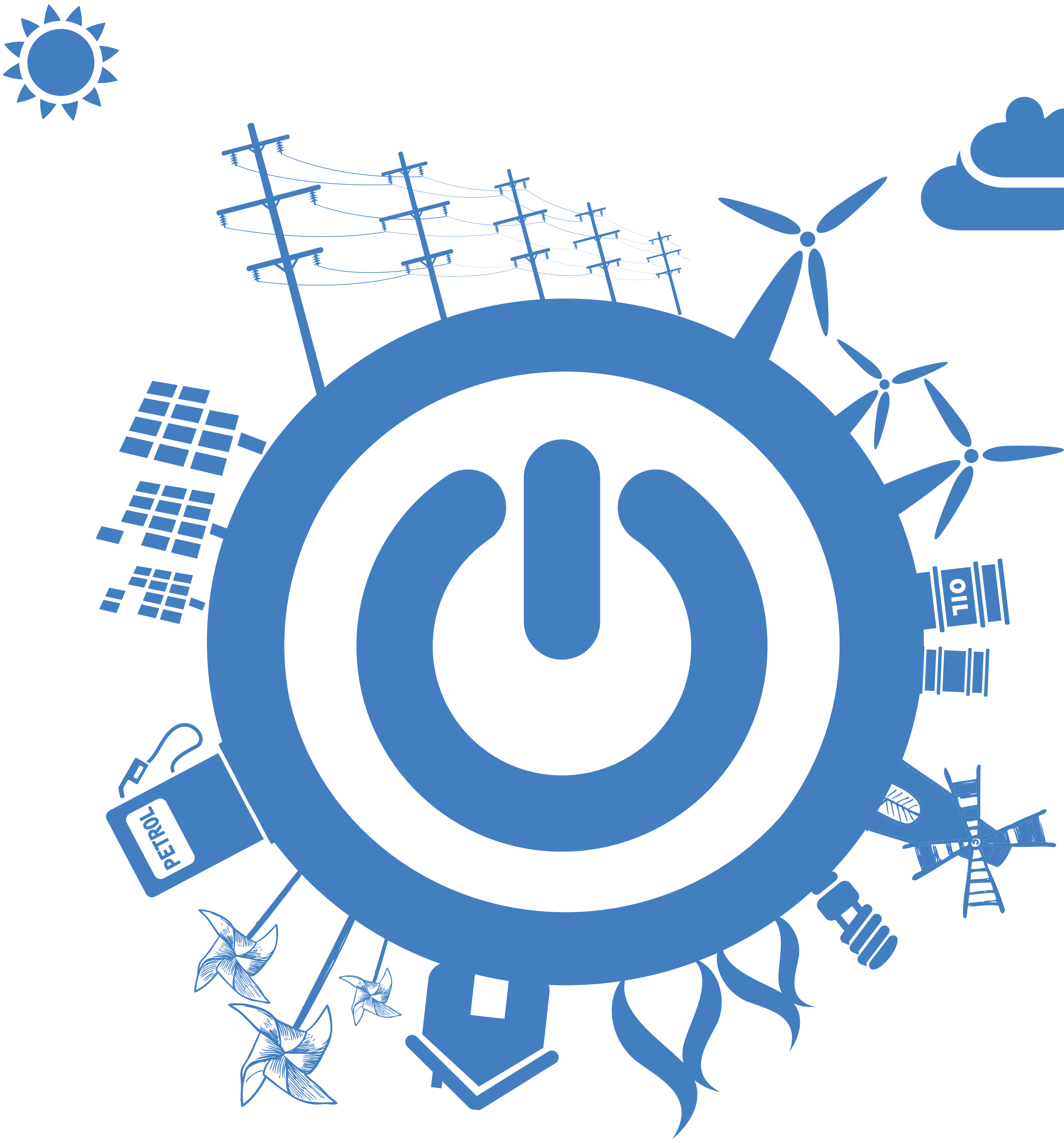
Greenhouse Gas Mitigation Analysis



3. Greenhouse Gas Mitigation Analysis

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

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

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

3.1. Energy Sector

3.1.1. Electricity

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

3.1.1.1. Baseline scenario

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

3.1.1.2. Projected Emissions

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

Table 3-1 Main components of MoEW policy

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

Source: MoEW, 2010

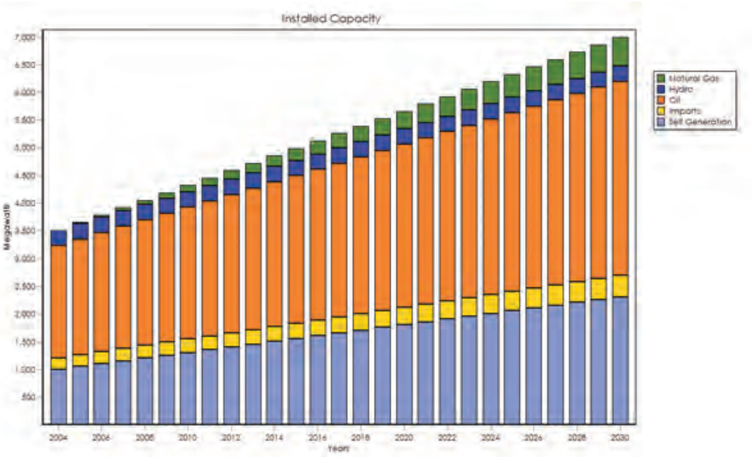


Figure 3-1 Breakdown of total installed capacity under the baseline scenario

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

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

3.1.1.3. Mitigation scenarios

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

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

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

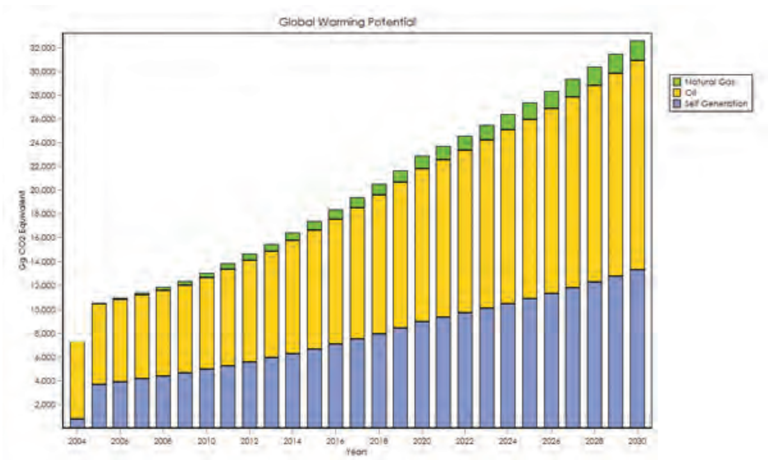


Figure 3-2 GHG emissions from the electricity sector under the baseline scenario

Table 3-2 Data and assumptions for Mitigation scenario

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

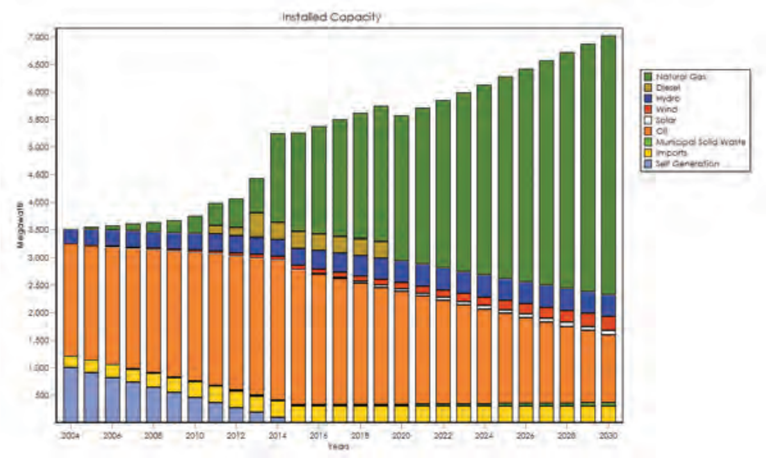


Figure 3-3 Breakdown of total installed capacity under mitigation scenario 1

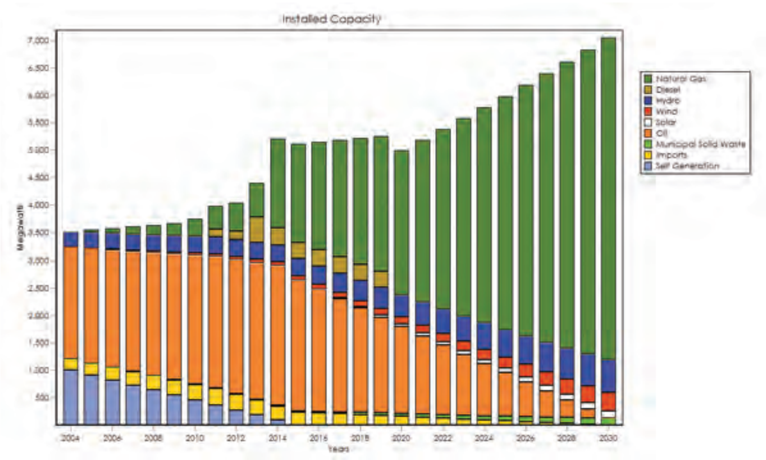


Figure 3-4 Breakdown of total installed capacity under mitigation scenario 2

3.1.1.4. Emissions reduction and costs of mitigation scenarios

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

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

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

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

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

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

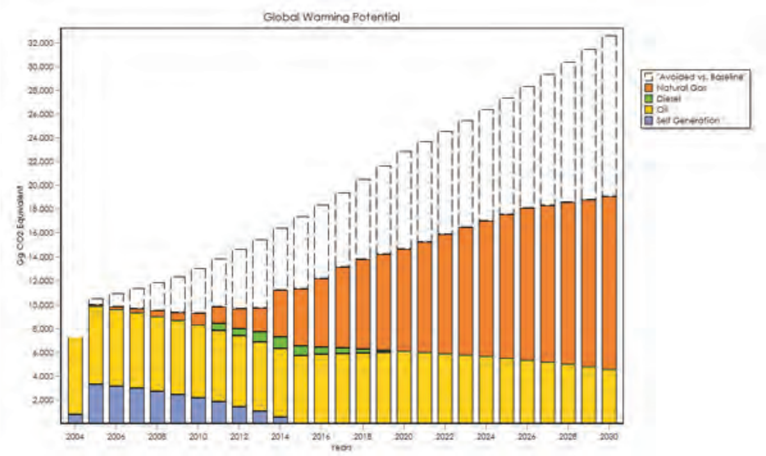


Figure 3-5 GHG emissions and avoided emissions under mitigation scenario 1

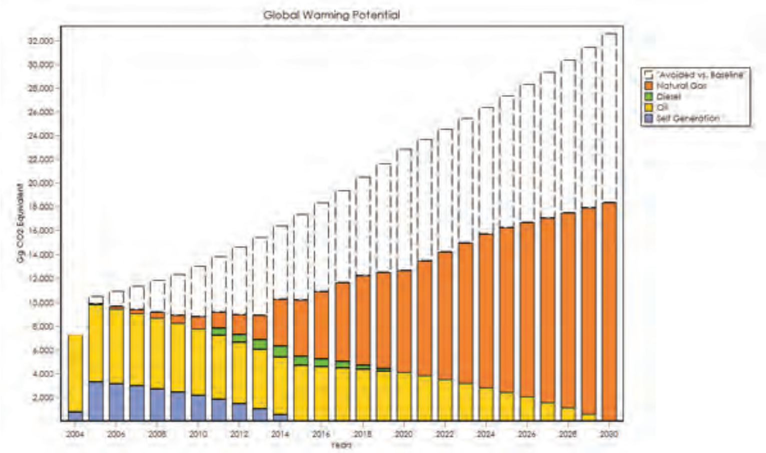


Figure 3-6 GHG emissions and avoided emissions under mitigation scenario 2

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

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

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

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

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

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

