GREENHOUSE GAS MITIGATION ANALYSIS

SOLID WASTE

Lebanon's Second National Communication

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1. SOLID WASTE

1.1. 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 1-1). 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 1-1 shows the contributions of the different categories to GHG emissions.

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

	2000		2001		2002		2003		2004		2005		2006	
Category \ CO_2-eq	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).

1.2. 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 1-2. It is worth noting that the emissions appearing in Table 1-3 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.

1.2.1. 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.

1.2.2. 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 1-2).

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 1-2 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 1-1 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.

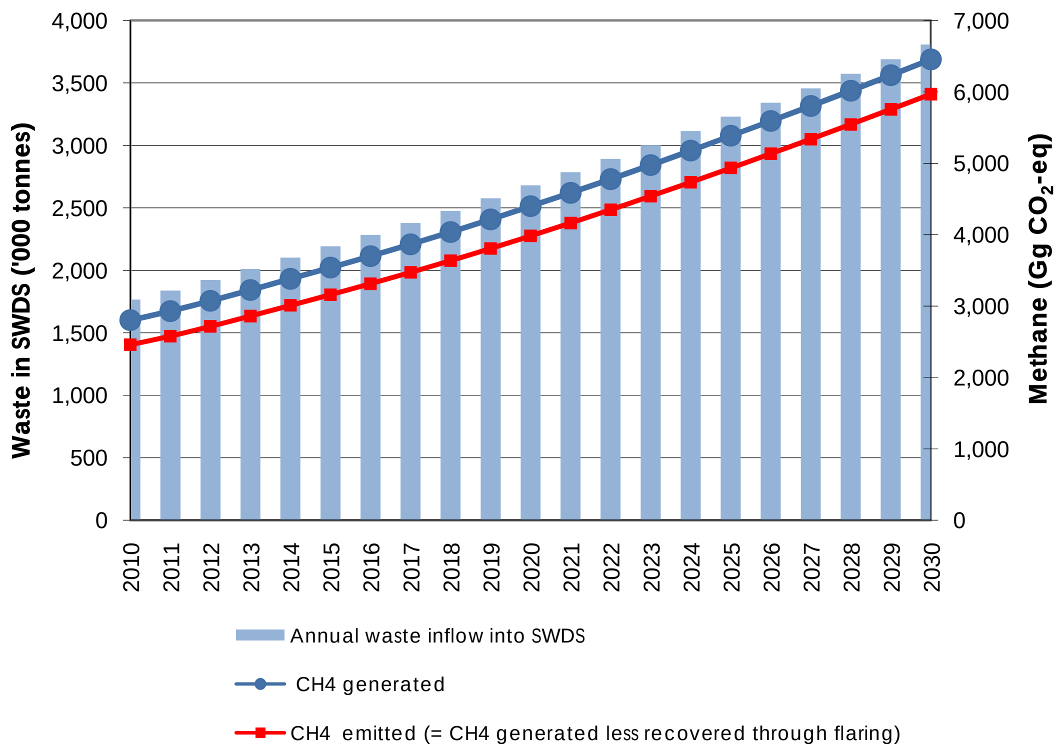

Figure 1-1 Projected baseline quantities of municipal solid waste in disposal sites and methane generation from SWDS

1.3. 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.

1.3.1. 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 1-1). 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 1-3.

Table 1-3 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 1-4 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 1-4 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 1-5 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 1-5 Power capacity needed, energy potential from landfills' methane and methane emissions avoided for selected years

	2010	2015	2020	2025	2030
Methane generated (Mm^3 CH_4)	163.32	209.85	264.65	327.89	396.52
Methane captured (Mm^3 CH_4)	81.66	104.93	132.32	163.94	198.26
Methane used for power generation (Mm^3 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 1-6).

Table 1-6 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

1.3.2. 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 1-7, Figure 1-2). The cumulative GHG emission savings (or mitigation) from waste incineration for energy recovery is represented in Figure 1-2 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 1-7 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

