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NATIONAL GREENHOUSE GAS INVENTORY REPORT AND MITIGATION ANALYSIS

FOR THE WASTE SECTOR IN LEBANON

2015 MINISTRY OF ENVIRONMENT

National Greenhouse Gas Inventory Report and Mitigation Analysis for the Waste Sector in Lebanon

May 2015

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National Greenhouse Gas Inventory Report and Mitigation Analysis for the Waste Sector in Lebanon

Reference projects

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Foreword

Ministry of Environment

Through the publications of Lebanon's Initial and Second National Communications to the United Nations Framework Convention on Climate Change, and the Technology Needs Assessment for Climate Change, the Ministry of Environment drew the large climate change picture in the country. The picture shed the light on a number of climate change matters: Lebanon's contribution to global greenhouse gas emissions, the sectoral share of national emissions, the socio-economic and environmental risks that the country faces as a result of climate change, and the potential actions that could and should be undertaken to fight climate change both in terms of mitigation and adaptation.

Through these series of focused studies on various sectors (energy, forestry, waste, agriculture, industry, finance and transport), the Ministry of Environment is digging deeper into the analysis to identify strengths, weaknesses, threats and opportunities to climate friendly socio-economic development within each sector.

The technical findings presented in this report (National Greenhouse Gas Inventory Report and Mitigation Analysis for the Waste Sector) will support policy makers in making informed decisions. The findings will also help academics in orienting their research towards bridging research gaps. Finally, they will increase public awareness on climate change and its relation to each sector. In addition, the present technical work complements the strategic work of the National Climate Change Coordination Unit. This unit has been bringing together representatives from public, private and non-governmental institutions to merge efforts and promote comprehensive planning approach to optimize climate action.

We are committed to be a part of the global fight against climate change. And one of the important tools to do so is improving our national knowledge on the matter and building our development and environmental policies on solid ground.

Mohammad Al Mashnouk

Minister of Environment

Foreword

United Nations Development Programme

Climate change is one of the greatest challenges of our time; it requires immediate attention as it is already having discernible and worsening effects on communities everywhere, including Lebanon. The poorest and most vulnerable populations of the world are most likely to face the harshest impact and suffer disproportionately from the negative effects of climate change.

The right mix of policies, skills, and incentives can influence behaviour and encourage investments in climate development-friendly activities. There are many things we can do now, with existing technologies and approaches, to address it.

To facilitate this, UNDP enhances the capacity of countries to formulate, finance and implement national and sub-national plans that align climate management efforts with development goals and that promote synergies between the two.

In Lebanon, projects on Climate Change were initiated in partnership with the Ministry of Environment from the early 2000s. UNDP has been a key partner in assisting Lebanon to assess its greenhouse gas emissions and duly reporting to the UN Framework Convention on Climate Change. With the generous support of numerous donors, projects have also analysed the impact of climate change on Lebanon's environment and economy in order to prioritise interventions and integrate climate action into the national agenda. UNDP has also implemented interventions on the ground not only to mitigate the effects of climate change but also to protect local communities from its impact.

This series of publications records the progress of several climate-related activities led by the Ministry of Environment which UNDP Lebanon has managed and supported during the past few years. These reports provide Lebanon with a technically sound solid basis for designing climate-related actions, and support the integration of climate change considerations into relevant social, economic and environmental policies.

Ross Mountain

UNDP Resident Representative

Acknowledgements

This work could not be accomplished without the full and efficient cooperation of Eng. Bassam Sabbagh, head of the Service of Urban Environment at the MoE who provided detailed information for preparing/updating the national inventory. In addition, the meticulous follow up and critical support provided by the Climate Change team was essential in the preparation of this report.

Great thanks are extended to the participants in the experts' consultation meeting who had valuable input, namely: Nicolas Gharib (UNDP/MoE), Naji Chamieh (SES), Mohamad Baraki (OMSAR), Raji Maasri (MORES), Maria El Kotob (MORES), Farouk Merhebi (AUB), Rana Ghoussainy (LACECO), Arwa El Zein (LACECO), and Jean Khoury (BATCO).

Special thanks to Dr. Mutasem El Fadel (AUB) and Mr. Ismail Makke (CDR) for their support in providing useful information during one to one meetings and phone conversations.

Finally, the Ministry of Environment would like to thank UNDP/GEF for funding the whole greenhouse gas inventory exercise.

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Acronyms

AUB	American University of Beirut
BAU	Business as Usual
BOD	Biological Oxygen Demand
CAS	Central Administration of Statistics
CDR	Council for Development and Reconstruction
CoM	Council of Ministers
COSV	Coordinamento delle Organizzazioni per il Servizio Volontario (Italian NGO)
DOC	Degradable Organic Carbon
EF	Emission Factor
EIA	Environmental Impact Assessment
EU	European Union
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIS	Geographic Information System
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GoL	Government of Lebanon
GWP	Global Warming Potential
HCW	Healthcare Waste
INC	Initial National Communication
IPCC	Intergovernmental Panel on Climate Change
ISWM	Integrated Solid Waste Management
MCF	Methane Correction Factor
MoE	Ministry of Environment
MoEW	Ministry of Energy and Water

MoIM	Ministry of Interior and Municipalities
MSW	Municipal Solid Waste
NGO	Non-Governmental Organization
NIMBY	Not In My Back Yard
NIR	National Inventory Report
NWSS	National Water Sector Strategy
O&M	Operation and Maintenance
OMSAR	Office of the Minister of State for Administrative Reform
QA/QC	Quality Assurance/Quality Control
SAR	Second Assessment Report
SNC	Second National Communication
SWDS	Solid Waste Disposal Site
SWM	Solid Waste Management
SW	Solid Waste
TNC	Third National Communication
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNRWA	United Nations Relief and Works Agency
USAID	United States Agency for International Development
WtE	Waste-to-Energy
WW	Wastewater
WWE	Water and Wastewater Establishment
WWTP	Wastewater Treatment Plant

Executive summary

In the framework of Lebanon's Third National Communication (TNC) to the United Nations Framework Convention on Climate Change (UNFCCC), Greenhouse Gas (GHG) emissions resulting from the waste sector in Lebanon were estimated for the years 2005 through 2011. However, considering newly available data and/or better access to available data, a recalculation of GHG emissions from 1994 through 2004 was undertaken. Calculations were performed using the Revised 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories (IPCC, 1997) and the 2000 Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000). The tier 1 approach of the IPCC guidelines was adopted in the calculation of GHGs and consequently for the development of the national greenhouse gas inventory. Data collection was the main limitation in the development of the GHG inventory given the decentralized and inaccurate data available at a national level.

Inventory

The result of this exercise showed the following trend analysis which increases in a linear fashion starting 1994. A significant change in the trend is noted in 1997/1998 when the Naameh landfill started its operations thus increasing the amount of methane (CH_4) generated.

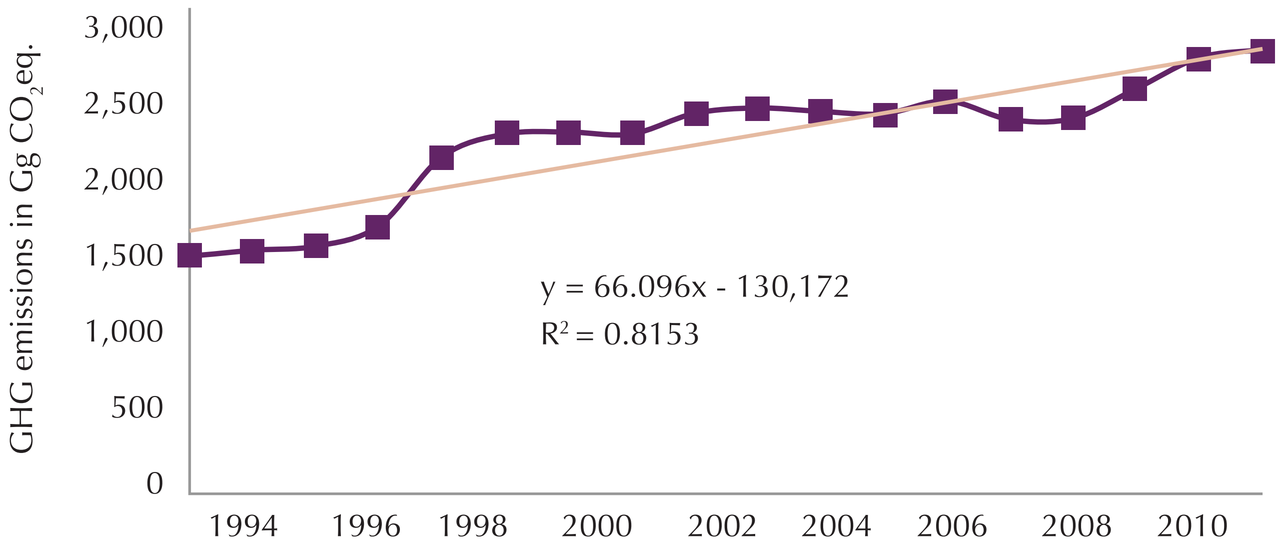


Figure i: Trend of GHG emissions in CO_2eq. between 1994 and 2011

The increase in GHG emissions – expressed in CO_2eq. – of around 1,300 Gg from 1994 to 2011 appears to be directly related to population increase considering the unchanged waste and wastewater management practices, independent of national Gross Domestic Product (GDP) growth throughout the years.

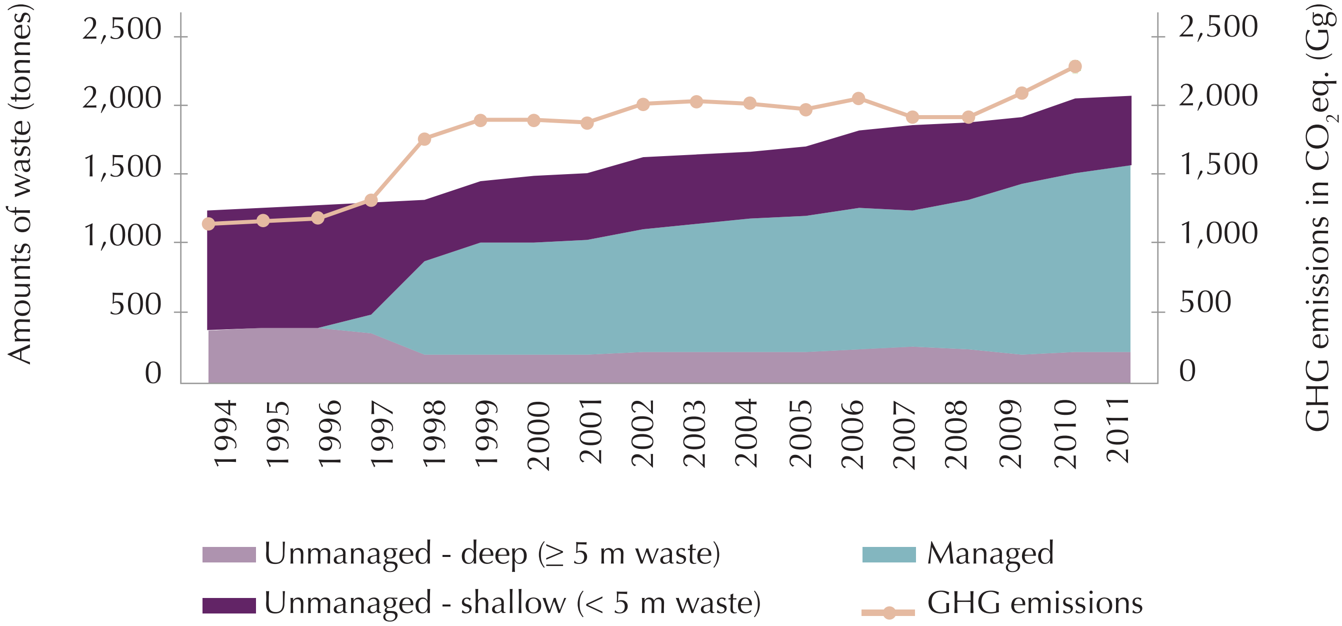


Figure ii: GHG emissions per disposal method

The GHG emissions trend from solid waste follows the trend of the waste that is being dumped in controlled dumpsites. Moreover, GHG emissions increase with the rise of quantity of waste disposed in controlled landfills, with a significant jump in the year 1997.

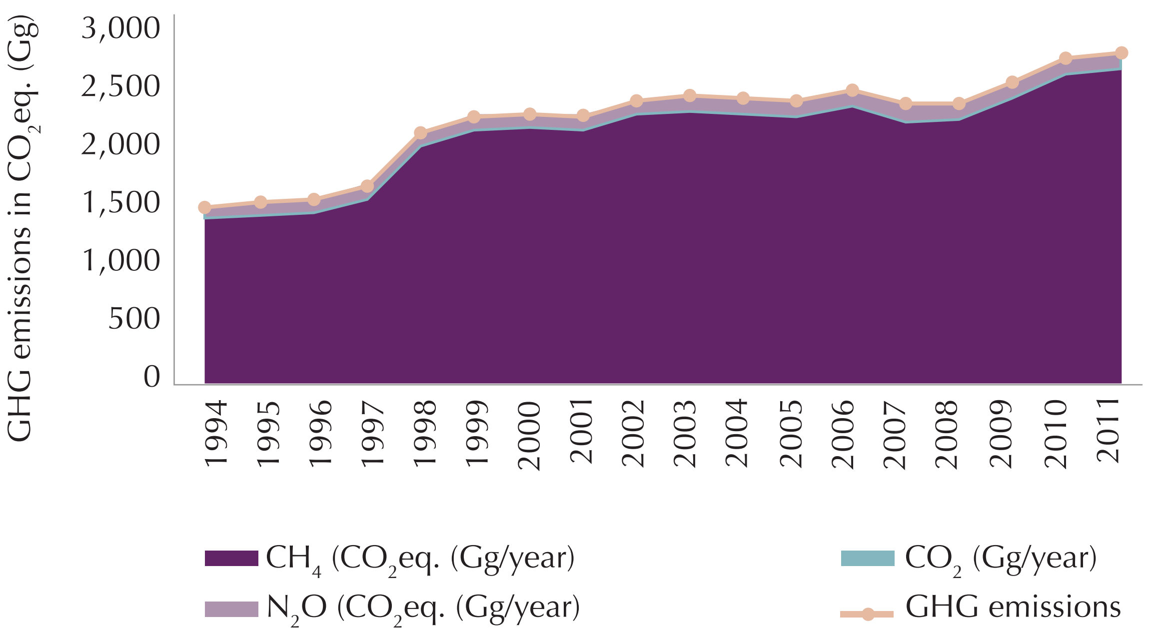


Figure iii: GHG inventory of emissions per gas for the years 1994 - 2011

As reflected, methane is the main GHG emitted from the waste sector as more than 80% is generated from the disposal of solid waste in landfills (which is currently the only practice adopted in Lebanon, where final disposal is in managed and unmanaged Solid Waste Disposal Sites (SWDS)) and Wastewater (WW) discharge. This is followed by N_2O from wastewater handling and CO_2 from Healthcare Waste (HCW) incineration.

Mitigation

Based on the inventory of GHG emissions prepared for the years 1994 through 2011, the impacts of the mitigation options for the waste sector in Lebanon are as follows: a "Business as Usual" (BAU) case was considered in addition to two scenarios for each of the years 2020 and 2040. While the BAU may be the worst case option with no mitigation actions applied, scenarios 1 and 2 reflect the effect of increasingly optimistic mitigation measures with solid waste and wastewater mitigation measures considered both applicable and realistic. The scenarios proposed for Solid Waste (SW) and wastewater are summarized as follows:

BAU scenario:

a. Solid waste: Partial landfilling with gas recovery for flaring or electricity generation.

b. Wastewater: No successful treatment for municipal WW; industrial WW remains mixed with municipal waste.

Scenario 1:

a. Solid waste: Waste incineration with energy production in Beirut and Mount Lebanon and landfilling in the rest of Lebanon.

b. Wastewater: 35% of the WW is treated by 2020 and 51% by 2040; 50% of industrial WW is treated.

Scenario 2:

a. Solid waste: Waste incineration with energy production on the coastal zone of Lebanon and landfilling in the Bekaa.

b. Wastewater: 51% of the WW is treated by 2020 and 74% by 2040; 100% of industrial WW is treated.

The GHG emissions profile under the three scenarios from solid waste and wastewater is presented in the figures below.

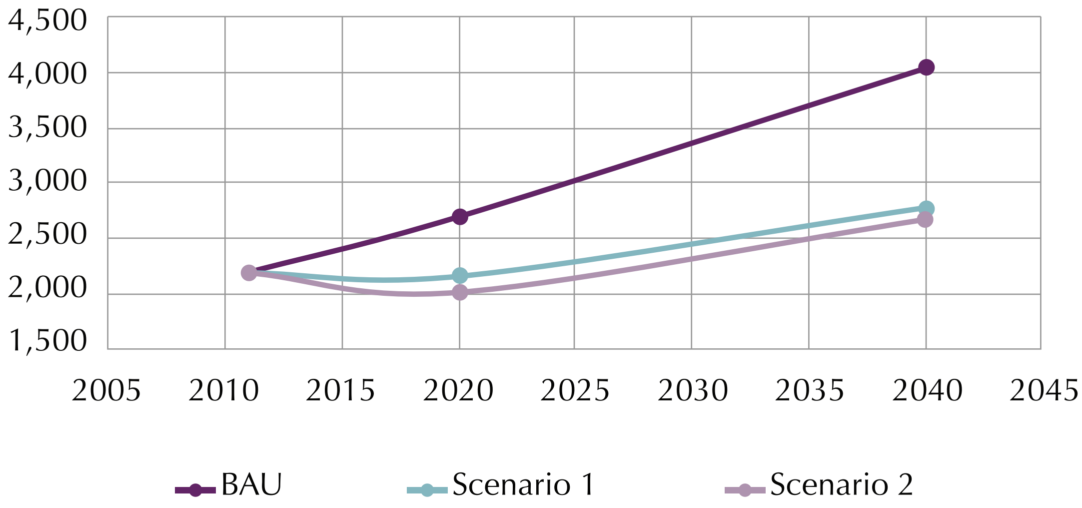


Figure iv: GHG emissions for MSW per scenario (CO_2eq. Gg/year)

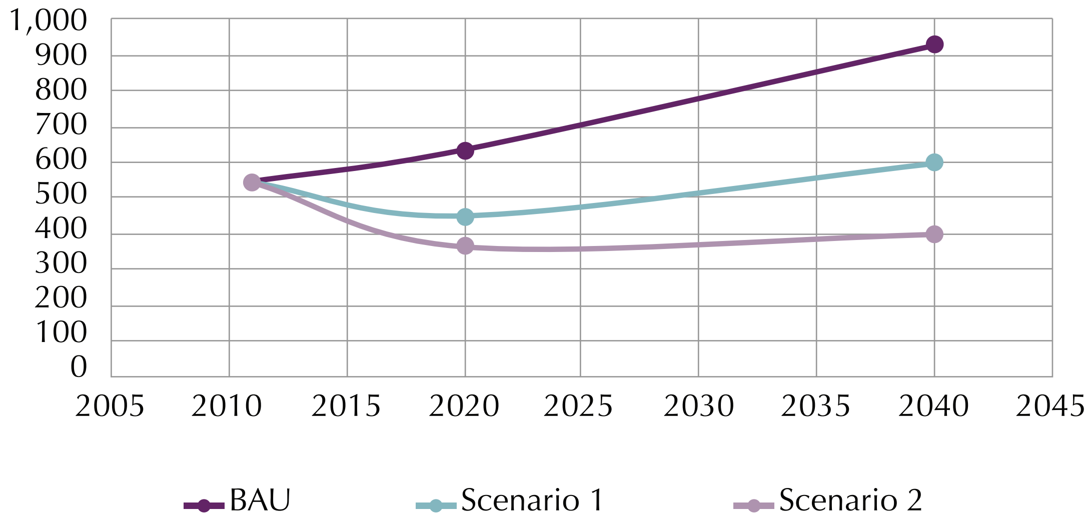


Figure v: GHG emissions for wastewater per scenario (CO_2eq. Gg/year)

Considering that the impact of solid waste is much higher than that of wastewater in terms of GHG emissions potential, mitigation measures for the solid waste scenarios were considered more closely and their impacts assessed in line with a phased implementation by the years 2020 and 2040.

