MITIGATION ASSESSMENT

LEBANON'S SECOND NATIONAL COMMUNICATION

MINISTRY OF ENVIRONMENT/UNDP

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LIST OF ACRONYMS

AAFRD	Alberta Agriculture Food and Rural Development
ADEME	French Agency for the Environment and Energy Management
ADFD	Abu Dhabi Fund for Development
ADFD	Abu Dhabi Fund for Development
AFESD	Arab Fund for Economic and Social Development
ALI	Association of Lebanese industrialists
AMR	Automatic Meter Reading
ARLA	Assistance to the Re-habilitation of the Lebanese Administration
BIA	Beirut International Airport
BIS	Bureau of India Standards
BRT	Bus Rapid Transit System
BTU	British Thermal Unit
BUTP	Beirut Urban Transport Project
CAS	Central Administration of Statistics
CBD	Convention on Biological Diversity
CCGT	Combined Cycle Gas Turbine
CCTV	Closed Circuit Television
CDM	Clean Development Mechanism
CDR	Council for Development and Reconstruction
CFL	Compact Fluorescent Lamp
CKD	Cement Kiln Dust
DGLMT	Directorate General for Land and Marine Transport
DGUP	Directorate General for Urban Planning
DMC	Distribution Management Center

DOC	Degradable Organic carbon
DSM	Demand Side Management
EDL	Electricité Du Liban
EE	Energy Efficiency
EFL	Environmental Fund for Lebanon
EFR	Effective Fenestration Ratio
EIB	European Investment Bank
EPA	Environmental Protection Agency
EPI	Energy Performance Index
ESCO	Energy Service Company
EU	European Union
FAO	Food and Agriculture Organization
FEED	Frond End Engineering and Design
FEMIP	Facility for Euro-Mediterranean Investment and Partnership
FSRU	Floating Storage and Regasification Unit
GAP	Good Agricultural Practices
GB	Green Buildings
GBA	Greater Beirut Area
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse Gases
GJ	Gigajoule
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit
GWh	Gigawatt hour
GWP	Global Warming Potential

HEV	Hybrid Electric Vehicle
HPC	Hydrofluorocarbon
IFAD	International Fund for Agriculture and Development
IFC	International Finance Corporation
IMF	International Monetary Fund
INC	Initial National Communication
IPCC	Intergovernmental Panel on Climate Change
IPP	Independent Power Producer
IRR	Internal Rate of Return
JAL	Jaiprakash Associates Ltd
KFAED	Kuwait Fund for Arab Economic
KVA	Kilovolt-Ampere.
LBP	Lebanese Pound
LCC	Lebanese Commuting Company
LCEC	Lebanese Center for Energy Conservation
LEAP	Long Range Energy Alternatives Planning System
LEISA	Low External Input Sustainable Agriculture
LENCC	Lebanese Electricity National Control Center
LGBC	Lebanon Green Building Council
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gases
LT	Long Term
LTSB	Lebanese Thermal Standards for Buildings
MD	Medium Term
MENA	Middle East and North Africa

MoA	Ministry of Agriculture
MoE	Ministry of Environment
MoE	Ministry of Environment
MoEW	Ministry of Energy and Water
MoPWT	Ministry of Public Works and Transport
MSC-IPP	Management Support Consultant and Investment Planning Project
MSW	Municipal Solid Waste
MW	MegaWatt
NAP	National Action Plan
NEAP	National Environmental Action Plan
NEEREA	National Energy Efficiency and Renewable Energy Account
NG	Natural Gas
NIMBY	Not In My Back Yard
NPMPLT	National Physical Master Plan of the Lebanese Territory
NRP	National Reforestation Plan
NWFP	Non Wood Forest Protection
OAPEC	Organization of Arab Petroleum Exporting Countries
ODS	Ozone Depleting Substances
OWL	Other Wooded lands
PFC	Perfluorocarbons
PM	Particulate Matter
PV	Present Value
PV	Photovoltaic
RPTA	Rail and Public Transport Authority
SAR	Surface Area Ratio

ST	Short Term
STP	Standard Temperature and Pressure
SWDS	Solid Waste Disposal Sites
SWH	Solar Water Heaters
TJ	Terajoule
TMO	Traffic Management Organization
TMS	Traffic Management System
TOU	Time Of Use
TSP	Total Suspended Particles
UN	United Nations
UNDP	United Nations Development Programme
UNFCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
UN-REDD Programme	United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation
UoA	University of Alberta
USAID	United States Agency for International Development
US CARS	US government's Car Allowance Rebate System
USD	US dollars
UTDP	Urban Transport Development Project
UTDP	Urban Transport Development Plan
VFD	Variable frequency drive
WB	World Bank

I. OVERVIEW OF GHG EMISSIONS BY SECTOR

1.1. INTRODUCTION

The Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCC) has determined six Greenhouse Gases (GHG) to be controlled, namely Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), Hydrofluorocarbon (HFC), Perfluorocarbons (PFC) and Sulfur hexafluoride (SF_6). In spite of the high Global Warming Potential's emissions (GWP)[1] of SF6, HFC and PFC (Table 1-1), their contribution is less significant in Lebanon. The following factors contribute to the lesser important emissions of these gases:

- SF_6 has been imported in a limited quantity every two years since 2002, and is used in Lebanon in double-glazed sound proof windows.
- HFCs (HFC and PFC) are used in Lebanon as alternatives to Ozone Depleting Substances (ODS) in the domestic and commercial refrigeration. In Lebanon, there is no HFCs production; they were first introduced in the country in1996.

Table 1-1 Global Warming Potential's emissions of the six Greenhouse Gases

Gas	GWP
CO_2	1
CH_4	21
N_2O	310
HFCs	140 – 11700
PFCs	6500 – 9200
SF_6	23900

The GHG emissions in Lebanon, prepared for the years 2000 to 2004 inclusive, show that the largest contributor to global warming is CO2 with 84 percent of the total GHG emissions in 2004; CH4 contributed 12 percent and N_2O 4 percent (Figure 1-1)

Lebanon's First National Communication was submitted in 1999; it included a GHG inventory based on the year 1994; concerning the years 1995 to 1999, GHG emissions were not registered. GHG are

1 The GWP is an index that compares the relative potential of the greenhouse gases to contribute to global warming. The additional heat/energy impact of all greenhouse gases are compared with the impacts of carbon dioxide (CO2) and referred to in terms of CO2 equivalent (CO2eq)

generally measured in Gigagrams (Gg = 10^9g) or Megatons (Mt = 10^{12}g) of carbon dioxide (CO_2) or CO_2 equivalent (CO_2-e)[2] for the other GHGs. In Lebanon, since emissions of HFCs and SF_6 are very low (as stated above), the following equation has been used to calculate the GHG emissions:

$$\text{Total GHG emissions} = \text{CO2 emissions} + \text{CO2equivalent (CH4)} + \text{CO2 equivalent (N2O)}$$

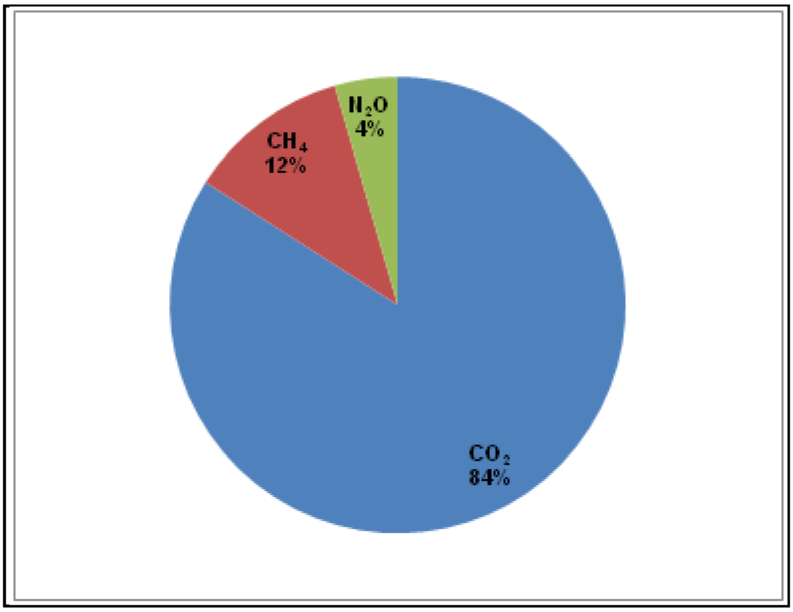

Figure 1-1 Percentage of GHG emissions (CO2 equivalent)

The long term total GHG emissions trend is an increasing one with emissions in 2004 being 42 per cent above the 1994 total of 14,255 Gg. They have attended a peak of 20,299 Gg of CO2-e where the largest contributor was the energy sector with nearly 74 per cent of the total emissions in 2004 (Figure 1-2).

2 The universal unit of measurement used to indicate the global warming potential (GWP) of each of the 6 greenhouse gases. It is used to evaluate the impacts of releasing different greenhouse gases.

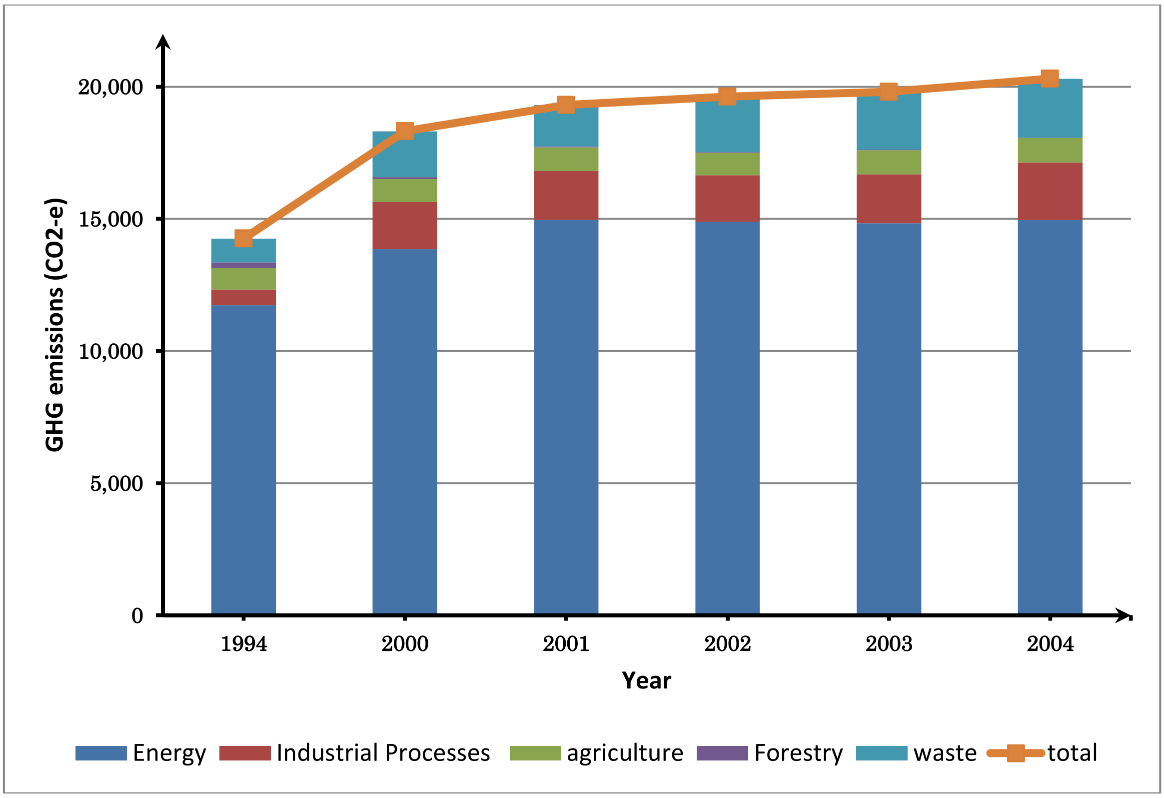

Figure 1-2 GHG emissions trend by sector

1.2. EMISSION TRENDS BY GAS

1.2.1. CO_2 Emissions

The predominant source of anthropogenic CO_2 emissions is the combustion of fossil fuels. The Energy sector is the main CO_2 emitter since 1994; it contributes to more than 87% of CO_2 emissions in Lebanon. Hence it influences the CO_2 trend as it is obvious in the graph below (Figure 1-3). Industrial processes contribute in the CO2 emission but this sector is less important relatively to the Energy sector, therefore it affects less the overall CO_2 trend.

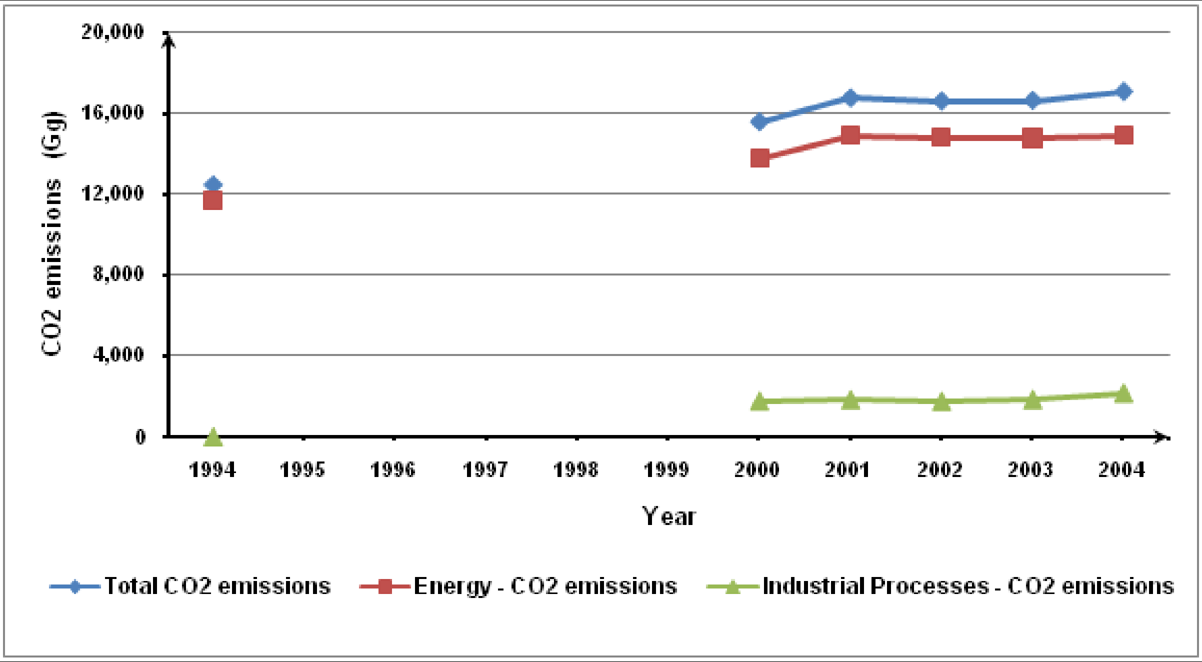

Figure 1-3 CO_2 emission trend by sources

1.2.2. CH_4 emissions

CH_4 emissions have more than doubled since 1994 according to the available data of GHG emissions estimates. The overall trend of CH_4 emissions is an increasing one since 1994 where emissions reached a peak of 111 Gg in 2004 (Figure 1-4). The waste sector is the principal contributor of CH_4 emissions with a share of more than 90% of the total methane emissions in Lebanon since 2002. CH_4 emissions from solid waste disposal are the largest source of GHG emissions in the waste sector.

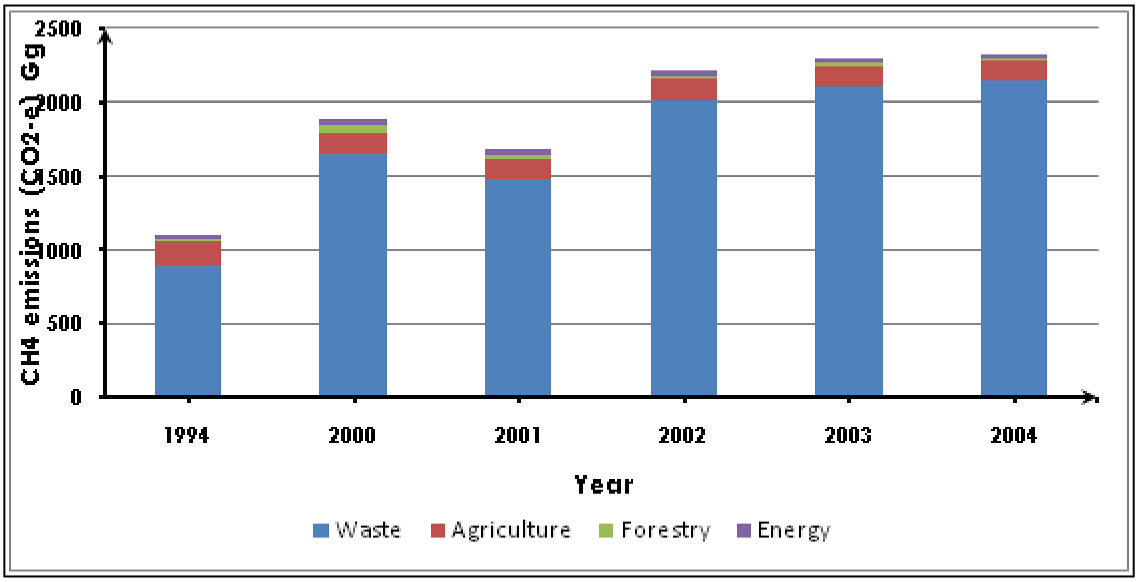

Figure 1-4 Total CH_4 emissions trend by sources

1.2.3. N_2O emissions

N_2O emissions contribute approximately to an average of 4% of the total GHG emissions. They have reached a peak of 906 Gg of CO_2-eq in 2004 (Figure 1-5). Around 87 per cent of the N_2O emitted are from the agriculture sector especially from the management of agricultural soil. Other sectors contribute in the N_2O emissions such as the wastewater handling and manure management but they have less influence on the N_2O emission trend.

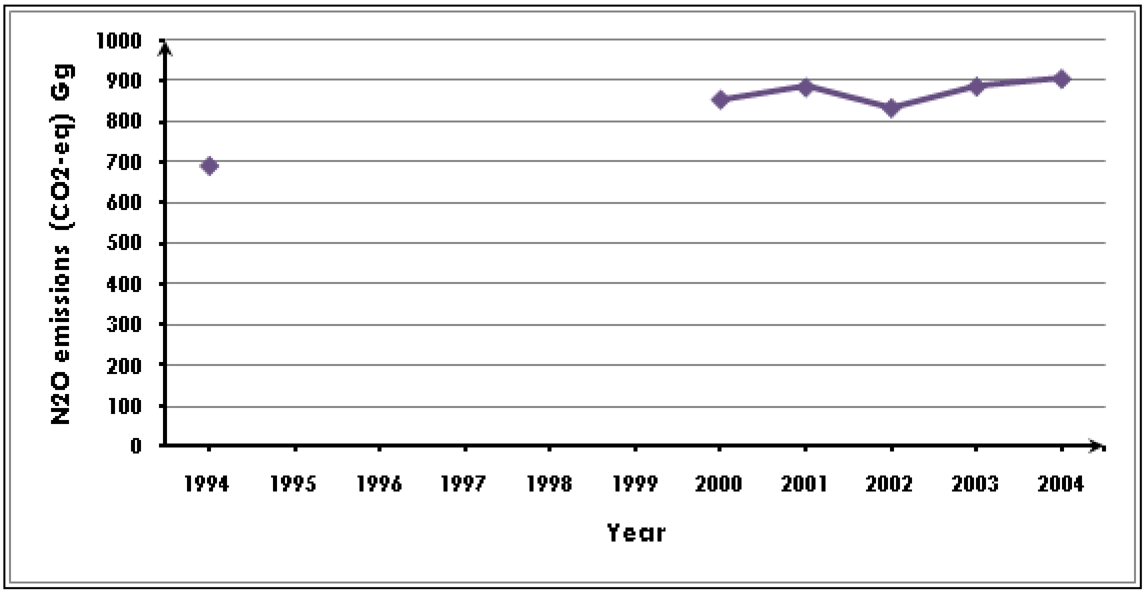

Figure 1-5 Total N_2O emissions trend

1.3. EMISSIONS TRENDS BY SOURCE

1.3.1. Energy

Energy-related activities were the primary sources of Lebanon anthropogenic GHG emissions accounting for 73.7 percent of total emissions on a carbon equivalent basis in 2004. This included 84, 11.5 and 4.5 percent of the nation's CO_2, CH_4 and N_2O emissions respectively. Major sources include power stations, road transport and combustion from industrial sources as well as from residential and commercial sources. Emissions from Fossil Fuel Combustion (IPCC Source Category 1A) comprise the total emissions of energy-related activities, with CO_2 being the primary gas emitted. Fossil Fuel combustion also emits CH_4 and N_2O, as well as ambient air pollutants such as nitrogen oxides (NO_x), carbon monoxide (CO), sulphur dioxide (SO_2) and non-methane volatile organic compounds (NMVOCs). In this sector, GHG emissions mainly depend on the amount of carbon in fuels, hence the type of fuel. The major fuel types used in Lebanon are: gasoline, gas oil, diesel oil, fuel oil, jet kerosene, Liquefied Petroleum Gases (LPG), Bitumen, coking coal and wood.

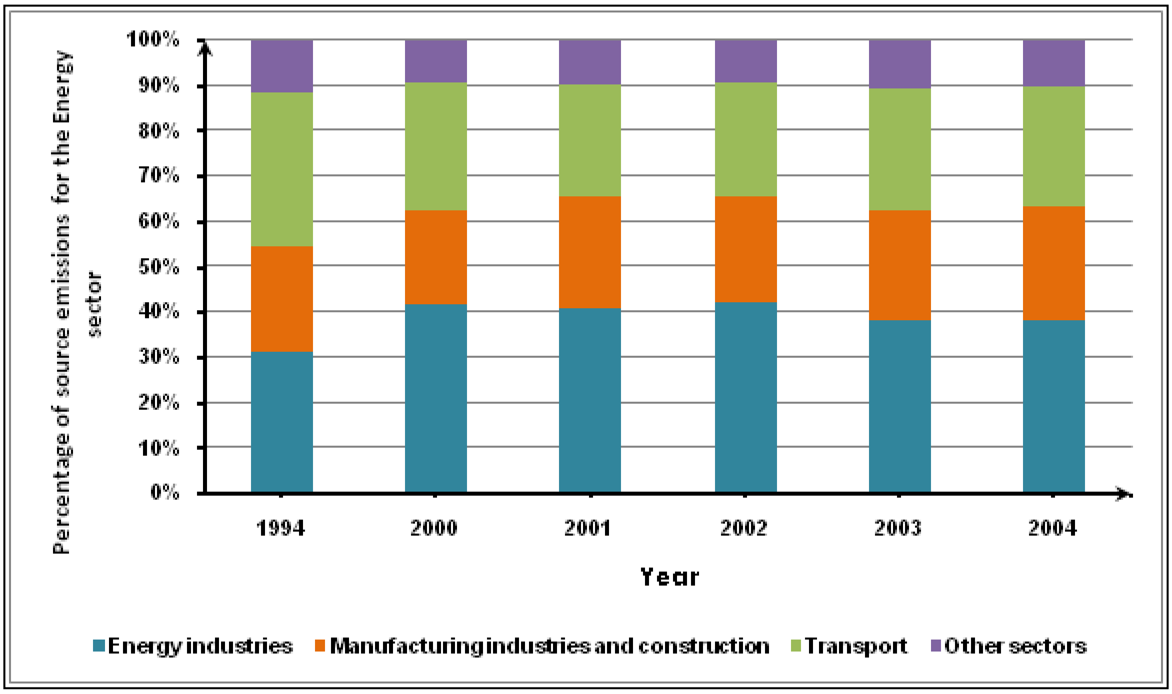

Figure 1-6 Percentage of source emissions for the Energy sector over the years

<u>Energy industries</u> include electricity generation, the use of fossil fuels for petroleum refining, and heat plants among others, but in Lebanon it is limited to electricity generation. Electricity generation accounted for the largest share of GHG emissions from fossil fuel combustion, approximately 38 per cent in 2004 (Figure 1-6). The main fuel types used are Gas/diesel oil and fuel oil.

<u>Manufacturing industries and construction</u> covers the use of fossil fuels by industrial processes, including the use of fuels to generate electricity in cases where the generation of electricity is not the principal activity of the process operator (auto-generators). Emissions from Manufacturing Industries and Construction are composed of CO_2, SO_2, CO, NO_x and less than 1% of CH_4, N_2O and NMVOCs. The main fuel types used in the manufacturing industries and in construction are Gas/diesel, oil fuel, LPG and coking coal. This category accounted for 25 per cent of GHG emissions from fossil fuel combustion in 2004 (Figure 1-6) resulting from the direct consumption of fossil fuels for stream and process heat

production of from the consumption of electricity for uses as motors, electric furnaces, ovens and lighting.

Transport reports emissions from road transport, aviation (civil and international) and shipping where road transport is by far the largest contributor. Road transport includes all types of light-duty vehicles such as automobiles and light trucks, and heavy-duty vehicles such as tractor trailers and buses, and on-road motorcycles. Transport accounted for 26 per cent of GHG emissions from fossil fuel combustion in 2004 (Figure 1-6). The main fuel types are gasoline, diesel oil and kerosene (for aviation). Emissions from transport are composed of CO_2, CH_4, N_2O, CO, NO_x, SO_2, particulate matter (PM) and NMVOCs.

Other sectors include emissions from the fuel consumption of the institutional/commercial buildings, residential buildings (households) and from the fuel consumption of the agriculture, fishing and forestry sector such as the off-road transport. Emissions are composed mainly from CO_2, CO, NOx SO_2, NMVOCs CH4 and N2O and they count around 10 per cent of GHG emission from the fossil fuel combustion in 2004 (Figure 1-6).

1.3.2. Industrial processes

The processes addressed in this sector include mostly cement production as well as lime manufacture, glass, steel and ceramics production and soda ash/lubricants, and paraffin wax use. GHG emissions are produced from the industrial process itself and are not directly a result of energy consumed during the process. They are the by-product of the various non-energy related industrial activities. Since 1994, the GHG emissions trend has been an increasing one; in 2004, industrial processes generated emission of 2,178 Gg of CO_2-e where the main GHG released is CO_2 or 10.7 percent of total GHG emissions (Figure 1-7).

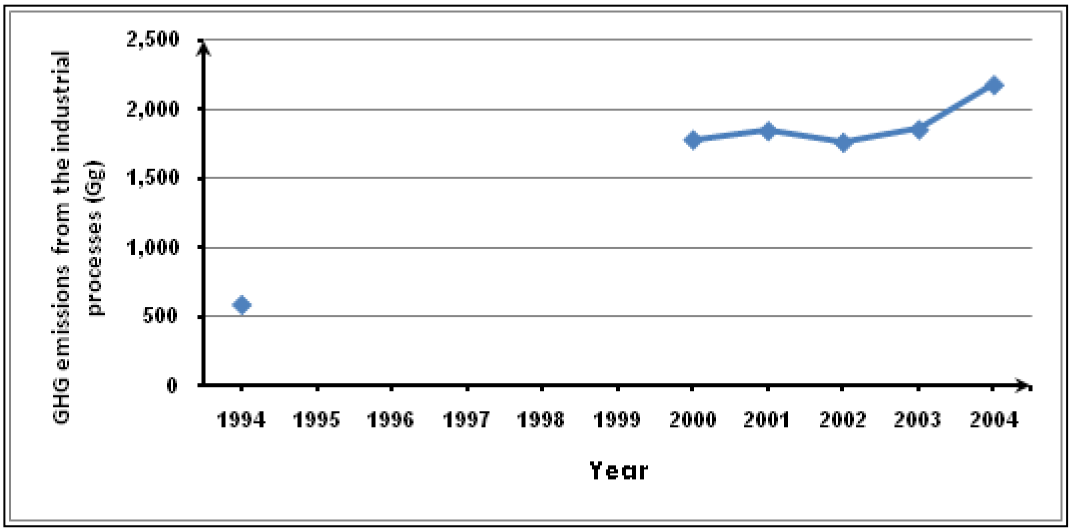

Figure 1-7 GHG emissions from the industrial processes sector from 1994 to 2004

1.3.3. Agriculture

Emissions from this sector represent essentially non-carbon dioxide emissions from different source categories mainly enteric fermentation in domestic livestock, livestock manure management, agricultural soil management and field burning of agricultural residues.

The GHG emissions trend for agriculture has been stable fluctuating between 800 and 900 Gg. In 2004, agriculture sector was responsible for emissions of 925 Gg CO2-e or 4.6 per cent of total GHG emissions (Figure 1-8). Methane (CH_4) and Nitrous oxide (N_2O) were the primary GHG emitted by agriculture activities. Methane emissions from enteric fermentation and manure management represent about 6 per cent of total CH_4 emissions from anthropogenic activities. Agricultural soil management activities, manure management and field burning of agricultural residues were sources of N_2O emissions, accounting for 85 percent of GHG emissions from the agriculture sector.