3.1.1.5. Mitigation Strategy

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

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

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

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

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

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

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

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

3.1.2. Manufacturing Industries and Construction

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

3.1.2.1. Mitigation scenarios and costs

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

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

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

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

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

Table 3-5 Assumptions considered for the case of Lebanon

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

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

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

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

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

Table 3-8 CO_2 emissions per type of fuel

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

Source: IPCC, 2006

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

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

3.1.3. Transportation

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

3.1.3.1. Baseline scenario

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

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

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

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

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

3.1.3.2. Projected growth in the vehicle fleet

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

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

3.1.3.3. Mitigation scenarios

Mitigation scenario 1: Revitalization of the Public Transport System

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

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

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

Source: MoE, 2005

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

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

Mitigation scenario 2: Implementation of a car scrappage program

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

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

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

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

3.1.3.4. Mitigation strategy

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

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

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

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

3.1.4. Building Envelops

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

3.1.4.1. Application of Thermal Standards in new buildings

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

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

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

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

3.1.4.2. Retrofitting Existing Buildings

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

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

3.2. Industry

This section focuses on the mitigation of GHG emissions from cement industries, since they are the most important industrial source of CO_2 emissions reaching 92% of total industrial GHG emissions. In Lebanon, there are three Portland cement plants with a total production of clinker of 4,143,809 tonnes in 2004 and total emission of 2,156 Gg of CO_2 eq.

3.2.1. Baseline Scenario

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 3-7 represents forecasts of cement production and CO_2 emissions under scenario A (3,607 Gg CO_2 eq.) and scenario B (5,976 Gg CO_2 eq.).

3.2.2. Mitigation scenario

Mitigation scenario: 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. 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 cement in Lebanon depends on the current application level, on the availability of blending materials, and on standards and legislative requirements. An increase of the share of additive (i.e., fly ash) from 27.66% to 35% would reduce the emissions by an estimated average of 1.32% of CO_2 emissions, at a cost between USD 15 and USD 30/Gg for fly ash and USD 24/Gg for blast furnace slag (UNFCCC, 2005).

3.2.3. Mitigation Strategy

Other mitigation measures could be applied or further explored in Lebanon to reduce GHG emissions from the cement sector such as:

- Substitution of conventional pre-calcination method by a pre-calcination method aimed at CO_2 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;
- Applying energy management and process control in grinding;
- Modification of clinker cooler (use of mechanical flow regulator);