The impact analysis of mitigation actions indicates that GHG emissions in the BAU scenario are expected to double in 2040 if no action is taken by the Government of Lebanon (GoL). Scenario 1 is considered a realistic case and any other mitigation scenario will most likely be drawn between the BAU and scenario 2. The following graph summarizes the GHG emissions profiles under the BAU, and the scenarios considered for the waste sector including solid waste and wastewater.

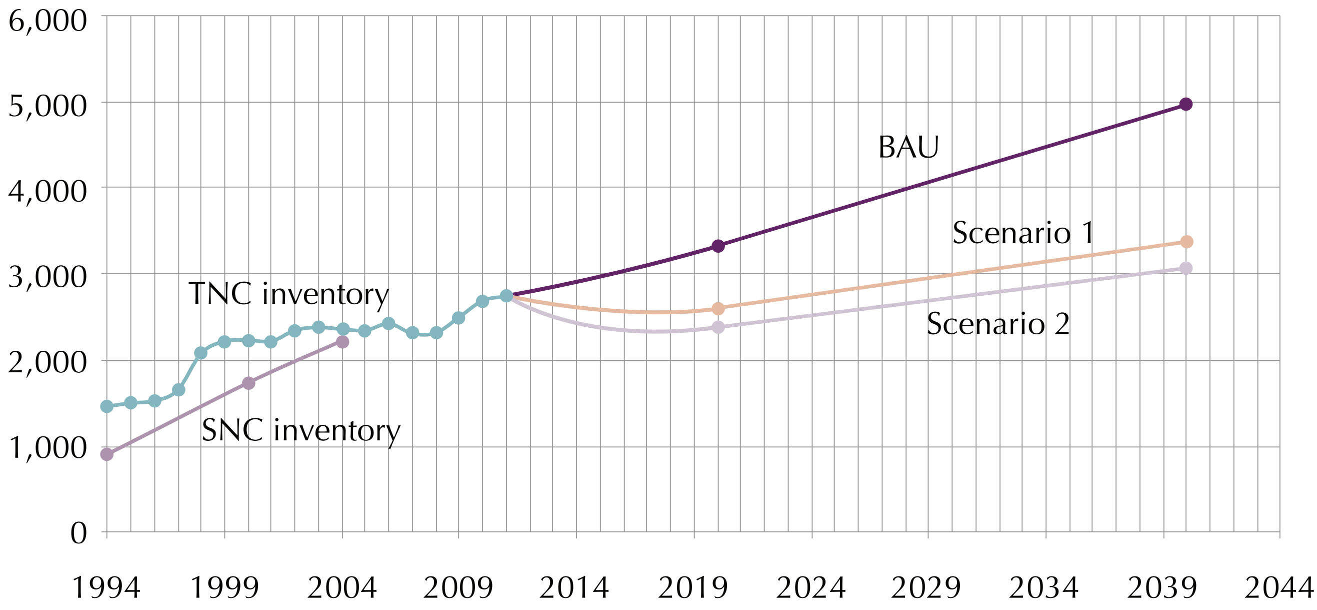


Figure vi: GHG emissions (CO_2eq. Gg/year) (total)

The following figure shows a comparison of total estimated GHG emissions between the BAU case and the two scenarios.

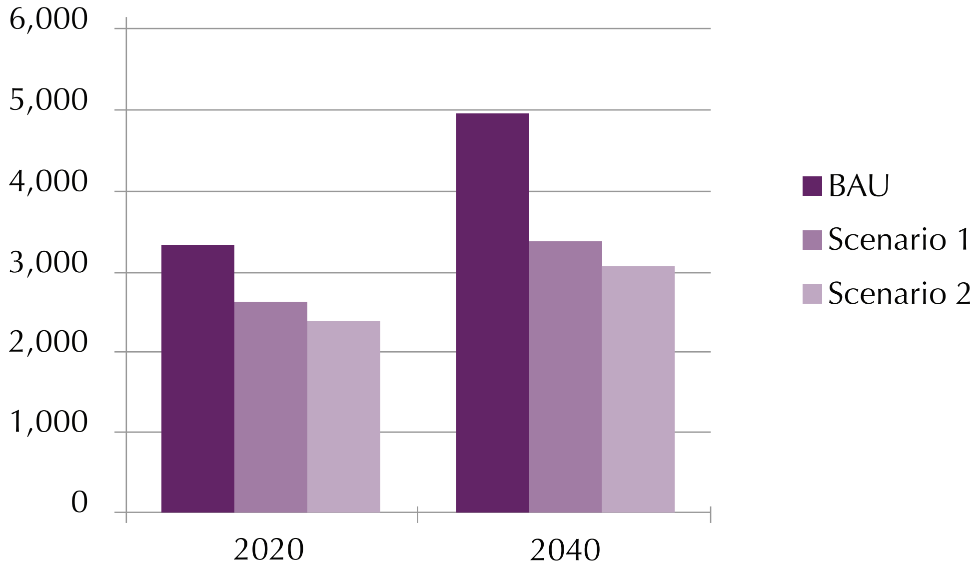


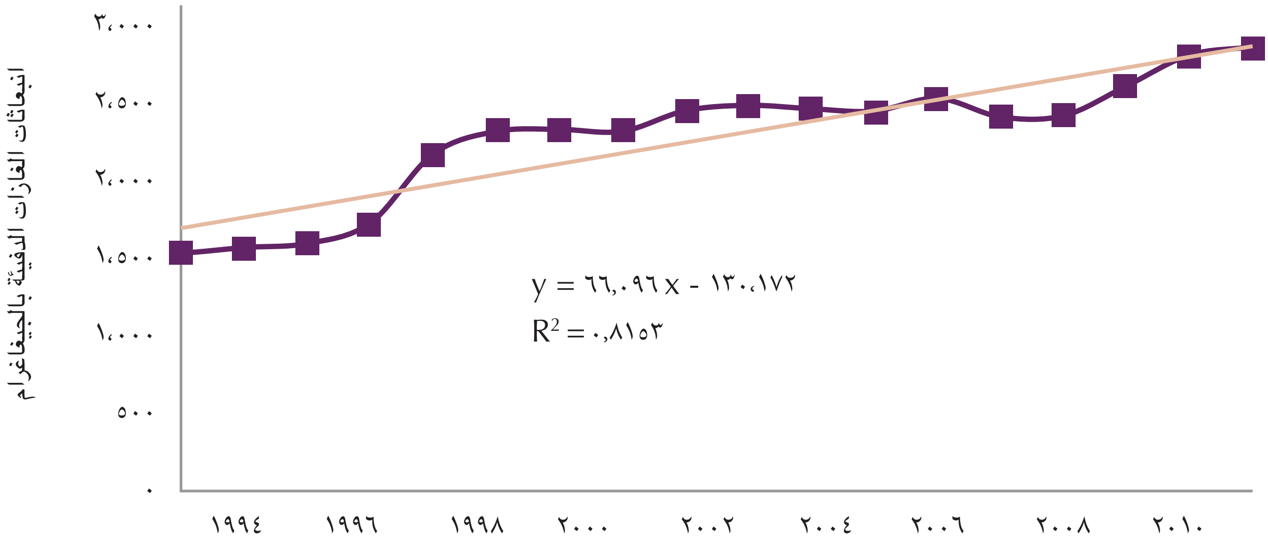
Figure vii: Comparison of GHG emissions (CO_2eq. Gg/year)

الملخص التنفيذي

في إطار البلاغ الوطني الثالث للبنان إلى اتفاقية الأمم المتحدة الإطارية بشأن تغير المناخ، تم تقدير انبعاثات غاز الاحتباس الحراري (الغازات الدفيئة) الناجمة عن قطاع إدارة النفايات في لبنان للأعوام ٢٠٠٥ حتى عام ٢٠١١. إلا أنه، وبالأخذ بعين الاعتبار البيانات المتوفّرة حديثًا و/أو إمكانية الوصول الأفضل إلى البيانات المتوفرة، تم القيام بعملية إعادة احتساب لانبعاثات الغازات الدفيئة من العام ١٩٩٤ وحتى العام ٢٠٠٤. وتمت العملية الحسابية باستخدام الخطوط التوجيهية المنقحة للهيئة الحكومية الدولية المعنية بتغير المناخ لعام ١٩٩٦ بشأن عمليات الجرد الوطنية لغازات الإحتباس الحراري ودليل الممارسات السليمة في عمليات الجرد الوطنية لغازات الإحتباس الحراري و درجة عدم اليقين في تقديراتها. وتم اعتماد المبادئ التوجيهية لمنهجية المستوى ١ للهيئة الحكومية الدولية المعنية بتغير المناخ المبادئ التوجيهية (IPCC) في احتساب الغازات الدفيئة ومن ثم لتطوير قوائم الجرد الوطنية للغازات الدفيئة. أما عملية تجميع البيانات، فقد كانت العقبة الرئيسية في وضع قوائم جرد الغازات الدفيئة نظرًا للبيانات اللامركزية وغير الدقيقة المتوفرة على المستوى الوطني.

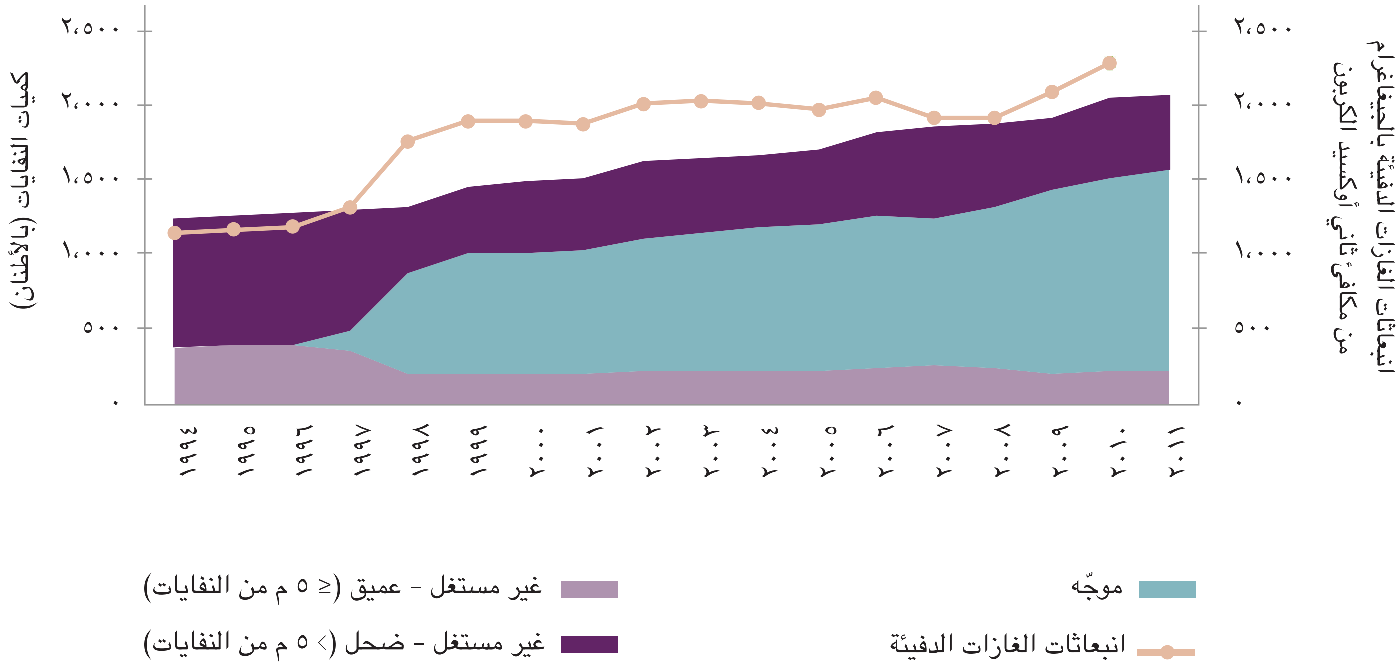
قوائم الجرد

أظهرت نتيجة هذا التمرين تحليل الاتجاهات التالي والمتزايد بشكل مستقيم منذ العام ١٩٩٤. وتم تسجيل تغيرًا بارزًا في هذا الاتجاه في فترة ١٩٩٧/١٩٩٨ عندما بدأت عملية الطمر في مطمر الناعمة، مما زاد بالتالي من كمية غاز الميثان المولّدة.



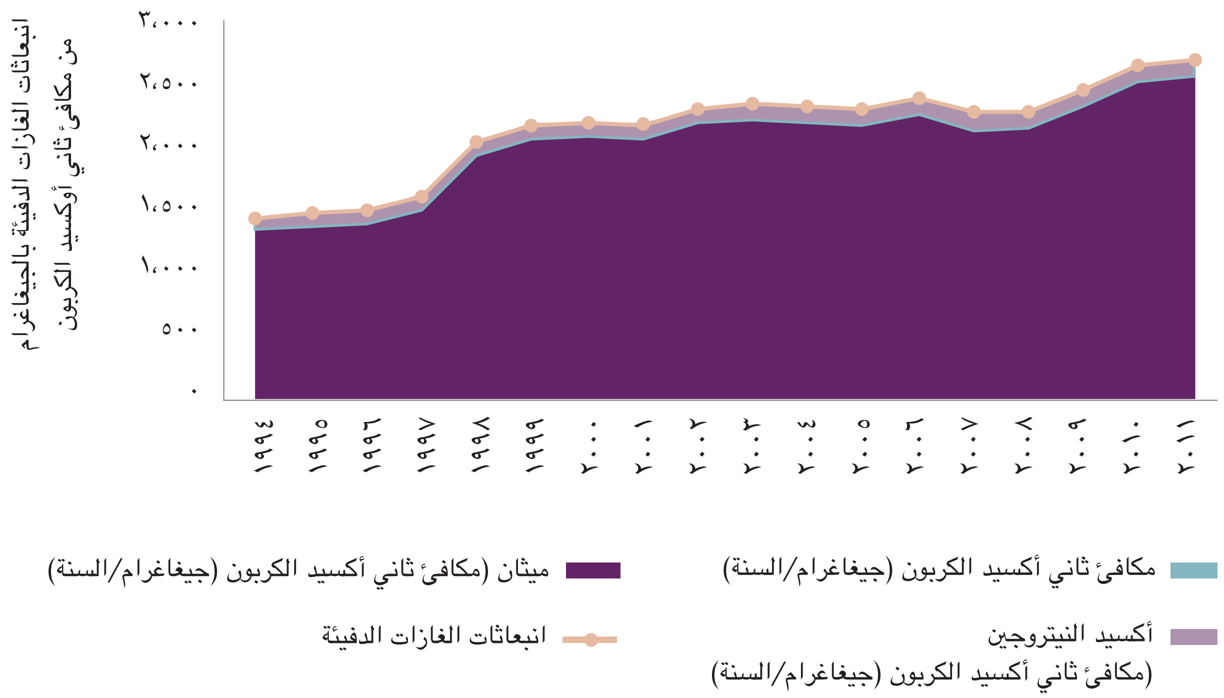
الشكل أ: اتجاه انبعاثات الغازات الدفيئة في مكافئ ثاني أكسيد الكربون بين العام ١٩٩٤ و ٢٠١١

ويبدو أن الزيادة المستمرة في انبعاثات الغازات الدفيئة في مكافئ ثاني أكسيد الكربون من حوالي ١،٣٠٠جيغاغرام من العام ١٩٩٤ وحتى ٢٠١١ هي زيادة مرتبطة بشكل مباشر بالزيادة السكانية نظرًا إلى ممارسات إدارة النفايات ومياه الصرف الصحي غير المتغيّرة وبغض النظر عن نموّ الناتج المحلي الإجمالي الوطني عبر مر السنين.



الشكل ب: انبعاثات الغازات الدفيئة بحسب طريقة التخلص من النفايات

يتبع اتجاه انبعاثات الغازات الدفيئة الناتجة عن النفايات الصلبة اتجاه النفايات التي يتم إلقاؤها في مكبات النفايات الخاضعة للرقابة حيث تتزايد انبعاثات الغازات الدفيئة مع تزايد كمية النفايات التي يتم التخلص منها في المطامير الخاضعة للرقابة، مع قفزة بارزة في العام ١٩٩٧.



الشكل ج: قائمة جرد الغازات الدفيئة للانبعاثات للسنوات ١٩٩٤ – ٢٠١١

كما هو مبين، فإن غاز الميثان هو من الغازات الدفيئة الرئيسية المنبعثة من قطاع إدارة النفايات حيث أن أكثر من ٨٠٪ منه هو نتيجة التخلص من النفايات الصلبة في المطامير (والذي هو حاليًا الممارسة الوحيدة المعتمدة في لبنان، حيث يكون التخلص النهائي في مكبّات النفايات الصلبة العشوائية والصحية، والمساهمة بشكل مختلف في انبعاثات غازات الدفيئة) وتصريف مياه الصرف الصحي. ويلي ذلك غاز أكسيد الكربون الناتج عن معالجة مياه الصرف الصحي وثاني أكسيد الكربون، والذي يمكن نسبه بشكل أساسي إلى ممارسات حرق النفايات الطبية، على التوالي.

تخفيف الانبعاثات

بناءً على قوائم جرد انبعاثات الغازات الدفيئة التي تم تحضيرها للأعوام ١٩٩٤ وحتى ٢٠١١، تأتي آثار خيارات التخفيف لقطاع إدارة النفايات في لبنان على الشكل التالي: تم أخذ نهج «العمل المعتاد» إضافة إلى سيناريوين لكل من السنتين ٢٠٢٠ و ٢٠٤٠. وفي حين قد يكون خيار «العمل المعتاد» الخيار الأسوأ مع عدم تطبيق أي إجراءات تخفيف، يعكس السيناريو ١ و السيناريو ٢ آثار تدابير التخفيف المتفائلة على نحو متزايد مع اعتبار إجراءات التخفيف للنفايات الصلبة ومياه الصرف الصحي كإجراءات واقعية ويمكن تطبيقها. ويمكن تلخيص السيناريوهات المقترحة للنفايات الصلبة ومياه الصرف الصحي على النحو التالي:

سيناريو العمل المعتاد:

١. النفايات الصلبة: الطمر الجزئي مع استخلاص الغاز للحرق أو توليد الكهرباء.
٢. مياه الصرف الصحي: لا علاج ناجح للمياه الصرف الصحي؛ مياه الصرف الصحي الصناعية لا تزال مختلطة بنفايات البلدية.

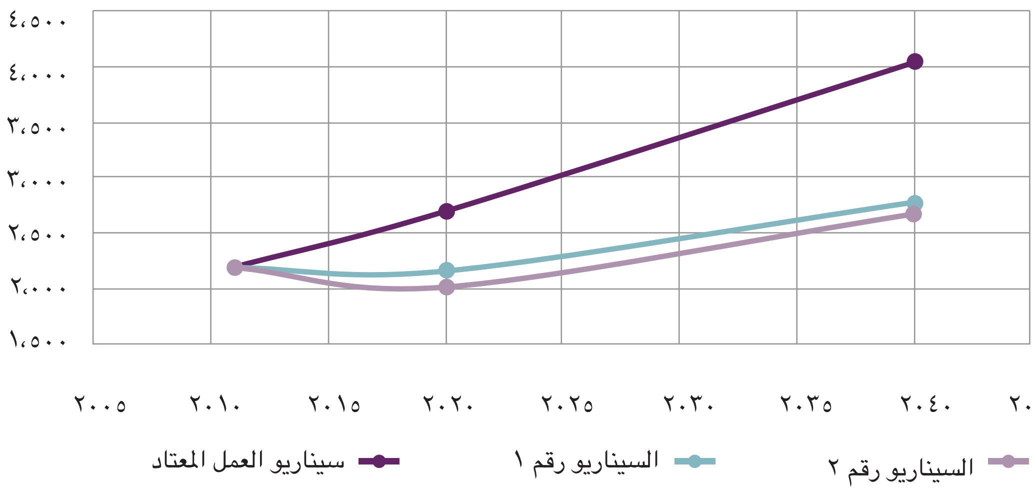
السيناريو رقم ١:

١. النفايات الصلبة: حرق النفايات مع إنتاج الطاقة في بيروت وجبل لبنان وطمر النفايات في باقي أنحاء لبنان.
٢. مياه الصرف الصحي: تتم معالجة ٣٥٪ من مياه الصرف الصحي بحلول ٢٠٢٠ و٥١٪ بحلول ٢٠٤٠؛ تتم معالجة ٥٠٪ من مياه الصرف الصحي الصناعية.