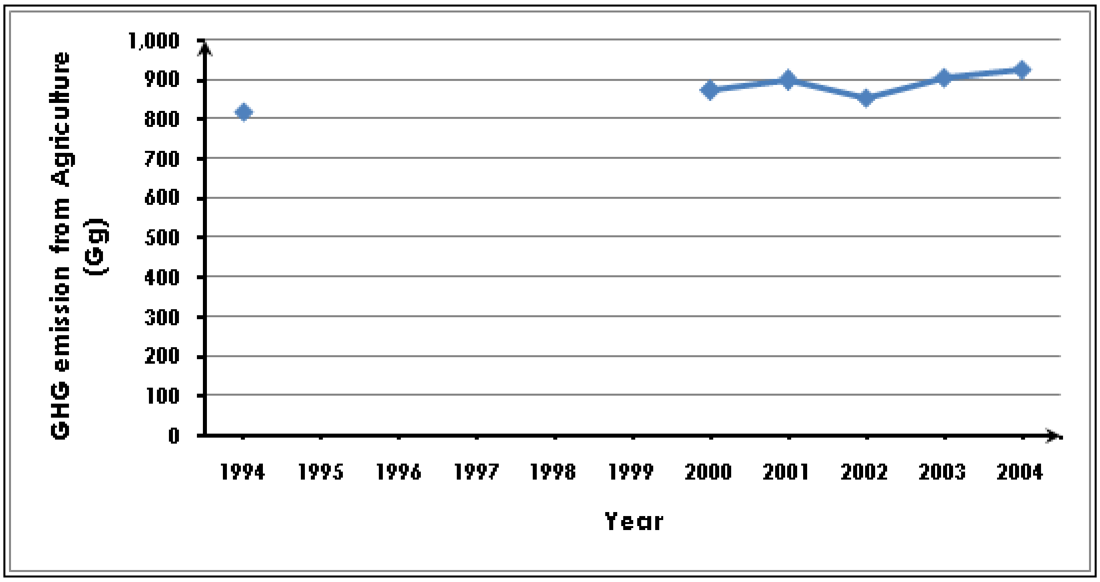

Figure 1-8 GHG emissions from Agriculture from 1994 to 2004

1.3.4. Land Use Change & Forestry

This sector provides an assessment of the net greenhouse gas flux resulting from forest lands, croplands and settlements. GHG flux has been estimated for the following categories changes in forest and other woody biomass stocks and forest and grassland conversion. Land use change and forestry activities in 2004 resulted in a net carbon sequestration of 605 Gg CO_2–e. The GHG emissions trend for the Land Use Change and Forestry Sector is a decreasing one since 1994 as this sector is a major sink of GHG (Figure 1-9).

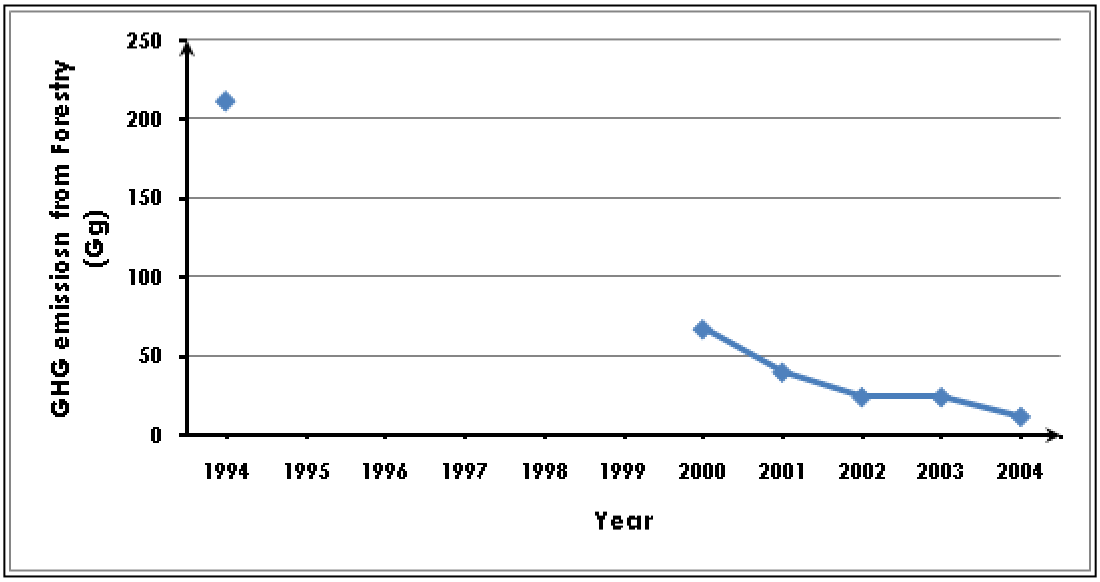

Figure 1-9 GHG emissions from Forestry from 1994 to 2004

1.3.5. Waste

The categories assessed in this sector are the solid disposal site, solid waste incineration and wastewater handling. Landfills are the largest source of anthropogenic methane (CH_4) emissions, accounting for 90 percent of total CH_4 emissions. Smaller amounts of CH_4 are emitted from wastewater systems; wastewater treatment systems are also a potentially significant source of nitrous oxide (N_2O) emissions. The GHG emissions trend for waste has more than doubled since 1994 to reach a peak in 2004 of 2,227 Gg CO_2–e accounting for 11 percent of total GHG emissions (Figure 1-10).

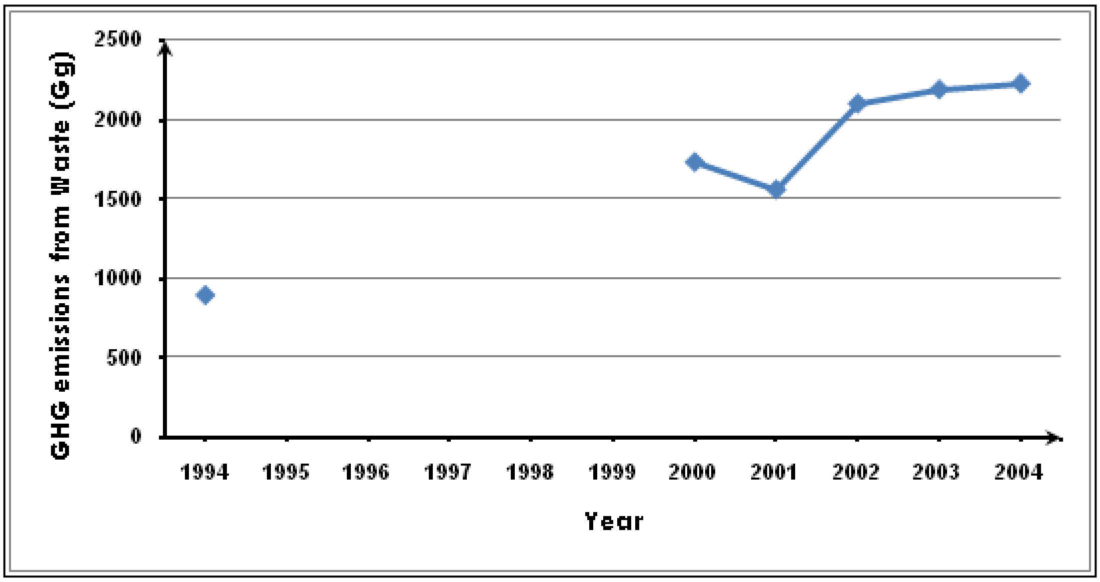

Figure 1-10 GHG emissions from Waste from 1994 to 2004

2. MITIGATION MEASURES FOR THE ENERGY SECTOR

2.1. ELECTRICITY

2.1.1. Background

Electricity in Lebanon is supplied through Electricité du Liban (EDL) that is responsible for the generation, transmission, and distribution of electrical energy in Lebanon (EDL, no date). The sector has faced many challenges and difficulties, mainly the inability of meeting demand over the last few decades, as well as a considerable deficit necessitating continuous government transfers.

Indeed, total production by existing power plants does not meet actual demand: the peak electric load in Lebanon climbed from 1,510 MW in 1998 to 1,936 MW in 2004 (OAPEC, 2005). Average demand in 2009 was 2,000-2,100 MW, with an instantaneous peak of 2,450 MW in summer (MoEW, 2010). Consumption reached 10,249 GWh in 2004 (OAPEC, 2005). Taking into account self-generation, the peak load and consumption in 2004 are estimated at 2,575 MW and13, 841 GWh respectively (World Bank, 2008).

As for generation, electricity is produced through 7 power plants of which 6 are owned by EDL and one is owned indirectly by the Establishment (the Hreysheh Concession); and five hydroelectric power plants. According to the Policy paper for the electricity sector, thermal power plants' installed capacity is about 2,038 MW and available capacity amounts to1,685 MW of installed capacity (MoEW, 2010). This capacity is generated using fuel oil in all thermal power plants. Only recently (in October 2009) did natural gas reach the Deir Aamar power plant in the North equipped with Combined Cycle Gas Turbine (CCGT) technology, such that around 217 MW are now produced using natural gas. Since power plants mainly operate on fuel oil and given the increase in oil prices during the last decade, coupled with other constraints, EDL has been in a state of drastically increasing deficit for decades. This has necessitated government transfers to EDL to reachLBP 2,430 billion (USD 1.6 billion) in 2008, which translates roughly to USD 400 per person per year. If total expenditures are taken into account, transfers to EDL constitute the third largest public expenditure item, after interest payments and personnel cost (MoF, 2010).

Hydropower plants' installed capacity currently amounts to 274 MW, while available capacity amounts to190 MW; accounting for 4.5% of total power production in 2009 (MoEW, 2010) without taking into consideration self-generation (3.4% if self-generation is accounted for).

Electricity demand met by EDL grew from 7,839 GWh in 2000 to 10,124 GWh in 2005 based on EDL's official annual statistics (Figure 2-1).

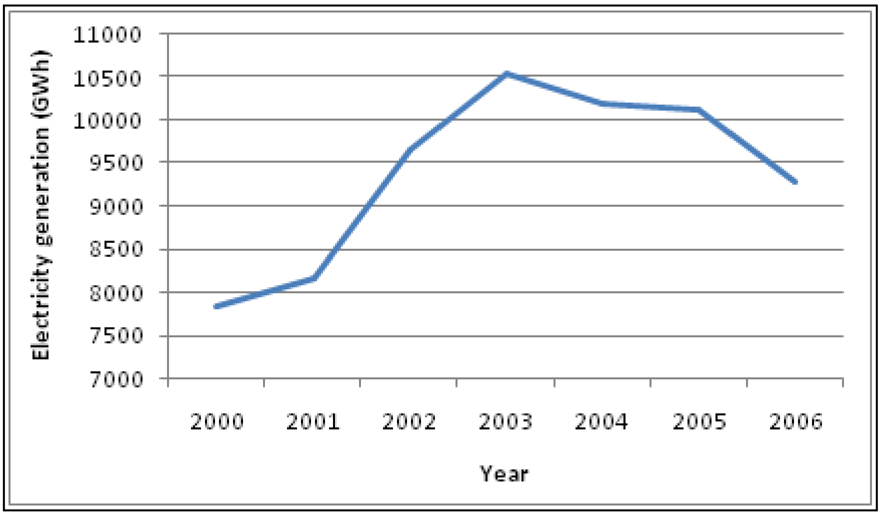

Figure 2-1 Electricity generation from 2000 to 2006

Source: EDL Official Annual Statistics 2000 to 2006

In addition, technical losses are reported to be in the order of 15%, according to EDL (World Bank, 2008 and MoEW, 2010).

The inability of EDL to meet the existing demand creates a deficit that has led throughout the years to the import of electricity from Syria and later from Egypt -as of Oct 2009, in addition to private self-generation in order to complement the existing supply and reduce suppressed demand.

According to EDL Official Annual Statistics, Lebanon imported up to 200 MW in 2006 from Syria; this figure has increased as of 2009 due to imports from Egypt. Imports represented around 7.5% of the electricity supplied by EDL in 2009, and this value which is closer to most years was adopted in this chapter, since it was found to be more representative). If self-generation is accounted for, imports represent around 5% of total generation.

As for self-generation, it accounts for around 33% of total demand. Self-generation also incurs an additional 25% in spending on electricity per month (World Bank, 2008).

2.1.2. Baseline Scenario

This section presents an overview of the latest plan for the Electricity sector in Lebanon, and the baseline scenario and associated emissions between 2004 (baseline year) and 2030.

2.1.2.1. Relevant Plans and Strategies

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. Following are the main components of MoEW's latest policy paper for the Electricity sector released in June 2010, endorsed by the Council of Ministers and 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):

Infrastructure

GENERATION

The generation policy targets a total installed capacity of 4,000 MW by 2014 and 5,000 MW thereafter to meet a load of 2,500 MW (recorded in summer 2009), 500 MW of demand not currently supplied (i.e., self-generation), future demand corresponding to an annual load growth of 7%, and around 15% of peak load reserve. This can be achieved through:

- The possibility of renting 250 MW (barges, small generators or imports) between 2010 and 2013; the values figuring in the plan and those adopted for the current analysis are shown in Table 2-1 below:

Table 2-1 Additional rental capacity

ITEM	Capacity (MW)	Values adopted for the analysis (MW)
Barges	110-280	150
Import from Turkey	100-150	100

- Rapid increase of the installed capacity by 600-700 MW using CCGT and/or Reciprocating Engines starting end of 2010/ beginning of 2011 and over a period of 3 years. The values adopted in this analysis were: 1) 400 MW additional capacity from CCGT to be operational as of 2013; and 2) 300 MW from reciprocating engines operating on diesel to be operational as of 2013.
- Rehabilitating, maintaining, replacing, or upgrading existing plants to increase their overall capacity by about 245 MW (Table 2-2).

Table 2-2 Rehabilitation and upgrading of existing thermal power plants

ITEM	IMPLEMENTATION (TENTATIVE)	CAPACITY (MW)	BUDGET (MILLION $)	ITEM
	From year	To year		
Rehabilitate Zouk, Jieh	2011	2015	~100	180
Upgrade Deir Ammar	2011	2013	75	108
Add CC to Tyre, Baalbeck	2011	2012	70	130

This component was translated as an improvement of oil-fired power plant efficiency from 36.5% to 53% in 2015.

- 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. For the purpose of the current analysis, it was assumed that the immediate 1,500 MW would be distributed as 1,000 MW CCGT and 500 MW oil-fired to be operational in 2014. Then another 1,000 MW of CCGT would be added and operational in 2020.

- Increasing the share of hydraulic power production between 2012 and 2015 through maintenance, rehabilitation and/or replacement of existing hydropower plants, and facilitating the implementation of additional capacity on a BoT basis, with storage dams (no less than 120 MW according to EdF draft Master Plan, to be added in the mid-term (40MW) and long term (80 MW)). In the current analysis, it was assumed that hydropower capacity would increase from 274 MW in 2004 to 310 MW in 2015 and 400 MW by 2020.
- Introducing wind power via the private sector by building wind farms (60-100 MW) between 2011and 2013. In the current analysis, the introduction of 80 MW of wind power was adopted in 2015, with an average growth rate of 8% per year (reaching 253.8 MW in 2030).
- Encouraging the private sector to adopt the technologies of "waste to energy" for power generation and investigate in geothermal energy in order to add a capacity of 15-25 MW between 2013 and 2014. In the current study, it was assumed that waste to energy was more feasible in the short term, such that 20 MW would be introduced by 2015, with an average growth rate of 8% per year (reaching 63.4 MW in 2030), which is in accordance with the capacity generation from waste advocated in the solid waste mitigation chapter.

TRANSMISSION

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

- Completing the 220 kV loop in Mansourieh in 2010.
- Completing the infrastructure at the 400 kV Ksara substation for the Arab interconnection.
- Completing the Lebanese Electricity National Control Center (LENCC) in 2011.
- Building regional substations, reinforcing the existing system to reduce technical losses and remove bottlenecks, and expanding the transmission system to increase evacuation capacity in accordance with the increase in generating capacity.

DISTRIBUTION

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

- Improving the distribution services in 2010 and equalize respectively the supply and collection between regions in order to reinforce collection and limit all types of theft and losses.
- Implementing a transparent bidding process to subcontract the improvement of the quality of distribution services (Upgrade/ rehabilitation of the distribution system) while adhering to performance benchmarks that would lead to progressively higher revenues between 2011 and 2014.

- Developing simultaneously a center able to monitor automatic meter reading, perform remote connection/ disconnection of supply and demand management functions and its reduction. The implementation of this component would take place between 2012 and 2014.
- Introducing new services and payment facilities for consumers, and adopt new tariff structures and mechanisms (feed-in tariff, prepaid cards, net metering, etc.).
- Envisaging the possibility of developing a Distribution Management Center (DMC) to be implemented between 2012 and 2014.

A. Supply and Demand

FUEL SOURCING

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

- Studying and developing an infrastructure plan to supply and distribute natural gas based on the land pipeline in Beddawi and LNG marine station(s), and interconnect them with the power plants, thus providing a flexible and stable supply of natural gas.
- Gradually converting/ building power plants on natural gas while diversifying the sources of supply though contracts from Turkey, former Soviet republics, Russia, Syria, Egypt (with whom the gas agreement needs to be finalized), Qatar, Algeria, etc., while emphasizing the potential of finding natural gas in the territorial waters of Lebanon (a relevant draft law for extraction has been prepared by the MoEW).
- 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 (onshore and sub-marine where necessary) to feed all power plants from Beddawi to Tyre to reduce their operating costs. The project will be implanted between 2011 and 2013.

RENEWABLE ENERGY

The main goal is to reinforce all public, private and individual initiatives to adopt the utilization of renewable energies so as to reach 12% of electric and thermal supply, through:

- Completing a wind atlas for Lebanon and launch IPP wind farms with the private sector (2010).
- Starting a prefeasibility study on Photovoltaic (PV) farms.
- Encouraging public and private sectors to adopt incineration technologies to produce electricity from waste.
- Encouraging all individual and private initiatives to produce hydropower, even micro-hydro.

DEMAND SIDE MANAGEMENT / ENERGY EFFICIENCY

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

- Adopting the Energy Conservation law, institutionalizing the Lebanese Center for Energy Conservation (LCEC) and launching a national plan for energy conservation in 2010.
- Widely spreading the use of Compact Fluorescent Lamp (CFL) starting 2010, with the aim of banning energy guzzling devices in the future.
- Increasing the penetration of Solar Water Heaters (SWH) and devising innovative financing schemes in collaboration with the banking sector to achieve the slogan "A solar heater for each household".
- 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 dealing with energy audit applications, as a national financing mechanism.

The implementation of LCEC/CFL/SWH/ public lighting projects would take place between 2010 and 2014.

TARIFFS

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

- Gradually increasing tariff in conjunction with improvements in the electric service provision until reaching the goal of a sustainable 24-hour electric service, hence eliminating the need for private generators and abolishing the financial deficit.
- Adopting special tariffs and fees for low income consumers and productive sectors.
- Implementing Time of Use (TOU) tariffs (e.g., night reduced) in conjunction with the implementation of Automatic Meter Reading (AMR) schemes.

B. Legal Framework

NORMS AND STANDARDS

The objective of this policy consists of setting norms and standards for the provision of electric services that are safe, equitable and fair with the best quality and lowest cost, through:

- Resolving the problems with the current concessions through a fair and equitable compromise.
- Developing rules and laws that promote the largest penetration of "Green Buildings (GB)" and "Energy Efficiency (EE)" in collaboration with concerned institutions.
- Comply and respect international norms and standards in the energy efficiency, environmental and public safety domains.

This will be based on intelligent systems (SmartGrid) in order to position Lebanon to the highest regional and international level in the electric arena.

CORPORATIZATION OF EDL

The success of this policy necessitates the "revitalization" of EDL because it is the core entity of the sector. This entails providing the financial, administrative and human resource flexibility needed to cope with the rapid and vital changes. According to this plan, to achieve this goal corporatization is the ideal solution, through:

- Increasing the human resource capacity of EDL by direct and gradual hiring and by relying on the private sector using outsourcing contacts for the various positions.
- Updating the legal due diligence needed to corporatize EDL as per the three functions of generation, transmission and distribution.
- During the transition phase, MoEW will take measures to relieve EDL of certain responsibilities using Service Providers, independent power production, Operation & Maintenance (O&M) contracts in such a way that EDL will become responsible for overseeing, supervising and administering these contracts in addition to the transmission and existing production.

LEGAL STATUS

This component covers:

- Initiating the process of revising Law 462 with concerned parties, in order to:

Introduce the necessary amendments to Law 462 after correcting its deficiencies and contradictions;

Prepare and approve all the execution decrees of the amended law, including the development of the regulatory, organizational and operational requirements; and

Complete the process with the associated recruitment and procurement procedures.

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

2.1.2.2. Projected Emissions

Since several plans have been formerly developed and endorsed without being effectively implemented, and since the implementation of the plan developed in 2010 has not started as planned, as a baseline scenario it is considered that the current trend will continue until 2030, specifically:

- Demand exceeding generation;
- Heavy reliance on self-generation that will continue to constitute around 33% of total demand; and
- Oil and diesel as the main fuels in power plants and private generators (oil-fired power plants alone will constitute 50% of total capacity).

Table 2-3 summarizes the data and assumptions used for the baseline scenario of the Electricity sector, based on the studies cited in this chapter, the 2010 policy paper for the Electricity sector, and expert judgment for variables that do not have documented values. These were entered into LEAP, and IPCC Tier 1 emission factors were used in the calculation of relevant emissions. It should be noted that the emission factor used for electricity generation from diesel in LEAP is the same as for oil according to these emission factors. Thus, oil-fired power plants and diesel generators were assumed to have the same emission factors, even though this assumption leads to differences in total emissions when compared to the GHG inventory results.

Moreover, the value of 500 MW reported for self-generation in the Policy Paper for the Electricity sector was found to be too low compared to the 33% estimate provided by the World Bank (2008), and so was inflated to 1,000 MW for this analysis.

As for the dispatch of power plants, it was set to be by process share for all technologies except hydropower, solar, wind, and waste-to-energy technologies for which it was set in proportion to available capacity.

Table 2-3 Data and assumptions used in the development of the baseline scenario

	EXOGENOUS CAPACITY (MW)	EFFICIENCY (%)	AVAILABILITY (%)
2004	**2030**	**2004**	**2030**
2,038	**3,500**	**36.5**	**40**
0	**0**	**35**	**35**
0	**518**	**48**	**48**
274	**274**	**100**	**100**
0	**0**	**100**	**100**
0.5	**0.5**	**15**	**15**
0	**0**	**90**	**90**
200	**392**	**100**	**100**
1,000	**2,310**	**35**	**35**
3,512.5	**6,994.5**	**-**	**-**

The breakdown of the total installed capacity of power plants in Lebanon under the baseline scenario is illustrated in Figure 2-2.

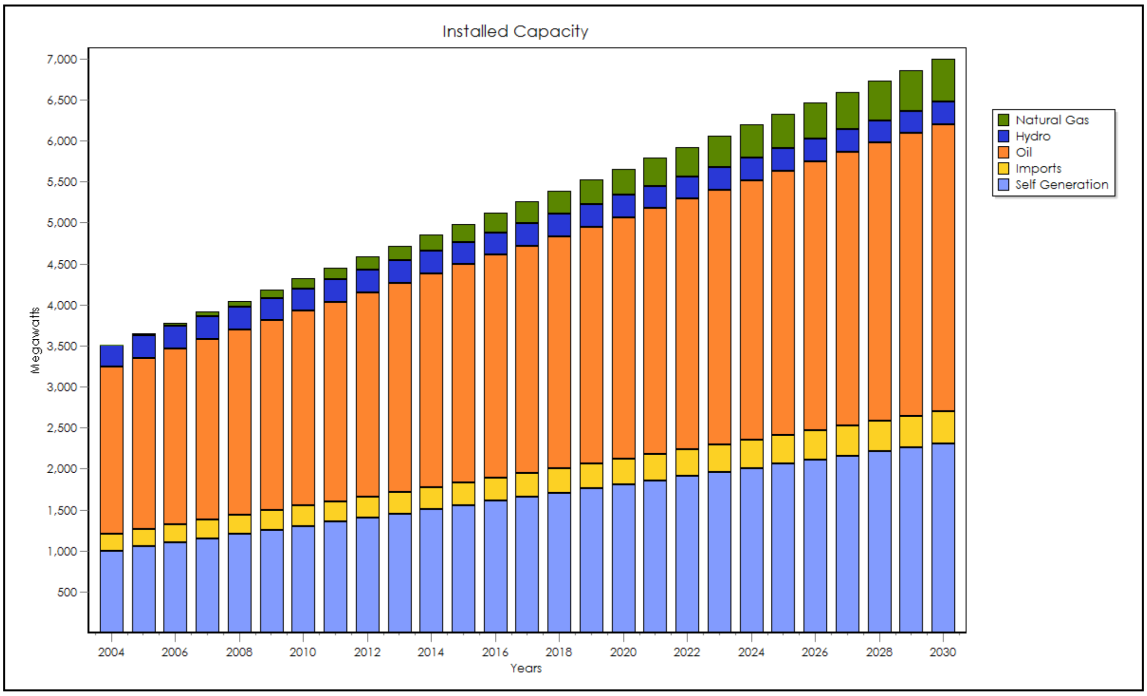

Figure 2-2 Breakdown of total installed capacity under the Baseline scenario

Based on the values in Table 2-3, GHG emissions for the year 2004 amount to around 7,261 Gg of CO_2 equivalents, which is lower than the value obtained in the GHG inventory (5,685 + 3,738 = 9,423 Gg CO_2 equivalents from energy industries as well as manufacturing industries and construction which account for self-generation, as per Section … on the GHG inventory). The difference can be attributed to several factors, including:

- Differences in the approach used for calculating GHG emissions (based on fuel consumption in the inventory versus power plant technology and capacity in LEAP);
- Differences in the efficiencies of power generation, especially for self-generation, that were considered as a lump sum in the inventory calculations, in contrast to specific process efficiencies in LEAP;
- Differences in emission and conversion factors; for instance, LEAP uses the same emission factor for diesel and oil processes, in contrast to the GHG inventory.

As for projected emissions between 2004 and 2030, they are expected to reach 32,569 Gg CO_2 equivalents by 2030 under the baseline scenario, including self-generation (Figure 2-3); the emissions from the electricity imports from neighboring countries are not reported as they do not account for national emissions.

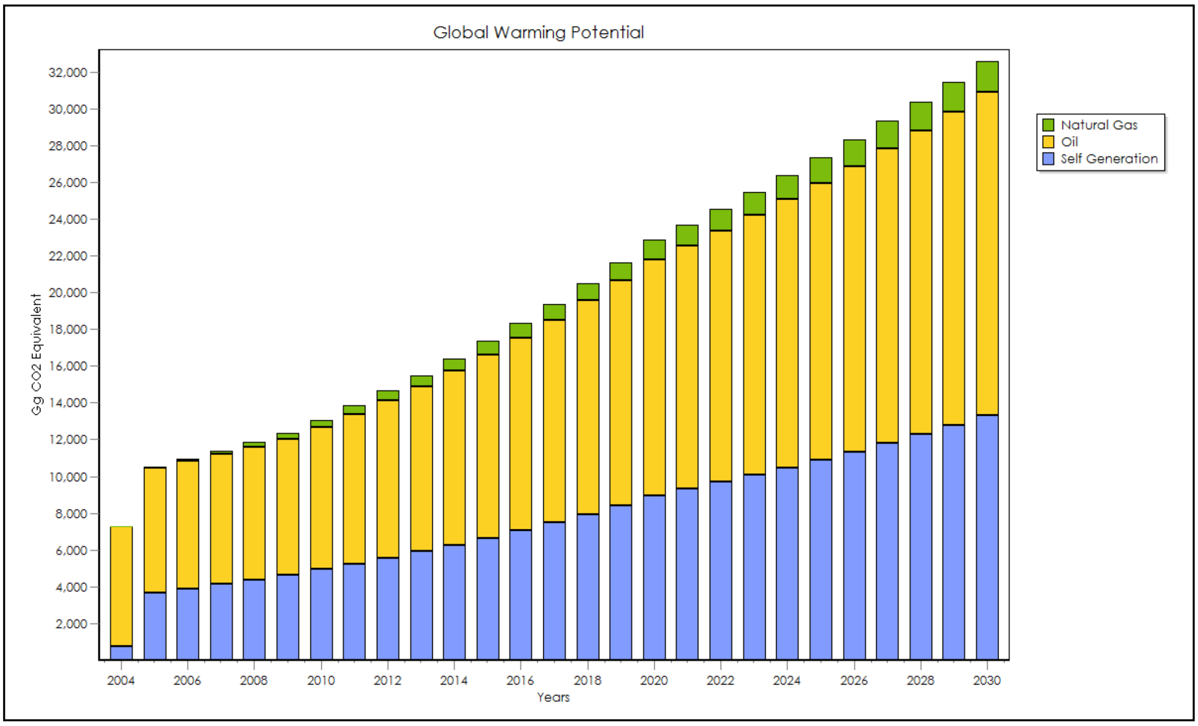

Figure 2-3 GHG emissions from the Electricity sector under the baseline scenario

2.1.3. Mitigation Scenarios

2.1.3.1. Mitigation scenarios selected

Two mitigation scenarios were considered and analyzed for the Electricity sector, as presented below.

Mitigation scenario 1: Implementation of MoEW's latest policy paper for the Electricity sector, in addition to capacity expansion post-2015 to keep up with demand.

Since the implementation of the sector policy paper did not start as planned in summer 2010, like most previous plans, the first scenario will be considered to consist of the implementation of this plan that looks at the 2015 horizon, together with capacity expansion of power plants (around 3,500 MW between 2015 and 2030 based on the 2/3 natural gas fuel mix, in addition to renewable energy) to keep up with the increasing demand until 2030. The fraction of renewable energy technologies would reach 11.4% by 2030, which is a conservative estimate.

The data and assumptions for this scenario are summarized in Table 2-4. It is worth noting that availability figures do not change in the mitigation scenarios, and thus they were not included in Table 2-4 and Table 2-5.

Table 2-4. Data and assumptions for Mitigation Scenario 1

	Exogenous capacity (MW)	Efficiency (%)
Oil	2004: 2,038 2014: 2,538 2030: 1,230	2004: 36.5% 2015: 53%

	Exogenous capacity (MW)	Efficiency (%)
Diesel	2004: 0 2011: 150 2013: 450 2014: 300 2020 - 2030: 0	90
NG	2004: 0 2009: 217.5 2013: 617.5 2014: 1617.5 2020: 2,617.5 2030: 4,690	48
Hydro	2004: 274 2015: 310 2020 - 2030: 400	100
Wind	2004: 0 2015: 80 2030: 253.8 (8% growth as of 2016)	100
Solar	2004: 0.5 2015: 0.5; 2020: 50; 2030: 81.4 (5% growth between 2021 and 2030)	100
MSW	2004: 0 2015: 20 2030: 63.4 (8% growth as of 2016)	90
Imports	2004: 200 2011: 300 2030: 300	100
Self-Generation	2004: 1,000 2015: 0; 2030: 0	35
Total in 2030: **% renewable energy:**	7,019 MW 11.4%	

The breakdown of total installed capacity of power plants under Mitigation scenario 1 is illustrated in Figure 2-4.