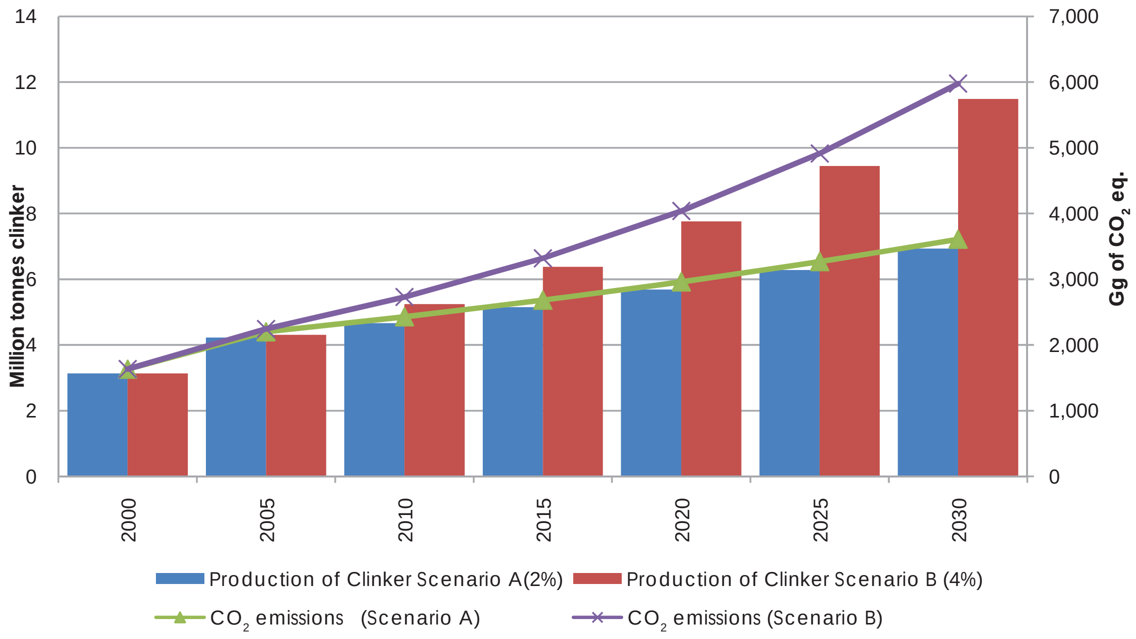


Figure 3-7 Projected clinker production and CO_2 emissions under scenario A and scenario B

- Optimization of heat recovery/upgrade clinker cooler;
- Using efficient transport system (mechanical transport instead of pneumatic transport);
- 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;
- Creation of a dialogue platform between the government and the cement factories management representatives.

3.3. Agriculture

The total GHG emissions from the agricultural sector do not constitute more than 3.7% of the national total emissions. The main GHGs are N_2O and CH_4, generated from agricultural soils, manure management and enteric fermentation. 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.

3.3.1. 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.). Therefore, the 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 as shown in Table 3-10. 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).

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 at the expense of other land uses (construction, land reclamation, forests) that vary with time. The national GHG emissions inventory shows a decrease of 3.5% in N_2O emissions between 2004 and 2006, while the IPCC report on mitigation measures in agriculture (Smith et al., 2007) estimates 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, it is estimated that N_2O, CH_4 and NO_x emissions from agriculture soils will decrease by 3.5% annually 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 (Table 3-11) 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 add value to the NAP's contribution.

3.3.2. Mitigation scenarios

It is to be noted that the mitigation scenarios developed hereafter are to be considered as complementary.

Mitigation scenario 1: Field level measures

Improve Manure management: Large modern farms need to better manage their manure and other agricultural

Table 3-10 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.

Table 3-11 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

wastes by producing compost or biogas which would reduce GHG emissions considerably. Compost can be restituted to the soil as an organic fertilizer, which would increase water conservation and soil fertility (FAO, 2009b). Biogas could be used as an autonomous energy source for farms generating it, thus reducing their energy import from non-renewable sources. For instance, 1.7 cubic meters of biogas is equivalent to one liter of gasoline, thus 1 kg of cow manure will 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).

Manure management is an essential practice in minimizing GHG emissions caused by microbial activities during manure decomposition. 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 3-12.

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 3-13. 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 mainly local breeds, put in small scale traditional shelters and their manure is stocked and sold to farmers to be used as organic fertilizer.

Plowed agricultural soils 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 such as purpose of plowing (land reclamation, tubers harvesting, etc.) and type of soil (plowing soil with excessive nitrogen fertilization or soils previously planted with legumes emits N_2O) and

Table 3-12 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

Source: IFAD, 2009; Berg and Pazsiczki, 2006; AAFRD & UoA, 2003

Table 3-13 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

geographic area (soil texture in semi-arid areas is easily degraded). Mitigation measures include encouraging organic farming, with appropriate crop rotation, intercropping, the use of compost and green cover fertilization instead of chemical fertilizers, and 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).

Use efficient irrigation system: 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 through reduced plowing, reduced use of herbicides, pesticides and fertilizers and reduced water pumping.

Mitigation scenario 2: Research, education, assistance, infrastructure, and institutional measures

Research measures: Agricultural research institutions and programs in Lebanon should be strengthened and enhanced to elaborate research programs in fields related to adaptation to climate change. The existing governmental research institutions (LARI, NCSR, etc.) should join venture with local universities and regional institutions with long past experience in arid and semi-arid areas (ICARDA, ACSAD). Ultimately, a network of research institutions that address research on agriculture and climate change in Mediterranean countries could provide invaluable insight and direction on critical areas for action. Some topics to be studied include:

- Identifying 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;
- Modifying animal nutrition in order to cope with changing cropping patterns for fodder species, and minimize nitrogen losses in manure;
- Analyzing the economic feasibility for newly adopted agricultural systems.