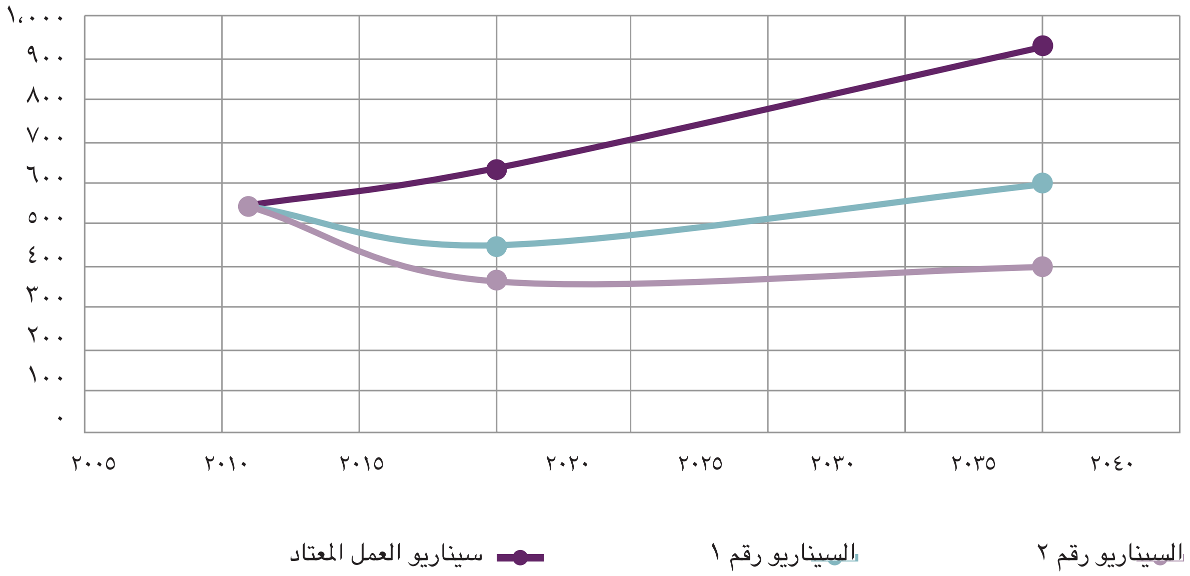
السيناريو رقم ٢:

١. النفايات الصلبة: حرق النفايات مع إنتاج الطاقة في المنطقة الساحلية في لبنان وطمر النفايات في البقاع.
٢. مياه الصرف الصحي: تتم معالجة ٥١٪ من مياه الصرف الصحي بحلول ٢٠٢٠ و٧٤٪ بحلول ٢٠٤٠؛ تتم معالجة ١٠٠٪ من مياه الصرف الصحي الصناعية.

أما عرض انبعاثات الغازات الدفيئة الواردة تحت السيناريوهات الثلاثة للنفايات الصلبة ومياه الصرف الصحي فهو مبيّن في الأرقام أدناه.



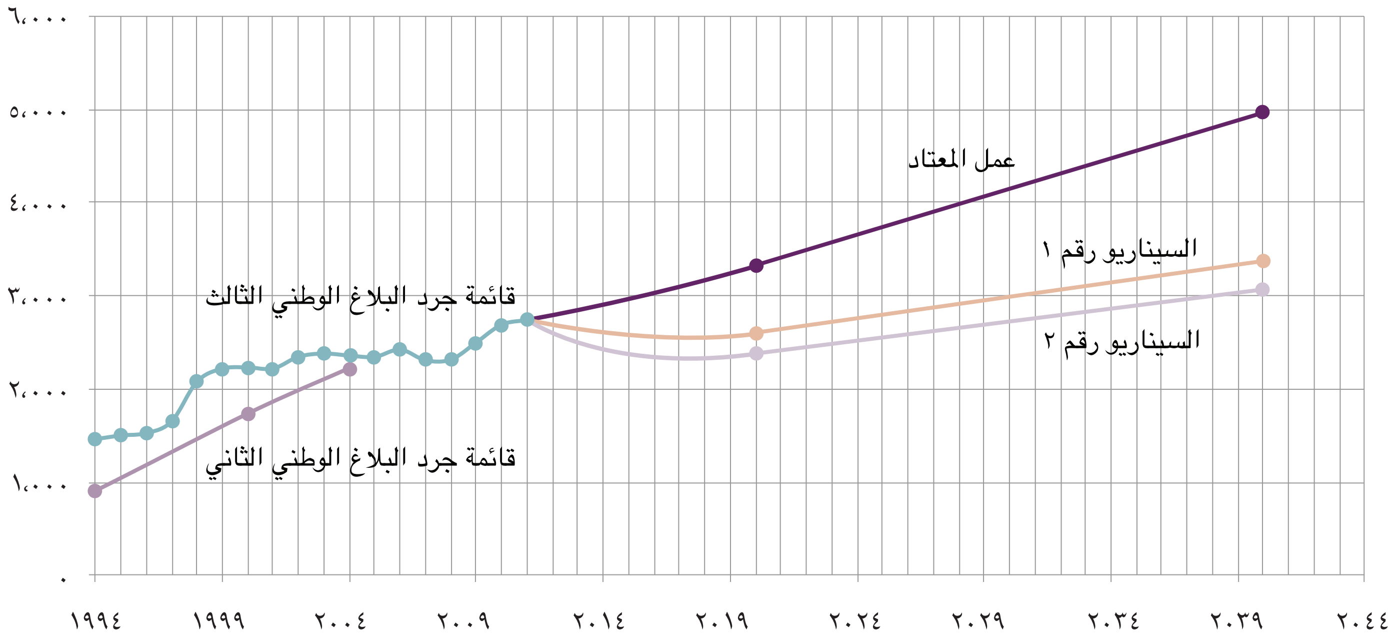
الشكل د: انبعاثات الغازات الدفيئة من النفايات الصلبة بحسب السيناريو (مكافئ ثاني أكسيد الكربون بالجيغاغرام/السنة)



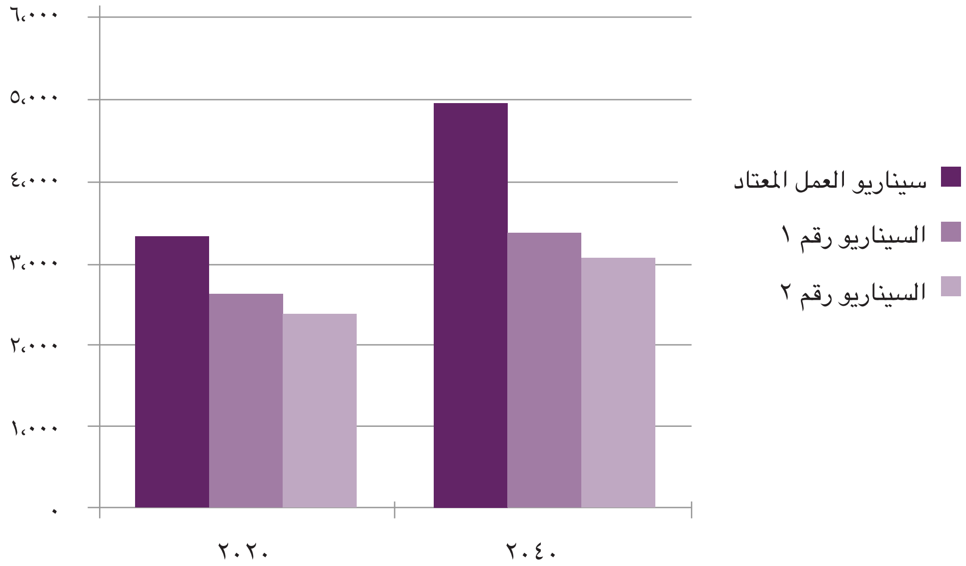
الشكل ه: انبعاثات الغازات الدفيئة من المياه المبتذلة بحسب السيناريو (مكافئ ثاني أكسيد الكربون بالجيغاغرام/السنة

ونظرًا إلى أن تأثير النفايات الصلبة هو أعلى بكثير من تأثير مياه الصرف الصحي، من حيث انبعاثات الغازات الدفيئة المحتملة، تم درس إجراءات التخفيف لسيناريوهات النفايات الصلبة بشكل وثيق أكثر وتم تقييم آثارها تماشيًا مع التنفيذ التدريجي بحلول العام ٢٠٢٠ و ٢٠٤٠.

ويشير تحليل إجراءات التخفيف إلى أن انبعاثات الغازات الدفيئة في سيناريو العمل المعتاد من المتوقع أن تتضاعف في العام ٢٠٤٠ في حال لم يتم اتخاذ أي إجراء من قِبل الحكومة اللبنانية. ويُعتبر السيناريو رقم ١ حالة واقعية وعلى الأرجح أن يتم وضع أي سيناريو تخفيف آخر بين سيناريو العمل المعتاد والسيناريو رقم ٢. يلخص الرسم البياني التالي الصور العامة لانبعاثات غازات الدفيئة تحت سيناريو العمل المعتاد والسيناريوهات الأخرى المدروسة لقطاع النفايات، بما في ذلك النفايات الصلبة ومياه الصرف الصحي.



الشكل و: انبعاثات الغازات الدفيئة (مكافئ ثاني أكسيد الكربون بالجيغاغرام/السنة) (المجموع)



الشكل ز: مقارنة انبعاثات الغازات الدفيئة (مكافئ ثاني أكسيد الكربون بالجيغاغرام/السنة)

Part 1: Inventory

1. Scope

In the framework of Lebanon's Third National Communication (TNC) to the United Nations Framework Convention on Climate Change (UNFCCC), the Lebanese Ministry of Environment (MoE) is prepared with the support of the United Nations Development Programme (UNDP) the national inventory of Lebanon's anthropogenic emissions for the years 2005 through 2011 and this for the Greenhouse Gases (GHG) covered by the Kyoto Protocol in addition to the indirect GHGs. The National Greenhouse Gas Inventory has been prepared on the basis of the Revised 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories (IPCC, 1997) and the 2000 Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000) for each of the sectors: energy, industrial processes, agriculture, land-use change, land-use and forestry and waste, the latter including solid waste and wastewater.

The current report presents the inventory of emissions from the waste sector in Lebanon. This report serves as a basis for the elaboration of mitigation options or measures based on sector developments and plans. An assessment of reduction levels (achieved or projected) is included.

The below sections reflect the national waste management context as well as gaps and constraints flagged as being determinant for the findings of the GHG inventory. Most importantly, the report presents an estimate of GHG emissions from the waste sector using the IPCC Guidelines for National Greenhouse Gas Inventories and the 2000 Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories while assessing the uncertainty derived from the data quality used in the calculations.

2. National circumstances

2.1. Solid waste management

The legal framework for the management of solid waste in Lebanon remains to be defined. A draft law prepared by the MoE was endorsed by the Council of Ministers (CoM) in 2012 and approved by the inter-parliamentary committee. It now awaits final endorsement by the general assembly. Box 1 below presents the main chapters addressed in the proposed draft law.

In March 2013, the MoE, Council for Development and Reconstruction (CDR) and Ministry of Interior and Municipalities (MoIM) prepared a national solid waste management plan that was submitted to the CoM. This plan is simply based on the adoption of Waste-to-Energy (WtE) for the treatment of solid waste after conducting necessary sorting for recyclables and organic materials.

Box 1 – Solid waste draft law

1. Provides a legal and institutional framework of Integrated Solid Waste Management (ISWM) in Lebanon for the protection of the environment.
2. Assigns responsibilities to a specific ministerial committee headed by the MoE to prepare strategies.
3. Adopts the "Polluter Pays Principle" and assigns responsibilities to the local authorities in general to manage solid waste.
4. Provides guidelines for the management of hazardous solid waste.
5. Provides guidelines for financing solid waste management including cost recovery and incentives.
6. Provides enforcement mechanisms.
7. Endorses strategies and management plans.

Solid waste management in Lebanon is yet to be properly monitored and managed. Data on solid waste generation is not readily available and where available, information is often disaggregated (by site, operator, local authority, etc.), decentralized and often reported in hard copy reports making any manipulation and analysis time-consuming and difficult. Furthermore, solid waste amounts are generally estimated based on the population and generation rate per capita. Surveys and assessments conducted for the years 1994 (El Fadel and Sbayti, 2000), 2006 (CDR, 2006), and 2010 (MoE, 2010) produced generation rates for these respective years. For other years, the per capita generation rates were computed by extrapolation as noted in Figure 1.

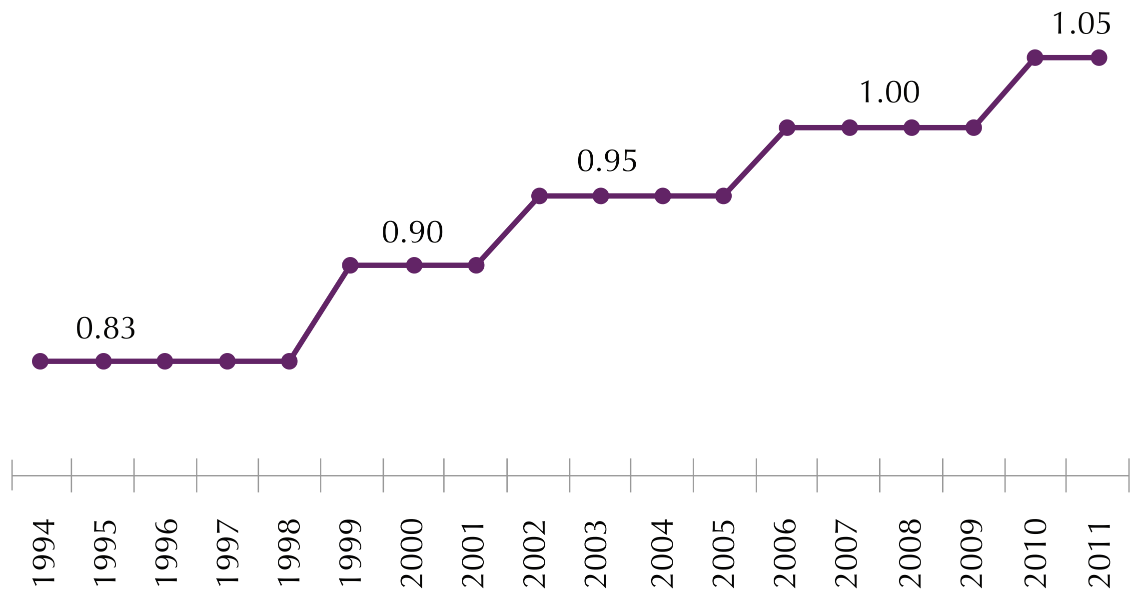


Figure 1: Per capita municipal solid waste generation rates for the years 1994-2011 (kg/capita/d)

While solid waste generally refers to municipal, industrial and Healthcare Waste (HCW), in Lebanon this segregation is generally inapplicable due to the absence of well-defined legislation and more stringent controls. Accordingly, most of the industrial and hazardous wastes are being mixed with the municipal waste. The HCW, is disposed of in the municipal waste bins (after some being autoclaved) and transferred to landfills or dumpsites.

Solid waste disposal sites

The section below presents a description of the main existing landfills in Lebanon namely the Naameh landfill, the Zahle landfill, and the Tripoli controlled dumpsite; these are the main methane generating sites.

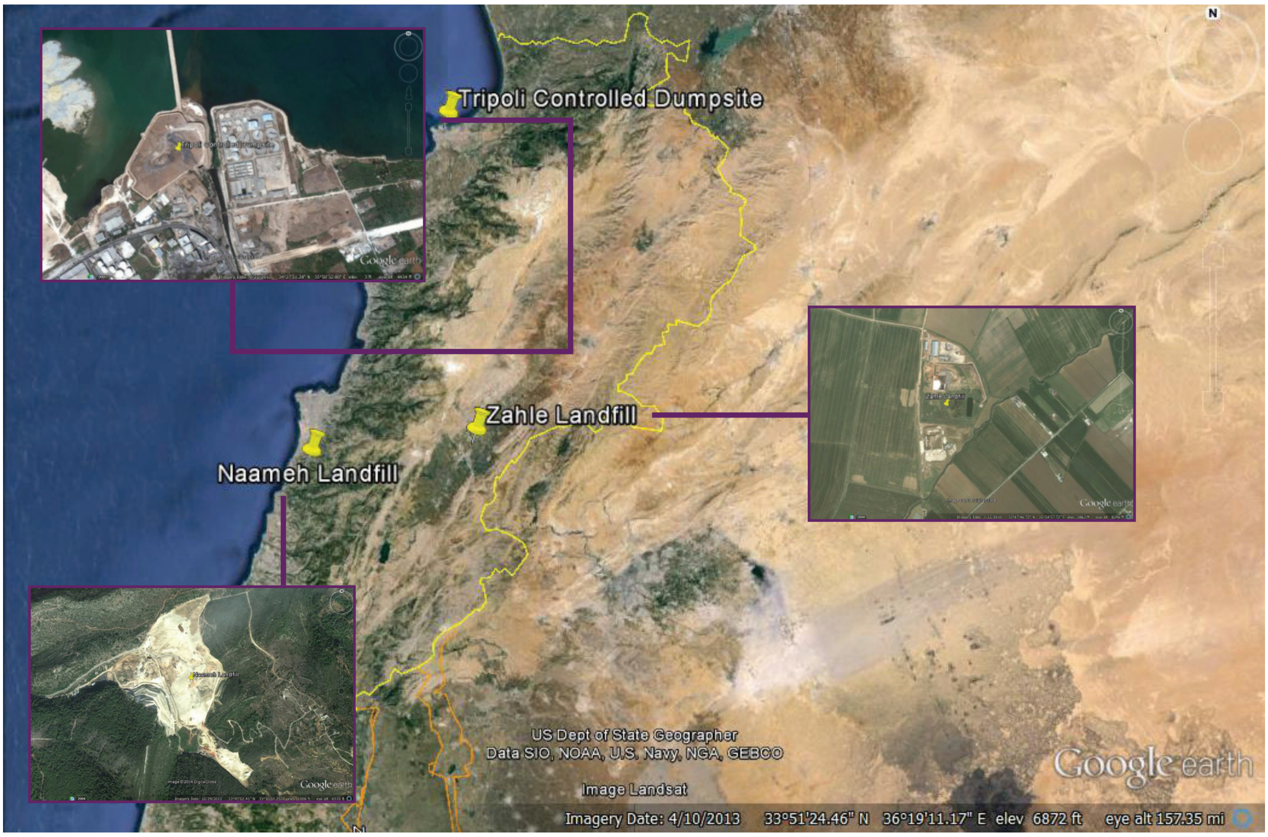


Figure 2: Distribution of solid waste disposal sites

These three “official” Solid Waste Disposal Sites (SWDS) in Lebanon have received around 55% of the total generated solid waste in Lebanon since 1998, as shown in Figure 3. The remainder is partially recycled/composted and partially disposed in open dumpsites by the local authorities such as municipalities and/or unions of municipalities.

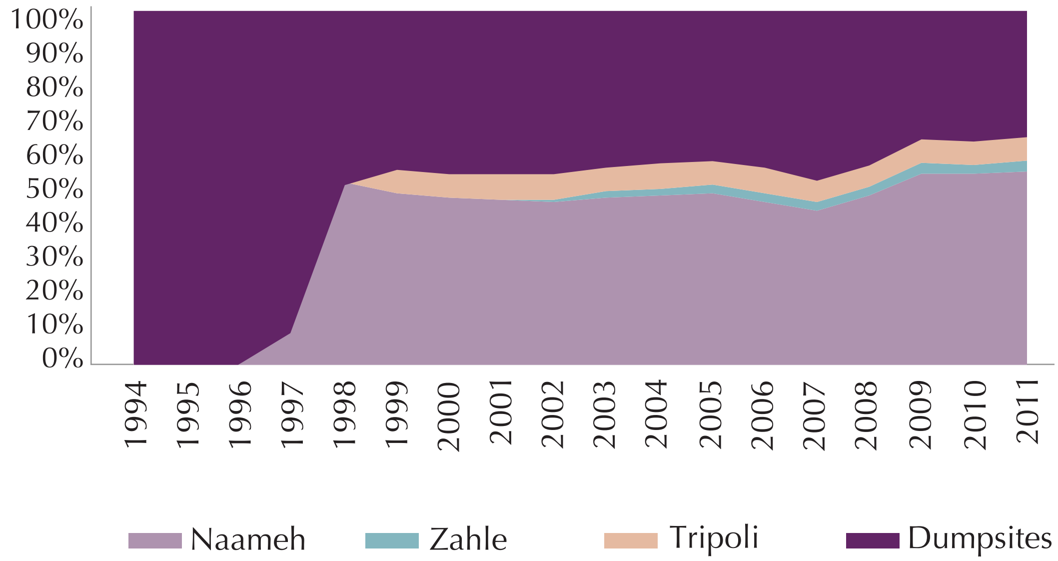


Figure 3: Evolution of solid waste final disposal sites (1994 – 2011)

The Naameh landfill

The Naameh landfill was created in 1997 as an emergency to stop the open dumping of waste especially in the Normandy and Bourj Hammoud dumpsites. The Naameh landfill has been operational since then and has received some 10 million cubic tonnes of Municipal Solid Waste (MSW) following sorting at the Karantina or Amroussieh sorting facilities. The sorting facilities and Naameh landfill receive the MSW collected from Beirut and Mount Lebanon (except Jbeil) regions. The landfill was originally designed to cover 120,000 m^2 and receive 2 million tonnes of waste in two cells denoted cell 1 and cell 2. In April 2001, the two cells reached maximum capacity and the CDR requested SUKOMI[1] to build cell 3 over an area of 62,000 m^2. This cell was further divided into cells 3A, 3B, and 3C, which reached their full capacity in 2005 and were expanded in 2006 by an additional 25,000 m^2. In 2008 and concurrently with the extension of SUKOMI's contract period through 2011, SUKOMI built two new cells denoted 3D1 and 3D2, which extended the landfill service period until July 2010.