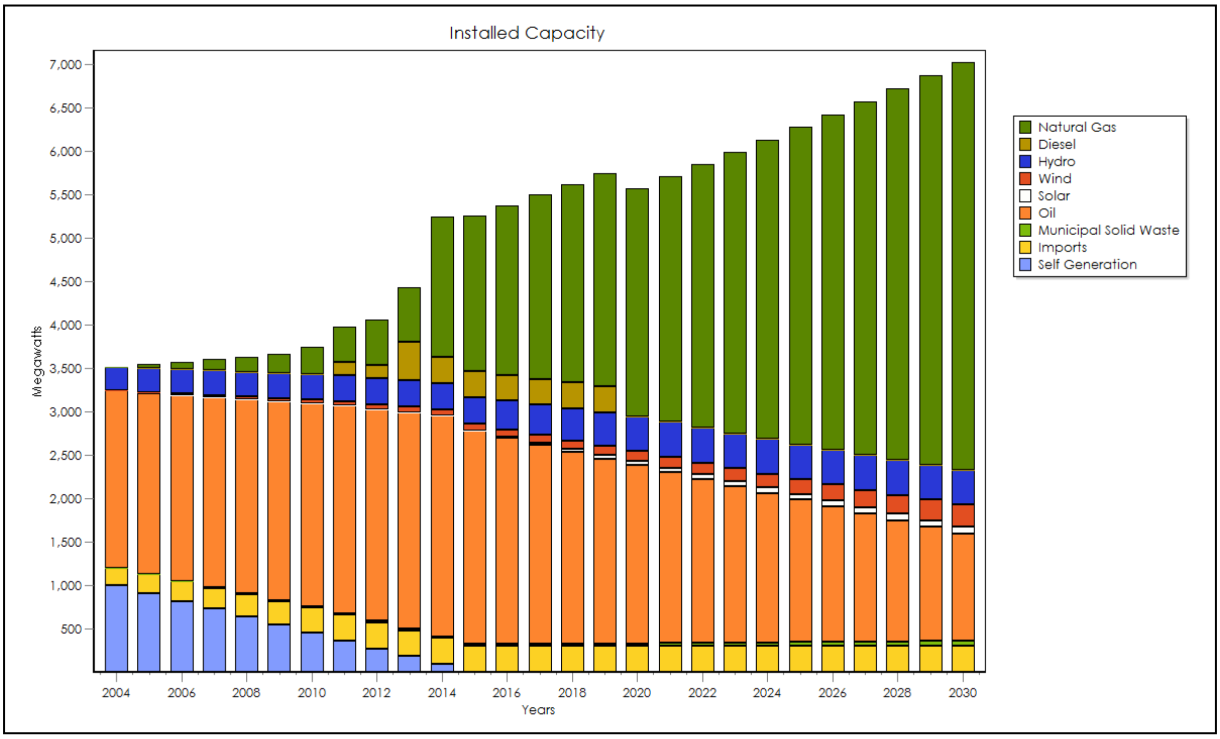

Figure 2-4. Breakdown of total installed capacity under mitigation scenario 1

Mitigation scenario 2: Implementation of MoEW's policy paper in addition to full gas switch, no imports and an increase in the penetration rate of renewable energy technologies by 2030.

The second scenario considered consists of the implementation of the MoEW plan but with a full switch of oil-fired power plants to natural gas by 2030, no electricity imports by 2030, and a higher penetration rate of renewable energy technologies (17% as compared to 11.4%). The data and assumptions for this scenario are summarized in Table 2-5. Efficiency values are the same for both mitigation scenarios, and thus were not included in this table.

Table 2-5 Data and assumptions for Mitigation Scenario 2

	Exogenous capacity (MW)	
Oil	2004:	2038
	2014:	2538
	2030: 0	
Diesel	2004:	0
	2011:	150
	2013:	450
	2014:	300
	2020: 0	

	Exogenous capacity (MW)	
NG	2004:	0
	2009:	217.5
	2013:	617.5
	2014:	1617.5
	2020:	2,617.5
	2030: 5,850	
Hydro	2004:	274
	2015:	310
	2020 2030: 600	
Wind	2004:	0
	2015:	80
	2030:334.2	
	(10% growth as of 2016)	
Solar	2004:	0.5
	2015:	0.5
	2020:	50
	2030:	129.7
	(10% growth between 2021 and 2030)	
MSW	2004:	0
	2015:	20
	2020:	50
	2030:	129.7
	(10% growth as of 2021)	
Imports	2004:	200
	2011:	300
	2030: 0	
Self-Generation	2004:	1,000
	2015: 0; 2030: 0	
Total in 2030:	**7,044 MW**	
% renewable energy:	**17%**	

The breakdown of total installed capacity of power plants under Mitigation scenario 2 is illustrated in Figure 2-5.

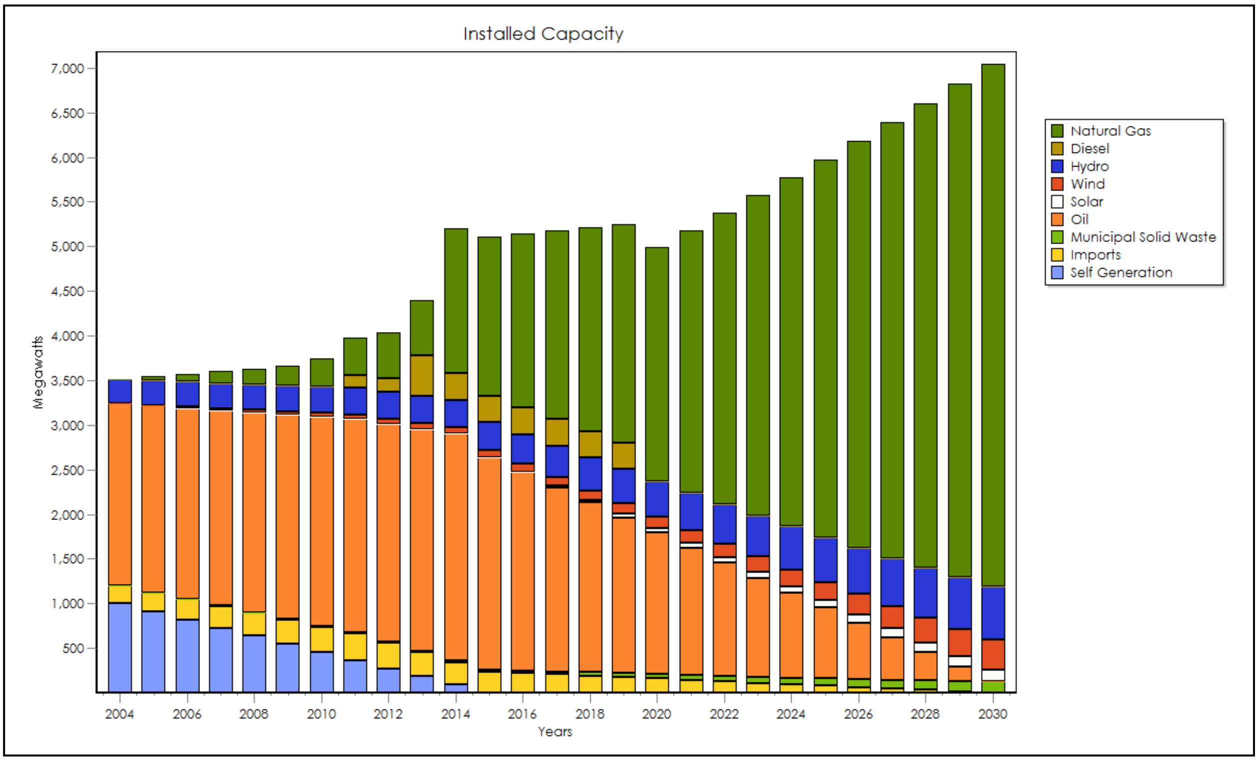

Figure 2-5 Breakdown of total installed capacity under mitigation scenario 2

2.1.3.2. Emissions reduction and costs of mitigation scenarios

Scenario 1

Figure 2-6 shows the cumulative reduction in GHG emissions from Scenario 1 that adds up to 177,912 Gg of CO_2 equivalents between 2011 and 2030, or a 33% reduction from 2004, which is considerable. The emissions reduction in 2030 is around 41.6%.

It should be noted that the emissions reduction is shown to start in 2004 in the figure, since when entering new values and additions for the different technologies in specific years, the change is averaged over the entire time period considered.

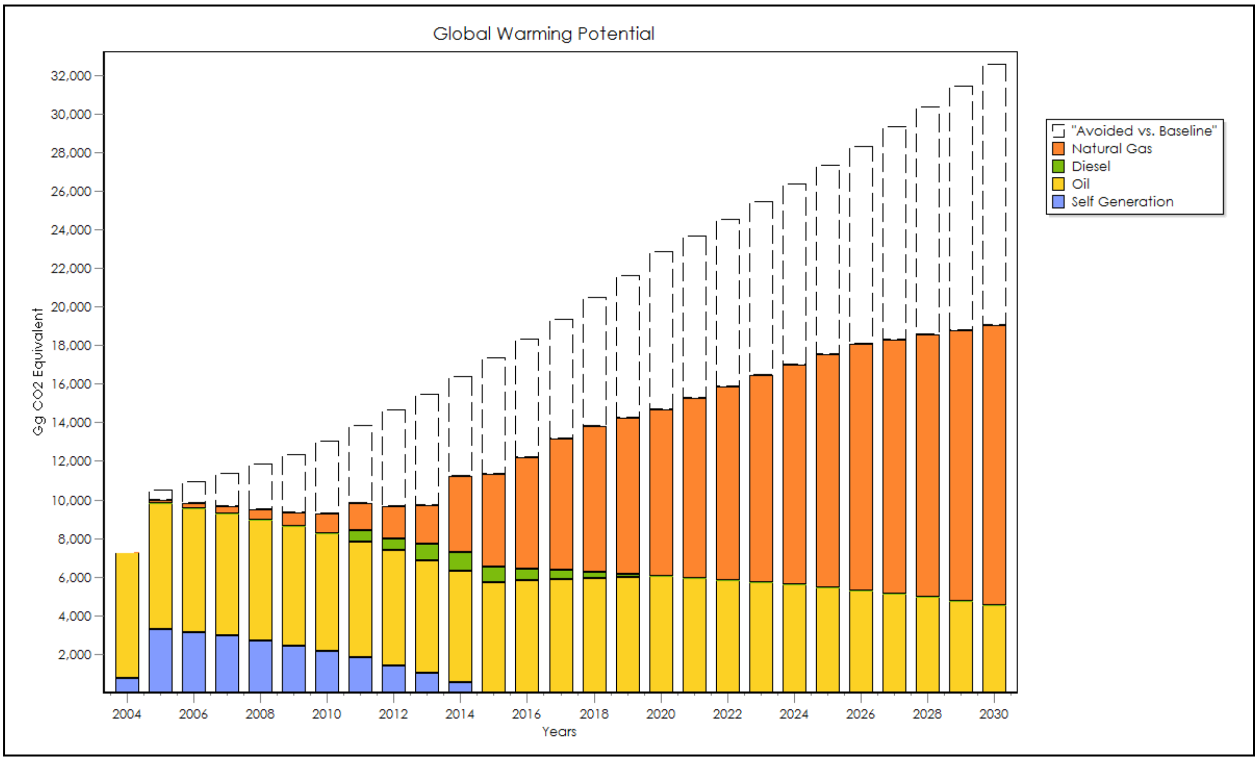

Figure 2-6. GHG emissions and avoided emissions under mitigation scenario 1

The cost of implementation of MoEW's plan for the Electricity sector was estimated at around USD 4.87 billion, covering all aspects (generation, transmission and distribution, supply and demand, legal and institutional, awareness). The cost of the additional investments to keep up with demand beyond 2015 is around USD 3.27 billion, as shown in Table 2-6. The total cost of Scenario 1 is therefore around USD 8.14 billion. It is assumed that all CCGT capacity to be added will consist of new power plants rather than conversion of oil-fired power plants, since the conversion in Lebanese power plants is either not feasible or too costly, depending on the plant. These will therefore be retired rather than converted. The resulting unit cost of emissions reduction from mitigation scenario 1 is USD 42.9/ tonne of CO_2 equivalent.

Another assumption (and limitation) in the calculation of discounted costs is that the USD 4.87 billion investment is made at once in 2011, and the USD 3.27 billion investment is made at once in 2016, as a result of the difficulty of coming up with figures on gradual spending. The resulting discounted total costs and unit costs were calculated on this basis at 10% and 15% discount rates, as shown in Table 2-7.

Table 2-6 Cost of installed capacity expansion needed in addition to MoEW's plan- Scenario 1

TECHNOLOGY	Cost/MW (Million USD)	Capacity to be added beyond MoEW's plan (MW)	Total cost (USD)
CCGT	1	2,072	2 billion
Hydropower	5.8	90	522 million
Wind	1.95	173.8	339 million
Solar	4*	80.9	324 million

Waste to energy	1.9	43.4	82.5 million
Total	-	**2,460.1**	**3.27 BILLION**

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

Table 2-7. Discounted total cost and unit cost for Mitigation Scenario 1 at different discount rates

DISCOUNT RATE	DISCOUNTED TOTAL COST (USD)	DISCOUNT UNIT COST (USD/T CO_2 EQ)
10%	6.94 billion	41.08
15%	6.53 billion	38.63

Scenario 2

Figure 2-7 shows the cumulative reduction in GHG emissions from the Scenario 2 that adds up to 204,768.3 Gg of CO_2 equivalents between 2011 and 2030, or a 38% reduction from 2004, which is higher than Scenario 1. Emissions reduction reaches 43.6% in 2030. As in Scenario 1, the emissions reduction is shown to start in 2004 in the figure, since when entering new values and additions for the different technologies in specific years, the change is averaged over the time period involved.

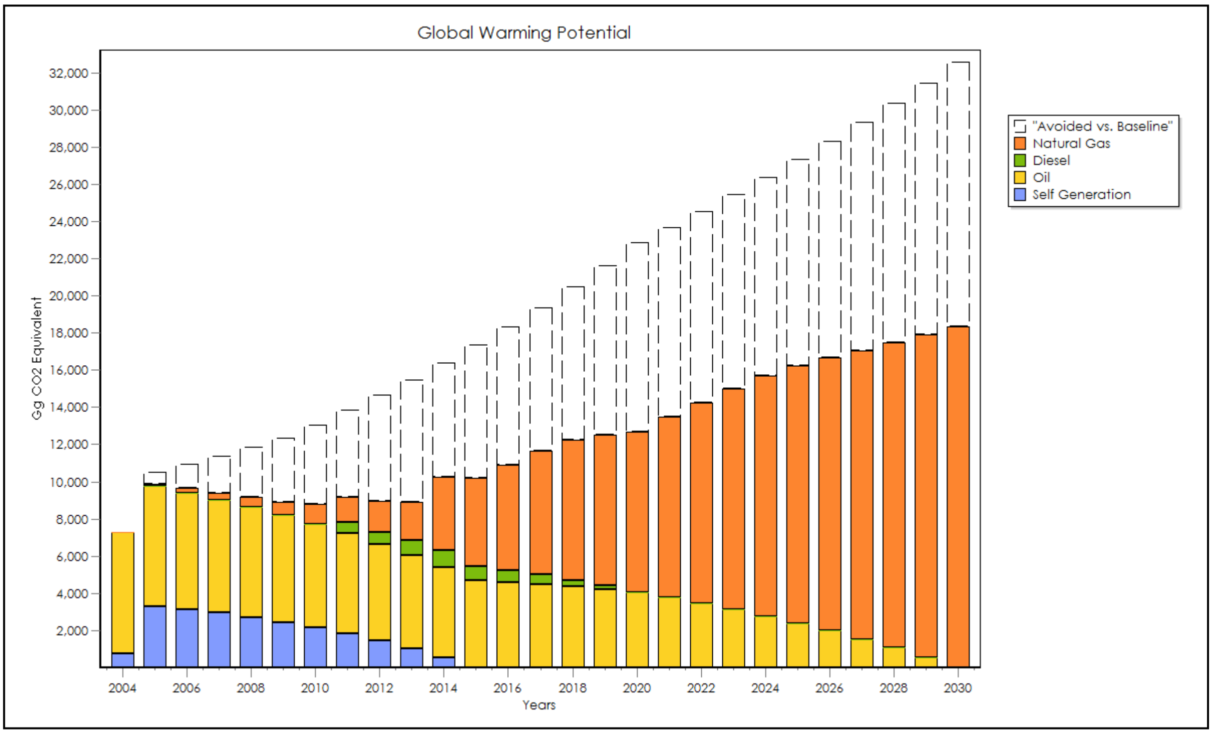

Figure 2-7 GHG emissions and avoided emissions under mitigation scenario 2

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 (Figure 2-8).

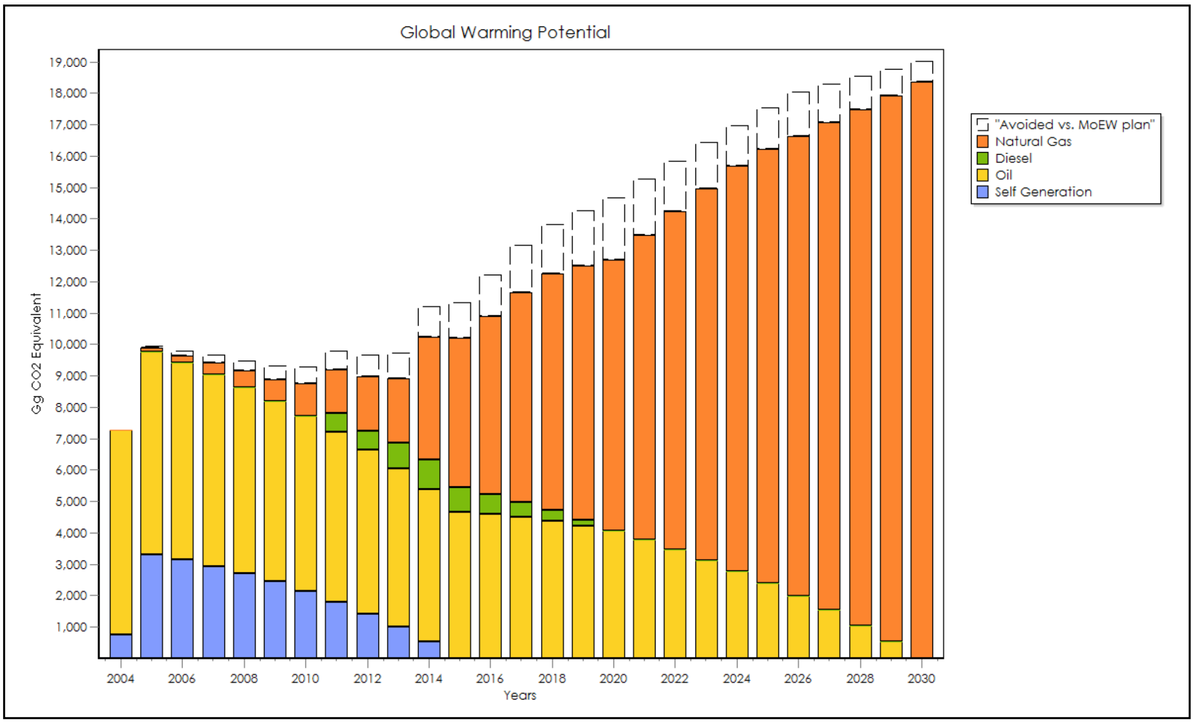

Figure 2-8 Comparison of GHG emission reduction from Scenario 2 compared to Scenario 1

In addition to the cost of implementation of MoEW's plan for the Electricity sector that was estimated at around USD 4.87 billion (covering all aspects as mentioned in Scenario 1), the cost of the additional investments to keep up with demand beyond 2015, ensure a full switch of oil-fired to CCGT, and increase the percentage of electricity produced from renewable energy is around USD 6.12 billion, as shown in Table 2-8. The total cost of Scenario 2 is therefore around USD 11.0 billion. As in Scenario 1, it is assumed that all CCGT capacity to be added will consist of new power plants rather than conversion of oil-fired power plants, since the conversion in Lebanese power plants is either not feasible or too costly, depending on the plant.

The resulting unit cost of emission reduction from mitigation scenario 2 is USD 57.6/ tonne of CO_2 equivalent, 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.

As in Scenario 1, it was assumed that the USD 4.87 billion investment is made at once in 2011, and the USD 6.12 billion investment is made at once in 2016, as a result of the difficulty of coming up with figures on gradual spending. The resulting discounted total costs and unit costs were calculated on this basis at 10% and 15% discount rates, as shown in Table 2-9.

Table 2-8. Cost of installed capacity expansion needed in addition to MoEW's plan- Scenario 2

TECHNOLOGY	COST/MW (MILLION USD)	CAPACITY TO BE ADDED BEYOND MOEW'S PLAN (MW)	TOTAL COST (USD)
CCGT	1	3,232.5	3.2 billion
Hydropower	5.8	290	1.7 billion
Wind	1.95	254.2	496 million
Solar	4*	129.2	517 million
Waste to energy	1.9	109.7	208 million
Total	-	**4,015.6**	**6.12 BILLION**

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

Table 2-9. Discounted total cost and unit cost for Mitigation Scenario 2 at different discount rates

DISCOUNT RATE	Discounted total cost (USD)	Discount unit cost (USD/t CO_2 eq)
10%	8.68 billion	44.59
15%	7.92 billion	40.69

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 extent of emissions reduction possible and associated costs. It is expected that the greater the shift to cleaner technologies, the greater the cost, as 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.

2.1.4. Mitigation Strategy

The mitigation strategy mainly consists of the elements elaborated in the Policy Paper for the Electricity Sector (MoEW, 2010) as mentioned in (Section) covering:

- Infrastructure: generation, transmission, distribution;
- Supply and demand: fuel sourcing, renewable energy, demand side management, tariffs; and
- The legal and institutional setting: norms and standards, corporatization of EDL, legal status.

The policy paper addresses the problem of the Electricity sector in a comprehensive, integrated way. Thus, the main recommendation consists of implementing this plan over the timeframe mentioned.

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 & Partners, 2009):

- Significantly reducing generation cost, especially at the Zahrani CCGT power station by displacing distillate oil;
- Favoring the expansion of CCGT generation capacity in the South.

Even though a gas pipeline running along the coast between Baddawi (where gas is currently supplied from Egypt through the Arab Gas Pipeline and Gasyle 1 pipeline) and Tyre was advocated in the MoEW plan to feed all power plants falling along that coastal strip, a study conducted by Poten & Partners (2009) states this would be expensive, in addition to the fact that gas volumes coming to Baddawi would not suffice.

In the case of the Zahrani power plant, the lack of port infrastructure and the shallow water depth constitute major constraints if any terminal construction is considered for securing gas to the power plant. The optimal solution would therefore consist of taking advantage of the favorable market conditions in the next few years through the implementation of 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. 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.

More than 80 million tonnes/year of new supply is projected to reach the market from projects under construction. The MENA region stands out as the best source to supply Lebanon, especially Algeria, Qatar, Yemen and Egypt that are experiences players in the LNG trade with available supply. 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, such that suppliers might require additional government guarantee and potentially a World Bank partial-risk guarantee.

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 & Partners, 2009).

Table 2-10 below presents the mitigation strategy for the Electricity sector, and Table 2-11 shows the constraints associated with its implementation.

Table 2-10 Mitigation strategy for the Electricity sector

IMPACT	PROPOSED MITIGATION STRATEGY	ACTIVITIES	RESPONSIBILITY	PRIORITY (ST/ MT/ LT)	INDICATIVE BUDGET (USD)
Increase in energy demand	Increase efficiency and capacity of power generation sector, and reduce demand (implementation of MoEW's plan)	Rehabilitation of old power plants until new capacity is added.	EDL MoEW	ST	8 - 11 billion
		Installation of new capacity		MT	
		Diversification of power supply (2/3 natural gas, renewable energy)		MT	
		Reduction of technical losses in the distribution network		ST	
		Tariff adjustments		MT	
		Implementing DSM programs		ST	
		Corporatization of EDL		MT	
		Strengthening the legal framework to promote the implementation of MoEW's plan		MT	
		Establishing partnership with the private sector		MT	
		Mandating the use of catalytic converters for generators with capacities above 50 KVA		ST	

Table 2-11 Constraints to the implementation of the mitigation strategy

MITIGATION STRATEGY	CONSTRAINTS/ GAPS				
	Legal/ policy	Institutional	Technical/environmental	Capacity and Awareness	Data/ Information Gaps
ncrease efficiency and acity of power generation tor , and reduce demand nplementation of MoEW's plan)	Current tariff schemes do not reflect global oil prices Insufficient incentives to promote renewable energies	Weak institutional structure of EDL and lack of involvement of the private sector	Insufficient budget available for implementing MoEW's plan High cost of clean technologies Decrease in hydropower generation potential due to expected reduction of precipitation	None	Insufficient studies on bioenergy and wind energy generation potential and feasibility – studies are however on-going and should address these gaps

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2.2. MANUFACTURING INDUSTRIES AND CONSTRUCTION

2.2.1. Background

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 3,738 Gg of CO_2-eq in 2004. 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.

2.2.2. Mitigation option 1: Waste heat recovery and utilization for power generation in cement plants

The main objectives of this option are to meet the electrical supply needs of cement plants and to reduce greenhouse gas 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.

Waste heat recovery from the cement industry has been largely applied in China. Table 2-12 illustrates four case studies of heat recovery and utilization for power generation projects in China (UNFCCC 2007, 2008a, 2008b, 2009).

In summary, the projects implemented in China reveal the following:

- The amount of electricity generated through heat recovery and utilization in a selection of Chinese cement plants ranges between 65,000 and 118,000 MWh/year, where annual cement production ranges between 1,825 Gg and 3,650 Gg per year.
- Projects at these scales are expected to lead to emission reductions ranging between 55 and 95 Gg CO_2-eq per year.
- The estimated investment cost of heat recovery and utilization for power generation ranges between 12.5 and 28 million USD with an average of 20 million USD.
- The average operational lifetime of such projects is 15-20 years.

Table 2-12. Heat recovery and utilization projects for power generation from cement plants in China

TITLE OF THE PROJECT	AMOUNT OF ELECTRICITY GENERATED (MWH/ YEAR)	AMOUNT OF CO2-EQ REDUCED (GG CO2-EQ PER YEAR)	AMOUNT OF CEMENT PRODUCED (GG/YEAR)	COST OF INVESTMENT (USD)	EXPECTED OPERATIONAL LIFETIME OF THE PROJECT (YEARS)
Waste Heat Recovery and Utilization for Power Generation Project of Anhui Conch Cement, China1	65,100	55	1,825	12,556,992	15
Henan Nanyang Zhenping Cement Waste Heat Recovery and Utilization for Power Generation Project2	103,930	95	2,790	19,470,812	20
Liaoyuan Jingang Cement Waste Heat Recovery as Power Project3	104,000	101	2,920	27,805,512	21
Inner Mongolia Wulanchabu Volan Cement Waste Heat Recovery Project4	118,238	124	3,650	21,825,248	20

Sources: [1] UNFCCC, 2007

[2] UNFCCC, 2009

[3] UNFCCC, 2008a

[4] UNFCCC, 2008b

Based on figures of heat recovery and utilization projects in China summarized above, the following assumptions (Table 2-13) are considered concerning the case of Lebanon. In addition, to portray the possible future clinker production and CO_2 emissions from the cement industry in Lebanon until year 2030, two baseline scenarios are suggested: Scenario A which assumes a low growth rate of 2% in the cement industry, and Scenario B which uses a higher growth rate of 4%. Figure 2-9 represents forecasts of clinker production and CO_2 emissions under Scenario A and Scenario B and

Table 2-14 summarizes the results of the mitigation option 1 under scenario A and scenario B.