Educational and assistance measures: Educational measures should be targeted at owners and employees of major modern farms, farmers in semi-arid areas, veterinarians, agricultural engineers, and technicians.

Infrastructure measures: The major infrastructure changes to be undertaken are among the private sector, and include the use of units for composting and/or recovering biogas manure in modern poultry and animal husbandry farms, the improvement of irrigation systems and the use of appropriate machinery for conservation agriculture techniques (for seeding, harvesting in no-till agriculture, etc.).

Institutional measures: The legislative framework related to agriculture and natural resources management should be reviewed and harmonized with the conventions that are ratified by the Government in relation to climate change, combating desertification, and biodiversity. The inter-linkages and conflicting mandates between different institutions should be resolved and responsibilities should be well defined and distributed. The human resources and organizational structure of the Ministry of Agriculture should be reviewed according to law amendments in order to provide the desired services related to adaptation measures.

Since most of the measures for adaptation and mitigation are linked, the major administrative institutions and departments to be reinforced are:

- 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.

3.3.3. Cost of mitigation measures

Field and infrastructure measures could only be addressed at the level of individual, major poultry and animal husbandry farms, since the 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/tCO_2eq./yr). For instance, livestock feeding and nutrient management costs USD 60 and USD 5/tCO_2 eq./yr respectively, while animal breeding costs USD 50/tCO_2 eq./yr (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./yr will be the mean of two values, i.e. USD 55/tCO2-eq/yr. Improved nutrient management practices are expected to result in a reduction of 60% of baseline N_2O emissions, at an assumed cost of USD 5 /tCO_2 eq./yr (Smith et al., 2008) (Table 3-14).

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 adopting no-till agriculture in the MENA region has been estimated to around USD 88/ha to USD 600/ha according to the country (FAO, 2009b). Other more expensive measures include shifting from surface to drip irrigation which is estimated to cost USD 3,500/ha in Lebanon. Subsequently, in order to convert by 2030, 30,000 ha of cereals, legumes, and fruit orchards in the Baalback-Hermel area to no-till agriculture, a budget of USD 18 million is needed, (excluding the

Table 3-14 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 (USD/tCO_2 eq.)	55	5
Total Cost (in USD million)	4.33	2.0

cost of machinery) while a budget of USD 105 million is needed to convert the same area to drip irrigation. 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 tCO_2 eq.

3.4. Forestry

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. Mitigation actions are designed to increase carbon sequestration by forests and soil by maintaining and conserving existing forest carbon sinks and increasing forest cover by reforestation and afforestation.

3.4.1. Baseline scenario

The MoE's and MoA's reforestation/afforestation plan aims at increasing the forest cover from 13% of Lebanon's land surface area to 20%. 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 3-15 shows the area of forests in kha and the number of fruit trees in Lebanon for the year 2004, as well as projections under a baseline scenario with a 2030 horizon. The GHG inventory has estimated the annual total carbon uptake increment in Lebanon for the year 2004 at around 249.19 kt of carbon.

3.4.2. Mitigation options and costs

Mitigation scenario 1: Maintaining and conserving existing forest carbon sinks

Maintaining forests and nature reserves can be achieved through:

- Adopting sustainable forest management practices such as grazing, Non Wood Forest Poducts (NWFP), and harvesting of wood in forests and other wooded lands (OWL) to address the possible threats to these ecosystems and improve their status;

Table 3-15 Forest area and number of trees in the baseline scenario

<table>
<tr><th></th><th colspan="2">Total for the year 2004</th><th>Expected trend</th><th>2030 Total expected</th><th>2030 projections</th></tr>
<tr><td>Area Evergreen stands (ha)</td><td rowspan="2">139,522</td><td>134,298</td><td rowspan="2">Increase from 13% to 20% cover</td><td rowspan="2">211,836</td><td>206,612</td></tr>
<tr><td>Area Deciduous stands (ha)</td><td>5,224</td><td>5,224</td></tr>
<tr><td colspan="2">Number of non-forested evergreen fruit trees (1,000)</td><td>25,492</td><td>10% increase in number of fruit trees</td><td colspan="2">28,041</td></tr>
<tr><td colspan="2">Number of other fruit trees (1,000)</td><td>20,056</td><td>10% increase in number of fruit trees</td><td colspan="2">22,061</td></tr>
<tr><td colspan="2">Total Carbon uptake increment (kt)</td><td>249.19</td><td></td><td colspan="2">347.32</td></tr>
</table>

- Preventing forest degradation and habitat fragmentation through sustainable management, land use management, 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;

- Rehabilitating abandoned lands and degraded zones to ensure natural or assisted forest regeneration and development.