As shown in Figure 4, the Naameh landfill is one of 3 solid waste disposal sites with methane flaring systems. However, quantities recovered from Naameh can reach levels 4,000 times higher than the remaining 2 sites in a given year. The quantities of methane recovered are reported by LACECO, the main consultant managing the Naameh landfill. Additional investigation is needed to further explain the decreasing trend since 2008. Lower generation rates might be attributed to slower methane generation from specific cells or to the absence of final capping in other cells, leading to methane leaks and consequently less capturing and recovery.

[1] SUKOMI is the contractor assigned by CDR for the construction and operation of the Naameh landfill.

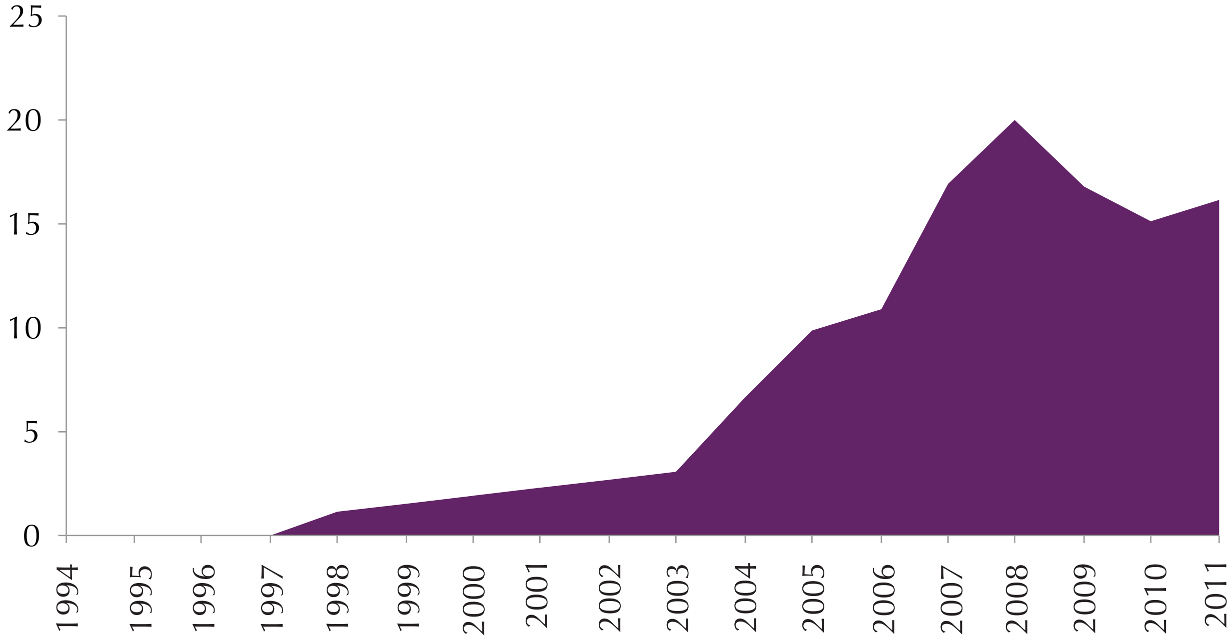


Figure 4: Quantity of methane recovered from the Naameh landfill (Gg/year)

The Zahle landfill

The Zahle landfill was opened in 2002 in the Bekaa Valley in the Caza of Zahle. It was designed and built under the World Bank-funded project "Solid Waste Environmental Management Project" to serve 15 out of 29 municipalities in the Caza of Zahle. It is designed to receive 150 tonnes per day. In 2006, the United States Agency for International Development (USAID) in Lebanon signed a USD 2.4 million agreement with the Municipality of Zahle to expand the existing sorting plant and build a composting plant adjacent to the landfill. The sorting plant was completed in 2007 with a design capacity of 300 tonnes of waste daily and started operating in 2008. The compost plant (90 tonnes/day) has yet to start operating. The landfill today comprises of five cells (average height of 24 meters) and receives about 150 tonnes/day, i.e. around 55,000 tonnes per year. At the Zahle sanitary landfill, one flaring unit has been installed since 2003 where collected gas is directly flared on site. However, the quantity of gas flared is minimal compared to the Naameh landfill and this is mainly due to the quantity of waste collected in Zahle which is less than 5% of the waste collected in Beirut and Mount Lebanon.

The Tripoli controlled dumpsite

The Tripoli controlled dumpsite is located on the Tripoli seafront and serves the city of Tripoli as well as the neighboring towns of Al-Mina, Biddawi and Qalamoun with an estimated population of 400,000 inhabitants. In 2000, the CDR contracted BATCO, a local waste contractor, to improve waste disposal practices and manage the dumpsite by retrofitting it with gas extraction wells and flaring units. In 2003, CDR commissioned Dar Al Handasah to prepare a study to expand the dumpsite and extend its service life. The approved study recommended building a waste sorting and composting plant (requiring the expropriation of 13,000 m^2) and building a gabion wall around the dump (9 to 10 m high) to contain the waste and prevent breakage into the sea. The CDR executed the sea wall in 2006 and the European Union (EU) funded the Solid Waste Management (SWM) program through the Office of the Minister of State for Administrative Reform (OMSAR) which tendered the construction of a 150 tonnes/day sorting plant in 2009 which was contracted but still not operational. At the Tripoli dumpsite, one flaring unit has been installed since 2000 where collected gas is directly flared on site. However, the quantity of gas flared is minimal compared to the Naameh landfill and this is mainly due to the quantity of waste collected in Tripoli which is less than 15% of the waste collected in Beirut and Mount Lebanon.

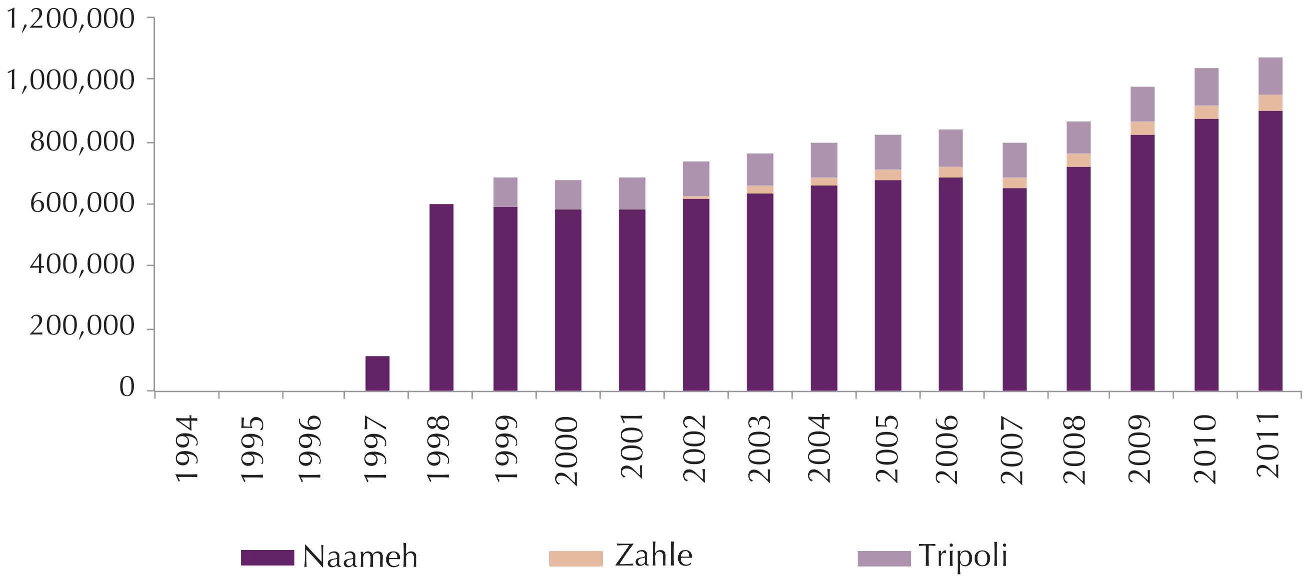


Figure 5: Evolution of solid waste quantities deposited at the main SWDS (1994-2011)

Source | Naameh (LACECO annual reports), Zahle (Municipality of Zahle), Tripoli (BATCO)

Open dumping sites in Lebanon

Open dumping and most often open burning of MSW are still practiced in Lebanon. Around 670 dumpsites have been reported in 2010 (MoE, UNDP, ELARD, 2011), out of which 504 are MSW dumpsites and the rest are construction and demolition dumpsites. Their distribution on the Lebanese territory is presented in Figure 6, Figure 7 and Figure 8.

To this date, municipal solid waste incineration is not practiced in Lebanon. In 2012, the municipality of Chekka purchased a MSW incinerator with a capacity of 8 tonnes per day. However, it was not operated since it had not undergone an Environmental Impact Assessment (EIA) study clearing its operation by the MoE. A small quantity of HCW is being incinerated by hospitals.

Industrial solid waste is still dumped with MSW since no industrial waste treatment facilities exist in the country.

A number of municipalities have received technical and/or financial assistance from international development organizations to improve their SWM services by building small and medium sized solid waste sorting and composting plants. Therefore, OMSAR is trying to secure funding for around 3 years of operation for its projects in an attempt to support the municipalities during the initial phase of the project.

Table 1 is a summary of solid waste projects supported by international donors.

The projects have known limited success due to lack of financing of Operation and Maintenance (O&M) services and lack of technical capabilities of the municipalities to ensure efficient solid waste management. Therefore, OMSAR is trying to secure funding for around 3 years of operation for its projects in an attempt to support the municipalities during the initial phase of the project.

Table 1: International donors for solid waste projects

Donor	Beneficiary	Service
EU grant	OMSAR	The SWM program of EUR 14.2 million financed 18 SWM activities targeting 177 municipalities representing about 1.15 million inhabitants. Some municipalities received waste containers and others received waste collection vehicles and/or sorting and composting facilities. This program was completed in 2010 and the operation and maintenance of the built facilities was transferred to the Government of Lebanon (GoL) who dedicated public treasury funds towards this end (decree 3860 dated 19-04-2010).
Italian Development Cooperation	Coordinating Committee for Voluntary Service (COSV)	A solid waste management program to improve solid waste management systems in 4 municipalities in South Lebanon was funded by the Italian Development Cooperation. The assistance included facility rehabilitation/reconstruction services in addition to training in operation and management. Furthermore, and in collaboration with OMSAR, the Italian Cooperation financed the project of the SWM improvement in Baalbeck. It covered the closure rehabilitation of the Kayal dumpsite along with the construction of a new sanitary landfill for the whole Caza to be finalized in 2014.
USAID	Several municipalities in the South	In addition to the Zahle center for solid waste treatment, USAID assisted several medium to small size municipalities and unions of municipalities mostly in the South for the construction of solid waste (SW) treatment facilities.

Healthcare waste

As for the HCW, it is difficult to estimate its quantities as it is generated from several sources including laboratories and clinics. Therefore, this report focuses on quantities of healthcare waste generated by hospitals. Assuming 60% occupancy and an average generation rate of 1.0-1.5 kg per bed per day, Lebanon's 164 public and private hospitals (about 15,342 hospital beds) produce about 9.2-13.8 tonnes of healthcare waste daily (about 3,358-5,037 tonnes per year). Starting 2002, and after the enactment of decree 8006 (date 11-06-2002) on the proper management of the healthcare waste in Lebanon, several hospitals and organizations started managing their healthcare waste in an environmentally-appropriate manner. A local Non-Governmental Organization (NGO) called Arcenciel started collecting and treating the healthcare waste through autoclaving in 1998. As of 2010, Arcenciel is treating 55-60% of the total HCW stream (about 90% of the waste stream in Beirut), collected from 81 public and private hospitals. The remaining portion (around 35-40%) of the HCW is being incinerated at the hospitals without permits or dumped illegally with MSW.

In this report, it is considered that around 1.25 Gg per year of healthcare waste since 2003 is being incinerated (MoE, ELARD, 2004). An extrapolation was used to determine quantities incinerated during the period covered by the study, assuming that Arcenciel started its autoclaving operations in 1998 in Beirut and then it expanded towards the Bekaa region in 2003. Table 2 summarizes the quantity of estimated incinerated healthcare waste in Lebanon.

Table 2: Estimated amount of HCW being incinerated in Lebanon

Year	1994	1995	1996	1997	1998	1999
HCW incinerated (Gg/year)	2.34	2.34	2.34	2.34	1.56	1.56
Year	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
HCW incinerated (Gg/year)	1.56	1.56	1.56	1.25	1.25	1.25
Year	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
HCW incinerated (Gg/year)	1.25	1.25	1.25	1.25	1.25	1.25

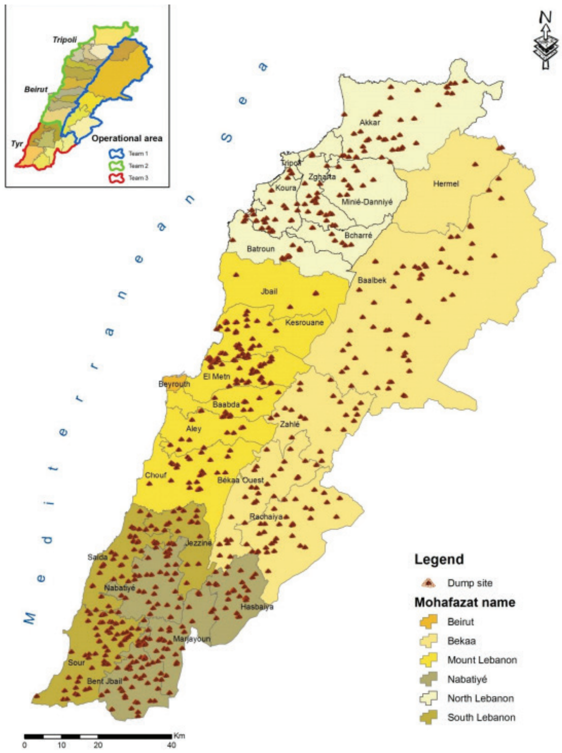


Figure 6: Location of dumpsites in Lebanon
Source| MoE, UNDP, ELARD, 2011

Municipal Solid Waste Dumps

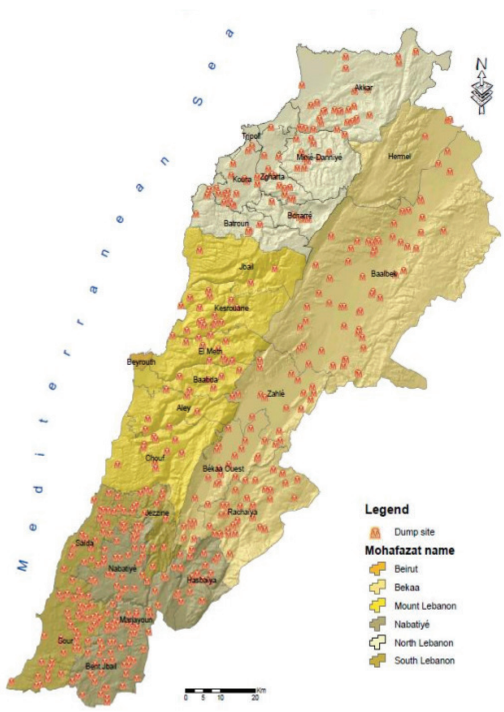


Figure 7: Location of MSW dumpsites in Lebanon
Source | MoE, UNDP, ELARD, 2011

Construction and Demolition Dumps

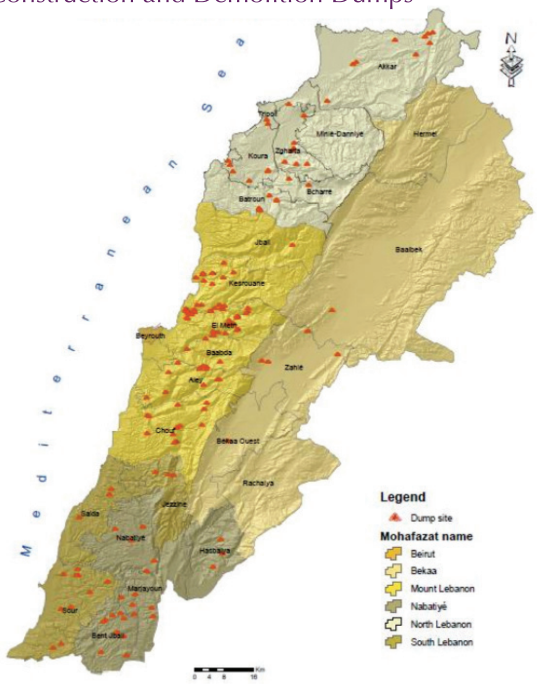


Figure 8: Location of construction and demolition dumpsites in Lebanon
Source | MoE, UNDP, ELARD, 2011

2.2. Wastewater generation and management

Currently, most of the generated Wastewater (WW) is discharged in nearby surface water without prior treatment. Small septic tanks are still widely adopted in rural areas. Industrial wastewater is rarely treated at the industry level prior to its discharge in the environment or in the public sewer network.

The management of wastewater is the responsibility of the Ministry of Energy and Water (MoEW) who developed the National Water Sector Strategy (NWSS) adopted by the GoL in 2012 (refer to Box 2). The strategy sets a number of targets on wastewater management. To date, the collection and treatment of wastewater is under the responsibility of the four Water and Wastewater Establishments (WWE) as per law number 221 of the year 2000 and its subsequent amendments. However, the WWEs still lack the technical and financial capabilities to efficiently and effectively manage the sector although international donors such as GIZ and USAID are providing financial and institutional support to the MoEW and WWEs.

Although many Wastewater Treatment Plants (WWTPs) were built in the recent years through grants and/or loans, only a few of them are currently operational and at various treatment levels due to the lack of financing of O&M services and lack of technical capabilities of the municipalities or WWEs to ensure efficient wastewater management. Table 3 summarizes the number of treatment plants currently operational in Lebanon.

Table 3: Status of WWTPs in Lebanon

		Status			
Location	Total Number	Planned	Under construction	Constructed but not operational	Operational
Beirut and Mount Lebanon	9	4	2	2	Ghadir: preliminary treatment
Bekaa	9	2	1	-	Aitanit, Baalbeck, Ferzol, Jib Jannine, Saghbine, Iaat: all secondary treatment
North Lebanon	7	3	-	4	0

Source | MoE, 2013; CDR, 2013

As reported by the World Bank (2011), the construction of wastewater network systems is lagging behind. With the exception of the Beirut administrative region, all districts have large gaps in the wastewater networks connections even though extensive developments to wastewater infrastructure have been made since 1998 with an annual growth of 7.2% on average. The households which are not yet connected to the sewerage system either use septic tanks, cesspools or simply discharge the wastewater directly into the environment.