Table 2-13 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

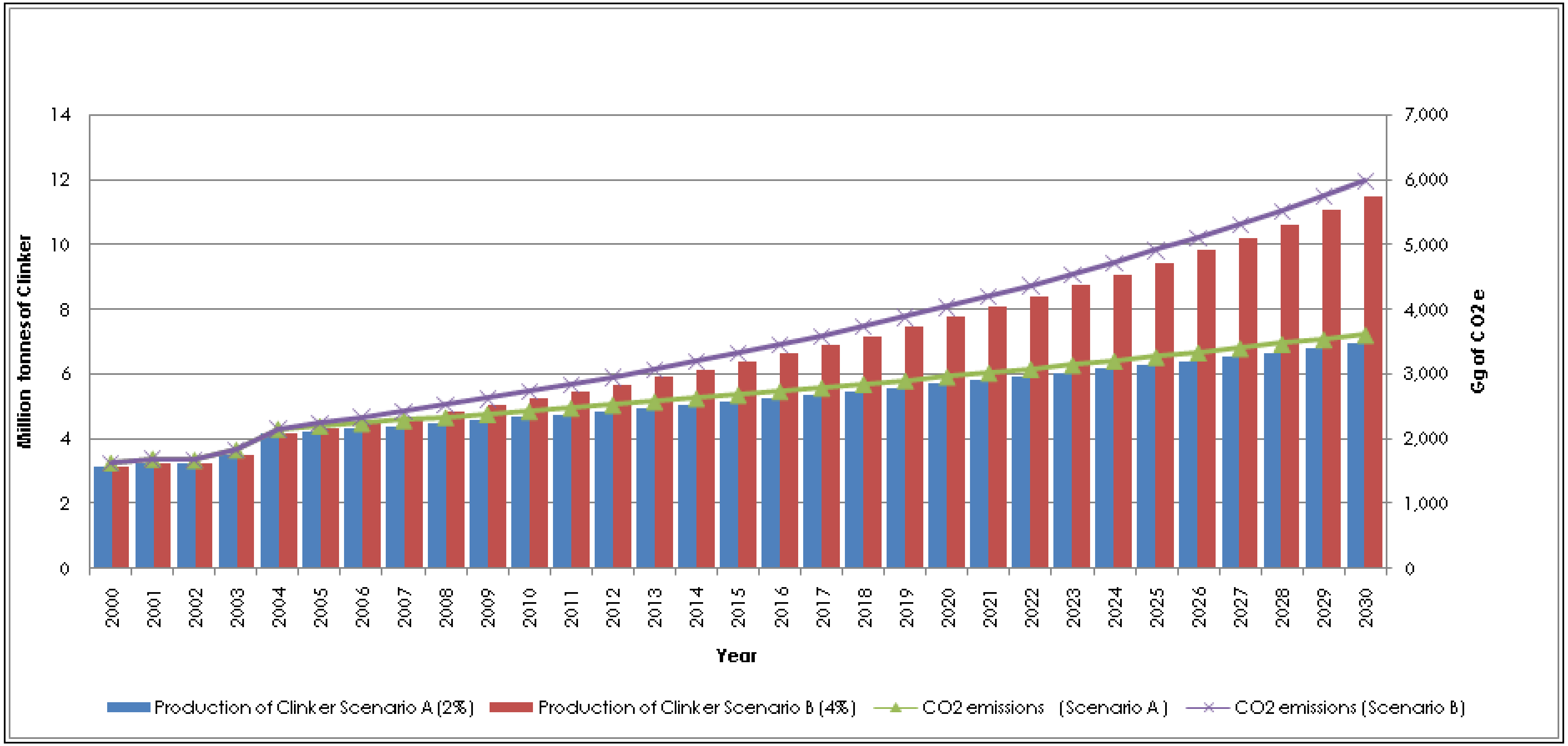

Figure 2-9 Projected clinker production and CO2 emissions under Scenario A and Scenario B

Table 2-14 Results of Mitigation option 1 under Scenario A and Scenario B for selected years

YEAR	2010	2015	2020	2025	2030
SCENARIO A					
Production of Cement (tonnes)	4,666,602	5,152,306	5,688,562	6,280,632	6,934,325
Amount of electricity generated (MWh/year)	168,835	186,408	205,809	227,230	250,881
Amount of CO_2-eq reduced (Gg CO_2-eq)	155	171	189	208	230
SCENARIO B					
Production of Cement (tonnes)	5,243,240	6,379,204	7,761,277	9,442,780	11,488,585
Amount of electricity generated (MWh/year)	189,698	230,797	280,799	341,635	415,652
Amount of CO_2-eq reduced (Gg CO_2-eq)	174	212	258	313	381

Breakdown of the capital and operational costs of mitigation option 1 under Scenario A and Scenario B are shown in Table 2-15. It is worth noting that the costs per tonne of CO_2-eq reduced are gross, since the savings from energy production through heat utilization were not included in the analysis. This is due to data unavailability as to the costs of energy use at the cement plants in Lebanon.

Table 2-15 Breakdown of the cost of mitigation option 1 under scenario A and Scenario B for the period 2010-2030

	INVESTMENT COST (MILLION USD)	OPERATIONAL COST (USD)	TOTAL COST (MILLION USD)	TOTAL DISCOUNTED COST (10%) (MILLION USD)	COST/GG CO_2-EQ (USD/GG CO_2-EQ)	TOTAL DISCOUNTED COST (15%) (MILLION USD)	COST/T CO_2-EQ (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

2.2.2.1. *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 carbon dioxide emissions is to reduce the carbon content of the fuel by using less carbon intensive fossil fuels, e.g., shifting from petroleum coke to natural gas.

Less carbon intensive fossil fuel is a fossil fuel type that has a lower CO_2 emission factor on a net calorific value basis (t CO_2/GJ) than any fossil fuel type that has been already used in the plant. CO_2 emissions per type of fuel are shown in Table 2-16.

Another option is the application of waste-derived alternative fuels, which could at the same time reduce the disposal of waste material.

Alternative fuels include the following fuel types:

- Wastes originating from fossil sources;
- Biomass residues; and/or
- Renewable biomass from a dedicated plantation.

In considering using waste-derived fuels in cement industries specifically, a number of issues should be considered (Hendriks et al., 2004):

- Energy efficiency of waste combustion in cement kilns;
- Constant cement product and fuel quality;
- Emissions to atmosphere;
- Trace elements and heavy metals;
- Alternative fate of waste; and
- Production of secondary waste.

Table 2-16 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	3.1525
Residual fuel oil	40.4	0.0774	3.126
Diesel oil	43	0.074	3.182
Alternative Fuels			
Natural gas	48	0.0561	2.6928
Municipal waste	10-11.6	0.0917-0.1	0.971-1.16

Source: Garg et al., 2006

Based on a project of fuel switching (coal to natural gas) in Peru (UNFCCC, 2008c), the cost of fuel switching entails:

- The cost of installation of natural gas burners, estimated at approximately 1.5 million USD per burner.
- The operating cost of the project.
- The cost of natural gas compared to other fuels already in use.
- The cost of importing, transport and distribution of natural gas3
- The annual average of estimated reductions from a fuel switch is in the order of 269,851 tonnes of CO2-eq per annum.

Manufacturing plants in Lebanon have assessed the feasibility of substituting part of the fuel with wastes, namely in cement industries. Such an option should be further explored in Lebanon.

A study on the potential of using biomass as a source of energy in Lebanon is also being conducted. The results of this study, if favorable to the use of biomass in industries, should also be encouraged.

2.2.3. Mitigation Strategy

Table 2-17 below presents the mitigation strategy for the energy generation from industries, and Table 2-18 summarizes the constraints associated with its implementation.

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[3] The Energy Policy Paper submitted on June 2010 suggested building a gas pipeline along the coast to feed power plants from Bedawi to Tyre. In case the gas pipeline is built, it will be used in the industrial sector and thus reduce the cost of transport of Natural Gas.

Table 2-17 Mitigation strategy for the Industry sector (energy generation)

TARGET	PROPOSED MITIGATION STRATEGY	ACTIVITIES	RESPONSIBILITY	PRIORITY (ST/ MT/ LT)	INDICATIVE BUDGET (USD)	SOURCES OF FINANCING/ IMPLEMENTATION PARTNERS
Reduction of GHG emissions from the industrial energy generation.	Reduce GHG emissions from energy generation.	The main activities include: Waste heat recovery and utilization for power generation in cement industries. Partial substitution of fossil fuels with alternative fuels or less carbon intensive fuels.	Industries, specifically cement companies (private sector) MoI MoE ALI (Association of Lebanese Industrialists)	ST	Cost of waste heat recovery: 700 USD/Gg CO_2-eq	The Arab Fund for Economic and Social Development (AFESD) The European Investment Bank (EIB) Kuwait Fund for Arab Economic Development (KFAED) The Abu Dhabi Fund for Development (ADFD) USAID UNIDO

Table 2-18 Constraints to the implementation of mitigation measures

Mitigation Strategy	Constraints/ Gaps				
	Legal/ Policy	Institutional	Technical/ environmental	Capacity and Awareness	Data/ Information Gaps
Reduction of GHG emissions from industrial energy generation	Lack of standards and their enforcement relating to GHG emissions from large scale generators	Lack of enforcement power by MoE, which is in charge of monitoring industrial emissions	High cost of technology and lack of financial support and incentives for industries to promote low emission technologies.	None	None

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2.3. TRANSPORTATION

2.3.1. Background

General overview

The transportation sector in Lebanon suffers from major problems including lack of organization. The major cities, particularly the Greater Beirut Area (GBA), suffer from severe congestion and chaotic traffic conditions. Travel demand is growing more rapidly than the transport system's ability to accommodate it; in the GBA alone, daily passenger trips were expected to rise from 1.5 million in 1995 to 5 million in 2015. Major arterial roadways, highways, and intersections suffer from severe under-capacity and delays. The current transport system is dominated by the automobile, which constitutes more than 86% of the Lebanese fleet. Vehicle kilometers traveled are low, reflecting the fragmentation and the localization of the economy. Private passenger cars account for the majority of intra-city trips (approximately 70%), and both automobile ownership and usage are growing. The total cost of urban congestion in Greater Beirut and other major cities and towns is estimated at over $2 billion annually, which represents up to 10% of GDP. This, together with other external costs, such as accident and pollution costs, has serious impacts on the economy (MoE, 2005).

The transportation system in Lebanon encompasses land transport, marine transport, and air transport subsystems. The transport infrastructure consists of the road and rail networks, the Beirut-Rafic Hariri International Airport (BIA) and the main sea ports of Beirut, Tripoli, Saida and Tyre. As the existing railway has become idle for the transport of passengers and goods, the land transport infrastructure is practically characterized by the national road network, the vehicle fleet and the public transport system. The government plays an exclusive role in the development, maintenance and management of the transport infrastructure and a limited role in the operation of transport services, namely in the operation of public transport and the currently non-operational railway.

Intra-city public transport is dominated by service-taxis (shared taxis), with an increasing number of buses, mini-buses, and mini-vans. Most of these vehicles are owner-operated as private enterprises, and function in the absence of any regulation of schedules or routes. Governmental decisions have resulted in almost a threefold increase in the number of licensed public transport vehicles between 1994 and 2004 (MoE, 2005).

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 more developed countries. The transport sector accounts for 19.5% of Lebanon's GHG emission (equivalent to 3,976 Gg of CO_2 equivalents), and around 98.5% of total CO emissions, according to the National Greenhouse Gas Inventory for 2004 (Section …).

The Lebanese vehicle fleet is dominated by private cars which are poorly maintained. The vehicle inspections procedure was interrupted for over 15 years up until 2004, which further contributed to poor conditions of the vehicle fleet. In spite of the annual inspection that is undertaken, there is no legislation governing passenger vehicle emissions (a regulation that new vehicles should comply with one category below the latest EU emission norm is still pending). Decree 6603/1995 sets emission standards for diesel vehicles (trucks and buses) relating to CO, NO_2, hydrocarbons and TSP, but is not enforced.

The fleet size reported in 2003 in Lebanon was 1,081,477 (MoE, 2005). Figure 2-10 shows the vehicle fleet size between 1997 and 2005 and projections for 2015, when the total size is expected to reach 1,406,103 vehicles- from 1,219,224 in 2005 (MoE, 2005).

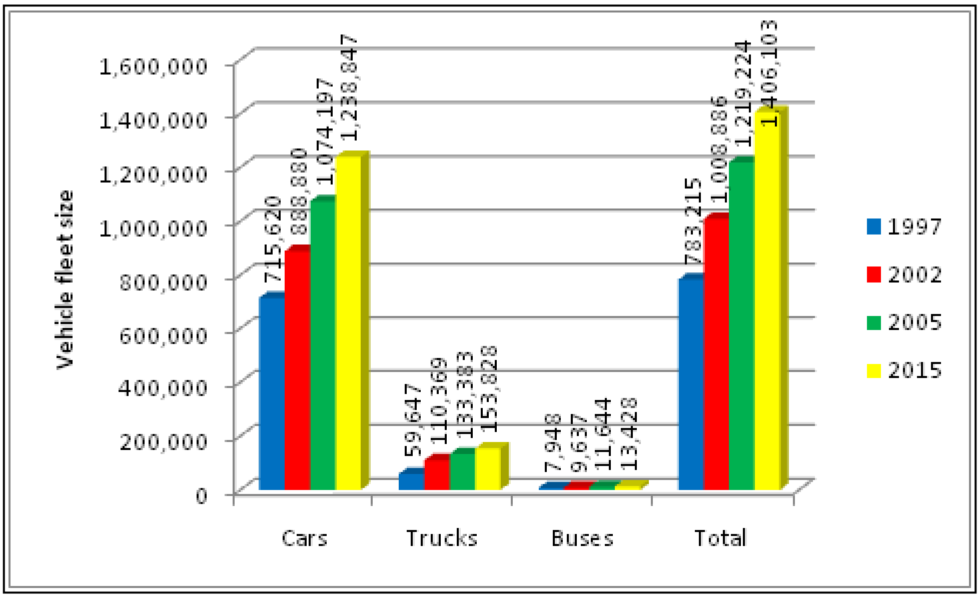

Figure 2-10 Vehicle fleet size between 1997 and 2005 and projections for 2015

Source: MoE, 2005

Vehicle age

The Lebanese vehicle fleet is relatively old and outdated where 62 percent of the fleet is older than 13 years (Table 2-19) based on data from the Vehicle Registration Office and MoE. The shared taxi category average age is estimated at 30 years since it is a remarkably old fleet, which consists mainly of Mercedes 200/230 series (1975 to 1979 models) (MoE, 2005).

Table 2-19 Vehicle fleet age structure

VEHICLE AGE BAND	0-2 YEARS	3-4 YEARS	5-12 YEARS	13 YEARS +
Number of vehicles	35,052	36,486	224,709	486,968
% of fleet	4.47%	4.66%	28.69%	62.17%

Source: MoE, 2005

Such a high fleet age is attributed to:

- The non-restricted import of vehicles prior to 1995, when the Lebanese authorities imposed new regulations banning the import of vehicles above 8 years old;
- The existing tax system is such that the newer (and more expensive) the vehicle is, the higher the tax level imposed for its import is;
- The fact that the cost of registering the vehicle and of the annual license decreases with vehicle age.

Vehicle Ownership

Lebanon has a very high car ownership. Nearly every third inhabitant possesses a car; less than 40 % of households do not own a car (MoE, 2005). CDR's recent figures (personal communication with E. Helou, August 31, 2010) estimate car ownership at around 526 cars for every 1,000 persons. The high car ownership may be attributed to several factors including (MoE, 2005):

- A weak and unreliable public transport system;
- Weak urban planning practices;
- Socio-cultural stigma associated with bus riding;
- Cultural attachment to car ownership;
- Availability of old and cheap vehicles;
- Availability of credit facilities for the purchase of new cars; and
- Inappropriate fiscal system (especially annual license payments) that favors older cars.

The number of new cars imported every year is around 50,000 to 60,000; in addition to a similar number of used cars imported yearly. This leads to an additional 100,000 cars/year (personal communication with E. Helou- CDR, August 31, 2010).

However, given the increasing fuel tariffs with time, the budget required to operate a car will inevitably rise. In addition, if restructuring of the vehicle tax system is envisaged together with stringent emission norms, it is expected that the retirement of old vehicles will be gradually promoted.

Traffic conditions

Road traffic growth in Lebanon from 2003 to 2004 was estimated to be 6.8 %, which corresponds to a rate well beyond economic growth, and is expected to remain stable over the coming years. As a result, more severe congestion will inevitably follow. Traffic problems are evident at the entrances to the city of Beirut where bottlenecks develop and long delays are experienced. The coastal highway leading from the north carries a daily traffic volume in both directions of close to 180,000 vehicles while the southern coastal highway has a volume of a little more than 50,000 vehicles. The average speed during the day along the major axes in the GBA ranges between 15 and 30 km/hr, dropping to 10 km/hr and less in the commercial districts within the city at peak times (MoE, 2005).

Moreover, in the absence of an operating railway system, roads are the only available option for both passenger and freight transport, which further complicates the problem.

Public Transport

Based on a study conducted in 2002, the modal share for inter-urban travel was calculated to be in the range of 60% for cars, 7% for service or taxis and approximately 20% for minibuses. Large buses are supposed to have only a share of 5 %. Around 40,000 public transport vehicles are distributed between shared-taxis (service-taxis), taxis, buses and minivans, which constitutes an oversupply at very low quality levels (oversupply is also to be seen from continuous cruising of taxis on their search for passengers, which unnecessarily increases mileage driven). These vehicles are increasing traffic congestion, transport delays and air pollution (MoE, 2005).

Table 2-20 shows the supply and market share of public transport in Greater Beirut in 2002. However, these figures have probably changed, due to the banning of diesel operations in 2002 which resulted in putting numerous taxi and minibus vehicles out of service (MoE, 2005).

Table 2-20 Supply and Market Share of Public Transport in Greater Beirut (2002)

MODE	SUPPLY IN LEBANON	SUPPLY IN GREATER BEIRUT (GB)	GB MARKET SHARE (%)
Rail and Public Transport Authority (RPTA) buses	130	117	3
Lebanese Commuting Company (LCC) buses	191	191	5
Exclusive Ride Taxis	1,300	1,000	1
Shared Ride Taxis	32,000	20,000	14
Minibuses	4,000	2,000	8
Private Intercity Buses	2,135	-	-
Total	39,756	23,308	31

Source: MoPWT, 2002

Based on more recent studies, the occupancy rate of service-taxis is 1.2 passengers/car, and the breakdown of the vehicle fleet as follows (personal communication with E. Helou- CDR, August 31, 2010):

- 18% buses and mini-vans;
- 1.7% long buses; and
- Around 80% private cars (including shared taxis).

Recent estimates of person-trips traveled by transport mode during the peak period in Lebanon (unpublished data from the MoPWT) are shown in Table 2-21:

Table 2-21 Distribution of person-trips traveled by transport mode

Vehicle type	Percent of person-trips					
	Beirut	Jounieh	South	North	Bekaa	Total
Private vehicles	80.6%	92.5%	67.6%	59.9%	52.8%	75%
Shared taxis	6.0%	3.2%	7.9%	15.7%	6.0%	7.5%
Private taxis	0.7%	0.6%	0.1%	0.2%	0.0%	0.5%
Vans	10.9%	1.8%	24.4%	24.2%	41.2%	15.7%
Buses (LCC)	1.2%	1.6%	-	-	-	0.9%
Buses (RPTA)	0.5%	0.3%	-	-	-	0.4%

The public transport sector in Lebanon suffers from major organizational and technical problems, such as:

- The lack of government planning, regulation and enforcement;
- The lack of an efficient, reliable, clean and cost-effective mass transport system where safety regulations are applied;
- Oversupply of vehicles resulting in low ridership and low revenues among operators, which in turn leads to the neglect of vehicle maintenance and insurance; and
- Improper allocation of the existing supply over the market. Some areas are over-served while others are under-served.

Therefore, the low-quality public transportation system does not provide a reasonable alternative to the automobile, restricting use to only few riders who have no choice.

Freight and logistics

Goods distribution in GBA has no clear logistics setup: the location of make-shift warehousing in residential buildings poses a serious safety as well as logistical concern. The chaotic loading and unloading procedures in urban streets are increasing roadway congestion, which is already in a difficult situation.

Issues impeding the development of efficient and competitive freight movement also include complex procedures across international borders, licensing requirements, high fees and lack of coordination among authorities. This results in a serious lack of competitiveness and impedes the growth of the Lebanese economy (MoE, 2005).

This chapter will focus on land transport of passengers, which is the largest contributor to GHG transport emissions in Lebanon.

2.3.2. Baseline Scenario

This section presents an overview of current plans and strategies for the Transport sector in Lebanon and their impact on the baseline scenario and associated emissions between 2004 (baseline year) and 2030.

2.3.2.1. Existing Legislation, Plans and Strategies

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, NO2, 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.
- 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.

Apart from the implementation of law 341/2001 and banning cars and buses with fewer than 24 passengers from operating on diesel, the enforcement of these legislations is still weak.

In addition Table 2-22 , 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. These were compiled in the National Environmental Action Plan-Transport Sector (MoE, 2005).

Table 2-22 Summary of formulated and on-going projects and studies relevant to the Transport sector

STUDY/ PROJECT	MAIN COMPONENTS	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)	Traffic Management System (TMS) consisting of centrally controlled traffic signals, red light enforcement, vehicle detection, and CCTV monitoring at numerous intersections and on selected high-volume corridors in the GBA. On-Street Parking Management System consisting of Pay and Display units (solar-powered electronic parking meters) to regulate parking usage in 17 high-density commercial areas throughout the GBA. Corridors Improvement Program to enhance traffic mobility along a number of road corridors in the GBA, through the construction of 12 over-passes and underpasses at heavily congested intersections. Establishment of the Traffic Management Organization (TMO) in charge of traffic control and surveillance, traffic enforcement, parking management and regulation, traffic operations planning, traffic engineering, and traveler information. Technical assistance component to the MoPWT (DGLMT) to prepare an air quality management program.	The original time frame of the UTDP was between 2005 and 2008; however, as a result of delays in implementation, the project is still on-going. 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. Upon completion, it may lead to a short-term relief; however any additional capacities will be occupied quickly by additional road traffic. Shortcomings of the program: Lack of proper enforcement of regulations; Yearly increase in power outages throughout GBA that hinders the operation of traffic signals as initially planned; No provision for improving traffic through upgrades to the public transport sector.
Revitalization of the Public Transport and Freight Transport Industries	Objective: assess the state of passenger transport by land in Lebanon, and propose measures to reorganize the sector at the regional scale, national scale, as well as the intra-city scale for the Greater Beirut Area (GBA) and other major cities and towns. The study is supposed to assist decision-makers by raising the level of information about	The background assessment for this study has been launched (personal communication with E. Helou- CDR, August 31, 2010).

STUDY/ PROJECT	MAIN COMPONENTS	STATUS AND COMMENTS
(Launched by the MoPWT)	the current conditions, and by evaluating the effectiveness of potential reform measures. Component related to the unsustainable land freight transport system: analysis of the freight transport sector's ability to serve the economy with the maximum degree of quality, efficiency and reliability, through reorganization.	
Restructuring of the Directorate General for Land & and Marine Transport Launched by the MoPWT	Study for the restructuring of the Directorate General for Land and Maritime Transport, as part of the ARLA program. The results of the study include a proposed draft law for organizing land and maritime transport in Lebanon through the establishment of the General Authority of Land Transport, General Authority of Maritime Transport and the National Company for Public Transport to replace the current RPTA.	No implementation to date.
The Road User Charges Study	Adoption of a Statement of Road Sector Policy in May 1996 regarding the need to move towards full recovery of costs from road users for the rehabilitation and maintenance of the road network, through the creation of a dedicated Transport Fund catering for all investments in the transport sector. The Fund would: Support bringing the national transportation system to a state of good repair, maintaining and improving it, and improving the public transportation system; Prioritize improving the quality and quantity of public transportation services, and upgrading the visual environment of streets and highways; Provide more disincentives against the use of the private auto.	No concrete action has been taken to date in order to establish neither the Road Fund nor the 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	Reducing air and noise pollution by reducing the use of automobiles and encouraging a shift to other modes, through strengthening public transport, reactivating rail transport, and adopting user fees and taxes that can restrain the demand for private cars (e.g., high parking and fuel prices). Increasing regulations on vehicles so as to make them more environment-friendly (e.g.,	No concrete implementation to date.

STUDY/ PROJECT	MAIN COMPONENTS	STATUS AND COMMENTS
Lebanon in 2002.	higher quality fuel standards, maximum vehicle age, strict requirements on the physical and mechanical conditions of vehicles).	
The National Physical Master Plan for the Lebanese Territories (NPMPLT)	The means of transport for export, import and international transit require solutions adapted to the volumes of goods and to the locations of exchange modes and destinations. The inter-urban links must assure efficient links between various town and agglomerations. An integrated plan for urban transport and transit is required with the main objective of dealing with traffic congestion. The level of service of the Lebanese road network globally leads to the problem of rehabilitation and maintenance. New local roads reserved for the expansion of cities and villages with the aim of directing urbanization and preventing urban sprawl. Interest in re-instating the services of parts of the railway network for freight transport, particularly the connection from Tripoli to the Syrian Borders, with the option of extending it towards Beirut to serve passenger traffic. Recuperation and preservation of the right of way of the coastal railway. Creation of a logistic apron connected to the three planned major industrial zones in Tripoli, Zahleh, and Zahrani, that would equally serve as storage and unloading zones for the agricultural produce of Akkar, Beqaa and the South. Attenuation of the current congestion problems in Beirut and Mount Lebanon and along the coastal corridor at two simultaneous levels: the road capacity expansion level and the public transport development and recovery level. Establishment of a sole transport authority to take charge of all planning, financing development, management, and operation responsibilities in the transport sector.	Although the NPMPLT 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.

STUDY/ PROJECT	MAIN COMPONENTS	STATUS AND COMMENTS
The Beirut Suburban Mass Transit Corridor Study	Given the constrained right-of-way, start at first with a Bus Rapid Transit System (BRT) providing passenger services. Importance of protecting and maintaining the existing right-of-way so as to allow for the future introduction of a full-scale rail service. BRT is economically sustainable until the year 2015 at which time the introduction of heavy rail is justified.	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 Beirut Urban Transport Project (BUTP) – Preparation Study (undertaken by the CDR) recommended the establishment of an autonomous body with jurisdiction and authority over the GBA, to be under the tutelage of the Ministry of Interior, and to have the following main functions and responsibilities: Traffic planning, engineering and management studies and strategies; Traffic signals design, installation and management; Monitoring of traffic, public transport, and pedestrian movements; Regulation and management of on-street parking; Coordination with other involved agencies, including traffic police; and Support traffic enforcement efforts.	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 as a result of the involvement of the administrative Directorate of Licenses and Vehicle Inspection. This has held the TMO from fulfilling the actual objectives and tasks it was created for. The current TMO needs restructuring – including hiring traffic experts – in order to fulfill its role as perceived in the UTDP (personal communication with E. Helou- CDR, August 31, 2010).
Regulation of the Public Transport Industry in Lebanon Carried out by the DGLMT - MoPWT in 2002	A short-term component, basically limited to low cost actions, which have immediate effect in enhancing the public transport image (safer and better vehicles, trained drivers, etc.), and in gaining government control over major aspects of the industry (e.g. licensing of companies, drivers and vehicles); A medium-term component, including management of recurrent regulations, distribution and assignment of existing supply, and continuation of enforcement; and	No concrete implementation to date.

STUDY/ PROJECT	MAIN COMPONENTS	STATUS AND COMMENTS
	A long term component, which aims at gaining full control over the public transport industry, through the management and distribution of supply, regulating passengers boarding and alighting, raising vehicles condition standards, and strict monitoring and enforcement procedures.	

Source: MoE, 2005

In short, 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 that is getting worse throughout the years, especially during high seasons (especially in summers and during holidays).

2.3.2.2. *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. This population growth over time will result as well in modifications in the community behavior and demands in relation with the transport sector, particularly mobility and demand in terms of number of daily trips as well as annual distance traveled, as a result of the tendency to move to the outskirts of major cities where residence is cheaper.

According to the National Environmental Action Plan estimates (MoE, 2005), the vehicle population is expected to grow to 1,400,000 in 2015. 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 difficulty of obtaining relevant official data, it was not possible to conduct a quantitative analysis using LEAP. The chapter is limited to a qualitative description of mitigation options without the possibility of quantifying the resulting emissions reduction. Table 2-23 shows some assumptions made for the Transport sector under the baseline scenario.

Table 2-23 Assumptions made for the baseline (business as usual) scenario in the Transport sector, 2004 - 2030

PARAMETER	2004 VALUE	2030 VALUE
Population‡	4.29 million	1% growth per year
Road transport of passengers	100% of total passenger trips	100% of total vehicle-km
Percent share of person-trips**	Private cars (gasoline engines): 75% Taxis (gasoline engines): 8% Vans (gasoline engines): 15.7% Buses (diesel engines): 1.3%	-
Occupancy of vehicles**	Passenger vehicles: 1.4 person/ car Long buses: 35 persons/ bus Vans: 6.5 persons/ van Buses: 13 persons/ bus	

‡ CDR, 2005

** Based on unpublished data from MoPWT.

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.

2.3.3. Mitigation options

The anticipated growth in daily trips and distance traveled will dramatically aggravate the capacity problems of the transport infrastructure and will magnify pressures and impacts on society and the environment, particularly in densely populated urban areas where the situation would reach a serious stage if adequate policy and management measures or alternative sustainable transport solutions are not implemented. Thus, Lebanon's transport sector urgently requires serious restructuring efforts. The most significant reductions in GHG emissions will result from:

- Improved standards of gasoline and diesel;
- Upgrade of technological control measures in vehicles;
- Introduction of vehicle retirement program;
- Improvements in traffic flows (decrease in congestion levels);
- Reductions in the number of vehicle trips;
- Reduction in the average lengths of vehicle trips; and
- Mode shift from single occupancy vehicles to high occupancy vehicles (public transport, transit).

The simplest and most basic measures are still non-existent in the country, and could make a drastic difference in terms of GHG emissions reduction. Therefore, two priority mitigation measures were considered for reducing GHG emissions in Lebanon by 2030:

2.3.4. Revitalization of the Public Transport System

This option consists of creating an efficient and reliable public transport system, whereby the distribution of pass-trips traveled by bus and car would be reversed (more than half of person trips to be traveled by bus).

Regarding the cost of short term (5 years) public transport revitalization relying on bus transport, , it is estimated that 507 buses will be needed in GBA, 85 in Tripoli, and 45 to serve intercity (between Mohafaza centers); i.e., a total of 637 buses countrywide. 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 million, which is modest compared to what is currently paid to employees as transport allowance. This cost should be considered starting 2011, in addition to 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 per tonne of CO_2 equivalent 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.

2.3.4.1. 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 vehicles that 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. Indeed, policymakers use incentive-based vehicle scrappage (or "Cash-for-Clunker") programs to pursue a range of social and economic goals such as decreasing vehicular emissions, preventing vehicle abandonment, lowering consumer spending on gasoline, and stimulating new vehicle sales. Car scrappage programs increase the vehicle turnover rate by incentivizing vehicle retirement. A number of recent scrappage programs make GHG emissions reduction an ancillary goal by setting fuel economy or grams of CO_2 equivalent per km requirements on the replacement vehicles. These upgrades range from a fuel economy improvement of 2.13 – 3.83 km/L in the US CARS program to 120 g CO_2 equivalent per km in Italy's scrappage program (Allan et al., 2009).

However, since newer cars are driven further per year than older ones, prematurely retiring a vehicle may have reduced short-term GHG emission reduction benefits if the replacement vehicle is driven considerably farther than the scrapped vehicle.

Incentives in vehicle scrappage programs can have various forms such as a voucher for a new vehicle, a tax rebate, a waiver for vehicle registration, or money towards public transportation. Vehicle owners will generally only scrap a vehicle if the incentive is larger than the trade-in value of the vehicle minus the expected repair and maintenance costs.