Additional activities for forest protection, management and leakage monitoring and their incurred costs between 2011 and 2030 are as follows (Table 3-16 and Table 3-17):

- 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 in case it is not already being undertaken by local people;

- 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 USD 100,000/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 USD 50,000, and these would serve for 10 years. 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 USD 600/month;

- Each vehicle will be run by 2 forest guards, who would be in charge of monitoring a specific region to prevent fires and control grazing and deforestation of newly reforested areas. Violations would be dealt with in coordination with the Internal Security Forces. The incurred costs are USD 1,000/month as salaries for the forest guards;

- 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 USD 9,000 for 80 lines as a capital cost, and a monthly USD 4,000 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 USD 400,000 every year that spraying is carried out. However, research and implementation of other more environment-friendly pest management practices are recommended.

Table 3-16 Breakdown of the costs of forest protection and management measures

Measure	Average annual cost (USD million/year)
Clipping and pruning	18.27
Clearing of grass and weeds	0.10
Vehicles (capital cost)	0.10
Vehicles (fuel & maintenance)	0.28
Forest guards	0.96
Communication system	0.04
Pest management	0.40
Total	20.15

Table 3-17 Costs of forest protection and management for selected years

Year	2015	2020	2030
Area of forests (ha)	166,371	180,289	211,836
Total CO_2 Uptake Increment (tCO_2)	1,048,471	1,117,674	1,273,499
Cost (USD/ha)	111.4	108.3	107.1
Cost (USD/tCO_2)	17.7	17.5	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 3-18. The costs reflect the investment and operational costs to be incurred between the years 2011 to 2030 to implement the proposed mitigation scenario.

Table 3-18 Total discounted costs for forest protection and management

Discount Rate	PV (cost in USD) up to 2030	Cost (USD/t of incremental C sequestered) (up to 2030)	Cost (USD/ tCO_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

Mitigation scenario 2: Afforestation and reforestation including agroforestry and sylvo-pastoral systems

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, the climate and soil characteristics in the related ecosystem and has banned the introduction of non-native species. However, very limited measures are currently taken to identify and prevent the introduction of alien species, ascertain the origin of the seedlings, encourage production of native species and monitor the establishment and development success of those reforestation campaigns. In addition to the control of the alien species, a forest genetic resources conservation and management strategy should be implemented, including the management of seeds provenances.

Reforestation success rate for coniferous, deciduous and mixed wood areas can be as low as 20-30% (Castro et al., 2004) in stressful environments such as Mediterranean ecosystems including Lebanon. 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.

Any action aiming at replanting trees on barren or degraded areas that were previously covered by forests and would contribute to the overall carbon sequestration balance is identified as “reforestation”. The action of establishing forests on sites that were not previously considered as forests is called afforestation. In this perspective, all efforts of agroforestry or even urban greening (recreation areas, urban parks, etc.) are included. Linking forests and OWL through corridors (forest trees, wild 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.

Mitigation scenario 3: Substituting fossil fuels by forest-based biofuels: a CDM option

In addition to their role in reducing global carbon equivalent rates, forests can positively contribute to mitigating climate change effects by substituting fossil fuels with forest-based 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 and should be considered with care. OWL can serve as the main source of biofuel from wood clipping and sylviculture practices. The density of forests and OWL can also be reduced to provide biofuel while also reducing the fire risk.

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

3.5. Waste

The waste sector, including wastewater, is the largest source of CH_4 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).

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.

3.5.1. 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, which consists of establishing regional sanitary landfills, sorting and composting facilities while rehabilitating existing dumpsites. The following assumptions are proposed for constructing a future baseline scenario:

- 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 CH_4 gas collection in the proposed sanitary landfills, and rehabilitation of the dumpsites through closure and collection of gas. Landfill gas recovery rates are projected to grow with the assumed increase in the proportion of waste going into 'managed' sites;
- Solid waste disposal on land would gradually decrease by an annual rate of 3.5%, thereby constituting 68% of the total waste generated by 2030 (compared to 84% in 2006). It is assumed that recycling and composting rates will increase to cover 32% of the total waste stream by 2030;
- The generated municipal waste stream that would be disposed of on land by 2030 is assumed to be managed;
- 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% (IMF, 2009).

Based on these assumptions, the projected future baseline CH_4 emissions and corresponding waste inflows into solid waste disposal sites were calculated (reaching 6,000 Gg of CO_2 eq.), as presented in Figure 3-8.

3.5.2. Mitigation scenarios and costs

The proposed mitigation options tackle both the waste and energy sectors as it considers energy recovery as an alternative waste management option. However, 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.