Box 2 - National Water Sector Strategy (NWSS)

In resolution number 2 dated 9 March 2012, the GoL adopted the strategy prepared by the MoEW that included the following targets for the wastewater sector:

- Collection and treatment to at least a preliminary level of 80% of generated wastewater quantities by 2015 and 95% by 2020.
- Pre-treatment of all industrial wastewater by 2020.
- Reuse of 20% of treated wastewater by 2015 and 50% by 2020 levels.
- Secondary treatment and reuse of all inland wastewater by 2020 and secondary treatment by 2020 of coastal wastewater where reuse is economically justified.

In addition, the strategy outlines a set of immediate and long-term initiatives that include studies and investments necessary to achieve the targets.

3. Gaps and constraints identified by INC and SNC

The Initial National Communication (INC) and Second National Communication (SNC) published by the MoE and UNDP in the years 1999 and 2011 respectively faced several challenges. Table 4 summarizes the gaps identified in the calculation of the GHG emissions from the waste sector in the INC and SNC, and how these gaps were tackled in the TNC. Further explanations are provided in Table 22.

In the preparation of the current GHG inventory, a different approach was considered for the population estimation, a main determinant of the calculations, considered as a gap or constraint since no official/detailed census is available in Lebanon. Nevertheless, inaccurate population count remains a major limitation in this exercise although figures adopted by the Central Administration of Statistics (CAS) were used.

Table 4: Gaps for the calculation of GHG emissions and measures to improve the gaps

	INC and SNC	Improvement measures in the TNC
Gaps	- Population information is acquired through reports of the CAS. However, these numbers are not based on detailed census. - Generation rate of waste is not based on a quantitative exercise and is often estimated based on population counts. - Number of dumpsites are estimated and not based on ground surveys. - Data on methane recovery is not made available for all reporting years. - Industrial wastewater is not clearly addressed and related information is missing. - Emission factors used for the GHG inventory from the wastewater require validation. - There are no specific national emission factors for Lebanon.	- Population is based on data from CAS only as it is the official source of statistical information. - Previous studies with waste generation analysis conducted by the American University of Beirut (AUB) and CDR. - The TNC considered a recent study on dumpsites conducted by MoE/UNDP. - The TNC considered the Zahle and Tripoli sites in addition to Naameh while the SNC considered only Naameh. - In the TNC, a new method was utilized with the help of the Geographic Information System (GIS) based on data collected by CAS for discharge fraction in WW. - Protein consumption/capita was considered as a variable in the TNC.

4. Methodology

4.1. Adopting the IPCC guidelines

The Revised 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories are approved internationally and developed through an international process. All developing countries parties are required to adopt them in the preparation of their national inventory, as per decision 17/CP.8.

According to these guidelines, the waste sector is categorized into "Solid Waste and Wastewater" while differentiating between the various waste management options. GHG emissions from the waste sector are estimated, taking into account specificities of solid waste disposal sites and wastewater handling.

The fundamental basis for the inventory methodology rests upon three assumptions:

1. The flux of methane (CH_4) to the atmosphere is assumed to be equal to the sum of emissions from solid waste disposal sites and wastewater treatment, and emissions from waste incineration (considered to be negligible);
2. The flux of nitrous oxide (N_2O) to the atmosphere is assumed to be equal to the sum of emissions from wastewater treatment and emissions from waste incineration;
3. Carbon dioxide (CO_2) can be estimated by first establishing the rates of organic content in waste incinerated.

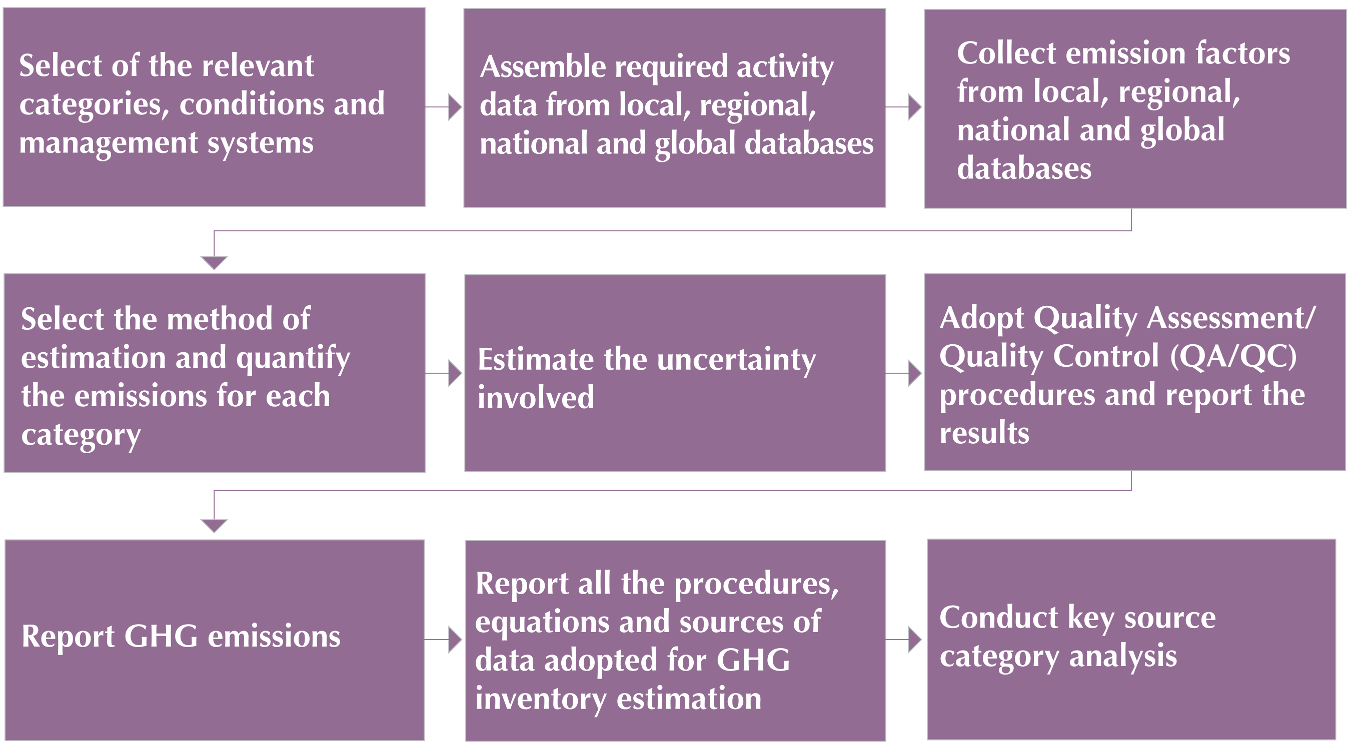


Figure 9: Steps for adopting the IPCC guidelines for the waste sector

Based on the availability and level of aggregation of the information on waste and wastewater characteristics in Lebanon, the tier 1 method was adopted for the emissions calculations. The difference between tier 1 and tier 2 approaches is presented in Table 5.

Table 5: Difference between tier 1 and tier 2 approaches in the calculation of GHG emissions

Tier 1	Tier 2
The tier 1 approach employs the basic default method provided for the waste sector in IPCC 1996 Guidelines. Tier 1 methodologies usually use activity data that are coarse, such as nationally available estimates as aggregate waste and wastewater statistics. Similarly the emission factors could be sourced from global or regional databases.	Tier 2 is only applied in the waste sector for estimating CH_4 emissions from SWDS using the "First Order Decay Method" and applying activity data and emission factors, which are obtained from national sources for several years.

4.2. Data collection

The data collection for this GHG inventory (for the years 1994 through 2011) was conducted using several references and studies that helped retrieving basic information to start building up the model. This information was mainly based on population statistics, waste statistics and review of literature made available through national reports and publications. In addition, an expert consultation meeting was held at the MoE on 12 February 2014 in order to present and validate the assumptions of the study and its findings.

4.2.1. Activity data

As mentioned above, the waste sector inventory entails the calculation of emissions from the solid waste sector and wastewater management. The main emitted gases expected are shown in Figure 10.

MSW (incineration)	MSW (SWDS)	Wastewater
N_2O	CH_4	CH_4
CO_2	CO_2	N_2O

Figure 10: Main GHGs of concern from the waste sector

4.2.1.1. Activity data for solid waste

The estimation of GHG emissions from solid waste disposal, incineration and open burning is the compilation of activity data on waste generation and management. Depending on the availability and type of country-specific data, information on solid waste management was collected through (i) literature review and personal communications where data is incomplete, and through (ii) extrapolations and interpolations. The collected data, assumptions, and sources are summarized in Table 6.

Table 6: Activity data for solid waste emissions calculations

Population	Published surveys from CAS for the years 1997, 2004 and 2010 were used to estimate the population. Foreign workers and Palestinian refugees were considered as well, based on sources such as United Nations Relief and Works Agency (UNRWA), 2008 for Palestinian refugees and personal communication with CAS for foreign workers. Interpolation and extrapolation were performed using a growth rate of 1.65% as commonly used in studies for World Bank (World Bank, 2011, SWEEP-Net, 2010).
Per capita waste generation rate	The generation rate was published for the years 1994 (El Fadel and Sbayti, 2000), 2006 (CDR, 2006), and 2010 (MoE, 2010). For other years, rates were calculated by extrapolation and interpolation.
Municipal solid waste generation	Waste generation for the years 1994 through 2011 was calculated based on the “per capita waste generation rate” (tonnes/capita/year) and the population (capita) for each year respectively.
Municipal solid waste disposed in SWDS	Three “managed” SWDS were considered in Lebanon (Naameh, Zahle and Tripoli). Information about the quantities landfilled/dumped in these sites was retrieved from LACECO reports, Zahle municipality and from BATCO, the contractor in charge of the management of the Tripoli dumpsite. Remaining quantities of solid waste were considered to be disposed of in uncontrolled dumpsites.
Open dumpsites	In 2011, a detailed survey was conducted on dumpsites in Lebanon (MoE, UNDP, ELARD, 2011). The study was used as a basis for analysis on the status of dumpsites in Lebanon and for emission factors estimations.
Percentage of treatment (composted, recycled, reused)	The information provided by personal communications with the MoE on the operational solid waste treatment facility was the base for calculating the percentage of waste composted, recycled and reused which is not taken to SWDS.
HCW	The portion of HCW incinerated was retrieved from MoE and extrapolated for the period 1994-2011. Autoclaving conducted by Arcenciel and specifically operations as of the year 2003 significantly reduced the amount of waste incinerated[2]. It should be highlighted however that incineration is still conducted at various medical establishments without permits or monitoring.
Quantity of recovered gas	The information of recovered gas in the operational landfills was provided in the supervising consultants’ reports for each of the landfills through MoE.

[2] The amount of incinerated HCW decreased from 2.34 Gg/year to 1.25 Gg/year.

Table 7 shows extracts of solid waste data computed for specific years based on acquired information.

Table 7: Main data collected and computed for solid waste

Year	Population	Waste generation rate (kg/cap/d)	Total waste generation (Gg/yr)	Quantity recovered CH_4 (Gg)	% deposited in SWDS	% deposited in sanitary landfills (managed)	% going to open dumpsites (unmanaged)	% recycled reused composted
1994	3,863,542	0.83	1,170.46	0	96%	0%	96%	4%
1999	4,192,977	0.90	1,377.39	1.50	90%	50%	40%	10%
2002	4,403,973	0.95	1,527.08	2.70	89%	48%	41%	11%
2004	4,550,503	0.95	1,577.89	6.70	88%	50%	38%	12%
2006	4,701,909	1.00	1,716.20	10.94	87%	49%	38%	13%
2007	4,779,490	1.00	1,744.51	16.90	87%	46%	41%	13%
2010	5,020,000	1.05	1,923.92	15.07	85%	54%	31%	15%
2011	5,102,830	1.05	1,955.66	16.11	85%	55%	30%	15%

In order to calculate the methane quantities generated throughout the years, the SWDS category and amount of waste received are needed. The calculation of methane quantities generated is performed according to the IPCC (IPCC, 2007) taking into account the SWDS category and its corresponding Methane Correction Factor (MCF). As reflected in Table 8, the MCF varies according to the depth of the unmanaged sites. Building on the results of the study "Preparation of a Master Plan for the Closure and Rehabilitation of Uncontrolled Dumps" (MoE, UNDP, ELARD, 2011), the unmanaged 504 dumpsites were classified into the methane generating classes. It is worth noting that some dumpsites were classified as shallow in this study despite having a depth of ≥ 5 m since they were reported to be regularly on fire, thus losing potential methane generation knowing that only inert materials remain after the burning of waste. Total amounts of waste received by the different managed and unmanaged classes are presented in Table 9 and Table 10.

Table 8: Description of SWDS categories

SWDS category	MCF	Description
Managed	1	- Sufficient depth - High compaction with suitable equipment - Properly designed and well-operated leachate and storm water systems - Proper site management with no scavenging at the operational area - Control of incoming waste types and quantities and environmental monitoring schemes established - Frequent surface covering - Prevention of landfill fires, litter and scavenging animals - Gas control and extraction/recovery
Unmanaged – deep (≥ 5 m waste)	0.8	- Sufficient depth - High compaction - Anaerobic degradation conditions in substantial or all parts of the sites - Poor and light operational equipment - Scavenging by people and animals
Unmanaged – shallow (< 5 m waste)	0.4	- Poor and light operational equipment - Scavenging by people and animals - Aerobic degradation conditions in substantial or all parts of the sites - Frequent fires, often used deliberately and systematically mainly to reduce volumes and to "get rid of" the SW

Table 9: Percentage of unmanaged sites

SWDS category	% of total estimated waste quantity received in unmanaged SWDS
Unmanaged (< 5 m or ≥ 5 m with open burning)	69 %
Unmanaged (≥ 5 m)	31 %

The percentages shown in Table 9 were assumed to be the same throughout the years in this inventory considering that "Preparation of a Master plan for the Closure and Rehabilitation of Uncontrolled Dumps" (MoE, UNDP, ELARD, 2011) is the only detailed survey conducted for MSW dumpsites in Lebanon.

Table 10: Proportion of waste in each SWDS category

	Proportion of waste (by weight) for each type of SWDS		
Year	**Managed**	**Unmanaged – deep (≥ 5 m waste)**	**Unmanaged – shallow (< 5 m waste)**
1994	0.00	0.31	0.69
1995	0.00	0.31	0.69
1996	0.00	0.31	0.69
1997	0.10	0.28	0.62
1998	0.51	0.15	0.34
1999	0.55	0.14	0.31
2000	0.54	0.14	0.31
2001	0.54	0.14	0.31
2002	0.54	0.14	0.32
2003	0.56	0.14	0.30
2004	0.57	0.13	0.29
2005	0.58	0.13	0.29
2006	0.56	0.14	0.30
2007	0.53	0.15	0.33
2008	0.57	0.13	0.30
2009	0.64	0.11	0.25
2010	0.63	0.11	0.26
2011	0.65	0.11	0.24

Figure 11 shows the percentage of managed SWDS per weight as utilized in this inventory.

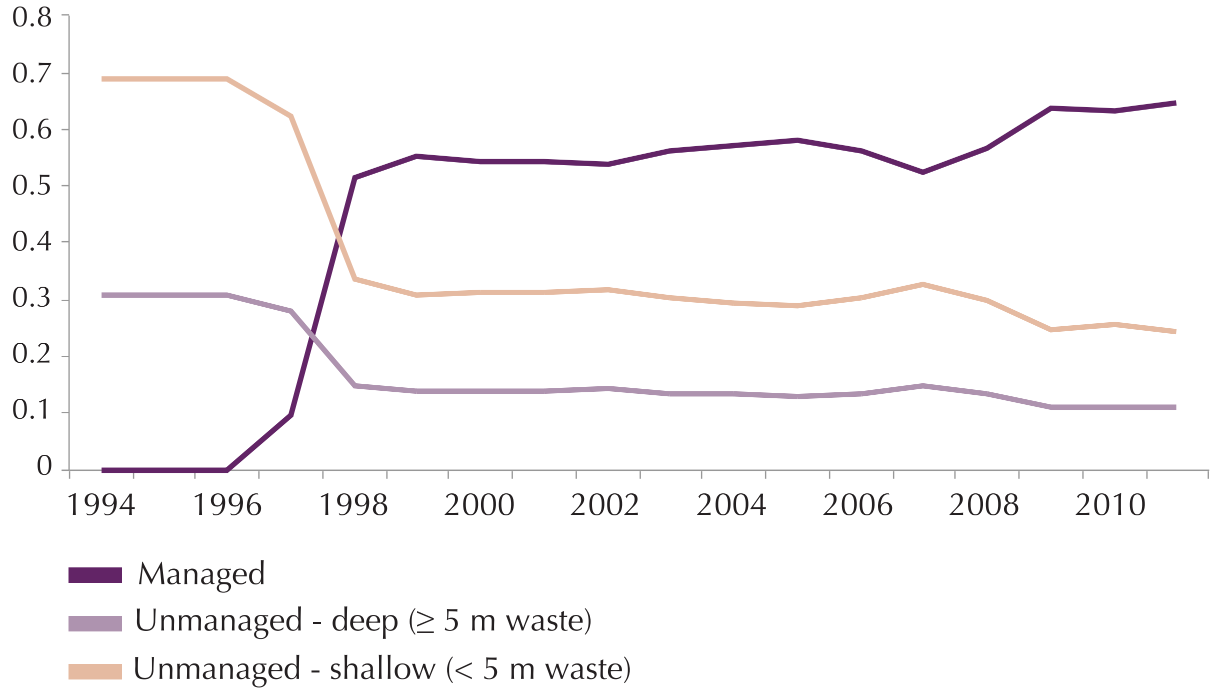


Figure 11: Proportion of waste deposited in each class of SWDS

4.2.1.2. Activity data for wastewater emissions calculation

The activity data used for the calculation of wastewater emissions is presented in Table 11 below. The table presents an overview of the data used, estimated or computed for the years of the assessment.

Table 11: Activity data for wastewater emissions calculations

Wastewater management	There is no large-size WWTP that is currently operational in Lebanon. Some small size rural WWTPs are reported to be partially operational and/or their efficiency questioned. These are therefore not considered in this inventory.
Wastewater discharge	Percentages were computed based on the percentage of households' sewerage connections onto the networks vs. connections to septic tanks as published by CAS in 2009. This information was analyzed with the help of GIS based layers showing information on rivers and population density which resulted in the discharge fraction adopted.
Industrial wastewater	In Lebanon, industrial wastewater is normally discharged in the same media as municipal wastewater. It is estimated to add a 20% fraction to the total municipal wastewater as reported by MoEW (MoEW, 2010).

In this report, the discharge media of wastewater considers only three options: river discharge, septic tank and sea. For each of these discharge media, a specific MCF is used for the calculation of methane emissions.

As mentioned in Table 11, the discharge fraction reported was computed using data on the percentage of households connected to sewer networks versus those connected to septic tanks as published by the CAS in 2009 and reflected in Table 12. This was complemented by overlaying GIS layers showing population data in various regions in Lebanon to calculate the percentage of the wastewater discharged in the different media (sea, river and septic tanks) assuming that the inside regions in Lebanon (Bekaa) discharge into rivers and/or septic tanks and coastal zones discharge into sea and/or septic tanks.

Table 12: Sewage connection survey results from CAS in 2009

	Means for domestic water drainage (%)			
	Public sewage system	Open air sewers	Sanitary pits	Does not exist/ other
Percentage household connection	66.9	4.6	28.3	0.2

Table 13: Specific data for wastewater

		Discharge fraction (%)			
Year	Population	River discharge	Septic tank	Sea	Treatment fraction
1994	3,863,542	0.15	0.26	0.59	-
2000	4,262,161	0.15	0.26	0.59	-
2006	4,701,909	0.15	0.26	0.59	-
2007	4,779,490	0.09	0.28	0.63	-
2010	5,020,000	0.09	0.28	0.63	-
2011	5,102,830	0.09	0.28	0.63	-

4.2.2. Emission factors

For the calculation of GHG emissions from solid waste, the following tables show the parameters and the methane correction factor used for each type of disposal site. The main source of information for the SWDS parameters and MCF used is the IPCC (2000) considering the unavailability of country specific and site specific data.

Expert judgment was used to estimate some of the parameters in the cases where ranges were provided in the guidelines or in the cases where no clear provision is taken in the guidelines. These parameters were discussed and validated during the expert consultation meeting.

Table 14: Parameters adopted for methane generation from MSW

Parameters	Values
Fraction of Degradable Organic Compound (DOC) in MSW (%)	17
Fraction of DOC which actually degrades (%)	77
Fraction of carbon released as CH_4 (%)	50
CH_4 oxidation correction factor (%)	0

Source | IPCC, 2000

Table 15: Methane correction factor from SWDS

Type of site	CH_4 correction factor
Managed	1.0
Unmanaged – deep (≥ 5 m waste)	0.8
Unmanaged – shallow (< 5 m waste)	0.4

Source | IPCC, 2000

For the calculation of emissions from waste incineration, the main parameters adopted are presented in Table 16.