Using a fuel economy based requirement in car scrappage programs provides an incentive by enabling consumers to save money on gasoline bills, while a mileage-based eligibility would provide certainty in emission savings and simplify the scrapping procedure. Regarding program length, a long-term Cash-for-Clunker program may be more suitable to CO_2 equivalent reduction because with such a program policymakers could send a clear, long-term signal to auto manufacturers to produce more fuel-efficient vehicles.

Moreover, a prolonged Cash-for-Clunker program working in tandem with emission standards would hasten the vehicle turnover rate, provide more fuel-efficient vehicle options for consumers, increase the effectiveness of emission standards and reduce market distortions. However, the longer a program runs the longer a vehicle owner will wait before scrapping a vehicle. This problem is easily overcome by having a maximum total mileage requirement (Allan et al., 2009).

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. Strict control needs to be exerted simultaneously in order to enforce the ban on old cars and therefore prevent the illegal import (or smuggling) of such old cars that need scrapping. In parallel, strict emission standards need to be defined and enforced, and I/M 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. A comprehensive feasibility study needs to be carried out to assess such an option,

2.3.5. Mitigation strategy

Table 2-24 and Table 2-25 below present the mitigation strategy for the Transport sector and associated gaps and constraints. It should be noted that the indicative budget is a rough estimate based on professional judgment, and sometimes reflects the cost of studies that need to be carried out prior to the implementation of the proposed activities. Each of the mentioned activities requires an in-depth assessment to determine its actual cost at the time of planning and implementation.

Table 2-24 Mitigation strategy for the Transport sector

OBJECTIVE	PROPOSED MITIGATION STRATEGY	ACTIVITIES	RESPONSIBILITY	PRIORITY (ST/ MT/ LT)	INDICATIVE BUDGET (USD)	SOURCES OF FINANCING/ IMPLEMENTATION PARTNERS
Reduce emission levels from the transport sector	Develop a sustainable transport strategy	Vehicle/ fuel technological changes including: 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. Road/ vehicle operations improvements including: Restructure, empower and enhance the role of the traffic management organization (TMO). Promote the creation of a transport fund and foster increased	MoPWT MoE MoIM CDR Syndicate of vehicle importers Private sector	ST	USD 2 to 5 million for designing the activities proposed. USD 400 million investment cost for public transport revitalization over a period of 5 years.	MoPWT budget AFESD (The Arab Fund) EU Mediterranean Investment and Partnership (FEMIP) World Bank EIB KFAED (Kuwait)

OBJECTIVE	PROPOSED MITIGATION STRATEGY	ACTIVITIES	RESPONSIBILITY	PRIORITY (ST/ MT/ LT)	INDICATIVE BUDGET (USD)	SOURCES OF FINANCING/ IMPLEMENTATION PARTNERS
		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. 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				

OBJECTIVE	PROPOSED MITIGATION STRATEGY	ACTIVITIES	RESPONSIBILITY	PRIORITY (ST/ MT/ LT)	INDICATIVE BUDGET (USD)	SOURCES OF FINANCING/ IMPLEMENTATION PARTNERS
		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. Implement a vehicle retirement program and car scrappage program with incentives. Demand management including modal substitution and pricing incentives/disincentives: Promote travel modes with lower emissions: improve and expand public transport while also increasing fuel taxation and parking fees, coupled with supporting awareness campaigns with respect to sustainable transport practices. Reduce the average number and				

OBJECTIVE	PROPOSED MITIGATION STRATEGY	ACTIVITIES	RESPONSIBILITY	PRIORITY (ST/ MT/ LT)	INDICATIVE BUDGET (USD)	SOURCES OF FINANCING/ IMPLEMENTATION PARTNERS
		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. Legislative reforms, particularly in relation to urban planning laws, expropriation laws, taxes and tariffs, traffic laws.				

Table 2-25 Constraints to the implementation of mitigation measures

MITIGATION STRATEGY	CONSTRAINTS/ GAPS				
	LEGAL/ POLICY	INSTITUTIONAL	TECHNICAL/ENVIRONMENTAL	CAPACITY AND AWARENESS	DATA/ INFORMATION GAPS
Develop a sustainable transport strategy	Lack of long-term transport strategy endorsed by the Government. Lack of implementation of legislation governing vehicle emissions (such as Decree 6603/1995). Lack of legislation regulating vehicle retirement. Limited incentives to promote the use of public transport and	Fragmentation of responsibility among concerned government agencies; gap in the transport system management function. Lack of technical expertise among TMO staff, inhibiting it from carrying out the traffic management mandates it was conceived for.	Low purchasing power slowing down renewal of the vehicle fleet. Improper allocation of the existing collective transport supply over the market. Distorted pricing of transport services. Poor road maintenance adding to the inefficiency of traffic controls.	Lack of awareness with respect to sustainable transport practices and proper driving habits. Lack of appreciation of the economic impacts of congestion, air pollution, and other adverse effects on users and the urban economy. Insufficient number of trained professional experts in the field of transportation and sustainable urban transport. Need for introducing the	Limited monitoring data to support transport studies aiming at the development of sustainable transportation strategies.

MITIGATION STRATEGY	CONSTRAINTS/ GAPS				
	LEGAL/ POLICY	INSTITUTIONAL	TECHNICAL/ENVIRONMENTAL	CAPACITY AND AWARENESS	DATA/ INFORMATION GAPS
	discourage the use of private vehicles.			transport engineering specialty in universities.	

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2.4. BUILDING ENVELOPS

2.4.1. *Introduction*

This chapter focuses on the thermal performance of buildings based on heating and cooling energy consumption. According to the greenhouse gas inventory (Section ...), *energy-related* emissions from the commercial, institutional and residential sectors, as well as from the agriculture, forestry and fishing sectors contributed 1,556 Gg CO_2 equivalents in 2004, i.e., 7.63% of total emissions in Lebanon. However, this figure does not account for electricity consumption in the residential sector. Therefore, it is difficult to make a conclusion regarding total emissions from the buildings sector (residential, commercial and institutional) alone..

Thermal standards for buildings in Lebanon were developed by the "Capacity Building for the Adoption and Application of Thermal Standards for Buildings" project that was implemented between 2002 and 2005. The project was funded by the Global Environment Facility (GEF), managed by the United Nations Development Programme, and executed under the Lebanese General Directorate of Urban Planning (DGUP), Ministry of Public Works and Transport. The project presented a forecast of the impact of the application of the thermal standards on GHG emissions at the macroeconomic level, based on an estimation of the area of residential buildings and office buildings which will be constructed on a 20-year horizon between the period 2010 and 2029 (MoPWT, 2005), assuming that the thermal building standards would become mandatory as of 2010; unfortunately, the standards are still not mandatory.

This chapter presents the project's analysis for *new* buildings, highlights differences and limitations, and proposes measures for existing buildings. It should be noted that the retrofitting of existing buildings was not considered in the project.

2.4.2. *The Thermal Standards for Buildings*

The proposed thermal standards for buildings suggest standards for walls, roofs and windows for residential and office buildings (commercial, institutional). Following is a brief overview of these standards.

U-value for Roofs and Walls

Recommended levels of roof and wall U-values for the thermal standards for buildings for the various climatic zones of Lebanon are presented in Table 2-26.

Table 2-26 Optimum roof and wall Insulation levels by climate zone

CLIMATE ZONE	BUILDING TYPE	ROOF		WALL	
		U-VALUE ($W/M^2.K$)	EQUIVALENT POLYSTYRENE (CM)	U-VALUE ($W/M^2.K$)	EQUIVALENT POLYSTYRENE (CM)
Coastal	Residential	0.57	6	2.10	Double cavity wall No insulation
	Office	0.57	6	2.10	4
Western mid-	Residential	0.57	6	0.77	4

CLIMATE ZONE	BUILDING TYPE	ROOF		WALL	
		U-VALUE (W/M².K)	EQUIVALENT POLYSTYRENE (CM)	U-VALUE (W/M².K)	EQUIVALENT POLYSTYRENE (CM)
mountain	Office	0.57	6	0.77	4
Inland plateau	Residential	0.57	6	0.77	4
	Office	0.57	6	0.77	4
High mountain	Residential	0.44	6	0.55	6
	Office	0.44	6	0.55	6

U-value for Windows

Table 2-27 summarizes the recommendations for the selection of the glazing U-value in Lebanon based on an economic analysis.

Table 2-27 Glazing thermal transmittance requirement

CLIMATE ZONE	BUILDING TYPE	WINDOW	
		U VALUE (W/M².K)	TYPICAL CHARACTERISTICS
Coastal	Residential	6.2	Single glass
	Office	6.2	Single glass
Western mid-mountain	Residential	4.3	Single glass, low-e
	Office	4.3	Single glass, low-e
Inland plateau	Residential	4.3	Single glass, low-e
	Office	4.3	Single glass, low-e
High mountain	Residential	2.8	Double glazing, clear, low-e
	Office	2.8	Double glazing, clear, low-e

Maximum Effective Fenestration Ratio (EFR)

The objective of the required Effective Fenestration Ratio (EFR_{req}) is to limit the solar load to a reasonable range. The EFR_{req} is 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).

FENESTRATION RATIO

Windows have a higher heat loss per unit area than walls; therefore, increasing the window to wall ratio will result in a higher energy requirement for both space heating and cooling.

On the other hand, since windows are desirable from the point of view of natural lighting, natural ventilation (for opening windows), occupant general visual comfort and aesthetics, it is necessary to allow reasonable window-wall-ratios, as long as this does not adversely affect the thermal energy requirements of the building. Options to offset heat losses/gains incurred by greater window areas can include specifying better U-values for walls and roofs, addition of external horizontal or vertical window shading devices and lower U-value window configurations (two panes or better frame).

GLAZING SHADING COEFFICIENT

Reflective windows are cost effective in most climates because the cooling energy cost saved is higher than the heating energy cost. The only exception would be in the high mountain zone where a clear double window outperforms the tinted window.

ARCHITECTURAL SHADING FACTOR

The architectural shading factor is an interesting measure that should be considered in all climates and can be combined with glass shading coefficient, orientation and fenestration ratio. In the coastal zone, the economic analysis revealed that the higher the architectural shading factor, the better. Thus the architectural shading factor must not be selected in the thermal standard based on the economic return only.

For the western mid-mountain and inland region, the architectural shading factor also makes sense but the economically optimal size of fins and overhang is more in a reasonable range (architecturally speaking) and could be applied to reduce the effective fenestration ratio of buildings in most designs.

For the high-mountain region, solar heat gain is beneficial most of the year so the only cost-effective alternative here lies in moderate overhangs and fins that will just limit the solar heat gain during summer and will still let most of the solar heat gain in winter get in.

Table 2-28 and Table 2-29 show the recommended EFR_{req} levels for office and residential buildings, based on an analysis of different combination scenarios of the above factors.

Table 2-28 Thermal standard requirement for EFR_{req} – office buildings

CLIMATE	EFR_{REQ}
Coastal	10%
Western mid-mountain	13%
Inland plateau	11%
High mountain	21%

Table 2-29 Thermal standard requirement for EFR_{req} – residential buildings

CLIMATE	EFR_{REQ}
Coastal	11%
Western mid-mountain	13%
Inland plateau	11%
High mountain	16%

2.4.3. *Energy Savings from the Application of Thermal Standards to New Buildings*

2.4.3.1. *Assumptions and Approach*

Economic and population growth

The "Energy Analysis and Economic Feasibility Study- 2005" (MoPWT, 2005) was built on several assumptions. A medium economic growth rate was adopted as shown in Table 2-30:

Table 2-30 Economic growth rate during the study period- Medium growth rate scenario

2005 - 2009	2010 - 2019
1.0%	3.0%

The projected population growth rate and the related family size were taken from the official projections of the National Physical Master Plan for the Lebanese Territories (NPMPLT) (CDR, 2005) as presented in Table 2-31 and Table 2-32.

Table 2-31 Projected population growth

	YEAR				ANNUAL GROWTH RATE 2000 - 2030
	2000	2010	2020	2030	
Population	4,052,531	4,606,036	5,123,557	5,573,398	0.96%

Source: CDR

Table 2-32 Projected number of households

	2020	2030
Family size	4.38	4.20
Total number	1,184,485	1,340,573

Source: CDR

Projected Built-up Area of Residential Buildings

The projected number of residential units over a 20-year horizon was also taken from the NPMPLT (Table 2-33). The demolition and replacement of buildings that are over 75 years of age was not considered in the analysis.

Table 2-33 Projected number of residences

	2020	2030
Primary	1,141,295	1,288,741
Secondary	81,484	91,830
Vacant	164,524	148,897
Total	**1,367,782**	**1,529,447**

Source: CDR

In order to translate the number of residential units constructed during the study period to square meters, an average surface area of the residential unit of 140 m^2 per residential unit was used in the study. The resulting annual and total number of primary residential building units that will be constructed during the study period and the resulting built-up area in m^2 are presented in Table 2-34.

Table 2-34 Forecast of the residential building area that will comply with the Thermal Standards

YEAR	HOUSING NUMBER (UNITS)	HOUSING AREA (M^2)
2010	15,648	2,190,788
2015	15,062	2,108,687
2020	14,549	2,036,791
2025	14,153	1,981,354
2029	14,004	1,960,563
Total (2010 to 2029- 20 years)	**294,002**	**41,160,216**

Projected Built up Area of Office Buildings

The 1996 survey of the Central Administration of Statistics (CAS) revealed that the number of vacant office units reached an average of 31% on the national level. Considering this high level of vacancy, the following assumptions were made about the number and the occupancy of offices built according to the thermal standards:

- The number of new office units up to 2010 will be considered negligible, and the 3% growth rate will be applied from 2010 onwards. It will be considered that all new offices constructed after 2010 will meet the thermal standards.
- The average surface area per office unit will be considered as 25 m2.

Table 2-35 presents the projection of the growth rate and occupancy of office space during the history period and for the forecast period. The resulting building area in m^2 per climatic zone constructed each year is also identified in this table, based on which it is expected that the thermal standards will apply to a projected total constructed built-up area of 1,548,928 m^2.

Climatic zones are divided as follows:

- Zone 1: Coastal
- Zone 2: Western Mid-Mountain
- Zone 3: Inland plateau
- Zone 4: High mountain.

Table 2-35 Forecast of the office building area that will comply with the thermal standards

YEAR	ECONOMIC GROWTH (%)	WORKING OFFICES (UNITS)	NEW OFFICES RATE (%)	NEW OFFICES ANNUAL (UNITS)	TOTAL NUMBER OF OFFICES (UNITS)	EMPTY OFFICES (UNITS)	AREA (M²) OF OFFICE COMPLYING WITH THE THERMAL STANDARDS			
							Zone 1 50%	Zone 2 20%	Zone 3 20%	Zone 4 10%
1996	-	188,162	0	0	301,853	113,691	0	0	0	0
1997	4.0	195,688	2	3,763	305,616	109,928	47,038	18,815	18,815	9,408
1998	2.2	199,993	1.1	2,153	307,769	107,775	26,913	10,765	10,765	5,383
1999	1.2	202,393	0.6	1,200	308,969	106,575	15,000	6,000	6,000	3,000
2000	0.4	203,203	0.2	405	309,374	106,170	5,063	2,025	2,025	1,013
2001	0.0	203,203	0	0	309,374	106,170	0	0	0	0
2002	0.0	203,203	0	0	309,374	106,170	0	0	0	0
2003	0.0	203,203	0	0	309,374	106,170	0	0	0	0
2004	1.0	205,235	0	0	309,374	104,138	0	0	0	0
2005	1.0	207,287	0	0	309,374	102,086	0	0	0	0
2006	1.0	209,360	0	0	309,374	100,013	0	0	0	0
2007	1.0	211,454	0	0	309,374	97,919	0	0	0	0
2008	1.0	213,569	0	0	309,374	95,804	0	0	0	0

YEAR	ECONOMIC GROWTH (%)	WORKING OFFICES (UNITS)	NEW OFFICES RATE (%)	NEW OFFICES ANNUAL (UNITS)	TOTAL NUMBER OF OFFICES (UNITS)	EMPTY OFFICES (UNITS)	AREA (M²) OF OFFICE COMPLYING WITH THE THERMAL STANDARDS			
							Zone 1 50%	Zone 2 20%	Zone 3 20%	Zone 4 10%
2009	3.0	219,976	0	0	309,374	89,397	0	0	0	0
2010	3.0	226,575	0	0	309,374	82,798	0	0	0	0
2011	3.0	233,372	0	0	309,374	76,001	0	0	0	0
2012	3.0	240,373	0	0	309,374	69,000	0	0	0	0
2013	3.0	247,584	0	0	309,374	61,789	0	0	0	0
2014	3.0	255,012	1.5	3,174	313,087	58,075	46,425	18,570	18,570	9,285
2015	3.0	262,662	1.5	3,825	316,913	54,250	47,813	19,125	19,125	9,563
2016	3.0	270,542	1.5	3,940	320,852	50,310	49,250	19,700	19,700	9,850
2017	3.0	278,658	1.5	4,058	324,911	46,252	50,725	20,290	20,290	10,145
2018	3.0	287,018	1.5	4,180	329,090	42,072	52,250	20,900	20,900	10,450
2019	3.0	295,629	1.5	4,305	333,396	37,767	53,813	21,525	21,525	10,763
2020	3.0	304,498	1.5	4,434	337,830	33,333	55,425	22,170	22,170	11,085
2021	3.0	313,633	1.5	4,567	342,398	28,766	57,088	22,835	22,835	11,418
2022	3.0	323,042	1.5	4,704	347,102	24,062	58,800	23,520	23,520	11,760

YEAR	ECONOMIC GROWTH (%)	WORKING OFFICES (UNITS)	NEW OFFICES RATE (%)	NEW OFFICES ANNUAL (UNITS)	TOTAL NUMBER OF OFFICES (UNITS)	EMPTY OFFICES (UNITS)	AREA (M^2) OF OFFICE COMPLYING WITH THE THERMAL STANDARDS			
							Zone 1 50%	Zone 2 20%	Zone 3 20%	Zone 4 10%
2023	3.0	332,733	3.0	4,846	351,948	24,062	60,575	24,230	24,230	12,115
2024	3.0	342,715	3.0	4,846	351,948	24,062	60,575	24,230	24,230	12,115
2025	3.0	352,996	3.0	4,846	351,948	24,062	60,575	24,230	24,230	12,115
2026	3.0	363,586	3.0	4,846	351,948	24,062	60,575	24,230	24,230	12,115
2027	3.0	374,494	3.0	4,846	351,948	24,062	60,575	24,230	24,230	12,115
2028	3.0	385,729	3.0	4,846	351,948	24,062	60,575	24,230	24,230	12,115
2029	3.0	397,301	3.0	4,846	351,948	24,062	60,575	24,230	24,230	12,115
Total (2010 to 2029 – 20 years)				**79,170**			**895,614**	**358,245**	**358,245**	**179,124**
							1,791,228 m^2			

2.4.3.2. Projected reduction in energy consumption

The potential impact of the application of Lebanese Thermal Standards for Buildings (LTSB) on energy consumption was calculated by deriving the following numbers:

D_i = Difference in annual specific energy consumption (GJ/m^2 of floor area) that each category (i) of building upgraded to the corresponding recommended level in the LTSB in each climatic zone (k) will consume (compared to a base case building of the same configuration);

A_ik1 = Floor area (m^2) by building category (i) of new buildings constructed in climatic zone (k) in year 1 since the implementation of the LTSB;

P_1 = Potential energy savings at the end of year 1 can then be calculated using the following formula:

$$P_1 = \sum_k \{ \sum D_i \times A_{ik1} \}$$

P_2 = Potential energy savings at end of year 2;

A_{ik2} = Floor area of new buildings by building class (i) built during year 2;

$$P_2 = P_1 + \sum_k \{ \sum_i D_i \times A_{ik2} \}$$

P_2 was summed over all building classes and over all climatic regions built in the second year. The same was applied for subsequent years.

2.4.3.3. Results: Energy Savings and Associated Costs

Energy savings in Office Buildings

The results of the economic analysis of various improvements in thermal transmission levels of walls, windows and roofs indicate that there would be substantial savings in requiring new buildings and building expansions to comply with the optimum levels of thermal insulation. The savings per m^2 of floor area between base office buildings and similar buildings complying with the thermal standard were calculated from model studies. By subtracting the energy budget per unit of floor area between the base building and the compliant building, the net annual savings per unit of floor area are obtained (Table 2-36).

Table 2-36 Annual base case office building energy consumption per m² and savings for heating and cooling

	Base case building energy usage		Energy savings	Energy savings with the Thermal Standards					
				Total		Heating		Cooling	
	GJ	GJ/m²	%	GJ	GJ/m²	GJ	GJ/m²	GJ	GJ/m²
Coastal	437	0.228	9.8%	43	0.022	16.7	0.0087	26.0	0.0135
Western mid-mountain	540	0.281	22.4%	121	0.063	119.0	0.0620	2.5	0.0013
Inland plateau	794	0.414	46.5%	369	0.172	368.9	0.1921	6.1	0.0032
High mountain	1,242	0.647	56.7%	704	0.367	686.0	0.3573	1.8	0.0009

From Table 2-36 , it is obvious that the coastal region is the one where the potential is the least important. This is understandable as this is the zone where there is a lower set of measures for the improvement of thermal transmittance that are cost effective. The main characteristic of buildings that can be improved in this case is the solar radiation reduction but there are practical limits that have to be considered in this case to avoid putting too much restriction on the architectural expression. The overall result for the Coastal zone is a lower potential. For the Cedars (high mountain), the climate is the coldest and the one where the largest improvement in thermal transmittance is possible. Thus a very high potential of improvement exists which translates into a 56.7% of improvement. The two other regions fall in between. The Inland Plateau zone, which has larger temperature amplitudes, has a higher potential than the Western mid-mountain.

The application of the above figures to the projected built-up area which will be constructed in the future and which will comply with the thermal standards yields the following projections of energy savings caused by the thermal standards application (Table 2-37 and Table 2-38). Total savings from this sector amount to 1,432,727 GJ.

Table 2-37 Projected cumulative office built-up area (2010-2029)

YEAR	AREA OF OFFICES COMPLYING WITH THE THERMAL STANDARDS							
	Zone 1 50%		Zone 2 50%		Zone 3 50%		Zone 4 50%	
	Yearly (m^3)	Cumulative (m^3)	Yearly (m^3)	Cumulative (m^3)	Yearly (m^3)	Cumulative (m^3)	Yearly (m^3)	Cumulative (m^3)
2010	0	0	0	0	0	0	0	0
2011	0	0	0	0	0	0	0	0
2012	0	0	0	0	0	0	0	0
2013	0	0	0	0	0	0	0	0

YEAR	AREA OF OFFICES COMPLYING WITH THE THERMAL STANDARDS							
	Zone 1 50%		Zone 2 50%		Zone 3 50%		Zone 4 50%	
	Yearly (m^3)	Cumulative (m^3)	Yearly (m^3)	Cumulative (m^3)	Yearly (m^3)	Cumulative (m^3)	Yearly (m^3)	Cumulative (m^3)
2014	46,425	46,425	18,570	18,570	18,570	18,570	9,285	9,285
2015	47,813	94,238	19,125	37,695	19,125	37,695	9,563	18,848
2016	49,250	143,488	19,700	57,395	19,700	57,395	9,850	28,689
2017	50,725	194,213	20,290	77,685	20,290	77,685	10,145	38,843
2018	52,250	246,463	20,900	98,585	20,900	98,585	10,450	49,293
2019	53,813	300,276	21,525	120,110	21,525	120,110	10,763	60,056
2020	55,425	355,701	22,170	142,280	22,170	142,280	11,085	71,141
2021	57,088	412,789	22,835	165,115	22,835	165,115	11,418	82,559
2022	58,800	471,589	23,520	188,635	23,520	188,635	11,760	94,319
2023	60,575	532,164	24,230	212,865	24,230	212,865	12,115	106,434
2024	60,575	592,739	24,230	237,095	24,230	237,095	12,115	118,549
2025	60,575	653,314	24,230	261,325	24,230	261,325	12,115	130,664
2026	60,575	713,889	24,230	285,555	24,230	285,555	12,115	142,779
2027	60,575	774,464	24,230	309,785	24,230	309,785	12,115	154,894
2028	60,575	835,039	24,230	334,015	24,230	334,015	12,115	167,009
2029	60,575	895,614	24,230	358,245	24,230	358,245	12,115	179,124
Total (m^2)	**895,614**	**7,262,405**	**358,245**	**2,904,955**	**358,245**	**2,904,955**	**179,124**	**1,452,495**

Table 2-38 Projected energy savings from office buildings (2010-2029)

CLIMATIC ZONE	DISTRIBUTION OF PROJECTED BUILT UP AREA (%)	CUMULATIVE M² PER ZONE 2010 - 2029	HEATING SAVINGS		COOLING SAVINGS		PROJECTED ENERGY SAVINGS PER ZONE (GJ)
			GJ/m²	GJ	GJ/m²	GJ	
Coastal	50%	7,262,405	0.0087	63,183	0.0135	98,042	161,225
Western mid-mountain	20%	2,904,955	0.0620	180,107	0.0013	3,776	183,883
Inland plateau	20%	2,904,955	0.1921	558,041	0.0032	9,295	567,336
High mountain	10%	1,452,495	0.3573	518,976	0.0009	1,307	520,283
Projected energy savings by type (GJ)				**1,320,307**		**112,420**	
Total projected energy savings (GJ)							**1,432,727**

Energy Savings in Residential Buildings

Following the same reasoning, the results in Table 2-39 to Table 2-41 are obtained, for a total saving of 63,354,468 GJ from the application of thermal standards in new residential buildings.

Table 2-39 Annual base case residential building energy consumption per m² and savings for heating and cooling

CLIMATIC ZONE	BASE CASE BUILDING ENERGY USAGE		ENERGY SAVINGS	ENERGY SAVINGS WITH THE THERMAL STANDARDS					
				Total		Heating		Cooling	
	GJ	GJ/m²	%	GJ	GJ/m²	%	GJ	GJ/m²	%
Coastal	341	0.245	12.8	44	0.031	8.8	0.0063	35.0	0.0251
Western mid-mountain	501	0.359	42.8	215	0.154	202.0	0.1449	12.5	0.0089
Inland plateau	683	0.490	44.7	305	0.219	276.9	0.1986	28.3	0.0203

High mountain	1,283	0.921	58.0	745	0.534	743.2	0.5331	1.7	0.0012

Table 2-40 Projected cumulative residential built up area (2010-2029)

YEAR	AREA OF RESIDENTIAL BUILDINGS COMPLYING WITH THE THERMAL STANDARDS	
	YEARLY (M^2)	CUMULATIVE (M^2)
2010	2,190,788	2,190,788
2011	2,184,019	4,374,806
2012	2,161,705	6,536,511
2013	2,155,746	8,692,257
2014	2,162,598	10,854,855
2015	2,108,687	12,963,542
2016	2,078,897	15,042,439
2017	2,078,699	17,121,138
2018	2,060,363	19,181,501
2019	2,061,130	21,242,631
2020	2,036,791	23,279,421
2021	2,019,407	25,298,829
2022	2,021,612	27,320,441
2023	2,010,290	29,330,731
2024	2,007,031	31,337,762
2025	1,981,354	33,319,116
2026	1,961,849	35,280,965
2027	1,963,599	37,244,565
2028	1,955,089	39,199,653
2029	1,960,563	41,160,216

YEAR	AREA OF RESIDENTIAL BUILDINGS COMPLYING WITH THE THERMAL STANDARDS	
	YEARLY (M^2)	CUMULATIVE (M^2)
Total (m^2)	*41,160,216*	*440,972,169*

Table 2-41 Projected energy savings from residential buildings (2010-2029)

CLIMATIC ZONE	DISTRIBUTION OF PROJECTED BUILT UP AREA (%)	CUMULATIVE M^2 PER ZONE 2010 - 2029	HEATING SAVINGS		COOLING SAVINGS		PROJECTED ENERGY SAVINGS PER ZONE (GJ)
			GJ/m^2	GJ	GJ/m^2	GJ	
Coastal	50%	220,486,084	0.0063	1,389,062	0.0251	5,534,200	6,923,262
Western mid-mountain	20%	88,194,433	0.1449	12,779,373	0.0089	784,930	13,564,303
Inland plateau	20%	88,194,433	0.1986	17,515,414	0.0203	1,790,347	19,305,761
High mountain	10%	44,097,217	0.5331	23,508,226	0.0012	52,916	23,561,142
Projected energy savings by type (GJ)				*55,192,075*		*8,162,393*	
Total projected energy savings (GJ)							*63,354,468*

Summary of the Energy Saving Results and Costs

Over a 20 year period (2010-2029), the Thermal Standards for Buildings in Lebanon can generate a reduction in energy use at building input consisting of around 56 million GJ of avoided heating energy and around 8 million GJ of avoided cooling energy, as summarized in Table 2-42.

Table 2-42 Summary of the energy savings at building input

BUILDING CATEGORY	Heating savings (GJ)	Cooling savings (GJ)	Energy savings (GJ)
Residential	55,192,075	8,162,393	63,354,468
Offices	1,320,307	112,420	1,432,727
Total	**56,512,382**	**8,274,813**	**64,787,195**

The environmental benefits include the avoidance of around 7 million tonnes of CO_2 over 20 years (Table 2-43), i.e., around 343,500 tonnes of CO_2 per year.

Table 2-43 Projected avoided CO_2 emissions (2010-2029)

	ENERGY TYPE	ENERGY IN GJ	ENERGY IN MTOE	MILLION TONS OF CO_2 EMISSIONS
Cooling energy	Electricity	8,274,813	0.18	1.75
Heating energy	Electricity	5,651,238	0.12	1.16
	Diesel oil/ Gas	45,209,906	1.00	3.34
	Wood	5,651,238	0.13	0.62
Total		**64,787,195**	**1.43**	**6.87**

However, it is important to note that the CO_2 emissions related to electricity were calculated using the electricity supply mix of 2005, which was merely fuel-based (the introduction of natural gas started at the end of 2009), and which results in the emissions of 780g of CO_2 for every kWh of electricity. Any change in the fuel mix affects emission rates. For instance, if the Electricity Mitigation plan (Section 2) is implemented, emissions per kWh will be considerably reduced.