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

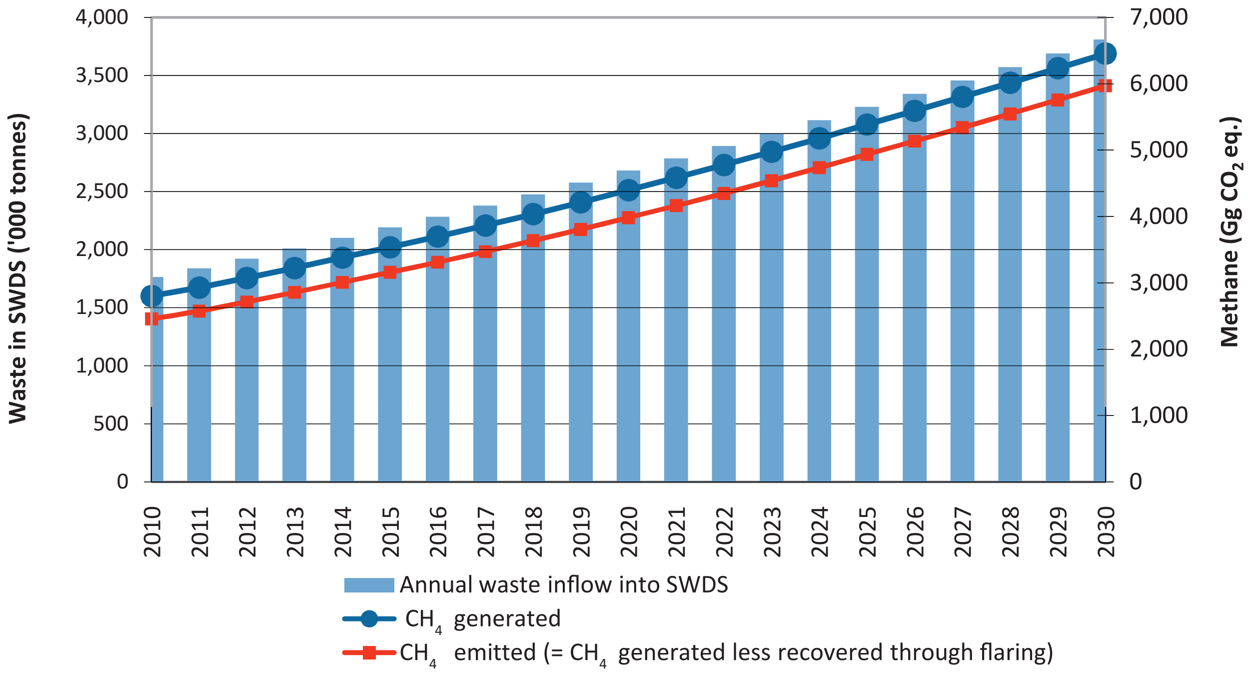


Figure 3-8 Projected baseline quantities of municipal solid waste in disposal sites and methane generation from SWDS

to generate electricity. 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). The determination of the engines' capacity needed for power generation from captured landfill gas is carried out by a series of conversions and assumptions of the portion of methane in landfill gas (50%), collection efficiency (50%), portion of captured methane used for power generation (90%) and other combustion engine parameters. Flares are installed even if the landfill gas is intended to be recovered for electricity generation in order to prevent accidental releases.

Regarding the collect and flare systems, the capital cost and operation and maintenance costs are driven by the amount of waste disposed. While absolute total costs increase with larger amounts, the unit costs per tonne of waste decrease reflecting economies of scale. Table 3-19 shows average costs of a collect and flare system for the generation of electricity. It should be noted that only additional costs represented by investments to utilise the methane gas for electricity production were taken into consideration. Table 3-20 shows the energy potential from the methane emissions and the power capacity needed 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

Table 3-19 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	USD 0.87/ tonne of MSW
Operation & maintenance cost	USD 0.13/tonne of MSW
Capital cost of an internal combustion engine/ generator	USD 1,791,000/MW
Operation & maintenance cost of an internal combustion engine/ generator	USD 181,000/MW
Depreciation period	10 years
Project Lifetime	20 years
Discount rate	10%, 15%

Source: USEPA, 1999. Estimated in 2004 USD

Table 3-20 Power capacity needed, energy potential from landfills' methane and methane emissions avoided for selected years

	2015	2020	2025	2030
Methane generated (Mm^3 CH_4)	209.85	264.65	327.89	396.52
Methane captured (Mm^3 CH_4)	104.93	132.32	163.94	198.26
Methane used for power generation (Mm^3 CH_4)	94.43	119.09	147.55	178.43
Energy content of "usable" methane (10^6 MJ)	3,563	4,493	5,567	6,732
Thermal energy generation potential (GWh_{th})	990	1,249	1,548	1,871
Electric energy generation potential (GWh_e)	225	284	352	426
Minimum engine capacity needed (MW)	29.0	36.6	45.3	54.8
Engine capacity to be installed (factoring in engine availability) (MW)	34.1	43.0	53.3	64.5
Methane emissions avoided (Gg CO_2 eq.)	1,579	1,992	2,468	2,984

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.

The marginal cost of the reduction in CO_2 eq. 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 USD 0.09 /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 USD 1.85 (at a discount rate of 10%) or USD 1.75 (at a discount rate of 15%) (Table 3-21).

Table 3-21 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/kWh)	Marginal Cost (USD/ 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

Mitigation scenario 2: Waste incineration and energy production

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. Deducting the CO_2 emissions from incineration from the avoided emissions, the effective cumulative savings would total 11,771,499 tCO_2 eq. (Table 3-22 and Figure 3-9).