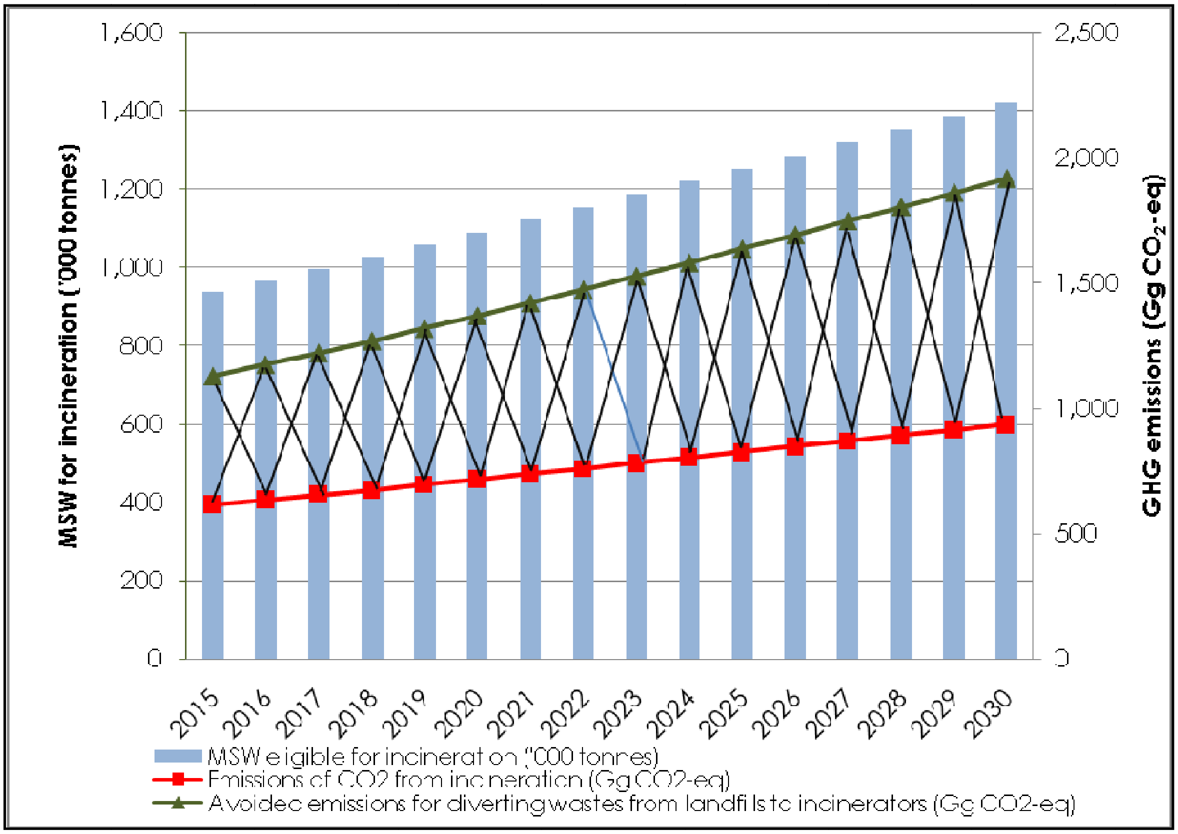

Figure 1-2 Projected quantities of municipal solid waste to be incinerated and avoided GHG emissions

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 1-8.

Table 1-8 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 1-9).

Table 1-9 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

1.4. 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. Table 6-10 provides an overview of 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.

1.5. 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

REFERENCES

Bogner, J., M. Abdelrafie Ahmed, C. Diaz, A. Faaij, Q. Gao, S. Hashimoto, K. Mareckova, R. Pipatti, T. Zhang, Waste Management, In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

CDR (Council for Development and Reconstruction). 2009. 2009 Progress Report: Solid Waste.

IMF (International Monetary Fund). World Economic Outlook, April 2009.

Jensen, J.E.F. and Pipatti, R. 2002. "CH_4 Emissions from Solid Waste Disposal." Background Paper: Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories.

MoE/MSC-IPP. 2005. "Technical and Economic Analysis of Solid Waste Incineration in Lebanon."

Rand, T., Haukohl, J. and U. Marxen. 2000. "Municipal Solid Waste Incineration: A Decision Maker's Guide." The World Bank, Washington D.C.

Schimel, D., D. Alves, I. Enting, M. Heimann, F. Joos, D. Raynaud, T. Wigley, M. Prather, R. Derwent, D. Ehhalt, P. Fraser, E. Sanhueza, X. Zhou, P. Jonas, R. Charlson, H. Rodhe, S. Sadasivan. K.P. Shine, Y. Fouquart, V. Ramaswamy, S. Solomon, J. Srinivasan, D. Albritton, I. Isaksen, M. Lal, D. Weubelles, 1996: Radiative Forcing of Climate Change. In: *Climate Change 1995: The Science of Climate Change. Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change* [Houghton, J.T., L.G. Meira Filho, B.A. Callander, N. Harris, A. Kattenberg, and K. Maskell (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 68pp.

SWEEP-Net. "Country Report on the Solid Waste Management in Lebanon." The Regional Solid Waste Exchange of Information and Expertise network in Mashreq and Maghreb countries, GTZ & ANGed, May 2010.

UN (United Nations) Population Division of the Department of Economic and Social Affairs, World Urbanization Prospects: The 2007 Revision, http://esa.un.org/unup.

UN (United Nations) Population Division of the Department of Economic and Social Affairs, World Population Prospects: The 2008 Revision, http://esa.un.org/unup.

US EPA. U.S. Methane Emissions 1990–2020: Inventories, Projections, and Opportunities for Reductions. September 1999. Chapter2: Landfills.