Another important factor that affects the results is that Thermal Building Standards are still being reviewed and have not become mandatory in 2010, and therefore the emissions reduction estimated in the "Energy Analysis and Economic Feasibility Study" (MoPWT, 2005) are overestimated. It is expected that these standards will not become mandatory before 2012.

However, the application decree for the Construction Law (Decree 15874/2005) stipulates that sunshades as well as stone/ wood/ metal cladding of outer walls are not accounted for in the computation of the surface area ratio (SAR), nor in the floor area ratio, provided that the outer walls' thickness does not exceed 15 cm. Moreover, in buildings with double walls, the surface of outer walls (including the thickness of walls and parts of columns falling within outer walls, but excluding the thickness of stone cladding) with a thickness between 22 cm and 35 cm is not accounted for in the computation of the two ratios mentioned above either. The void between the two walls should be at least 3 cm wide, and the thickness of the outer wall at least 10 cm. The former value can be reduced to 2 cm for buildings permitted before the enactment of this decree. In case the building is located at an altitude above 700 m, insulation material must be used between both walls. Outer doors and windows must also be double glazed. Decree 617/2007, which amends Decree 15874/2005, further specifies that the thickness of double glazed windows depends on the thickness of the double walls containing these windows; whereas the ratio of double walls surface to double glazed windows surface is the building owner's choice. These legislative texts provide an incentive for thermal insulation in new buildings, but remain optional.

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 from the study indicated savings in the range of 500 million USD in 2005. Based on the rise in fuel prices between 2005 and 2008 (peak price) and on the inflation and rise in construction costs during this same period, this figure should be inflated to reflect current prices. The price projections adopted in the "Energy Analysis and Economic Feasibility Study" for crude oil and diesel oil over the next 20 years (in constant dollars) are presented in Table 2-44. Three scenarios were developed with different costs of energy in USD per barrel for crude oil and in USD per liter for diesel oil. On one hand, oil price rose drastically to 97 USD/barrel in 2008 (MoF, 2010), and is not likely to decline below 70 USD/barrel by 2030. On the other hand, construction costs have also risen but at a much lower rate than oil price. Thus, the actual value of savings from the application of thermal standards for buildings can be assumed to be at least 1 billion USD per year.

Table 2-44 Crude Oil and Diesel Oil 20-year price forecast assumptions of the study

ALTERNATIVE	PRICE (USD 2002/BARREL)	REMARKS
Crude oil		
Low	20.452	- 20% from the base case
Base	25.565	
High	30.678	+ 20% from the base case
Diesel oil		
Low	0.24	20% lower than the base case
Base	0.30	
High	0.36	20% higher than the base case

In conclusion, the energy savings estimated come from cost effective measures and highlight the positive impacts of the application of the thermal standards for buildings in Lebanon.

2.4.4. The Case of 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.

Technically, and from a practical point of view, retrofitting of walls, roofs and windows is more difficult to implement in existing buildings compared to newly developed ones, especially that the building sector in Lebanon is characterized mostly by multiple storey facilities and not just individual homes. However, there are direct steps that could be implemented easily such as changing single glazing in all south west facades to double glazing, or alternatively installing a special window film.

The assessment of energy savings from retrofitting existing buildings and associated costs requires a comprehensive study similar to the "Energy Analysis and Economic Feasibility Study- 2005". It is not an understatement though to claim that tackling the existing building stock is a crucial step for Lebanon's goal of cutting GHG emissions from its building sector.

2.4.5. Mitigation Strategy

Table 2-45 and Table 2-46 below present the mitigation strategy for the Buildings sector, as well as the constraints associated with its implementation. It should be noted that the indicative budget is a rough estimate based on expert judgment, and should be refined on the ground at the time of implementation of measures.

Table 2-45 Mitigation Action Plan for the Buildings Sector

OBJECTIVE	PROPOSED MITIGATION STRATEGY	ACTIVITIES	RESPONSIBILITY	PRIORITY (ST/ MT/ LT)	INDICATIVE BUDGET (USD)	SOURCES OF FINANCING/ IMPLEMENTATION PARTNERS
Reduce emission levels from the buildings sector	Improve building envelopes thermal characteristics	Develop an Energy Performance Index (EPI) for existing buildings in order to classify them. Retrofit existing buildings with low EPI to improve their thermal characteristics Enforce the application of thermal standards to new buildings.	DGUP Municipalities LCEC LGBC	MT LT ST	Application of thermal building standards to new buildings: around $100/m^2$. Retrofitting existing buildings: around $125-150/m^2$.	EIB GEF IFC

Table 2-46 Constraints to the implementation of mitigation measures

MITIGATION STRATEGY	CONSTRAINTS/ GAPS				
	LEGAL/ POLICY	INSTITUTIONAL	TECHNICAL/ENVIRONMENTAL	CAPACITY AND AWARENESS	DATA/ INFORMATION GAPS
Improve building envelopes thermal characteristics	Thermal Standards for Buildings developed in 2005 still not mandated. Limited incentives to promote the application of thermal standards for buildings.	None	Higher cost of building insulation techniques compared to conventional building materials. Technical difficulty and higher cost of retrofitting existing buildings as compared to new buildings.	Lack of awareness with respect to thermal standards, energy conservation and associated benefits. Insufficient know-how in the field of energy-efficient building materials and techniques.	Limited energy data for the buildings sector, including EPI.

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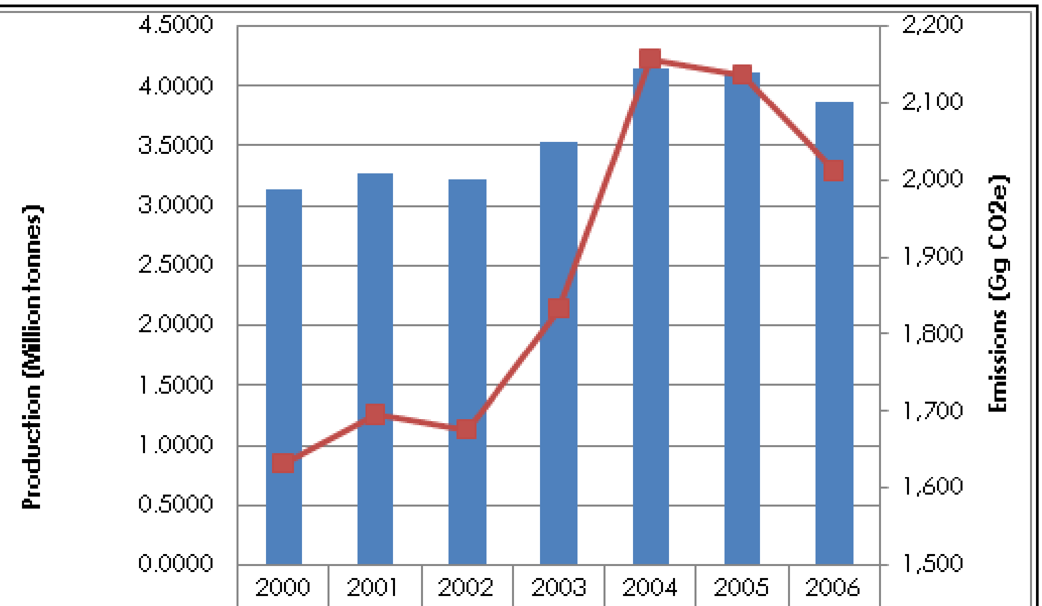
3. INDUSTRY

3.1. BACKGROUND

The cement industry is an important source of CO_2 emissions in Lebanon: emissions from the cement industry reached 2,156 Gg of CO_2-eq in 2004 representing 9.45 % of total GHG emissions for that year, and 92% of total industrial emissions (Refer to GHG inventory). Therefore, this chapter focuses on the mitigation of GHG emissions from cement industries.

In Lebanon, there are two Portland cement plants located in Chekka and one cement plant located in Sibline. While the two plants located in Chekka (Holcim and the National Cement Company) were established in 1929 and 1995 respectively, the Sibline plant (Ciments de Sibline) became operational in 1980.

According to the calculations made in the GHG inventory, the total production of clinker from all the plants is estimated at 4,143,809 tonnes in 2004, emitting 2,156 Gg of CO_2-eq (Figure 3-1).



	2000	2001	2002	2003	2004	2005	2006
Production (Million tonnes)	3.1351	3.2561	3.2188	3.5215	4.1438	4.1056	3.8681
Emissions (Gg)	1,631	1,694	1,674	1,832	2,156	2,135	2,011

Figure 3-1 Clinker Production and CO_2 emissions (2000-2006)

3.2. BASELINE SCENARIO: PROJECTED EMISSIONS

Two baseline scenarios are suggested to portray possible future clinker production and CO_2 emissions from the cement industry in Lebanon until year 2030. Scenario A assumes a low growth rate of 2% in the cement industry while Scenario B uses a higher growth rate of 4%. Figure 3-2 represent forecasts of cement production and CO_2 emissions under Scenario A and Scenario B.

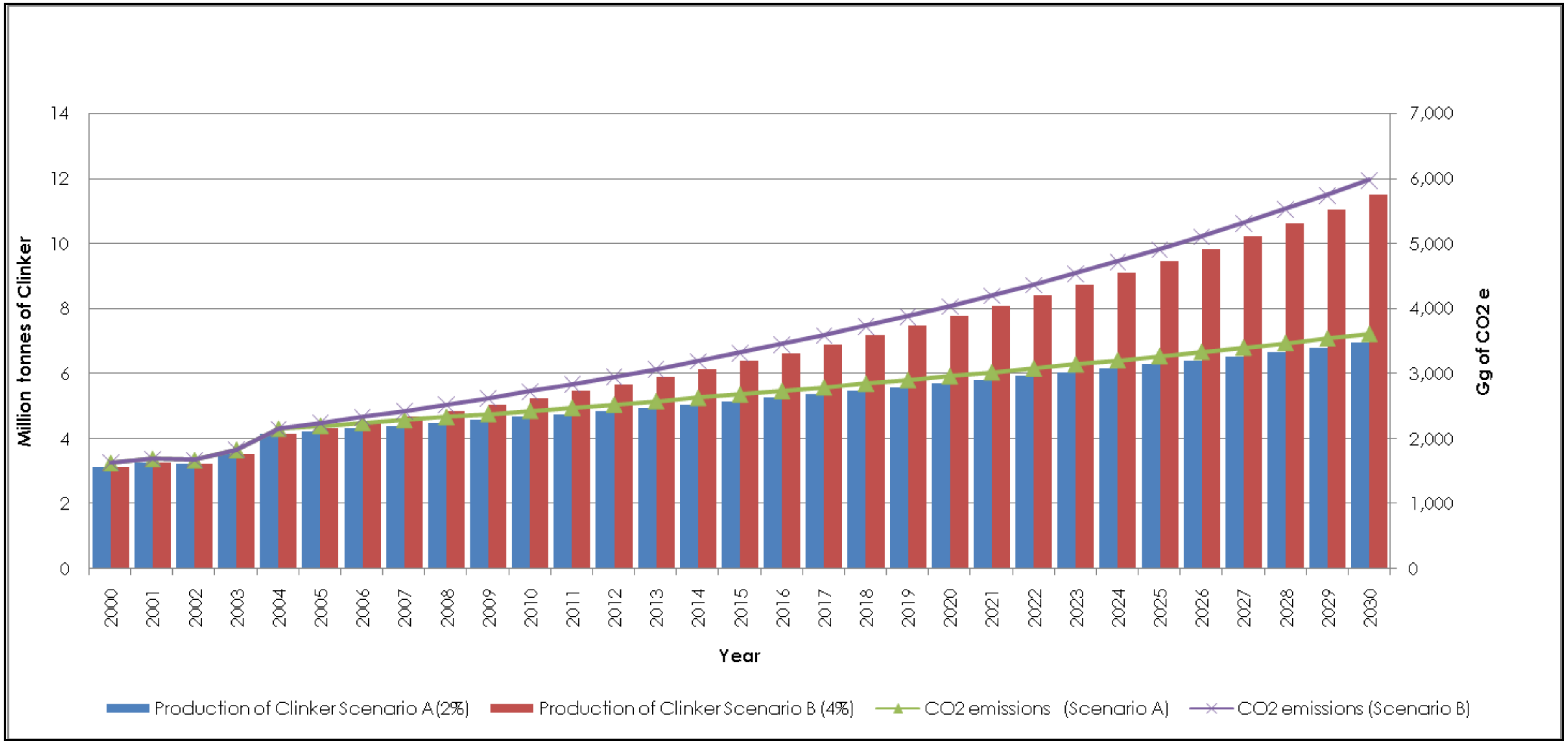


Figure 3-2 Projected clinker production and CO_2 emissions under Scenario a and Scenario B

3.3. Mitigation Option: Increasing the Additive Blend in Cement Production

The production of clinker is the most energy-intensive step in the cement manufacturing process and causes large process emissions of CO_2. In blended cement, a portion of the clinker is replaced with industrial by-products such as coal fly ash (a residue from coal burning) or blast furnace slag (a residue from iron making), or other pozzolanic materials (e.g. volcanic material) (Hendriks et al., 2004).

These products are blended with the ground clinker to produce a homogenous product which is blended cement. The reduction in clinker requirement in the production of cement results in reduction of CO_2 associated with calcination of limestone in kilns (UNFCCC, 2005):

The future potential for application of blended cements in Lebanon depends on the current application level, on the availability of blending materials, and on standards and legislative requirements. It was however not possible to obtain this information during the course of this study.

A case study in India (UNFCCC, 2005) revealed that an increase of the share of additive (fly ash in this case) from 27.66% to 35% (which is the maximum percentage of the fly ash that can be accepted in cement according to Bureau of India Standards BIS) would reduce the emissions by an estimated average of 33,608 tonnes of CO_2-eq per year resulting in a 1.32% reduction of total CO_2 emissions.

In the United States, the costs of blending materials may vary between 15 and 30 USD/Gg for fly ash and approximately 24 USD/Gg for blast furnace slag.

3.4. Limitations, Recommendations and Conclusions

Due to the difficulty of accessing local technical data, the option proposed in this report is based on international experience to provide an indication of the possibility of application in Lebanon.

A recent study has investigated a comprehensive list of possible measures in the cement sector in Thailand. A total potential for CO_2 abatement of up to 15% of total emissions was found to be cost-effective in Thailand. The most cost effective measures, based on Thailand's conditions along with other possible mitigation options applied in other countries, are summarized in Table 3-2 These options could be further explored in Lebanon. However, if the Lebanese government would like to see a genuine effort to reduce GHG emissions in the country from the cement sector, the following measures are proposed to be followed:

- Creation of a dialogue platform between the government and the cement factories management representatives;
- Establishment of annual targets for GHG emissions reduction in cement factories;
- Support to increase the flow of CDM revenues to encourage costly mitigation measures in the cement sector.

3.5. Mitigation Strategy

Table 3-1 below presents the mitigation strategy for the cement industry (relating to the cement production process), and Table 2-18 summarizes the constraints associated with its implementation.

Table 3-1 Mitigation strategy for the Industry sector (process)

TARGET	PROPOSED MITIGATION STRATEGY	ACTIVITIES	RESPONSIBILITY	PRIORITY (ST/ MT/ LT)	INDICATIVE BUDGET (USD)	SOURCES OF FINANCING/ IMPLEMENTATION PARTNERS
Reduction of GHG emissions from the Cement Industry	Reduce GHG emissions from the cement manufacturing process.	The main activities include: Increasing the additive blend in cement production. Substitution of conventional pre-calcination method by a pre-calcination method aimed at CO2 production in a highly concentrated form. Replacing parts of the plant (motors, raw mill vent fan, preheater fan, kiln drives, etc.) by high efficiency ones.	Cement companies (private sector) MoI MoE ALI (Association of Lebanese Industrialists)	ST	Cost to be determined based on technology selection and plant size.	The Arab Fund for Economic and Social Development (AFESD) The European Investment Bank (EIB) Kuwait Fund for Arab Economic Development (KFAED) The Abu Dhabi Fund for Development (ADFD) USAID UNIDO

Table 3-2 Constraints to the implementation of mitigation measures

MITIGATION STRATEGY	Constraints/ Gaps			
	Legal/ Policy	**Institutional**	**Technical/ environmental**	**Capacity and Awareness**
Reduce GHG emissions from the cement process	Insufficient regulation and standards relating to GHG emissions from cement factories	Lack of enforcement power by MoE, which is in charge of monitoring industrial emissions	High cost of technology and lack of financial support and incentives for industries to promote low emission technologies.	None

APPENDIX A: CO_2 ABATEMENT MEASURES FOR THE CEMENT INDUSTRY

CO_2 ABATEMENT TECHNOLOGY/ MEASURE	Average annual CO_2 abatement during scenario period (ktonnes CO_2/year)	CO_2 abatement cost (USD/tonne CO_2)
OPTIONS FROM THAILAND (HASANBEIGI ET AL., 2010)		
Adjustable peed drive for kiln fan	2.61	-73.62
Replacement of separator in coal mil circuit with an efficient grit separator	1.12	-72.93
Replacement of cement mill vent fan	0.06	-68.90
High-efficiency motors	18.99	-68.30
Variable frequency drive (VFD) in raw mill vent fan	1.79	-67.93
High efficiency fan for raw mill vent fan with inverter	0.15	-65.55
Bucket elevator for raw meal transport from raw mill to homogenizing silos	1.01	-64.75
Replacement of preheater fan with high-efficiency fan	0.30	-64.73
VFD in cooler fan of grate cooler	1.37	-62.79
Energy management and process control in grinding	36.73	-58.74
Adjustable speed drives	37.95	-56.82
Efficient vertical roller mill for coal grinding	5.21	-55.32
Installation of variable frequency drive and replacement of coal mill bag dust collector's fan	1.45	-54.02
Bucket elevators for kiln feed	0.53	-36.79
Replacing a ball mill with vertical roller mill	190.37	-35.26
Preventative maintenance	28.03	-32.76

Raw meal process control (vertical roller mill)	9.8	-32.72
High pressure roller press as pre-grinding to ball mill	100.12	-32.51
Efficient kiln drives	1.09	-27.58
Kiln shell heat loss reduction	545.73	-19.76
Energy management and process control systems for clinker making step	222.6	-17.04
Modification of clinker cooler (use of mechanical flow regulator)	37.55	-16.55
Portland limestone cement	156.86	-14.38
Optimize heat recovery/upgrade clinker cooler	34.97	-13.85
Upgrading the preheater from 4 stages to 5 stages or from 5 stages to 6 stages	377.34	-137
High-efficiency classifiers	2.16	22.01
High efficiency vertical roller mill for raw material grinding	19.97	47.33
Efficient transport system (mechanical transport instead of pneumatic transport)	1.33	145.15
Use of gravity system instead of pneumatic system in raw meal blending	23.92	246.35

CO_2 ABATEMENT TECHNOLOGY/ MEASURE	Average annual CO_2 abatement during scenario period (%)	CO_2 abatement cost (USD/ tonne CO_2)
	CASES FROM OTHER COUNTRIES	
Substitution of conventional pre-calcination method by a pre-calcination method aimed at CO_2 production in a highly concentrated form[1].	50% of CO_2 emissions associated with the cement manufacturing process	Not available

Utilizing CO_2 sequestration in the waste product Cement Kiln Dust (CKD)[2]	5% reduction in impact score over traditional Portland cement	Not available

Sources: 1- Rodriguez N. et al. (2009)

2-Huntzinger D. & Eatmon T. (2009)

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4. AGRICULTURE

4.1. BACKGROUND

The greenhouse gas emissions inventory for Lebanon shows that the agricultural sector is among the sectors that contribute least to emissions. These emissions mainly originate from agricultural soils, manure management (mainly emitting N_2O) and enteric fermentation (mainly emitting CH_4). The total emissions in CO_2 equivalent did not constitute more than 3.7% of the national total emissions between 2000 and 2004 (GHG Emissions Inventory). The 2004 total emissions from the agriculture sector amounted to 685 tCO_2-eq, distributed as follows: 131 tCO_2-eq from enteric fermentation; 127 tCO_2-eq from manure management; 426 tCO_2-eq from agricultural soils; and 1 tCO_2-eq from field burning of agricultural residues.

4.2. BASELINE SCENARIO

Many agricultural activities known to generate GHG emissions are not practiced in Lebanon (forest burning, rice cultivation, intensive fodder and leguminous species cultivation, intensive animal husbandry, etc.). Limited development in agricultural practices and activities could be seen as an advantage for Lebanon in terms of limiting GHG emissions from the agriculture sector.

The number of animals in the farming sector has not considerably increased over the past years, except for poultry, and the trend is expected to remain stable by 2030 (MoA, 2000, 2005, 2006, 2007) as shown in Table 4-1.

Table 4-1 Poultry and livestock head numbers per year

	2000	2004	2006	2007	2030
Dairy cows	38,900	43,850	36,500	45,300	55,719
Other cattle	38,100	36,550	36,500	40,100	45,634
Poultry*	10,898,630	13,200,000	13,389,534	12,676,712	18,508,000
Sheep and goat	591,575	732,000	854,800	759,100	950,000

* Number of birds per year is adjusted from an average bird life cycle of 38 days.

Source: MoA, 2000, 2005, 2007, 2007

The expected rise in emissions from the animal husbandry sub-sector is expected to be alleviated by ***improved breeding and feeding management***, and thus higher food conversion efficiency that lowers emissions from manure (Smith et al., 2007). Calculations for the livestock sector in Lebanon show that improved breeding and feeding management can reduce up to 32% of tCO_2-eq emissions from the livestock sector – dairy cows, other cattle and poultry – as shown in

Table 4-2. However, such measures are not likely to be applicable for the traditional rearing of small ruminants (sheep and goat) from which emissions are not expected to change, and would be difficult to mitigate, since manure is mostly daily spread in rangeland, and small ruminants are mostly dependent on natural seasonal pastures. Small ruminants are mostly local breeds, and put in small scale traditional shelters. Their manure is stocked and then sold to farmers to be used as organic fertilizer.

Table 4-2 GHG emissions from manure and enteric fermentation for major animal husbandry activities for the baseline year, 2004, and 2030, with and without mitigation measures

	CH_4 (GG)			N_2O (GG)			TOTAL CO_2-EQ. (GG)	
	2004	2030 WITHOUT MITIGATION	2030 WITH MITIGATION	2004	2030 WITHOUT MITIGATION	2030 WITH MITIGATION	2030 WITHOUT MITIGATION	2030 WITH MITIGATION
Dairy cows	1.666	2.117	1.906	0.082	0.104	0.100	76.764	33.196
Other cattle	1.206	1.506	1.431	0.052	0.065	0.062	51.631	20.562
Poultry	0.238	0.333	0.293	0.249	0.350	0.335	115.189	111.194
Total	3.110	3.956	3.629	0.383	0.518	0.497	243.584	164.953

Emissions from agricultural soils and field burning of agricultural residues are not expected to increase either, given the forecast that total agricultural area will fluctuate (increasing or decreasing) at the expense of other land uses (construction, land reclamation, forests) that vary with time. As a matter of fact, between 2006 and 2007, the MoA's Census showed that the total agriculture area contracted by 2% while calculations made following the IPCC manual for N_2O emissions, show a decrease of 3.5% in N_2O emissions which are mainly from N-fertilizers' application, N-fixing crops and field burning. The national GHG emissions inventory showed that between 2004 and 2006, N_2O emissions from agricultural soils dropped from 2.145 Gg to 1.373 Gg (GHG Emissions Inventory). On the other hand, the IPCC report on mitigation measures in agriculture (Smith et al., 2007) calculated a potential of 0 to 10% annual decrease in N_2O emissions in warm dry climates. Since such reductions can be easily obtained from annual variability in cropping patterns and yields in Lebanon, we estimate that an average annual decrease of 3.5% of N_2O, NOx and CH_4 emissions from agriculture soils is feasible under different scenarios, even if there is no clear policy for GHG reduction from the agriculture sector. Hence, by 2030, GHG emissions from agriculture soils could be at 60% less than the emissions in the baseline year, without taking into consideration CO_2 emissions or sequestration.

The National Action Plan (NAP) for Combating Desertification (MoA, 2003) developed by the Ministry of Agriculture is expected to help reduce GHG emissions from agricultural soils through the promotion of sustainable agriculture, improved rangeland management, and soil conservation practices. The implementation of the NAP for Combating Desertification could therefore count GHG emission reduction as a co-benefit, provided that more detailed and structured calculations are provided to value the NAP's contribution.

4.3. MITIGATION MEASURES

Even though agriculture is a minor contributor to GHG emissions in Lebanon, mitigation measures are suggested and coupled in most cases with the adaptation measures suggested for the sector. The agricultural sector in Lebanon can potentially become a carbon neutral sector. The mitigation measures are divided into two major groups (UNFCCC, 2007):

4.3.1.1. Field level measures

These measures apply to three major agricultural systems:

- Modern poultry and animal husbandry (dairy and meat production) farms which emit a notable proportion of CH4 and N2O gases;
- Plowed agricultural soils in areas prone to desertification and land degradation;
- Surface irrigated crops.

Modern animal production farms

Large modern farms need to better manage their manure and other agricultural wastes by producing compost or biogas which would reduce GHG emissions considerably. Manure management is an essential practice in minimizing GHG emissions caused by microbial activities during manure decomposition. The major gas emitted is methane (CH_4). The amount of gas emitted varies with: (1) the amount of manure, which depends on the number of animals and amount of feed consumed; (2) animal type, particularly the condition of the digestive tract, quality of feed consumed, etc., which in Lebanon consists of cattle and poultry; (3) manure handling method through solid or liquid disposal methods; and (4) environmental conditions such as temperature and moisture.

Common mitigation measures for manure management are summarized in Table 4-3 (IFAD, 2009; Berg & Pazsiczki, 2006; AAFRD & UoA, 2003).

Table 4-3 Common mitigation measures for manure management

GENERAL MANAGEMENT PRACTICES	FEED MANAGEMENT	MANURE STORAGE, HANDLING AND TREATMENT TECHNOLOGIES
▪ Avoid adding straw to manure as it acts as a food source for anaerobic bacteria ▪ Avoid manure application on extremely wet soil ▪ Animal grazing on pastures helps reduce emissions attributable to animal manure storage. Introducing grass species and legumes into grazing lands can enhance carbon storage in soils	▪ Select livestock to genetically improve food conversion efficiency ▪ Increase the digestibility of feed by mechanical, chemical or biological processing ▪ Feed less frequently ▪ Feed cattle additives (ionophores) that act to inhibit methane production by rumen bacteria ▪ Add edible oils that reduce methane emissions by rumen	▪ Covered lagoons: covers on the surface of the manure reduce the transfer of GHGs to the atmosphere. Methane under the cover is either flared and the emissions are released to the atmosphere, or burned in a generator to produce electricity. Methane emissions can be reduced by 80% ▪ Digesters: wastes are fermented under anaerobic conditions to produce methane, generating heat and electricity as an alternative energy source ▪ Filtering of exhaust from animal houses for GHG removal (still under research) ▪ Composting of manure

Compost can be restituted to the soil as an organic fertilizer, which would increase water conservation and soil fertility. Consequently, productivity of plants and removal of CO_2 are enhanced (FAO, 2009).

Biogas could be used as an autonomous energy source for farms generating it. Thus, their energy import from non-renewable sources is reduced, which in turn reduces their GHG emissions. For instance, 1.7 cubic meters of biogas is equivalent to one liter of gasoline, thus 1 kg of cow manure will thus generate 388 watt-hour at 28°C. For a cow dung generation rate of around 25 kg per day, energy production can reach around 20 kilowatt-hours daily (Singh, 1971; Reidhead, 2010).

Plowed agricultural soils (mainly in areas prone to land degradation)

Most agricultural soils in Lebanon are plowed. Even though plowing releases GHGs (N_2O, CO_2); these emissions vary according to several criteria. Deep plowing for land reclamation and for tubers harvesting are the most critical. Plowing soils with excessive nitrogen fertilization and soils previously planted with legumes increases N_2O emissions. Soil texture in semi-arid areas is easily degraded when plowed, and releases GHG gases. Mitigation measures to be proposed are linked to adaptation measures:

- Encouraging organic farming, with appropriate crop rotation, intercropping, the use of compost and green cover fertilization instead of chemical fertilizers.
- Encouraging no-till or conservation agriculture techniques that would reduce gas emission from soils by 40% and conserve soil fertility in semi-arid areas (GTZ/CoDeL, 2009).

Surface irrigated crops

Agricultural cropping patterns that are irrigated using surface techniques suffer from low water efficiency and low production. This irrigation method boosts weed proliferation and requires plowing and soil management. As a result, the use of herbicides, pesticides and fertilizers increases as well. The adoption of localized efficient irrigation systems (e.g., drip irrigation) is a win-win solution where productivity, and thus carbon uptake, increase, water efficiency is enhanced, and GHG emissions are reduced. Higher water efficiency would reduce pumping from the water table, and consequently reduce GHG emissions.

4.3.1.2. Research, education, assistance, infrastructure, and institutional measures

These measures follow the same approach as for adaptation measures, to which they should be coupled. They are summarized as follows:

Research measures

- Empirical studies that study the appropriate agricultural practices (till, no-till, weed control, irrigation methods, etc.) and agricultural production systems (organic farming, conservation agriculture, crop rotations, etc.) which can lead to reduction in GHG emissions from soils.
- Adapting agricultural machinery to no-till practices.
- Studies engaging in animal nutrition in order to cope with changing cropping patterns for fodder species, and in order to minimize nitrogen losses in manure.
- Economic feasibility studies for newly adopted agricultural systems.