Table 16: Incineration default values considered for HCW and municipal waste

Incineration default values			Source
	MSW	HCW	
Carbon content of waste (%)	40	60	(IPCC, 2000)
Fossil carbon as % of total carbon	40	40	(IPCC, 2000)
Efficiency of combustion	95	95	(IPCC, 2000)
CH_4 Emission Factor (EF) (%)	0	0	
N_2O EF (kg N_2O/Gg waste (dry))	400	0	(CDR, Ramboll, 2012)

For the calculation of GHG emissions from wastewater discharge, Table 17 summarizes the main parameters and conversion factors considered.

Table 17: Wastewater parameters and conversion factors

Parameters	Values	Source
Degradable organic component (kg Biological Oxygen Demand (BOD)/1,000pers/yr)	23,700	Expert judgment
Fraction of degradable organic component removed as sludge (%)	0	Expert judgment
CH_4 conversion factor for river discharge (0 to 1)	0.1	Expert judgment
CH_4 conversion factor for septic tank (0 to 1)	0.3	Expert judgment
CH_4 conversion factor for sea (0 to 1)	0.2	Expert judgment
Maximum CH_4 producing capacity (kg CH_4/kg BOD)	0.6	(IPCC, 2007)
EF (kg CH_4/kg BOD) for treatment system	-	(No treatment considered)
CH_4 recovered or flared (%)	0	
Organic content loading kg BOD/1,000pers/yr)[1]	23,700	

[1] This was used as the degradable organic component of the wastewater, equivalent to around 65 g of BOD per liter of wastewater based on the design of treatment plant.

For N_2O indirect emissions from wastewater generation, the main parameters considered are shown in Table 18.

Table 18: Parameters used for N_2O emissions calculation

Parameters	Values	Source
Per capita protein consumption (protein in kg/pers/yr)	25 to 30	Food and Agriculture Organization (FAO) reports for the years 1990-2007
Fraction of nitrogen in protein (kg nitrogen (N)/kg protein)	0.16	(IPCC, 1997)
Amount of sewage N applied to soils as sewage sludge (kg N/yr)	0	
EF (kg N_2O-N/kg sewage-N produced)	0.005	(IPCC, 1997)

4.3. Uncertainty assessment

The inaccuracy in several calculation parameters required the use of estimations and extrapolation specifically at the following levels:

- Population count: population count in Lebanon is at the basis of the GHG inventory of the waste sector. The last official census was done in the year 1932 and since then, studies that use the population as base data, usually calculate it based on the electoral lists or the surveys and reports published by the CAS. However, the best available data was analyzed and used to minimize the errors. The uncertainty can be estimated to around 15% based on expert judgment.

- The Solid Waste (SW) generation rate per capita was mainly based on the results of a survey conducted at the AUB in the years 1994-1997 (El Fadel and Sbayti, 2000). Following that study, solid waste generation rates were estimated using available data and studies, among others (CDR, 2006). The uncertainty can be estimated to around 15%.

- The amount of industrial wastewater generated could not be estimated and it was considered to be 20% of the total generated municipal wastewater based on MoEW, 2010. The uncertainty was estimated to around 30%.

Taking into consideration the emission factors adopted from the IPCC guidelines which also have a high level of uncertainty and using the tier 1 uncertainty calculation and reporting provided in IPCC, 2000 for the years 2010 and 2011 with the base year of 1994, the total uncertainty for the national inventory is calculated to be 49.3% for 2010 and 49.2% for 2011.

Table 19 summarizes the activity data and emission factor uncertainty values that were considered as support for the calculation of uncertainty.

Table 19: Emission factor uncertainty values

Source category	Activity data uncertainty	Emission factor uncertainty
Managed solid waste disposal	10% Use of a multiplying factor of two on the suggested value, (IPCC, 2000), page 5.12., table 5.2.	50% Estimated value according to (IPCC, 2000), p. 5.12., table 5.2.
Unmanaged solid waste disposal	10% Use of a multiplying factor of two on the suggested value, (IPCC, 2000), page 5.12., table 5.2.	50% Estimated value according to (IPCC, 2000), p. 5.12., table 5.2.
Wastewater handling	30% According to (IPCC, 2000), page 5.19., table 5.3., and page 5.23., table 5.5.	100% Estimated value according to (IPCC, 2000), page 5.19., table 5.3., and page 5.23., table 5.5.

5. Results and discussion

The current national inventory of Lebanon's anthropogenic emissions covers the years 2005 through 2011. However, considering newly available data and/or better access to available data, the below section presents recalculations and calculations of GHG emissions from 1994 through 2011.

5.1. GHG inventory for the years 1994 up to 2011

CH_4 emissions are mainly generated from solid waste disposal, N_2O emissions are mainly generated from the discharge of wastewater effluents into aquatic environments, while CO_2 gases are mainly emitted from the healthcare waste incineration. The Global Warming Potential (GWP) values used in converting the GHG into a CO_2 equivalent (CO_2eq.) follow the IPCC Second Assessment Report (SAR), based on the effects of GHGs over a 100-year time horizon.

Accordingly, the GWP values were 1 for CO_2, 21 for CH_4, and 310 for N_2O. A summary of GHG emissions from the waste sector is presented in Table 20 below:

Table 20: Lebanese GHG inventory for the solid waste and wastewater sectors (1994 – 2011)

GHG emissions between 1994 and 2011 (Gg)										
Year	CH_4			N_2O		CO_2		Total CO_2eq.		
	MSW	WW	Total	MSW	WW	MSW	WW	MSW	WW	Total
1994	51.38	13.94	65.33	0.00	0.288	1.96	0.00	1,080.97	382.22	1,463.19
1995	52.23	14.17	66.40	0.00	0.346	1.96	0.00	1,098.77	404.91	1,503.68
1996	53.09	14.41	67.50	0.00	0.352	1.96	0.00	1,116.87	411.59	1,528.46
1997	58.76	14.65	73.41	0.00	0.358	1.96	0.00	1,235.94	418.38	1,654.32
1998	78.78	14.89	93.67	0.00	0.363	1.30	0.00	1,655.72	425.28	2,081.00
1999	85.11	15.13	100.24	0.00	0.369	1.30	0.00	1,788.58	432.30	2,220.88
2000	85.17	15.38	100.55	0.00	0.390	1.30	0.00	1,789.87	443.80	2,233.67
2001	84.24	15.64	99.88	0.00	0.396	1.30	0.00	1,770.35	451.12	2,221.47
2002	89.93	15.89	105.83	0.00	0.403	1.30	0.00	1,889.87	458.56	2,348.44
2003	91.19	16.16	107.34	0.00	0.409	1.05	0.00	1,915.98	466.13	2,382.11
2004	89.81	16.42	106.24	0.00	0.416	1.05	0.00	1,887.13	473.82	2,360.95
2005	88.68	16.69	105.37	0.00	0.428	1.05	0.00	1,863.28	483.22	2,346.50
2006	92.05	16.97	109.02	0.00	0.435	1.05	0.00	1,934.08	491.19	2,425.27
2007	85.60	17.86	103.46	0.00	0.442	1.05	0.00	1,798.57	512.14	2,310.71
2008	85.53	18.16	103.69	0.00	0.449	1.05	0.00	1,797.20	520.59	2,317.79
2009	93.88	18.46	112.34	0.00	0.457	1.05	0.00	1,972.62	529.18	2,501.80
2010	102.56	18.76	121.32	0.00	0.464	1.05	0.00	2,154.89	537.91	2,692.80
2011	104.50	19.07	123.57	0.00	0.472	1.05	0.00	2,195.48	546.79	2,742.27

The emissions from the waste sector are shown in Figure 12.

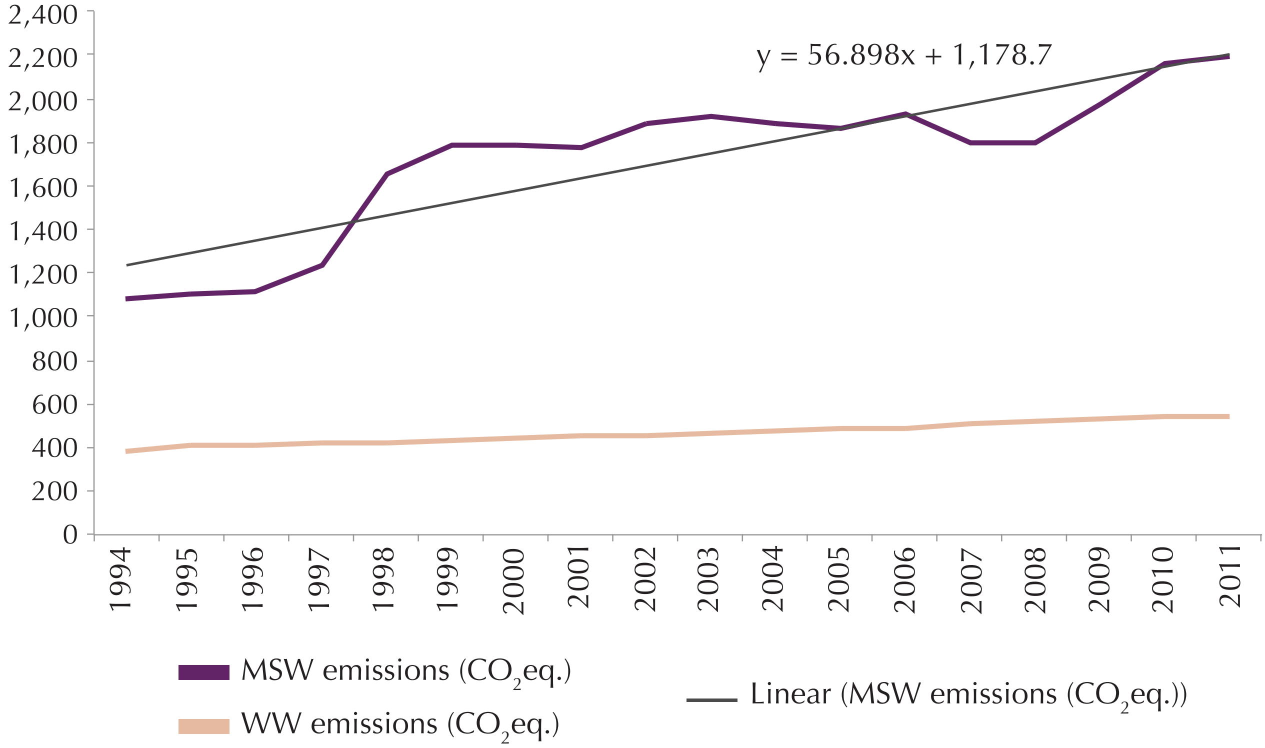


Figure 12: GHG emissions in CO_2eq. per year between 1994 and 2011 (Gg)

As reflected in Figure 12 and Figure 13, GHG emissions are highly dependent on the emissions from the solid waste sector, and any fluctuation in the emissions from the solid waste is directly reflected in the general GHG emissions of the entire waste sector.

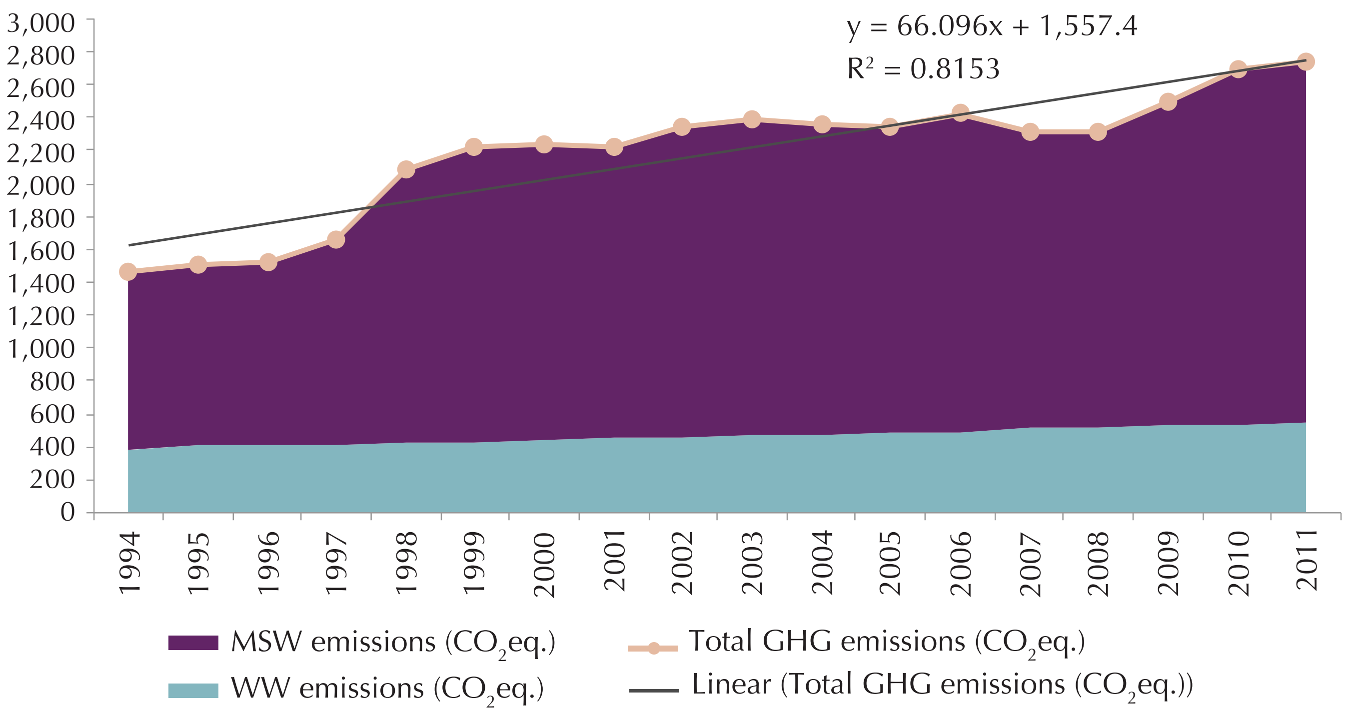


Figure 13: GHG emissions in CO_2eq. per year between 1994 and 2011 for the solid waste and wastewater sectors (Gg)

The incinerated portion of waste mainly relates to the healthcare waste which is very small in terms of contribution to GHG emissions as compared to other disposal methods of solid waste. The GHG emissions from the incineration of healthcare waste is less than 2 Gg CO_2/year, thus constituting a minimal portion as compared to emissions from solid waste disposal sites.

5.2. Changes in CO_2 emissions

CO_2 is mainly emitted from the incineration activities related to the management of HCW. Figure 14 shows the decreasing trend of CO_2 emissions that is directly related to the quantity of HCW incinerated. The decrease is due to a reduction of quantity of HCW being incinerated especially after the start of autoclaving activities by Arcenciel in the late 1990s. Another drop was noted in the year 2003 where Arcenciel expanded their operations to the Bekaa area.

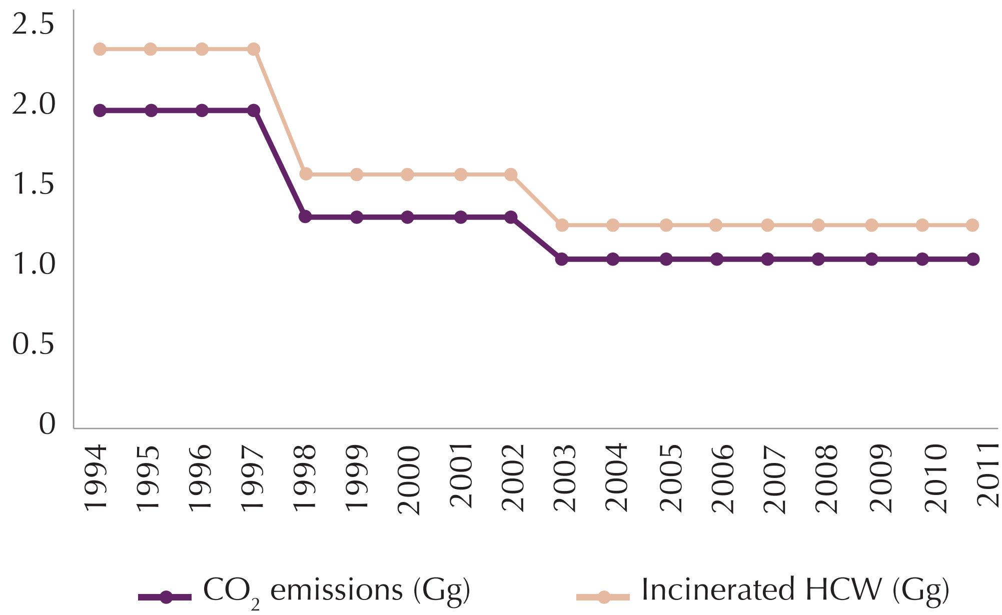


Figure 14: Evolution of CO_2 emissions from HCW for the years 1994-2011

5.3. Contribution of categories in GHG emissions

The most important greenhouse gas emitted by the waste sector, as expected, is CH_4 mainly generated from solid waste disposal sites and followed by wastewater discharge. Figure 15 presents GHG emissions from the waste sector per gas type in terms of "CO_2eq." where it is clearly shown that the related CO_2 emissions are insignificant compared to CH_4 emissions. Figure 16 presents the distribution of CH_4 emissions between the waste and wastewater sectors.

