of the bus fleet and its expansion by around 25% up to a size of 800 buses, in addition to upgrading and maintenance of infrastructure.

The cost-effectiveness of this mitigation scenario in terms of USD/tCO_2 eq. reduced would be too high in absolute terms since such a project is usually not carried out merely for GHG mitigation purposes, but is rather a basic infrastructure project that needs to be implemented for more general and broader purposes, and that would have additional advantages. Thus, its total cost cannot be considered as the mitigation cost.

Mitigation scenario 2: Implementation of a car scrappage program

This option consists of developing and implementing a complementary, integrated program to reduce emissions from the existing fleet through carrying out a car scrappage program whereby illegal private public transport vehicles which are old, highly emitting and carry duplicate license plates would be bought by the Government and scrapped.

A scrappage program would reduce the overall energy intensity of the vehicle fleet, and consequently GHG emissions from the sector. A number of recent scrappage programs make GHG emissions reduction an ancillary goal by setting fuel economy or g CO_2 eq./km requirements on the replacement vehicles. These upgrades range from a fuel economy improvement of 2.13 – 3.83 km/L to 120 g CO_2 eq./km (Allan et al., 2009). However, since newer cars are driven further per year than older ones, prematurely retiring a vehicle may reduce short-term GHG emission reduction benefits if the replacement vehicle is driven considerably farther than the scrapped vehicle.

The implementation of a car scrappage program in Lebanon can be considered a top priority measure that needs to be undertaken within an integrated framework. The estimated size of the vehicle fleet to be targeted is around 30,000 to 40,000 vehicles. Strict control needs to be exerted simultaneously in order to enforce the ban on old cars and therefore prevent any illegal import or smuggling. In parallel, strict emission standards need to be defined and enforced, and control made more stringent so as to identify those "legal" cars that are non-compliant and need repair or maintenance. In a second stage, once illegal vehicles have been scrapped, incentives would be provided to promote the replacement of non-compliant old vehicles that are too costly to repair and maintain, thus sustaining the renewal of the fleet throughout the years.

The promotion of technology measures such as hybrid vehicles would only be advocated once the above-mentioned measures, which are a pre-requisite to any other plan, less costly and lead to higher emission reductions, have been implemented and sustained. The introduction of hybrid and efficient vehicles to replace the taxi fleet has been advocated but is still controversial and will depend on its affordability, governmental support and provision of adequate subsidies.

3.1.3.4. Mitigation strategy

In addition to the scenarios presented above, the main strategy for the transport sector should include the following:

- Improve specifications relating to vehicle efficiency and fuel economy at the import stage;
- Provide incentives for increasing the share of new vehicle technologies in the fleet (e.g., HEV);
- Issue and enforce new vehicle emission control standards for imported used vehicles;
- Implement decree 6603/1995 relating to standards for operating diesel trucks and buses, monitoring and permissible levels of exhaust fumes and exhaust quality;
- Restructure, empower and enhance the role of the traffic management organization;
- Promote the creation of a transport fund and foster increased public/private partnership in order to reduce the financial burden of the transportation system on the budget of Lebanon;
- Adopt knowledge-intensive high-tech management approaches for solving complex urban transport problems;
- Amend vehicle taxation system and registration fees into a more environmentally oriented scheme;
- Endorse road network development and apply conventional traffic flow improvements;
- Discourage private car use in CBD areas through a reduction of road space for private vehicle operation and parking, coupled with a supporting fiscal structure that makes car use in CBD more expensive, assuming that a proper (efficient) alternative of transportation mode is provided;
- Proper training of drivers passing their license test so as to promote adequate driving habits that reduce emissions from cars;
- Redefine scarce urban road infrastructure for an increased (and partially exclusive) use of public transport means;
- Improve logistics and fleet management including upgrading and enforcing the car inspection program requirements and mandating the presence of catalytic converters;
- Introduce fuel taxation and parking fees, coupled with supporting awareness campaigns with respect to sustainable transport practices;
- Reduce the average number and length of vehicle trips through decentralization of public,

medical, academic and other institutions; as well as improved logistics and simplification of routine official procedures;

- Promote mass transit of freight through the introduction of electric rail in the long term;
- Reduce congestion in urban areas by reducing the penetration of trucks into urban areas, controlling loading/unloading operations, preventing the location of warehouses in the basements of buildings, etc.;
- Introduce legislative reforms, particularly in relation to urban planning laws, expropriation laws, taxes and tariffs, traffic laws.

3.1.4. Building Envelops

This section focuses on the thermal performance of buildings based on heating and cooling energy consumption. Thermal standards for buildings in Lebanon were developed by the "Capacity Building for the Adoption and Application of Thermal Standards for Buildings" project in 2005 by the General Directorate of Urban Planning (DGUP) and UNDP where the impact of the application of the thermal standards on GHG emissions at the macroeconomic level were forecasted, based on an estimation of the area of buildings which will be constructed on a 20-year horizon (MoPWT et al., 2005). Unfortunately, the standards are still not mandatory.

3.1.4.1. Application of Thermal Standards in new buildings

The proposed thermal standards for buildings suggest standards for walls, roofs and windows for residential and office buildings (commercial, institutional). These standards tackle:

- U-value for roofs and walls for the various climatic zones of Lebanon;
- U-value for windows for the various climatic zones of Lebanon;
- Maximum Effective Fenestration Ratio determined based on an analysis of several parameters that the building designer may act upon in order to reduce the solar heat gain of the proposed building, such as the orientation of the building, the glass shading coefficient, and the architectural shading factor (fins and overhang).

Over a 20-year period (2010-2029), the application of the Thermal Standards for Buildings can generate a reduction in energy use at building input (office and residential) consisting of around 56 million GJ of avoided heating energy and around 8 million GJ of avoided cooling energy. This leads to the avoidance of around 7 million tCO_2 over 20 years or around 343,500 tCO_2/year. The analysis is based on a merely fuel-based electricity supply mix; thus a change in the fuel mix towards cleaner fuel sources may result in a deeper reduction in emissions.

As for the cost of the reduction in GHG emissions from thermal insulation of buildings, the associated economic savings vary in magnitude depending on the price of fuel and diesel oil. Average estimations indicated savings in the range of USD 500 million in 2005, which can be considered as an underestimate as a result of the rise in fuel prices between 2005 and 2008 (peak price) and the inflation and rise in construction costs during this same period. The actual value of savings from the application of these standards can be assumed to be at least USD 1 billion/yr.

3.1.4.2. Retrofitting Existing Buildings

Regarding existing buildings, which represent the largest stock of buildings at any point in time, an Energy Performance Index (EPI) can be assigned to each building based on an assessment of its thermal performance. A development scheme can be put forward based on such an assessment with the aim of retrofitting existing buildings to improve their thermal performance. However, such a scheme would carry considerably high costs – higher than applying the standards to new buildings, and could only be effectively implemented if financing schemes and incentives are provided to the building owners.

Various efforts are being done to tackle existing buildings. The Lebanese Green Building Council and the International Finance Corporation have already launched activities to establish a voluntary green building rating system tailored to Lebanon to evaluate the "greenness" of existing non-residential buildings in comparison to similar buildings nationwide and provide structured guidelines to systematically improve resource and energy efficiency. A sustainable financing system is also being put in place to create incentives for retrofitting initiatives.