Educational and assistance measures

Since mitigation field measures were subdivided into three categories, educational measures should be targeted at the following groups:

- Owners and employees of major modern farms
- Farmers and farmers' groups in semi-arid areas
- Farmers and water users' associations using surface water for irrigation
- Veterinarians, agricultural engineers, and technicians

Infrastructure measures

Infrastructure measures need to be undertaken in order to mitigate GHG emissions. The major infrastructure changes to be undertaken are among the private sector, specifically within the target groups mentioned above. These include:

- Units for composting manure in moderni poultry and animal husbandry farms.
- Units for recovering biogas and producing clean energy from fermentation in modern farms.
- Water efficient irrigation systems at the farm level.
- Appropriate machinery for conservation agriculture techniques (for seeding, harvesting in no-till agriculture, etc.).

Institutional measures

Monitoring GHG emissions and proposals of adequate measures for mitigation are essentially mandated to the Ministry of Environment. The Ministry of Agriculture is responsible for the implementation of an eventual national action plan or governmental decisions relating to GHG emissions reduction from the agriculture sector. Such measures should be taken into consideration in the Ministry's agricultural strategies. Since most of the measures for adaptation and mitigation are linked, the major administrative institutions and departments to be reinforced are almost the same:

- The directorate of Animal Resources on manure management and fodder issues (as part of new legislation on organic agriculture)
- The directorates of Plant Resources and of Rural Development and Natural Resources on soil management and grazing/ rangeland management as well as organic farming
- Research institutes; to achieve the research measures to be addressed
- Green Plan; to implement the infrastructural mitigation/adaptation measures related to water
- Extension services; to disseminate information to farmers

Some of these major directorates and institutions, namely research and extension services, could be delegated or implemented in joint venture with the private sector (input and service providers, universities, etc.) and NGOs. Some international organizations are already involved in such measures (UNDP, GTZ, FAO, etc.). Financial incentives (such subsidies and loans) are crucial for all measures.

4.4. COST OF MITIGATION MEASURES

Field and infrastructure measures could only be addressed at the level of individual, major poultry and animal husbandry farms. This is the case because cost varies with the number of animals, and with the technologies used. Case studies could be undertaken in order to estimate the cost of ***processing the manure into compost***, or for the ***production of biogas and then energy at the farm level***.

The cost of each mitigation option can be estimated according to carbon price (USD per tCO_2-eq. per year). For instance, livestock feeding and nutrient management costs 60 USD and 5 USD/tCO_2-eq per year respectively, while animal breeding costs 50 USD/tCO_2-eq. per year (Smith et al., 2008).

Assuming that improved livestock feeding and animal breeding are implemented and have an equal impact on emission reduction, the cost per tCO_2-eq. per year will be the mean of two values, i.e. 55 USD/tCO_2-eq per year. Thus, for the year 2030 for example, 78,631 tCO_2-eq. reduced from animal husbandry would cost around 4.33 million USD (Table 4-4).

Improved nutrient management practices are expected to result in a reduction of 60% of baseline N_2O emissions. At an assumed cost of 5 USD/tCO_2-eq per year(Smith et al, 2008), the total cost of emission reduction from nutrient application would amount to 2 million USD (Table 4-4).

Table 4-4 Emission Reduction Potential and cost of mitigation from the proposed measures

	MITIGATION OPTION 1: IMPROVED BREEDING & FEEDING MANAGEMENT	MITIGATION OPTION 2: NUTRIENT MANAGEMENT
Emission Reduction (in tCO_2-eq)by 2030	78,631	399,000
Cost ($/$tCO_2$-eq)	55	5
Total Cost (in million USD)	4.33	2.0

The same approach could be used in order to estimate the cost of conversion of exploitations from conventional agriculture (for selected vulnerable crops like potato, tomato, wheat or olive) to conservation agriculture adopting no-till practices and eventual drip irrigation systems. In many cases, measures are almost costless. For example, the cost of converting an olive orchard to a no-till production system is around 88 USD/hectare in Syria (FAO, 2009). FAO sources estimate the cost of adopting no-till agriculture at 600 USD/hectare in Morocco. Other measures would be more expensive. For example, the cost of shifting from surface to drip irrigation is around 3,500 USD/hectare in Lebanon. Subsequently, in order to convert, by 2030, 30,000 ha of cereals, legumes, and fruit orchards in Baalback-Hermel area to no-till agriculture, a budget of 18 million USD is needed, excluding the cost of machinery (i.e., seeders for cereals and legumes). Hence, to convert 30,000 ha of fruit orchards and vegetables to drip irrigation until 2030 we will roughly need 105 million USD, without counting head units, and common water canalization. The lack of information on the sequestration of CO_2 by soils in Lebanon limits the analysis of the sequestration potential from the shift to drip irrigation, and the calculation of the cost of this measure per tonne of CO_2-eq.

Since many adaptation and mitigation measures are coupled together, it should be noted that costs should not be double counted (e.g., the cost of irrigation systems).

Table 4-5 and Table 4-6 present the mitigation strategy for the Agriculture sector as well as gaps and constraints associated with its implementation.

Table 4-5 Mitigation Strategy for the Agriculture Sector

TARGET	PROPOSED MITIGATION STRATEGY	ACTIVITIES	RESPONSIBILITY	PRIORITY (ST/ MT/ LT)	INDICATIVE BUDGET (USD)	SOURCES OF FINANCING/ IMPLEMENTATION PARTNERS
Reduction of GHG emissions from animal husbandry	Reduce GHG emission by 32% from modern poultry and bovine farms by 2030 by reducing/ recovering methane gas generated during anaerobic fermentation of manure disposed in ponds	- Survey farms and farmers then propose according to each case the following measures: (a) Improve manure management through better storage, handling and treatment technologies (including methane recovery) (b) Improve feeding practices by selecting additives or by choosing high feed conversion animal breeds (c) Improve pasture management and avoid manure storage and mixture with straw (d) Training for farmers	- Farmers/coops -MoA (extension) - Municipalities - Unions of municipalities -Universities (research) - Private sector (study/implementation) - MoE (monitoring)	MT-LT	USD38.33/t CO_2 eq./yr or the equivalent of USD 3 million for the year 2030 as an estimation.	Farmers, municipalities, unions of municipalities, GEF, GTZ, EFL, UNDP, FAO and NGOs/enterprises dealing with carbon trade, etc
Reduction of GHG from agricultural soils	Promote Good Agricultural Practices (GAP), no-till (conservation) agriculture and good agricultural practices especially in areas vulnerable to land degradation. GHG emissions reduction could reach up to 40% in such soils.	- Identify ongoing projects and join efforts to promote the adopted strategy for potential crops (rain fed crops, irrigated cereals ,fruit orchards and potato) - Identify the suitable measure for each crop/area - Follow up the implementation with farmers and introduce the necessary technology/practices	-Farmers/coops -MoA (extension, quality control, accreditation) -Universities (research) - Private sector (study/implementation) -NGOs (implementation/follow up, marketing)	MT-LT	USD88-600/ha according to the selected measure and crop without adding neither the cost of labeling and certification nor the managerial cost.	Farmers associations, GEF, GTZ, EFL, UNDP, FAO, and NGOs/enterprises dealing with carbon trade, etc.

TARGET	PROPOSED MITIGATION STRATEGY	ACTIVITIES	RESPONSIBILITY	PRIORITY (ST/ MT/ LT)	INDICATIVE BUDGET (USD)	SOURCES OF FINANCING/ IMPLEMENTATION PARTNERS
	30,000 ha could be converted by 2030.	- Ensure the certification of the products and promote their marketing - Train farmers	- Certification bodies (certification) - Traders (marketing) -MoE (monitoring)			

N.B: Refer to adaptation measures for irrigation and rangeland which can be also considered as mitigation measures in agriculture and natural ecosystems.

Table 4-6 Constraints to the implementation of mitigation measures

MITIGATION STRATEGY	CONSTRAINTS/ GAPS				
	LEGAL	INSTITUTIONAL	TECHNOLOGICAL	CAPACITY AND AWARENESS	DATA/ INFORMATION GAPS
Reduction of GHG emissions from animal husbandry	None	Limited specialized staff in relevant areas	- Lack of local breeding technology. - Lack of anaerobic digestion technology. - Lack of relevant expertise.	Essential to train farmers all the practices required for feed and pasture management	All data can be found or estimated and information can be imported when necessary.
Reduction of GHG from agriculture soils	- Constraints related to the import of biological material - Constraints related to accreditation and certification of products	Lack of staff in private enterprises. Constraints related to quality control and traceability	- Absence of insectariums and local providers of traps, pheromones, biological pesticides and natural enemies in Lebanon. - Absence of local technologies for the machinery required in no-till agriculture (seeders, harvesters, etc.) - Limited funds for the promotion of mitigation measures.	Essential to train engineers and farmers on conservation agriculture, good agriculture practices and organic farming practices (soil management, composting, etc.)	- Lack of data on the actual cropping pattern and actual agriculture practices in potential areas for conversion. - Lack of information about the quantity of reduction of GHG per crop, per region and per type of measure

APPENDIX A

Table 1 Principles advocated by the National Action Plan for Combating Desertification that contribute to the reduction of GHG emissions

Sustainable agriculture	Rangeland management	Soil conservation
▪ Implementation of a comprehensive land use plan. ▪ Development of a decision support system for farmers on trends and production techniques (including organic farming and low external inputs for sustainable agriculture - LEISA). ▪ Adoption of a system approach to improve agricultural productivity and to identify needed interventions in terms of provision of necessary infrastructure, credit, training, post-harvest and marketing. ▪ Development and adoption of integrated and sustainable agriculture practices including certification programs and procedures.	▪ Development of a comprehensive legislative and policy framework with the active participation of all rangeland users. ▪ Development of a national rangeland strategy. ▪ Provision of support for the establishment of proper land tenure systems so that users have long-term stake in sustainable use. ▪ Enhancement of biomass and vegetative cover of rangelands. ▪ Support for sustainable livestock production through the introduction of improved stock, animal husbandry, stock management, alternative feed resources and health programs; through the initiation of relevant pilot activities; and through the implementation of a participatory model for rangeland management in a pilot area. ▪ Support of research to develop a better understanding of rangeland dynamics, rehabilitation and management techniques. ▪ Support for technical trainings and efficient extension services for rangeland management, rehabilitation and sustainable livestock production.	▪ Protection of prime agricultural lands from further misuse through the establishment of a proper land use planning and zoning system. ▪ Development and enforcement of a comprehensive legislative framework for sustainable agricultural production. ▪ Promotion of soil conservation practices. ▪ Development of a proper extension service. ▪ Development of a strategy for relevant applied research in soil conservation and management issues. ▪ Mainstreaming of soil conservation and management topics in the curricula of agricultural schools and relevant departments at universities.

Source: MoA, 2003

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5. FORESTRY

5.1. INTRODUCTION

In reference to the IPCC Fourth Assessment Report (2007), ecosystems and humans will have to adapt to climate change to address the impacts resulting from the warming which is already unavoidable due to past emissions.

The assessment of the vulnerability of forests to climate change has described the ability of forests in Lebanon to adjust to climate change, and has presented a set of recommendations for policy making and action taking in this respect. Nevertheless, no matter how efficient the adaptation to climate change, if the trend of human pressure is sustained, the resilience of the systems would be seriously compromised. The land and forestry sectors are regarded as sinks for GHGs where in 2004 some 605 Gg CO_2-eq were estimated to have been sequestered. This section describes a set of actions/recommendations aiming to reduce Lebanon's contribution to climate change from land use, specifically forestry activities. The overall objective of the mitigation actions is to reduce the GHG levels in the atmosphere through increased carbon sequestration by forests and soil. In the perspective of reaching this goal, two alternatives could be envisaged:

- Maintaining and conserving existing forest carbon sinks: through forest and soil protection, management practices and preventing forest degradation;
- Improving carbon sequestration by forests and soils through reforestation and afforestation in order to ameliorate the forest cover.

5.2. BASELINE SCENARIO

The National Reforestation Plan (NRP), initiated in 2001 by the Ministry of Environment (MoE), aims at the restoration of the green cover lost throughout the years. Two phases of reforestation activities were executed and the third reforestation phase started in 2009 with a total budget of 2,255,000 USD (2009 - 2014).

The MoE's reforestation/afforestation plan aims to increase the forest cover from 13% of Lebanon's land surface area to 20%. As the reforestation/afforestation activities mainly target the coniferous forests, the forest area increase will concern evergreen forests which would increase from 134,298 to 206,612 ha by 2030, while the areas of deciduous forests should remain the same with sustainable management and conservation.

The net annual emissions of GHG from the forestry sector are negative since growing trees sequester carbon from the atmosphere, while adult trees lock the carbon sequestered in the bark. Table 5-1 shows the area of forests in kha and the number of fruit trees in Lebanon for the year 2004. The GHG inventory has estimated the annual total carbon uptake increment in Lebanon for the year 2004 at around 249.19 kt of carbon.

It should be noted that forests and fruit trees are expressed in different units (kha vs. number of trees) in accordance with IPCC guidelines.

Concerning the fruit trees, it is assumed that their number would increase by 10 percent by 2030, whereby the number of non-forested fruit trees would reach 28,041 thousand, and the number of deciduous fruit trees 22,061 thousand. Table 5-1 shows an estimation of forest areas in kha and the number of fruit trees in Lebanon for the year 2030. Hence, the total carbon uptake increment[4] for the year 2030 will be around 347.32 kt of carbon.

Table 5-1 Forest area and number of trees in the baseline scenario

	TOTAL FOR THE YEAR 2004	2004	EXPECTED TREND	2030 TOTAL EXPECTED	2030 PROJECTIONS
Area Evergreen stands (ha)	139,522	134,298	Increase from 13% to 20% cover	211,836	206,612
Area Deciduous stands (ha)		5,224			5,224
Number of non-forested evergreen fruit trees ('000)		25,492	10% increase in number of fruit trees	28,041	
Number of other fruit trees ('000)		20,056	10% increase in number of fruit trees	22,061	
Total Carbon uptake increment (kt)		249.19		347.32	

5.3. MITIGATION OPTIONS AND COSTS

To be able to fulfill the expected scheme, i.e. increase forest cover, sustainably manage existing stands, conserve and expand protected areas, a number of projects, efforts and measures should be followed and implemented. The challenge is to reach the high target of 20% forest cover of MoE's plan and to maintain the current and future tree stocks. This can be done through:

Maintaining and conserving existing forest carbon sinks

MANAGING NATURE RESERVES AND PROTECTED AREAS

Nature reserves in Lebanon occupy around 5% of the overall area (MoE, 2006), i.e., an area of 52,260 ha.

In reference to the CBD goal 1 target 1.1, an objective of 10% of the "world's ecological region" should be effectively protected (MoE, 2009). As per the Initial National Communication (1999), two targets that could be realized through reforestation - agro-forestry and urban forestry - were set at two levels:

- The expansion of the forest area from 75,000 hectares to 200,000 hectares (low target).
- The expansion of the forest area from 200,000 hectares to 282,000 hectares (high target).

[4] Total Carbon uptake increment (Kt C) = [(Area of forest $_{\text{per tree type}}$ x Annual growth rate) + (Number of trees $_{\text{per tree type}}$ x Annual growth rate)] x CF
The annual growth rate assumed is 2.5; 1.5; 0.004125; 0.002475 for evergreen forests, deciduous forests, evergreen fruits/olive trees and for deciduous fruit trees, respectively. The carbon fraction, CF = 0.5.

Working to maintain existing protected areas and to sustain the creation of new protected sites (whether nature reserves or other types of protection) will not only allow Lebanon to enhance biodiversity, but will contribute as well to the mitigation of emissions by conserving existing carbon sinks.

Maintaining forests and preventing forest degradation involves the following management practices:

- Adopting sustainable forest management practices in grazing, Non Wood Forest Protection (NWFP), and wood harvesting in forests and other wooded lands (OWL) to address the possible threats to these ecosystems and improve their status;
- Preventing forest degradation and habitat fragmentation through insect and pest management and forest fire fighting strategies, which will provide stability for ecosystems to permit the establishment of ecological equilibrium, and therefore the reduction of habitat loss and degradation; and
- Rehabilitating abandoned lands and degraded zones to ensure natural forest regeneration and development.

According to the current national plans, 72,314 ha will be reforested by 2030. Larger increases in the reforested areas are likely to conflict with the foreseen development and urban expansion trends which Lebanon is already witnessing. Hence, the mitigation option analyzed here consists of maintaining and sustainably managing the existing stocks as well as the new stock to be planted.

Reforestation costs, including initial costs, recurring maintenance costs and monitoring costs are considered to be baseline costs. Additional costs for forest protection and management as carbon sinks, in addition to costs of leakage monitoring, are considered to be mitigation costs and are accounted for (Table 5-2 and Table 5-3).

For this purpose, a management and conservation plan is defined and relevant costs are estimated as follows:

- **For existing forests and OWL,** the measures needed consist of:
  - Wood clipping and pruning of trees, including transportation of pruning residues, at a cost of 1,000 USD/ha. This measure would be repeated twice between 2010 and 2030.
  - Clearing of grass and weeds along the borders of all roads surrounding forests and OWL on a yearly basis for the purpose of fire protection, at a cost of around 100,000 USD/year.
  - Acquiring 40 vehicles equipped with water tanks and pumps for patrolling all forest and OWL areas throughout the country. The cost per vehicle would amount to 50,000 USD, and these would serve for 20 years. Each vehicle would be in charge of monitoring a specific region to prevent fires, and would simultaneously play the role of a fire monitoring tower by parking in a location with a view on a large green area. The effective duration of operation is 6 months, from June until November, where the vehicles are used in forest protection. The operation costs of these vehicles (fuel, repair and maintenance, etc.) would be 600 USD/month.
  - Hiring 80 forest guards (two guards per vehicle) who would be exclusively in charge of monitoring forests and OWL within a certain area and preventing forest fires. Their role would be to alternate between patrolling of forests and OWL within their area of jurisdiction and stationary monitoring forests from strategic locations in order to prevent fires and fight

potential fires with the water tank mounted on their vehicle while they are at their preliminary controllable stages. The role of these guards equipped with vehicles would be preventive and protective, and would also considerably save on firefighting costs. The monthly salary of these guards would be around 1000 USD/ month for 6 months per year.

- Setting up a communication system between guards (e.g., mobile lines with internal extensions between guards) to ensure optimal coordination and supervision of green areas. The cost of such a system would be around 9,000 USD for 80 lines as a capital cost, and a monthly 4,000 USD as O&M cost.
- Managing pests in forests and OWL by spraying pesticides by plane (as currently practiced). This measure would have to be implemented every other year. The cost would amount to around 400,000 USD every year that spraying is carried out. However, research and implementation of other more environment-friendly pest management practices are recommended.

▪ **For newly reforested areas:** the most cost-effective way of protecting the trees to be planted as per governmental plans until 2030 is to assign the responsibility of monitoring these zones and preventing grazing and deforestation to the forest guards that shall be hired for fire monitoring in existing forests and OWL. These guards would therefore have to be on duty for the remaining 6 months per year (wet season). Violations would be dealt with in coordination with the Internal Security Forces. The guards will be equipped with the communication systems and vehicles for the remaining 6 months, during the wet season.

▪ The timeframe for costing of the proposed measures for forest management and protection is assumed to be 2011 to 2030.

Table 5-2 Breakdown of the costs of forest protection and management measures

MEASURE	AVERAGE ANNUAL COST (MILLION USD/ YEAR)
Existing forests and OWL	
Clipping and pruning	18.26
Clearing of grass and weeds	0.1
Vehicles (capital cost)	0.1
Vehicles (fuel & maintenance)	0.14
Forest guards	0.48
Communication system	0.02
Pest management	0.40
Subtotal	19.50
Newly reforested areas	
Forest guards	0.48
Communication system	0.02

MEASURE	AVERAGE ANNUAL COST (MILLION USD/ YEAR)
Vehicles (Fuel & maintenance)	0.14
Subtotal	0.65
Total	**20.15**

Table 5-3 Costs of forest protection and management for selected years

YEAR	2004	2011	2015	2020	2025	2030
Area of forests (ha)	139,522	156,037	166,371	180,289	195,409	211,836
Total CO_2 Uptake Increment (t CO_2)	913,686	996,755	1,048,471	1,117,674	1,208,231	1,273,499
Cost (USD/ha)		112.2	111.4	108.3	109.7	107.1
Cost (USD/tCO_2)		17.6	17.7	17.5	18.0	17.8

The total present value cost (at different discount rates) of managing and protecting the existing forested areas and OWL, as well as managing reforested areas, to ensure that the stocks continue to sequester carbon, are presented in Table 5-4. The costs reflect the investment and operational costs to be incurred between the years 2011 to 2030 to implement the proposed mitigation scenario.

Table 5-4 Total discounted costs for forest protection and management

DISCOUNT RATE	PV (COST IN USD) UP TO 2030	COST (USD) PER TONNE OF INCREMENTAL CARBON SEQUESTERED (UP TO 2030)	COST (USD) PER TONNE OF CO_2 SEQUESTERED (UP TO 2030)
5%	242,899,386	39.4	10.76
10%	162,550,434	26.3	7.20
15%	117,495,326	19.0	5.21

Reducing carbon emissions through improving carbon sequestration by forests

Afforestation and reforestation (A/R) as defined in the CDM framework, which includes agroforestry and sylvo-pastoral systems.

The establishment success rate of seedlings after reforestation depends on the presence of native species and on the age of the seedlings at transplantation. A common misleading assumption might be to estimate the area planted during reforestation/afforestation and extrapolate it to the future area to be forested.

Accordingly, and in order to optimize the success rate of reforestation campaigns, the National Reforestation Plan (NRP) in Lebanon stipulated the use of native species in each site according to the ecological criteria, and the climate and soil characteristics in the related ecosystem. The NRP banned the introduction of non-native species but very limited measures are taken in Lebanon to identify and prevent the introduction of alien species, ascertain the origin of the seedlings, encourage production native species and monitor the establishment and development success of those reforestation campaigns.

Moreover, scientific evidence (Benayas et al, 2005; Castro et al, 2004) has shown that planting methods such as seeding or relying on bushes or species from the understory to initiate successful forest dynamics are more successful than direct planting, but require significantly more time to result in effective ecosystem development. While the reforestation success rate for coniferous, deciduous and mixed wood areas can be as high as 90% in northern humid environments such as parts of the USA (Department of the Environment, 2001), this rate could go as low as 20-30% (Castro et al, 2004) in stressful environments such as Mediterranean ecosystems including Lebanon. However, no direct assessments have been conducted in Lebanon to substantiate this claim.

When it comes to mitigating the emissions of GHGs, the term 'reforestation' could designate any action aiming at replanting barren or degraded areas with trees that would contribute to the overall carbon sequestration balance. In this perspective, all efforts of agroforestry or even urban greening (recreation areas, urban parks….) should be included. Linking forests and OWL through corridors (fruit trees and local species) is of utmost importance in enhancing the green cover and conserving existing stands. Spillover effects from creating contiguous forest lands include the reduced habitat fragmentation.

The reforestation initiative which has been accounted for in the baseline scenario already presents a huge challenge for Lebanon considering the rapid expansion of built areas. Hence, additional reforestation to exceed 20% of the land area is not a realistic option for Lebanon, and will not be analyzed.

Substituting fossil fuels by forest-based biofuels: a CDM option

Despite the global controversy on the exact contribution of forests in reducing carbon in the atmosphere and enriching it with oxygen, scientific data confirm that they positively contribute to reducing the atmospheric carbon balance (ADEME, 2007). In addition to their role in reducing global C-equivalent rates, forests can positively contribute to mitigating climate change effects by substituting fossil fuels with forest-based fuels.

In France, the energy value of forests was estimated at 9.2 million tonnes of fossil fuel equivalents and would contribute to reducing 4.3 million tonnes of CO_2 per year, which however values the role of forests as a carbon sink more than that of substitution for fossil fuels.

In Lebanon, the forest growth rate is relatively low when compared to the annual demand for wood fuel and unless sustainable forestry practices are adopted and implemented, a recommendation to increase the supply of forest-based fuels is hardly applicable to Lebanon and should be considered with care. OWL can serve as the main source of biofuel from wood clipping and horticulture. The density of forests and OWL can also be reduced to provide biofuel while also reducing the fire risk.

Over the past 15 years, the rate of forest expansion over the globe has been considerably slowed down (Lettens et al, 2008). In Lebanon the forest cover has been reduced to 13% of the total land area (section 5.1). Global future trends can be hardly assessed as they depend on how economy and agriculture would grow with respect to forest ecosystems, and thus the role of forests as a substitute to fossil fuels could gain importance with time.

The above-mentioned measures, if adopted, are expected to positively contribute to mitigating Lebanon's contribution to climate change from the forestry sector. It is well-acknowledged that forests have an important contribution to carbon sequestration even if there remain many uncertainties with regard to the exact magnitude of their contribution.

Past research studies and reports have estimated the cost of some measures related to reforestation, management and protection of the existing forest cover. Table 5-5 summarizes the cost of implementing those activities in Lebanon.

Table 5-5 Cost of forest restoration and protection activities in Lebanon

ACTION	COST (MILLION USD)	SOURCE
Forest protection	2.25 (over 46 years)	INC, 1999
Fire fighting and restoration of burnt sites	6	Sattout et al., 2005
Reforestation (reforested area = 207,000 ha)	500 (over 46 years)	INC, 1999
Reforestation	2.255 (over 5 years)	MoE, 2009
Management of Protected Areas	4.68 (over 5 years)	MoE, 2009 – MoE, 2006

In conclusion, even if the direct benefit of forests in Lebanon cannot be properly highlighted through their contribution to GHG emissions removal, the economic values of those forests in terms of ecosystem services and other secondary benefits (wellbeing, cultural, etc...) should be considered while valuing Mediterranean forests.

Table 5-6 and Table 5-7 present the mitigation strategy for the Forestry sector and associated gaps and constraints.

Table 5-6 Mitigation Action Plan

IMPACT	PROPOSED MITIGATION STRATEGY	ACTIVITIES	RESPONSIBILITY	PRIORITY (ST/ MT/ LT)	INDICATIVE BUDGET (USD)	SOURCES OF FINANCING/ IMPLEMENTATION PARTNERS
Decrease in the regeneration rate population rate and overall area for the most vulnerable species identified: Juniperus excelsa Cedrus libani Abies cilicica Quercus cerris Fraxinus ornus, Ostrya carpinfolia	Maintaining and conserving existing forest carbon sinks	Managing nature reserves and protected areas Adopting sustainable forest management practices Preventing forest degradation and habitat fragmentation, insect and pest management Ensure natural forest regeneration and development	MoA MoE	ST-MT	20 million USD/ year	MoE and MoA budgets UN-REDD Programme International agencies Municipal budgets
	Substituting fossil fuels by forest-based biofuels	Wood clipping and horticulture in OWL. Reduction of forest density to provide biofuel.	MoA MoE Municipalities	ST-MT	Local cost difficult to capture; negligible.	MoE and MoA budgets Municipal budgets

Table 5-7 Constraints to the implementation of Mitigation measures

MITIGATION STRATEGY	CONSTRAINTS/ GAPS				
	LEGAL	INSTITUTIONAL	TECHNICAL	CAPACITY AND AWARENESS	DATA/ INFORMATION GAPS
Maintaining and conserving existing forest carbon sinks	Lack of enforcement of regulations relating to forests	▪ Lack of active cooperation between different departments and authorities. ▪ Poor coordination among main players, including donors or funding agencies. ▪ Inadequate, conflicting or outdated policies.	▪ High cost is the main constraint to adopting better forest management. ▪ Limited budgetary support for effective management for many of the country's protected areas. ▪ High financial inputs required for ensuring natural forest regeneration and development. ▪ Lack of equipment to prevent or intervene in case of emergencies such as forest fires and pest outbreaks.	▪ Lack of vocational training for forest management. ▪ Weak training programs of the personnel at the management and supervisory level. ▪ Limited capacity to respond to emergencies such as fires.	▪ Insufficient data on forests and protected areas. ▪ Absence of a centralized portal database related to biodiversity available for research and management of protected areas and forests.
Substituting fossil fuels by forest-based biofuels	Inadequate enforcement of legislation to regulate and control such activities.		▪ The forest growth rate is relatively low when compared to the annual demand for wood fuel.	Insufficient awareness of the benefits of fossil fuel substitution by biofuels, and of the necessity and way of controlling clipping and horticulture	Insufficient valorization of research. Lack of relevant data and records.

MITIGATION STRATEGY	CONSTRAINTS/ GAPS				
	LEGAL	INSTITUTIONAL	TECHNICAL	CAPACITY AND AWARENESS	DATA/ INFORMATION GAPS
			▪ Lack of relevant plans and organization.	activities.	

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6. SOLID WASTE

6.1. INTRODUCTION

The waste sector, including wastewater, is the largest source of methane emissions in Lebanon. The sector generated 2,227 Gg CO_2-eq in 2004, or 11% of the total GHG emissions for the same year. Calculations for the years 2000 to 2004 indicate an increase of 28% in waste GHG emissions by 2004 (base year 2000).

For the purposes of the national inventory, the categories of waste for which emissions were accounted for consisted of: (1) solid waste disposal on land, e.g. landfilling, (2) wastewater handling and (3) waste incineration.

Solid waste disposal on land remains the highest emitting category; 94.5% of waste emissions in 2000, or 1,639 Gg CO_2-eq (Table 6-1). GHG emissions from solid waste disposal on land showed an increase of 36.0% between 2000 and 2006 when emissions from this category were calculated at 2,228 Gg CO_2-eq. Methane gas (CH_4) is the major GHG of concern in this category, with a warming potential of 21 over a 100-year horizon, as estimated by the IPCC in its Second Assessment Report (Schimel et al., 1996, p121).

GHG emissions from wastewater constituted 5.4% of waste emissions in 2000, or 93 Gg CO_2-eq. By 2006, GHG emissions from this category increased by 12.2% to reach 104 Gg CO_2-eq or a 4.5% share of the total waste GHG emissions. The major gases emitted from wastewater handling are nitrous oxide (N_2O) and methane. N_2O has a warming potential of 310 over a 100-year horizon (Schimel et al., 1996, p121).