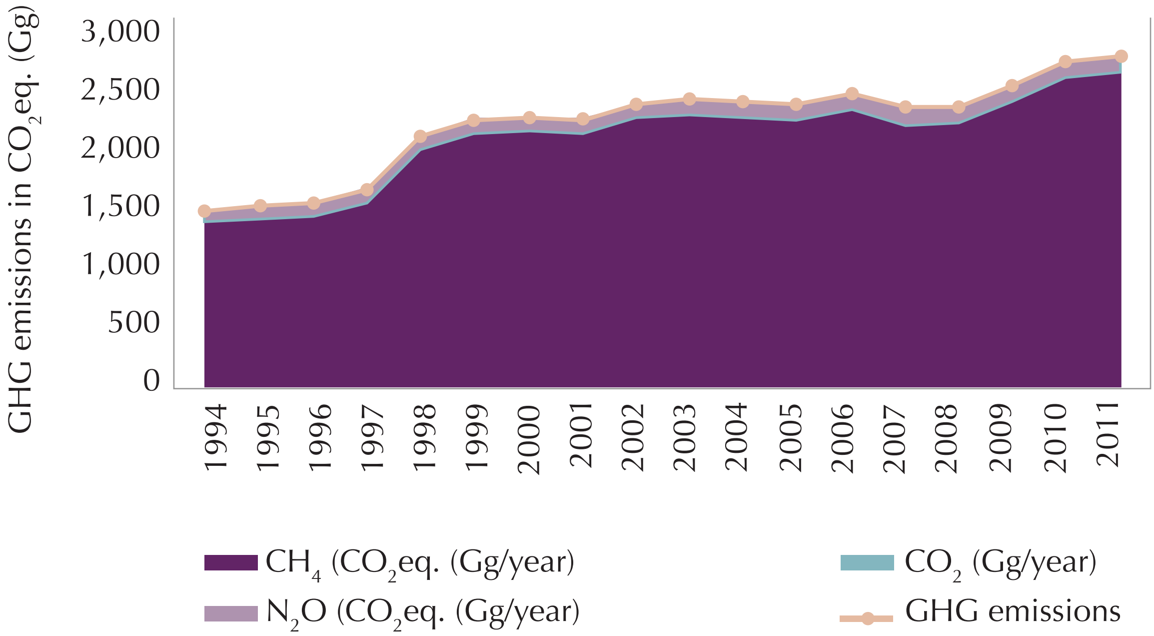


Figure 15: GHG inventory of emissions per gas for the years 1994-2011

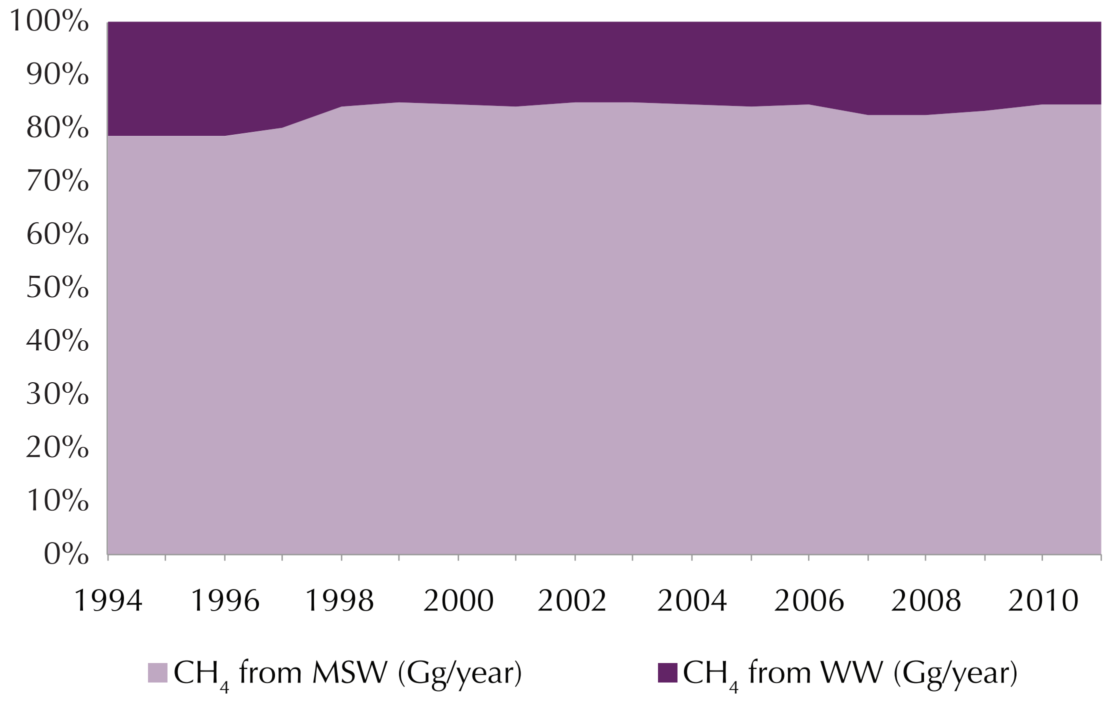


Figure 16: Percentage of CH_4 emissions per waste category

5.4. Trend in Lebanon's GHG emissions from the waste sector: 1994-2011

5.4.1. Trend analysis

The GHG emissions trend follows the trend of the waste that is being dumped in controlled dumpsites, as clearly observed in Figure 17 and Figure 18 where GHG emissions increase with the increase of quantity of waste disposed in controlled landfills with a significant jump in the year 1997, which is when the Naameh landfill started operating. A small decrease in the quantity of waste received in the Naameh landfill was noted in 2007 as compared to 2006; this could be attributed to the 2006 war, and more specifically due to the evacuation of a part of the population abroad. As a consequence, less waste was generated. Another reason could be the displacement that occurred in Lebanon where residents of the southern suburbs of Beirut had to flee the area only to return after a period of at least one year. It is possible that the displacement occurred from areas served by managed landfills (Beirut) in the direction of areas served by unmanaged solid waste disposal sites (mainly in the South) thus impacting the generation of methane and total of GHG emissions. It is worth noting that the quantity of waste collected from the southern suburbs of Beirut could reach around 1,000 tonnes per day.

It is to be noted that the recycled portion is displayed in Figure 17 for the purpose of presenting the complete waste treatment technologies, irrespective of their GHG generation potential.

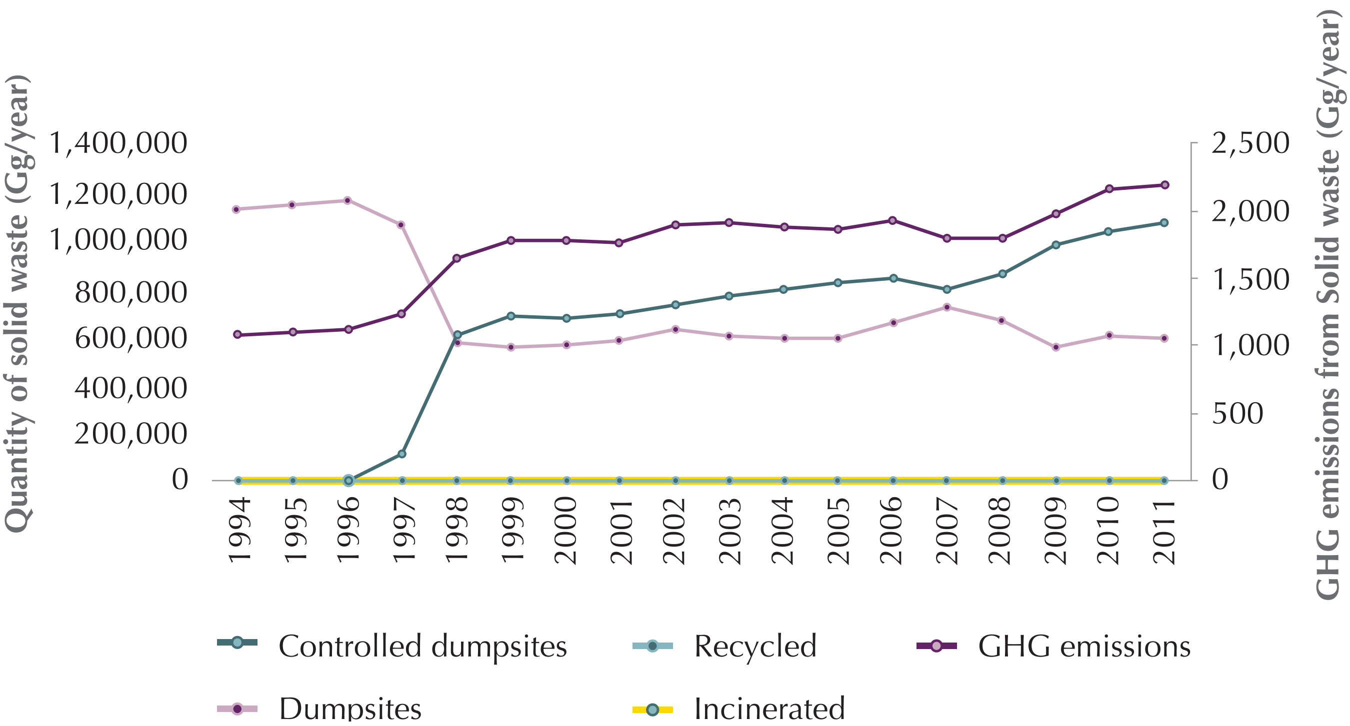


Figure 17: Evolution of GHG emissions by solid waste treatment technology

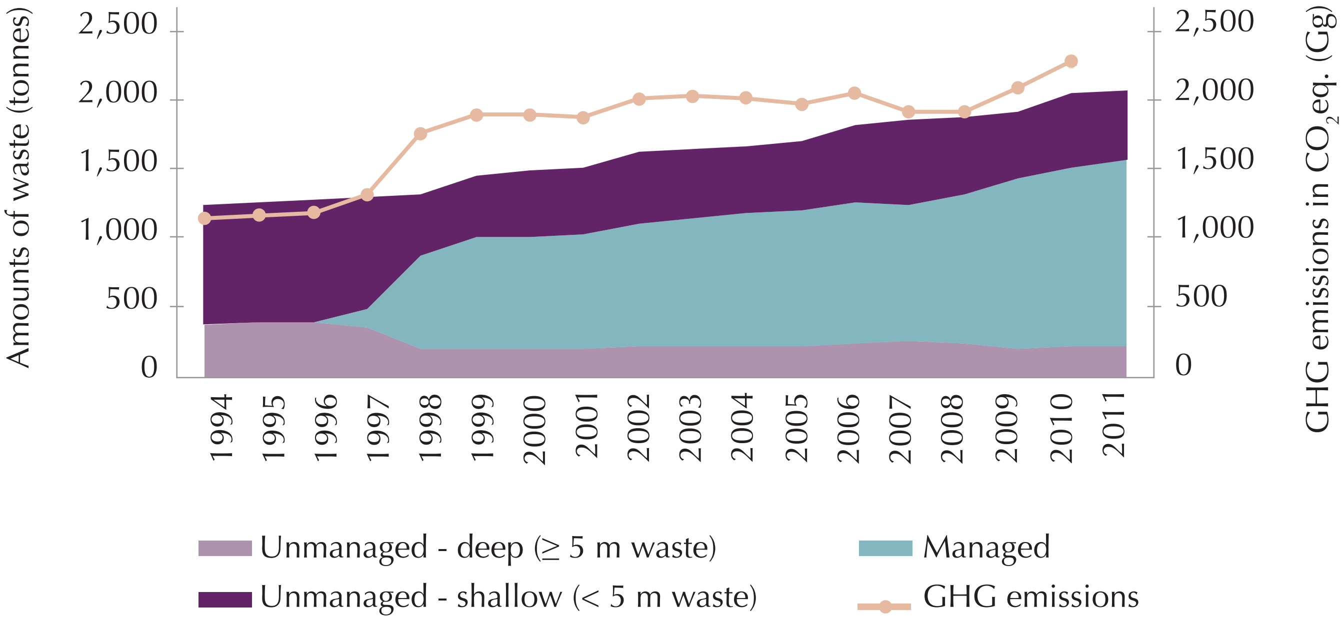


Figure 18: GHG emissions variation vs. solid waste disposal methods

The GHG emissions time series 1994 - 2011 was performed following the quality control procedures recommended by the IPCC (2000) for the waste sector to ensure temporal consistency. The consistency of input data for each waste category was analyzed and a new set of activity data was considered for the re-calculation using additional data.

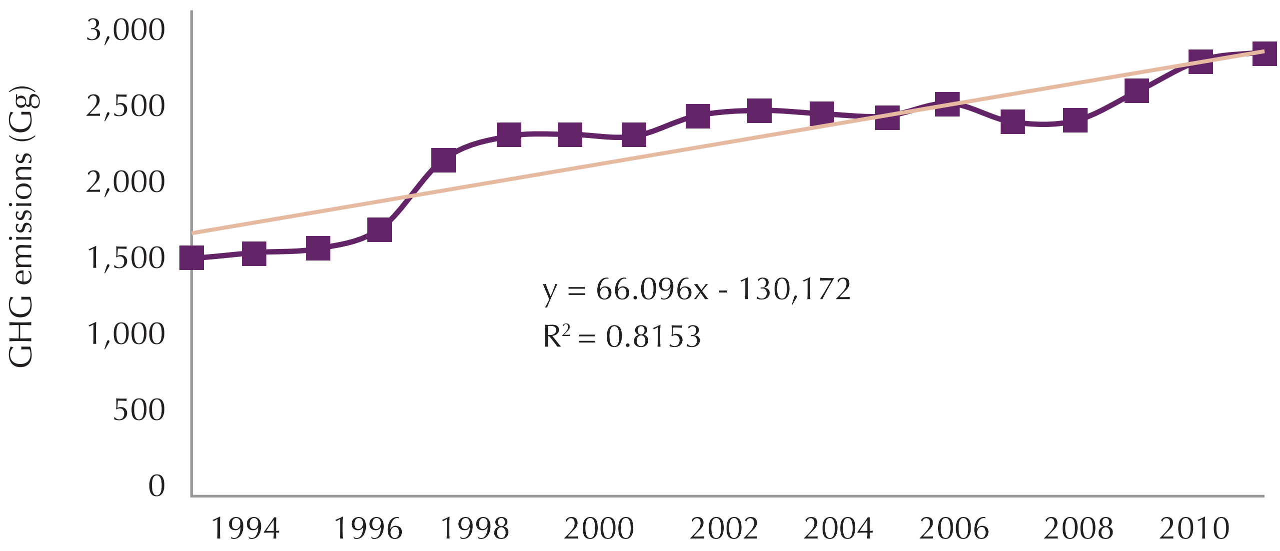


Figure 19: Trend analysis for CO_2eq. over the inventory period 1994-2011

The analysis of Figure 19 shows a constant increase in emissions expressed in CO_2eq. which increased by around 1,300 Gg (47%) from 1994 to 2011. The increase is directly related to population increase and the unchanged behavior in terms of waste and wastewater disposal. As previously discussed, the increase in 1997 is related to the start of operations of the Naameh landfill. In addition, the decrease shown in 2007 is mostly related to a decrease in the quantity landfilled which is based on the data received from LACECO; this could be due to the late return of residents of southern suburbs of Beirut in 2007 after the 2006 war.

The trend of the emissions follows a linear equation affected by the increasing waste generation rate. This linear increase can also, but not exclusively, be attributed to the linear increase of the Lebanese population as shown in Figure 20.

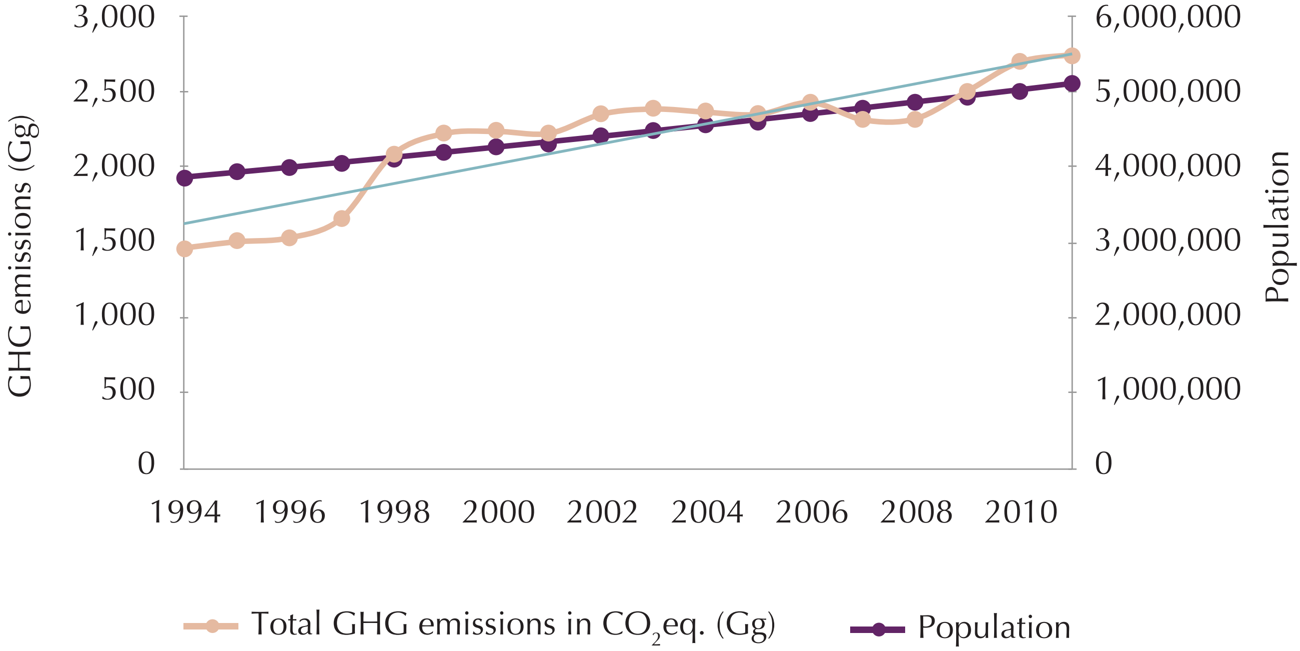


Figure 20: Increase of GHG emissions with increase of population count

After the start of the operation of the Naameh sanitary landfill in 1997-1998, an increase of the GHG emissions was noted. This increase is normal due to the expected development of anaerobic conditions in the landfill resulting in the generation of methane gas. Tripoli and Zahle are relatively small SWDS and the recovered gas through flaring is very low compared to Naameh and therefore their respective operations do not show a visible impact in the graph specifically for the start of operations in the years 2000 and 2002, respectively.

The waste generation in reference to the GDP growth is shown in Figure 21 below. It is noted that the waste generation is continuously increasing while the GDP shows irregular trends as it is not based on a linear extrapolation. Therefore the two are not related.

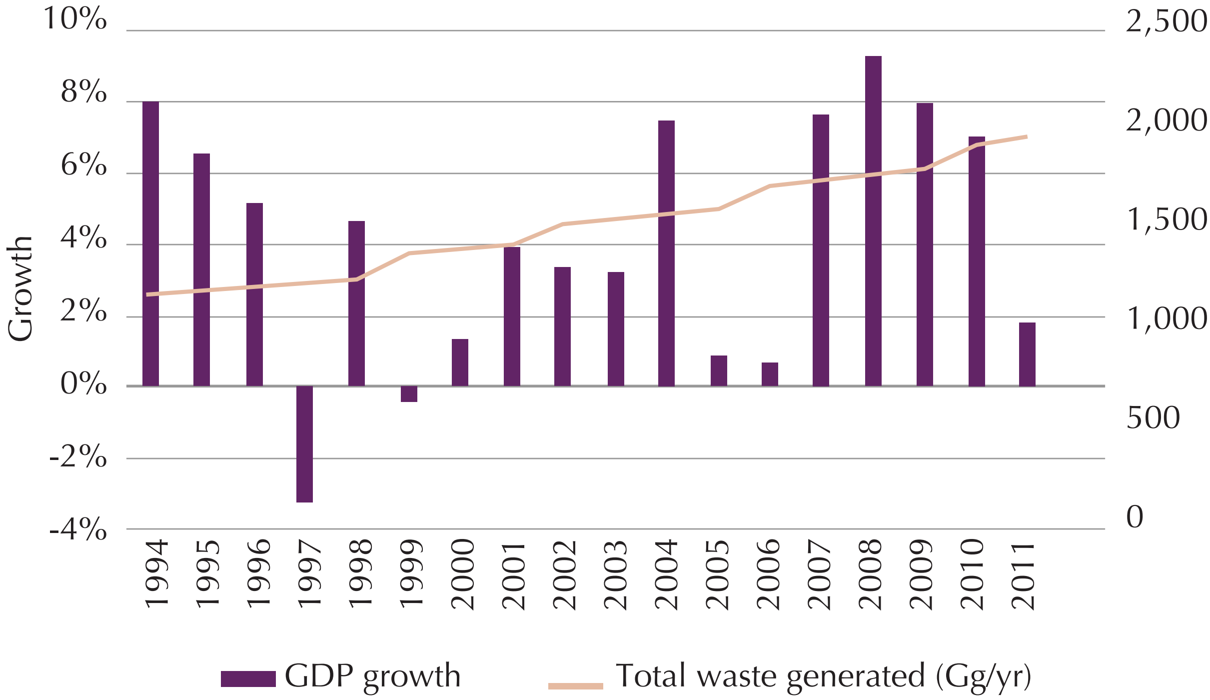


Figure 21: GDP growth in reference to waste generation

5.4.2. GHG emissions in Mediterranean countries

Two main indicators in the waste sector are considered for comparison with other Mediterranean countries, namely (i) total GHG emissions per capita expressed in CO_2eq. and (ii) CH_4 emissions from land-based solid waste disposal sites. These indicators are described as follows:

1. (i) Total GHG emissions (CO_2eq.) per capita emitted from the waste sector that include CH_4 from solid waste and wastewater, N_2O from wastewater and incineration of healthcare waste, and CO_2 from incineration of healthcare waste.

2. (ii) CH_4 emissions from disposal of solid waste on land as being the main source of GHG emissions in the waste sector.

The UNFCCC website provides national emission data from all countries and the following tables show a comparison of the above referred indicators for Lebanon, Egypt, Tunisia, Greece, Cyprus and Turkey for the year 2000. The population in each of those countries is provided for better comparison.