Table 3-22 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

For Lebanon, the use of the grate technology with three different scenarios for flue gas treatment has been recommended (MoE-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 3-23. It should be noted that since 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 the reduction in CO_2 eq. 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 similarly as in

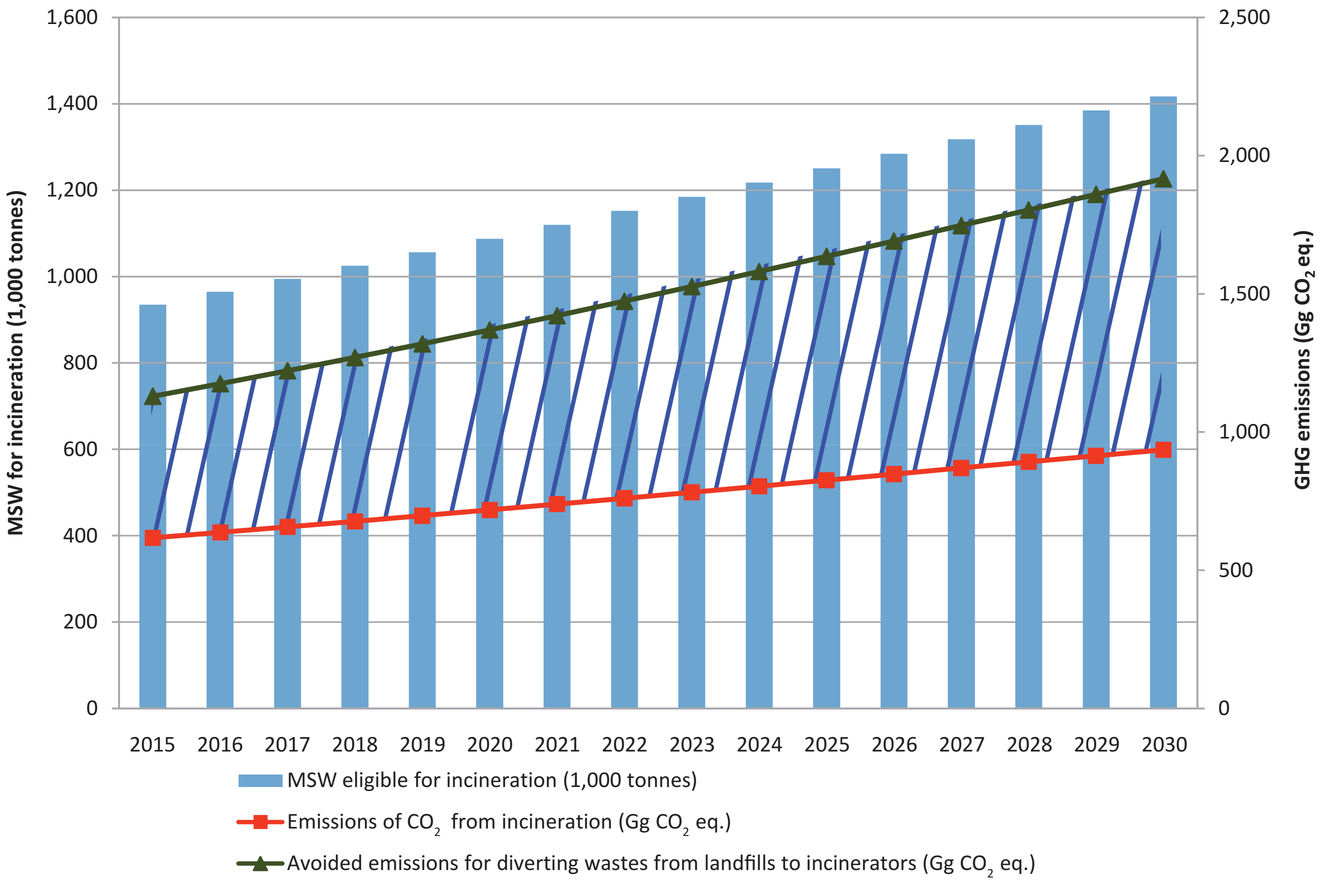


Figure 3-9 Projected quantities of municipal solid waste to be incinerated and avoided GHG emissions

Table 3-23 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	USD 469.8 million
Average annual Operation & Maintenance cost for all the proposed incineration capacity	USD 92.9 million
Depreciation period	15 years
Project Lifetime	20 years

Estimated in 2004 USD
Source: MoE - MSC-IPP, 2005

mitigation scenario 1 above. 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 USD 69.8 to USD 80.3 depending on the discount rate used (Table 3-24).

Table 3-24 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/kWh)	Marginal Cost (USD/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

The marginal cost of abatement 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 (Rand et al., 2000).

3.5.3. 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. Additional activities to complement the action plan should include the development of the necessary legislation to ease barriers and provide incentives for landfill operators to invest in electricity generation from LFG.