Open burning of municipal waste is practiced across the country, especially in dumpsites located on the outskirts of towns and villages outside the Greater Beirut Area and Mount Lebanon, where 74% of all the wastes generated are openly dumped. Recent figures estimate the amount of openly dumped municipal waste at 1,554 tonnes/day (SWEEP-Net, 2010). The inventory recorded the emissions from the controlled incineration of medical waste, which constituted 0.2% of all waste GHG emissions in 2000, or 3 Gg CO_2-eq.

Table 6-1 shows the contributions of the different categories to GHG emissions.

Table 6-1 GHG emissions from the waste sector by category between 2000 and 2006

	2000		2001		2002		2003		2004		2005		2006	
CO_2-eq / Category	Gg	%	Gg	%	Gg	%	Gg	%	Gg	%	Gg	%	Gg	%
Solid Waste Disposal on Land	1,639	94.5	1,463	93.7	2,002	95.2	2,089	95.4	2,121	95.2	1,910	95.2	2,228	95.5
Wastewater Handling	93	5.4	96	6.2	98	4.6	99	4.5	96	4.3	95	4.7	104	4.5
Waste Incineration	3	0.2	3	0.2	3	0.1	3	0.1	3	0.1	2	0.1	2	0.1
TOTAL	**1,734**	**100**	**1,562**	**100**	**2,102**	**100**	**2,191**	**100**	**2,227**	**100**	**2,006**	**100**	**2,333**	**100**

Solid waste management policy

In 2006, the Government of Lebanon approved a 5-year national solid waste management plan which has set out to implement the following:

- The establishment of five or six new sanitary landfills across Lebanon and the closure of the existing Naameh landfill
- Each landfill site is to have its sorting and composting facilities which are expected to reduce the volume of landfilled waste by 30%
- Incineration was ruled out
- Closure and rehabilitation of existing dumpsites is to be carried out.

Currently, the plan is under way; however it is running behind schedule (CDR, 2009).

6.2. BASELINE SCENARIO AND EMISSIONS

The discussion on mitigation potential from the waste sector will focus on solid waste management which accounts for the majority of emissions in this sector as shown in Table 6-2. It is worth noting that the emissions appearing in Table 6-3 were calculated using the IPCC Tier 1 methodology or default method. The default method results in an overestimation of the emissions because it does not account for time factors in the waste accumulation and decomposition (Jensen & Pipatti 2002). In calculating the **future baseline emissions**, the same method was used to remain in consistency with the method used for the inventory calculations.

6.2.1. Baseline Scenario

With the absence of actual targets for waste reduction, sorting at the source, composting and landfilling, it is difficult to predict how the different waste streams are going to be managed by 2030. However, it is acknowledged that the infrastructure and installations are being set up to realize the national solid waste management plan of 2006; sorting and composting facilities are ready for operation in a few regions, and nation-wide awareness campaigns are planned for execution in order to increase the chances for successful composting through encouraging separation at source . Based on professional judgment and past history of implementation schedules of solid waste management projects in Lebanon, the following assumptions are proposed for constructing a future baseline scenario to be used in predicting future baseline GHG emissions from solid waste.

- The current 2006 plan would be implemented over the next 20 years (2010-2030).
- The open dumpsites would be rehabilitated therefore transferring the waste from unmanaged sites to managed sites with methane gas collection in the proposed sanitary landfills, and rehabilitation of the dumpsites through closure and collection of gas.
- Solid waste disposal on land would gradually decrease by an annual 3.5%, thereby constituting 68% of the total waste generated by 2030 (compared to 84% in 2006). The decrease in land disposal would result from the following actions:
  - Composting rates would increase to 16% of the total waste generated, which is twice the current rate (~9%). A current nation-wide project that targets sorting at the source, coupled with improved facilities and equipment to facilitate the handling of source separated waste is expected to improve composting operations and eventually compost quality.
  - Recycling would also increase to 16% of the total waste generated by 2030 (current rate ~8%). Despite the absence of 'announced' actual targets for recycling, the continuation of

considerable scavenging activities and launching of awareness campaigns for source separation are expected to increase the diversion of recyclables from landfills.

- The generated municipal waste stream that would be disposed of on land by 2030 is assumed to be managed at the following rates;
  - A decreasing proportion of disposed solid waste on land would be in 'unmanaged, deep' sites – from 31% in 2004 to 10% in 2030, as a result of the planned dumpsites' rehabilitation
  - A decreasing proportion of disposed solid waste on land would be in 'unmanaged, shallow' sites – from 12% in 2004 to 10% in 2030.
  - An increasing proportion of disposed solid waste on land would be in 'managed' sites – from 57% in 2004 to 80% in 2030
- The per capita MSW generation rates are assumed to follow the GDP growth that is predicted for Lebanon at an annual average rate of 4.3%, in line with the IMF's projections for Lebanon (IMF, 2009).
- The total population is assumed to grow at an annual average rate of 0.7%, in line with the UN Population Division's projections for Lebanon (UN, 2008). Although it is customary to account for the growth in urban population rather than the total population growth for developing countries, the total population growth was considered for Lebanon. The urban population is still predicted to grow, however at a declining annual average rate of 0.75% (UN, 2007).
- Landfill gas recovery rates are projected to grow with the assumed increase in the proportion of waste going into 'managed' sites.

6.2.2. Baseline Emissions

The increased reliance on proper landfilling, coupled with increasing per capita MSW generation rates, modest diversion rates, and changing waste stream properties would lead to an overall increase in methane generation. From current experiences in the Naameh and Zahleh landfills, some of the methane would be collected for flaring as a security measure against gas buildup.

The GHG mitigation potential from municipal waste closely follows the future waste management methods that Lebanon adopts. Current plans for waste management have stressed on observing environmental standards in planning and operation of waste management facilities to minimize environmental risks and safety hazards. Collection and flaring of landfill gas is expected to be carried out to minimize risks of fires in abandoned dumpsites and new sanitary landfills. No specific climate policies have been passed that would require operators in the future to recover methane to reduce GHG emission contributions from the waste sector.

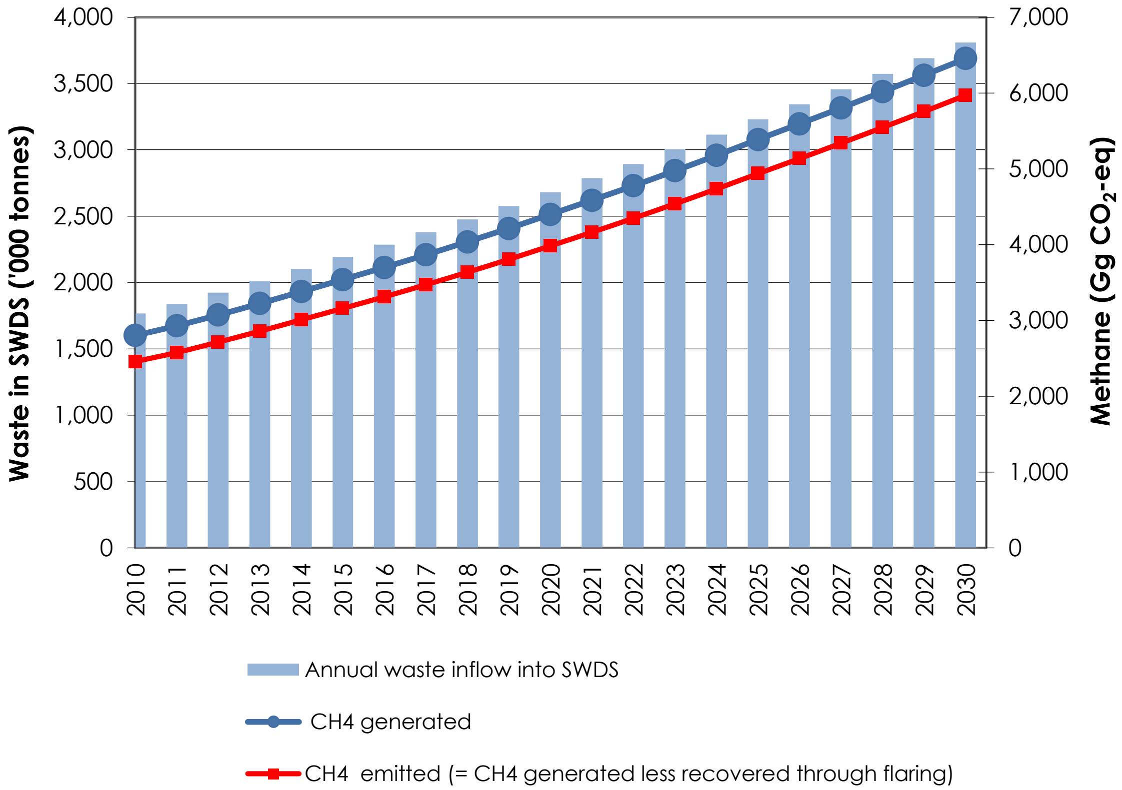
The baseline emissions from solid waste disposal on land were determined through applying the IPCC Tier 1 methodology for GHG emissions from solid waste disposal, equation using the following formula, and related assumptions (Table 6-2).

CH_4 emissions (Gg) = [(Population × Generation rate × % deposited in SWDS × CH_4 correction factor × Fraction of DOC in MSW × Fraction of DOC which actually degrades × Fraction of carbon released as CH_4 × 16/12) – Recovered CH_4 per year] × (1-CH_4 oxidation correction factor)

Table 6-2 **Assumed values of the technical parameters used in calculating methane emissions from landfills**

PARAMETER	VALUE
CH_4 correction factor	0.87
Fraction of DOC in MSW	0.17
Fraction of DOC which actually degrades	0.77
Fraction of carbon released as CH_4	0.5
CH_4 oxidation factor	0

Figure 6-1 shows the projected future baseline methane emissions and corresponding waste inflows into solid waste disposal sites, and which were calculated based on the list of assumptions mentioned



above.

Figure 6-1 **Projected baseline quantities of municipal solid waste in disposal sites and methane generation from SWDS**

6.3. MITIGATION OPTIONS

The general mitigation options considered in this document fall under the following two waste management options:

- Landfill gas recovery and use for electricity generation under the projected waste management scenario
- Waste-to-energy, which involves adopting new waste management methods, namely waste incineration with energy recovery.

It is highly recommended that in the implementation of any or both mitigation scenarios strict control and enforcement of pollution emissions controls be applied to prevent adverse impacts on public health and the environment.

6.3.1. Mitigation Scenario 1: Landfilling with gas recovery for electricity generation

Based on the assumptions of the baseline scenario for the different parameters mentioned, the amount of waste to be deposited on land was calculated, along with the volume of methane which could be used in the future to generate electricity (Figure 6-1). The estimated methane volumes from solid waste disposal on land exclude the recovered volumes which would undergo flaring under the current policy. Thus, measures to capture the increasing volumes of methane emissions are considered to be 'additional' mitigation measures and their cost is accounted for accordingly.

For this mitigation scenario, gas recovery projects for electricity generation are assumed to apply to all current and future sanitary landfills and rehabilitated dumpsites. However, the economic feasibility of such projects would need to be scrutinized on a site-by-site basis. The amount and composition of waste deposited are key factors that help determine the methane generation potential, which in turn determines the economic viability of gas recovery projects. A landfill gas energy project may not be feasible for small waste quantities with low organic fractions or high moisture content. Most landfill gas recovery projects for energy use run on internal combustion engines with capacities in the range of 1-15 megawatts (MW) (Bogner et al., 2007). A survey of 28 landfill gas to energy projects for electricity generation in the USA shows that engines in capacities that range from 0.2 to 8 MW are used to generate electricity from current and closed landfills with total waste loads in the range of 1 to 42 million tonnes. The medial waste quantity in landfills with gas utilization projects are 4 million tonnes with engine capacity of 2 MW (US EPA, 1999).

The determination of the engines' capacity needed for power generation from captured landfill gas is carried out by a series of conversions of the expected methane generation rate, collection efficiency and combustion engine parameters which are listed in Table 6-3.

Table 6-3 Parameters for calculation of methane gas generated in landfills and power capacity needed for conversion into electricity

PARAMETER	VALUE
Methane Density	716.8 g/m^3 at STP (T=0°C, P=1atm)
% of CH_4 in LFG	50%
Collection efficiency (% of CH_4 captured)	50%
% of captured methane used for power generation	90%
Thermal value of methane	37,729 KJ/m^3
Thermal to electric conversion rate	4.396
Electric engine availability	85%

Operating hours per year	7766 (353 days × 22 hours/day)
GWP CH_4	21 GWP CO_2

Regarding the collect and flare systems, the capital cost and operation and maintenance costs are driven by the amount of waste in a given disposal site (US EPA 1999). Flares are installed even if the landfill gas is intended to be recovered for electricity generation in order to prevent accidental releases. While absolute total costs increase with larger amounts, the unit costs per tonne of waste decrease reflecting economies of scale. Table 6-4 shows average costs per tonne of a collect and flare system, and the average costs per installed MW for the generation of electricity using landfill methane gas, in addition to assumptions for the calculation of annual costs.

Table 6-4 Capital and operational costs of a collect and flare system and internal combustion engine for electricity generation from landfill methane gas

PARAMETER	VALUE
Capital Cost of a Collect and Flare system	0.87 USD per tonne of MSW
Operation & maintenance cost	0.13 USD per tonne of MSW
Capital cost of an internal combustion engine/ generator	1,791,000 USD per MW
Operation & maintenance cost of an internal combustion engine/ generator	181,000 USD per MW
Depreciation period	10 years
Project Lifetime	20 years
Discount rate	10%, 15%

Source: US EPA, 1999. Estimated in 2004 USD.

Table 6-5 shows the energy potential from the methane emissions that could be captured and the power capacity needed to be installed in order to convert the thermal energy into electric energy. The methane emissions captured for energy generation are considered to be the emissions avoided. It is assumed that no CO_2 emissions from electricity production will be avoided, given that the current power generation rates do not meet the electricity demand. The installed capacity for electricity generation from landfill methane gas would start with 26.6 MW in 2010 and increase to 64.5 MW by 2030. It is assumed that the internal combustion engines will have to be replaced by 2020.

Table 6-5 Power capacity needed, energy potential from landfills' methane and methane emissions avoided for selected years

	2010	2015	2020	2025	2030
Methane generated (Mm³ CH_4)	163.32	209.85	264.65	327.89	396.52
Methane captured (Mm³ CH_4)	81.66	104.93	132.32	163.94	198.26
Methane used for power generation (Mm³ CH_4)	73.50	94.43	119.09	147.55	178.43
Energy content of "usable" methane (10^6 MJ)	2,773	3,563	4,493	5,567	6,732
Thermal energy generation potential (GWh_{th})	771	990	1,249	1,548	1,871
Electric energy generation potential (GWh_e)	175	225	284	352	426
Minimum engine capacity needed (MW)	22.6	29.0	36.6	45.3	54.8

Engine capacity to be installed (factoring in engine availability) (MW)	26.6	34.1	43.0	53.3	64.5
Methane emissions avoided (Gg CO_2-eq)	1,229	1,579	1,992	2,468	2,984

The marginal cost of the reduction in CO_2-equivalent was calculated using the net present value of the capital and operating costs for the landfill gas collection and electricity generation system and the net present value of the annual benefits from electricity generation. The revenues from electricity generation were calculated based on an average electricity price of 0.09 USD/kWh, and hypothetical increases in the price of 10 to 50% over the 20-year period. It is considered that the GHG emissions saved (tCO_2-eq) are those saved through the collection of 50% of the methane gas, as allows the technology. At current electricity prices, the marginal cost of reducing 1 tCO_2-eq landfill methane emissions is 1.85 USD (at a discount rate of 10%) or 1.75 USD (at a discount rate of 15%) (Table 6-6).

Table 6-6 Marginal cost of abatement of landfill methane per tCO_2-eq at varying electricity prices and discount rates

	DISCOUNT RATE = 10%	DISCOUNT RATE = 15%
Electricity Price (USD) per kWh	**Marginal Cost (USD) per tCO_2-eq saved**	
0.09	1.85	1.75
0.10	0.60	0.50
0.11	-0.65	-0.75
0.12	-1.90	-2.00
0.13	-3.15	-3.26
0.14	-4.41	-4.51

6.3.2. *Mitigation Scenario 2: Waste incineration and energy production*

Waste incineration has been ruled out as a waste management option in the National Solid Waste Management Plan of the CDR (2005) on the grounds of risk from inadequate air pollution control measures and high investment and operation costs. Nevertheless, it is considered here as a GHG mitigation option.

Lebanon is not equipped with any incineration plants. Nevertheless, open burning of waste is regularly practiced as a waste reduction method in controlled dumpsites. Given the relatively small and dispersed quantities of waste generated in Lebanon, it is assumed that three waste-to-energy plants could be installed in three urban poles: Beirut to serve Beirut and Mount Lebanon; Tripoli to serve urban Tripoli; and Saida to serve urban Saida. Given the current generated quantities in the three locations, it is assumed that two 300,000 tonnes/year plants would be built to serve Tripoli and Saida and one 600,000 tonnes/year would be built in the Greater Beirut Area to serve Beirut and Mount Lebanon.

It is assumed that the MSW quantity that would be diverted from landfills in 2015 in the event of adoption of waste incinerators, while maintaining the baseline recycling and composting rates, would be 935,195 tonnes, and would grow to 1,417,370 tonnes by 2030. Hence, the landfill methane emissions avoided would be 1,129,694 tCO_2-eq in 2015 and would grow to 1,916,302 tCO_2-eq by 2030. The cumulative avoided emissions would be 24,142,251 tCO_2-eq for the entire period extending from 2015 to 2030. However, to calculate the amount of GHG emissions avoided through adopting incineration, the CO_2 emissions from incineration, obtained through the formula below, are deducted from the avoided emissions. Therefore, the cumulative savings in GHG emissions from diversion of some of the MSW stream from landfilling to incineration would total 11,771,499 tCO_2-eq (Table 6-7, Figure 6-2). The cumulative GHG emission savings (or mitigation) from waste incineration for energy recovery is represented in Figure 6-2 as the thatched area between the two lines.

CO_2 emissions (Gg) = Amount of waste incinerated × Carbon content × Fraction of fossil carbon × Combustion efficiency × 44/12

Table 6-7 GHG emissions avoided through diverting MSW from landfilling to incineration in selected years

	2015	2020	2025	2030
Baseline emissions (Gg CO_2-eq)	3,159	3,984	4,936	5,969
MSW amount eligible for incineration (thousand tonnes)	935.19	1,087.71	1,250.96	1,417.37
Avoided CH_4 emissions due to the diversion of MSW from landfilling to incineration (Gg CO_2-eq)	1,130	1,370	1,636	1,916
CO_2 emissions from incineration (Gg CO_2-eq)	617	718	826	935
CO_2 emission saving (Gg CO_2-eq)	512	652	810	981

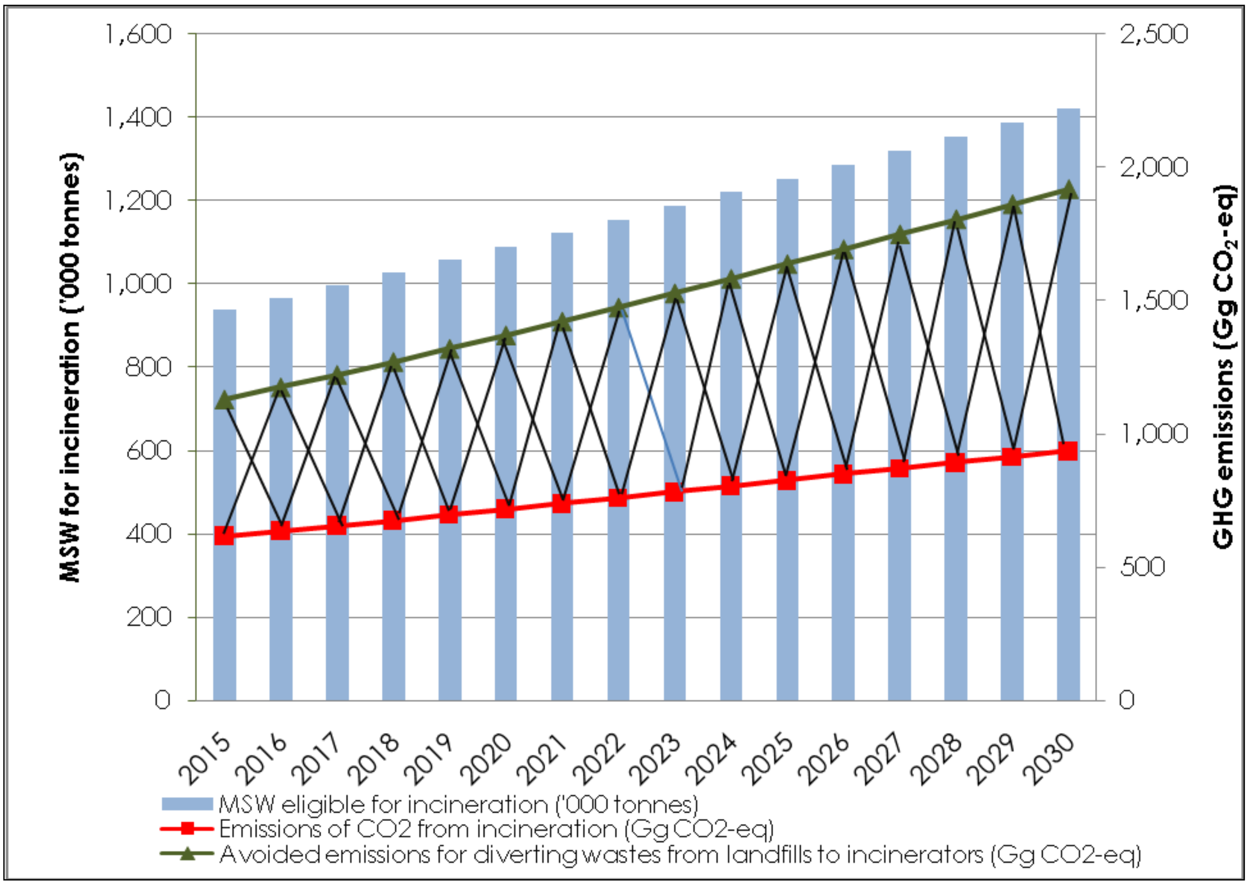


Figure 6-2 Projected quantities of municipal solid waste to be incinerated and avoided GHG emissions

For Lebanon, the use of the grate technology with three different scenarios for flue gas treatment has been recommended (MSC-IPP, 2005). Average values on energy production from incinerators of different capacities using different flue gas treatment techniques are used in this analysis. Values used for the calculation of costs are based on the MSC-IPP study (2005) and are shown in Table 6-8.

Table 6-8 Energy potential from waste incineration and investment and operational costs of waste incineration for energy production

PARAMETER	VALUE
Average energy production from a 300,000 tonnes/yr facility	118,750 MWh
Average energy production from a 600,000 tonnes/yr facility	243,650 MWh
Average investment cost for all the proposed incineration capacity	469.8 million USD
Average annual Operation & Maintenance cost for all the proposed incineration capacity	92.9 million USD
Depreciation period	15 years
Project Lifetime	20 years

Sources: MSC-IPP, 2005. Estimated in 2004 USD.

The marginal cost of the reduction in CO_2-equivalent was calculated using the present value of the capital and operating costs for the incineration technology with energy recovery and the present value of the annual benefits from electricity generation. The revenues from electricity generation were calculated based on an average electricity price of 0.09 USD/ kWh, and hypothetical increases in the price of 10 to 50%. It is considered that the GHG emissions saved (tCO_2-eq) are those saved through the diversion of MSW from landfilling to incineration. At current electricity prices, the marginal cost of reducing 1 tCO_2-eq of GHG emissions from solid waste using incineration ranges from 69.8 to 80.3 USD depending on the discount rate used (Table 6-9).

Table 6-9 Marginal cost of abatement of GHG emissions through incineration per tCO_2-eq at varying electricity prices and discount rates

	DISCOUNT RATE = 10%	DISCOUNT RATE = 15%
ELECTRICITY PRICE (USD) PER KWH	MARGINAL COST (USD) PER TCO_2-EQ SAVED	
0.09	80.33	69.80
0.10	77.21	67.34
0.11	74.09	64.89
0.12	70.98	62.43
0.13	67.86	59.97
0.14	64.74	57.52

6.4. MITIGATION ACTION PLAN

The two proposed mitigation scenarios can be grouped under one mitigation action plan which recommends an increase in the share of renewable energy (from waste) in electricity production due to the potential for energy recovery and the expected avoidance of future CH_4 emissions from landfills if one or both mitigation scenarios are adopted. **Error! Reference source not found.** provides an overview f the proposed mitigation action plan and the proposed activities, indicative budget and possible sources of funds. It should be noted that the indicative budget is a rough estimate based on professional judgment, and sometimes reflects the cost of studies that need to be carried out prior to the implementation of the proposed activities. Each of the mentioned activities requires an in-depth assessment to determine its actual cost at the time of planning and implementation. The feasibility of implementing mitigation projects in the waste sector depend on the scale of the project, and thus costs may differ among projects of different sizes. Table 6 - 10 presents a rapid analysis of the legal, institutional, technical, capacity and data constraints to the implementation of the proposed mitigation action plan.

6.5. CONCLUSIONS

In this document, two GHG mitigation scenarios from the solid waste sector were examined for their potential to reduce future emissions given the planned waste management strategy actions. The mitigation options analysed were landfilling with methane recovery for electricity generation and incineration with energy recovery. It should be noted that for the first mitigation scenario only additional costs represented by investments to utilise the methane gas for electricity production were taken into consideration. For the second scenario which dealt with waste incineration for energy recovery, and given that this waste management option is not part of any decreed plans in the Lebanese government, the full costs of investment and operation were taken into consideration in the cost analysis to reflect the fact that a completely new technology for waste management would have to be adopted to allow reductions in GHG emissions. The marginal cost of abatement per tCO_2-eq is significantly lower for landfill methane gas utilization given the larger potential to capture methane gas from the current waste management option in use in Lebanon. Waste incineration for energy production is an expensive mitigation option for Lebanon. Both mitigation scenarios can be applied successfully in settings with strict environmental and institutional controls to prevent any possible, inadvertent environmental pollution issues (see Rand et al., 2000 on waste incineration guidelines).

Table 6 -10 Mitigation Action Plan

TARGET	PROPOSED MITIGATION STRATEGY	ACTIVITIES	RESPONSIBILITY	PRIORITY (ST/ MT/ LT)	INDICATIVE BUDGET (USD)	SOURCES OF FINANCING/ IMPLEMENTATION PARTNERS
Collection and use of landfill gas for electricity generation and to offset fuel use	Increase the share of renewable energy (methane gas from landfills) in electricity production	- Equip current and soon-to-be-abandoned/rehabilitated dumpsites with LFG collection and flare systems - Assess the cost-effectiveness of LFG recovery for electricity generation in the current and soon-to-be abandoned/rehabilitated dumpsites - Study the feasibility of electricity generation for all planned landfills (based on size and waste-in-place) - Develop the necessary legislation to ease barriers and provide incentives for landfill operators to invest in electricity generation from LFG	Council for Development and Reconstruction Ministry of Energy and Water	ST-MT	Marginal costs of collecting and utilizing (up to 50% of) the generated methane gas (2010-2030) at current energy prices (i.e. 0.09 USD/kWh): 1.75-1.85 USD/tCO_2-eq avoided Total investment and operational cost (undiscounted): 607.94 million USD (2010-2030)	CDR Budget to implement the current SWM plan Private project finance to landfill operators (Clean Development Mechanism, national banks) Funding sources to be further explored: Multilateral Funds for Mitigation Projects: Climate Technology Fund (World Bank) The GEF Trust Fund - Climate Change focal area (for enabling activities) MDG Achievement Fund – Environment and Climate Change thematic window (UNDP) (for mainstreaming &

TARGET	PROPOSED MITIGATION STRATEGY	ACTIVITIES	RESPONSIBILITY	PRIORITY (ST/ MT/ LT)	INDICATIVE BUDGET (USD)	SOURCES OF FINANCING/ IMPLEMENTATION PARTNERS
						locally managed landfill sites) Bilateral Funds: Cool Earth Partnership (Japan) International Climate Initiative (Germany)
Use of waste as a source of renewable energy in thermal waste-to-energy schemes	**Increase the share of renewable energy sources in electricity production**	Develop the regulatory controls and technology standards for waste incineration Identify the number and locations of WtE facilities to balance economy of scale and proximity to major waste generation areas Develop the necessary legislation for private sale of electricity to the national grid	Ministry of Environment Council for Development and Reconstruction Ministry of Energy and Water	MT-LT	Marginal costs of reducing GHG emissions through waste to energy projects in three urban agglomerations (2015-2030) at current energy prices (i.e. 0.09 USD/kWh): 69.8-80.3 USD/tCO$_2$-eq avoided Total investment and operational cost (undiscounted): 2,314 million USD (2015-2030)	CDR Private project finance Funding sources to be further explored: Multilateral Funds for Mitigation Projects: Climate Technology Fund (World Bank) Bilateral Funds: Cool Earth Partnership (Japan) International Climate Initiative (Germany)

Table 6 - 11 Constraints to the implementation of the mitigation action plan

MITIGATION STRATEGY	CONSTRAINTS/ GAPS				
	LEGAL	INSTITUTIONAL	TECHNICAL	CAPACITY AND AWARENESS	DATA/ INFORMATION GAPS
Increase the share of renewable energy sources (biomass, LFG) in electricity production	Shortage of legislation regulating grid feed-in Inadequacy of legislation promoting safety and high technical operating standards for waste incineration facilities	Absence of a dedicated technical and strategic advisory body on waste management to guide target achievements and advance GHG mitigation concerns	Weak track record in successful waste management Potential small scale of individual facilities (WtE or landfills) to justify investments for energy recovery Local technologies are deficient, and technology transfer will be required	Limited capacity for enforcement of standards and operational guidelines, especially for WtE facilities Presence of a public stigma against waste incineration plans and a general NIMBY syndrome which will require additional investments to dispel misconceptions and raise awareness among the public	Limited (up-to-date) information on waste generation rates and composition outside of the GBA, Tripoli and Zahle that makes future baseline projections too reliant on assumptions

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