Table 21: Indicator comparison with Mediterranean countries for the year 2000

Year	Population	Total GHG (Gg in CO_2eq.)	Indicator 1 total GHG (kg in CO_2eq./capita)	CH_4 from solid waste (Gg)	Indicator 2 CH_4 from solid waste (kg CH_4/capita)
Lebanon	4,262,161	2,233.67	524.07	85.17	19.98
Egypt	63,000,000	17,300.00	270.91	557.00	8.72
Tunisia	9,607,050	1,882.30	195.93	78.10	8.13
Greece	10,917,480	5,782.47	529.65	148.39	13.59
Cyprus	694,000	639.00	920.75	28.59	41.20
Turkey	63,000,000	32,790.00	520.48	1,350.00	21.43

Figure 22 and Figure 23 show a comparison of the indicators for the six countries:

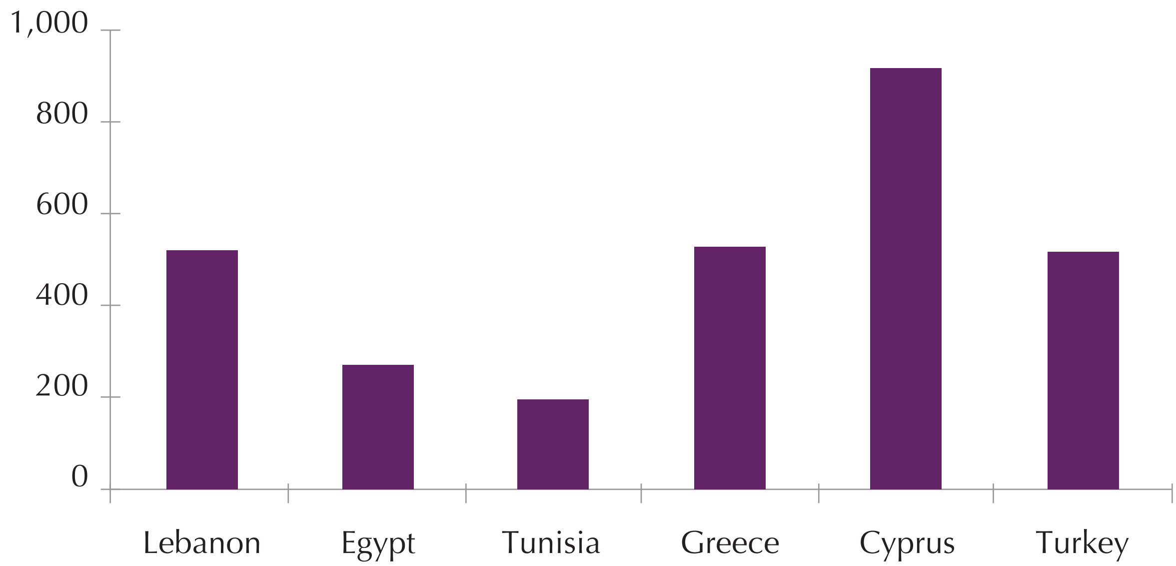


Figure 22: Indicator 1 - total GHG emissions from the waste sector for the year 2000 (kg in CO_2eq. per capita)

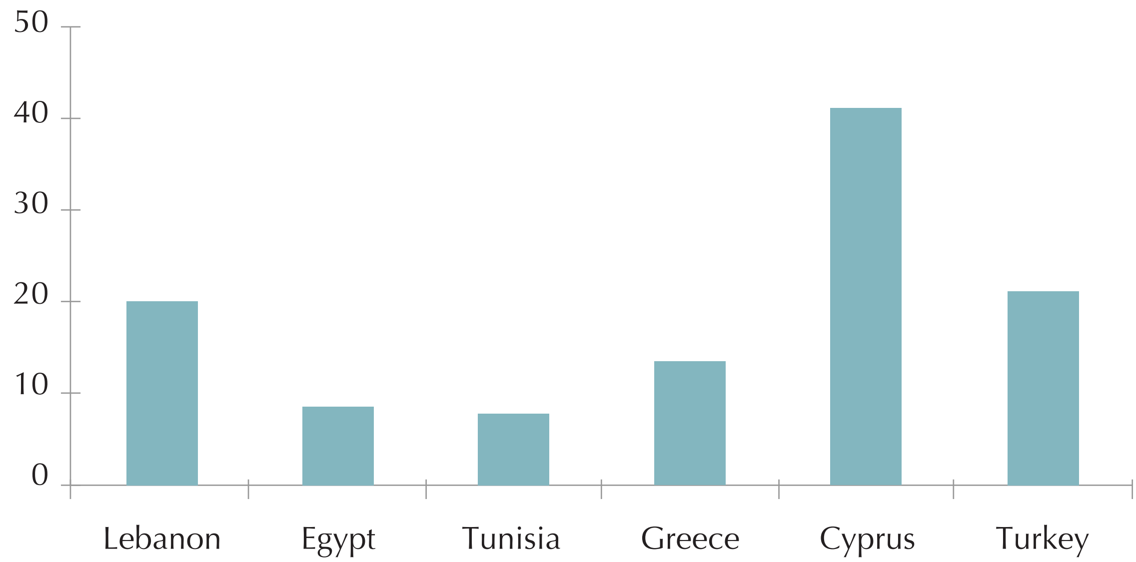


Figure 23: Indicator 2 - methane emissions from solid waste for the year 2000 (kg per capita)

As noted in the above table and graphs, Lebanon shows relatively low emissions of GHG from the waste sector. This comparison could be affected by a factor of uncertainties depending on the level of available information used for the preparation of the national inventories.

For better comparison between the selected countries, another indicator was calculated that is the rate WW of emitted CO_2eq. per each tonne of generated waste represented in Figure 24. As noted in Figure 24, the ratio of emissions of CO_2eq. per each tonne of generated waste varies for selected countries from 1.04 in Turkey where managed SWDS did not exist yet in the year 2000, to 1.6 in Lebanon where managed SWDS were already used for around 50% of the generated waste.

Overall, the differences in indicator 3 are considered acceptable for neighboring countries on the Mediterranean taking into consideration the level of uncertainties for the calculation of CO_2 emissions.

Figure 24: Indicator 3 - (tonne of CO_2eq. per tonne of generated waste)

While mitigation measures should be considered and adopted to reduce these emissions, these indicators could be further compared in consequent years when information is made available.

5.5. Recalculation

As previously mentioned, this report has conducted a recalculation for GHG emissions for the years 1994 through 2011. Table 22 provides a summary of the main differences between the SNC and the TNC including a short description of the activity data and assumptions considered.

Table 22: Recalculation summary and difference between SNC and TNC

Category	**Difference from SNC to TNC**	**Explanation**
Population	In the SNC, population is based on data from CAS and other international sources while the TNC considered only CAS data.	Population data was only based on information from CAS, being the only official source of information at the national level for several years. In addition, an estimation of foreign labor and refugees was considered.
Waste generation rate	The TNC considered previous studies with waste generation analysis conducted by AUB and CDR.	While there is a lack of exact data about the generation rate of MSW, this report considered the available studies while conducting necessary extrapolation between years of available studies.
CH_4 correction factor	The TNC considered a recent study on dumpsites conducted by MoE/UNDP.	The new study is the only survey on dumpsites in Lebanon that served as a tool to calculate the methane correction factors based on the type of SWDS.
CH_4 recovered gas	The TNC considered the Zahle and Tripoli sites in addition to Naameh while the SNC considered only Naameh.	While recovered gas quantities from Zahle and Tripoli are not very significant as compared to Naameh, it had to be included since it is being recovered and flared. In addition, the LACECO reports were analyzed in detail and quantity of recovered methane was corrected accordingly.
Fraction of WW treated in handling system	In the TNC, a new method was utilized with the help of GIS based on data collected by CAS.	While CAS had provided data on the connection from households to sewers in 2009, and since the location of operational WWTP and population distribution are well known, an analysis was done to calculate the fraction of WW treated which is variable over the years.
Protein consumption/ capita	It was considered as a variable in the TNC.	Since information from FAO was found available for several years, it was considered for per capita protein consumption.

Taking into consideration the above differences, a recalculation was performed resulting in significant differences in the values of GHG emissions for the years 2000 and 2004, which is shown in Figure 25. Furthermore, the trend of the emissions in the SNC was different which could result in higher estimates of the emissions in the forecasted years.

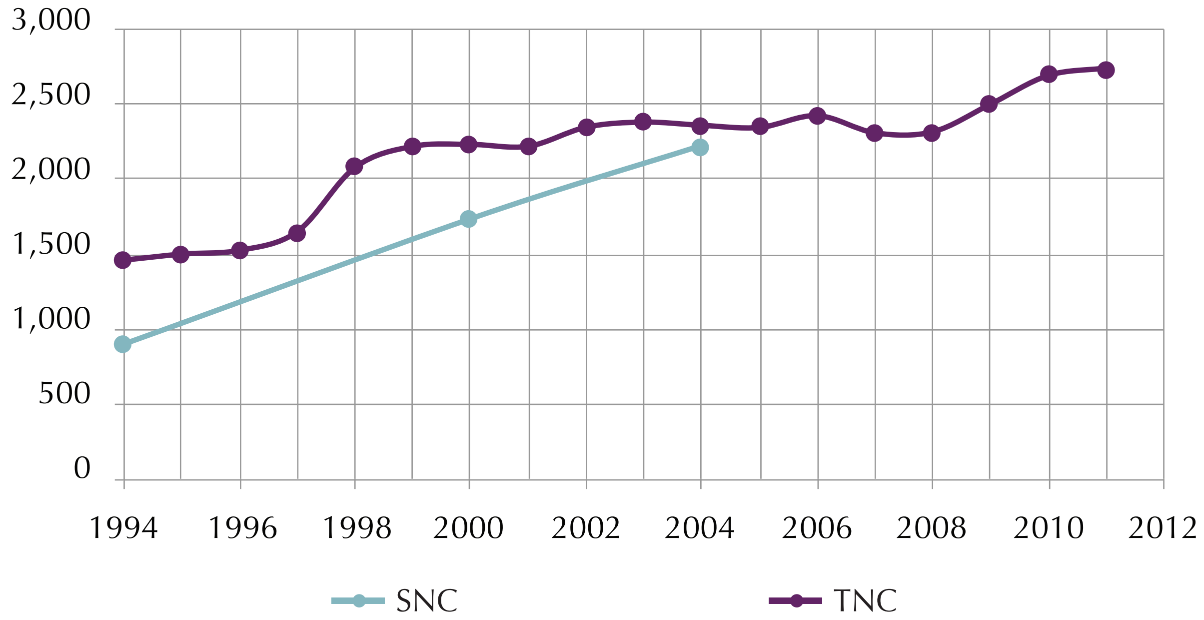


Figure 25: Comparison of GHG emissions from SNC and TNC based on recalculation (CO_2eq. Gg/year) (total)

6. Conclusions

The present inventory was compiled using newly available data or following improved data collection. A recalculation of GHG emissions was consequently undertaken for the years 1994 through 2004. A calculation was done for the years 2005-2011. The methodology of work and applied activity data and parameters were shared and validated by key experts in the field during an expert consultation meeting held at MoE on 12 February 2014.

The results shown in this report reflect the outcome of the adoption of the IPCC (1997). As expected, the main source of GHG emissions in Lebanon in the waste sector is the solid waste and specifically the generation of methane gas. Accordingly, mitigation measures should concentrate on the solid waste sector if reducing GHG emissions is considered as of one the national priorities.

The trend of GHG emissions was found to be linear and increasing through the years noting that no mitigation actions were executed in the past years.

For future updates of the inventory, it is recommended to keep collecting the same type of data to facilitate the preparation of the fourth national communication report.

More information should be sought to reduce the level of uncertainty of the assessment, namely related to the proportion of industrial wastewater discharged in the sewerage system.

Part 2: Mitigation analysis

7. Scope

The present report complements the National Inventory Report (NIR) and proposes possible mitigation options or measures to mitigate against climate change from the waste sector taking into account policies, strategies and plans approved by the government.

8. Introduction

This report presents 3 mitigation options defined as Business as Usual scenario (BAU), mitigation scenario 1, and mitigation scenario 2 in addition to an estimation of their potential impact on GHG emissions for the years 2020 and 2040. In the BAU scenario, no actions are expected to take place and the GHG estimation for this scenario will follow the same trend as identified in the inventory report; on the other hand, scenario 1 and scenario 2 (more optimistic) will take into consideration the current policies, strategies, or plans considered and approved at the national level. As presented in the inventory report, more than 80% of the GHG emissions are generated by solid waste in the waste sector and consequently, the assessment of GHG mitigation potential from the waste sector will consider solid waste management measures more closely.

Table 23: BAU and mitigation scenarios

Category	BAU scenario	Mitigation scenario 1	Mitigation scenario 2
Solid waste treatment	Partial landfilling with gas recovery for flaring or electricity generation. Percent of waste being composted, recycled and disposed of in dumpsites remains the same as in 2011.	Waste incineration with energy production in Beirut and Mount Lebanon and landfilling in the rest of Lebanon.	Waste incineration with energy production on the coastal zone of Lebanon and landfilling in the Bekaa.
Wastewater treatment	No successful treatment for municipal wastewater.	35% of wastewater is treated by 2020 and 51% by 2040.	51% of wastewater is treated by 2020 and 74% by 2040.
Industrial wastewater treatment	Industrial wastewater remains mixed with municipal waste.	50% of industrial wastewater is treated.	100% of industrial wastewater is treated.
Evaluation of scenario	This is a non-optimistic scenario where no action is taken.	This an optimistic realistic scenario where part of the national strategies is implemented.	This is a highly optimistic scenario which considers the strategies achieved.

Details on each scenario are presented in the following sections. A number of factors are considered in the development of management plans. The development of the solid waste related scenarios, i.e. the management assumptions/measures are based on the consideration of 2 main treatment alternatives based on the national solid waste management strategies:

- Sanitary landfills, which are the most common solution for waste management with gas recovery for flaring or electricity generation.

- Waste-to-Energy (WtE), where various scenarios can be considered for Lebanon which mainly involve waste incineration with energy recovery.

In addition to national strategies serving as guiding lines for the mitigation scenarios, other key factors are considered, namely:

- Period of implementation: the plan has to be implemented over the coming 20 to 30 years.

- Waste quantities: the quantities of generated waste by 2040 are expected to double when compared to 2011.

While the potential impact of wastewater-related mitigation measures on GHG emissions is much smaller than that of solid waste, mitigation options for the wastewater sector will still be analyzed. Wastewater generated 537.91 Gg CO_2eq. emissions in 2010, constituting 21% of emissions from the waste sector, mainly driven by emissions from discharges of untreated wastewater into surface waters or the sea.

With respect to wastewater, the NWSS developed by the MoEW foresees the collection and treatment of wastewater to at least a preliminary level of 80% by 2010 and 95% by 2020. Pre-treatment of all industrial wastewater by 2020 and secondary treatment and reuse for all inland and for coastal systems where reuse is applicable by 2020 are also planned for. In addition, the strategy outlines a set of immediate and long-term initiatives that include studies and investments necessary to achieve the set targets. At the time of the drafting of this study, elements of the strategy have not been implemented yet.

Mitigation actions reducing GHG emissions from the wastewater sector were also analyzed in the Second National Communication (SNC) (MoE, UNDP, 2011). Unfortunately, despite investments in WWTPs, only few of them are currently operational and at various treatment levels due to the lack of financing of O&M services and lack of technical capabilities of the municipalities or water and wastewater establishments to ensure efficient wastewater management, which did not allow a significant reduction of GHG emissions from wastewater.

9. Existing and planned mitigation actions

Since the publication of Lebanon's SNC to the UNFCCC in 2011, no major developments took place in the solid waste management system in Lebanon. As mentioned in the SNC, the national solid waste management plan of 2006 consisted of establishing regional sanitary landfills, sorting and composting facilities while rehabilitating the existing dumpsites at the same time. The proposed plan was not adopted due to various reasons mainly related to the difficulty of finding the locations for construction of solid waste facilities without having public or political oppositions, and since

2006 no actions were taken. In early 2014, protests by the inhabitants of the Naameh and neighboring villages stirred the status quo requesting the closure of the landfill. As a consequence, the GoL set a date for the final closure of the Naameh landfill in 2015 but did not propose any disposal/treatment alternatives. The sanitary landfill of Naameh was supposed to represent a model to be adopted throughout Lebanon, however, although engineered and sanitary, landfills have become a major debate and concern at the national level due to the Not In My Back Yard (NIMBY) effect and to the lack of land availability.

Currently, the MoE is pursuing its efforts to prepare a strategy for the management of solid waste in an attempt to find a sustainable solution for solid waste management. The various drafts of the strategy always consider landfilling and WtE as main treatment/disposal methods. With the current status quo, GHG emissions will continue increasing within almost the same trend.

The management of the wastewater in Lebanon, as mentioned above, is the responsibility of the MoEW. Since 2005, several WWTPs were built but none were executed after 2012, explaining the current conditions and the BAU scenario. Accordingly, GHG emissions resulting from the wastewater sector will follow the same increase in the BAU scenario.

10. Mitigation analysis

10.1. Mitigation options proposed for solid waste

Based on the proposed solid waste management strategy approved by the CoM and taking into consideration the feasibility study prepared by Ramboll (CDR, Ramboll, 2012) on adopting WtE alternatives as a treatment for solid waste, the proposed waste management profile is presented in Table 24 below.

Table 24: Summary of mitigation measures for SW

Year	Population	Total waste generated (Gg/yr)	% deposited in SWDS	% deposited in sanitary landfills	% going to dumpsites	% recycled reused composted	% of MSW incinerated
1994	3,863,542	1,170.46	96%	0%	96%	4%	-
2000	4,262,161	1,400.12	89%	48%	41%	11%	-
2011	5,102,830	1,955.66	85%	55%	30%	15%	-
2020-BAU	5,912,587	2,589.71	80%	48%	32%	20%	-
2040-BAU	8,202,103	4,191.27	70%	56%	14%	30%	-
2020-scenario 1	5,912,587	2,589.71	50%	30%	20%	20%	30%
2040-scenario 1	8,202,103	4,191.27	30%	24%	6%	30%	40%
2020-scenario 2	5,912,587	2,589.71	40%	24%	16%	20%	40%
2040-scenario 2	8,202,103	4,191.27	20%	16%	4%	30%	50%

The above mentioned assumptions regarding waste disposal options and quantities are based on information made available through existing studies and approved texts by the CoM and were validated by participants in the expert consultation meeting held at the Ministry of Environment on 12 February 2014. Needless to say that the actual implementation of these plans is a function of a number of factors, political and financial, that could hinder or delay the implementation of the approved strategy and consequently introduce changes in the GHG reduction potential of the mitigation measures. Indeed, the implementation of the strategy, although approved by the CoM, remains in a deadlock due to the following:

- At the political level: no commitment from the CoM on the allocation of funds needed for the implementation of the adopted National Strategy for Solid Waste Management in Lebanon (CDR, Ramboll, 2012);

- At the financial level: financing for the phased implementation of the strategy is not readily available;

- At the implementation level: the complex and lengthy administrative procedures for the tendering process are delaying actual implementation (approval of the strategy, design, tendering and award of the project, implementation of the works, commissioning, passing through the complex institutional set-up at the central and local levels simultaneously).

Despite the above mentioned challenges and barriers, the current report considers the approved strategy as the building block of the mitigation scenarios (scenario 1 and scenario 2) as described in Table 25 summarizing the roll-out of WtE facilities for the future years.

Table 25: Proposed action plan for the implementation of scenarios 1 and 2

	Scenario 1	**Scenario 2**
Milestones	Finalize tender documents for WtE projects	Finalize tender documents for WtE projects
Responsible party	CDR	CDR
Time scale	2 incinerators: Incinerator 1: year 4 Incinerator 2: year 15	4 incinerators: Incinerators 1 and 2: year 6 Incinerators 3 and 4: year 15
Estimated cost	USD 500 million	USD 950 million

10.2. Mitigation options proposed for wastewater

Mitigation scenarios in wastewater management have been based on the most recent policy text of the sector, namely the NWSS developed by the Ministry of Energy and Water (MoEW, 2010), which lays out plans of the GoL in the management of wastewater and consequently quantities of wastewater treated and/or discharged without treatment in the various bodies. These plans were considered as basic assumptions for the elaboration of the mitigation scenarios, as per Table 26 below.

Table 26: Various treatments' scenarios for wastewater mitigation

Year	Population	Septic tank	River discharge	Sea	Treatment fraction
2020 - BAU	5,912,587	0.28	0.09	0.63	-
2040 - BAU	8,202,103	0.28	0.09	0.63	-
2020 - scenario 1	5,912,587	0.28	0.07	0.30	0.35
2040 - scenario 1	8,202,103	0.28	0.01	0.20	0.51
2020 - scenario 2	5,912,587	0.28	0.01	0.20	0.51
2040 - scenario 2	8,202,103	0.15	0.01	0.10	0.74

10.3. BAU scenario

10.3.1. Description of the BAU scenario

The baseline scenario follows the BAU trend and is mainly a continuation of the current waste management practices whereby new sanitary landfills (with gas recovery) will be built and dumpsites will be closed simultaneously while the percentage of waste disposed in sanitary landfills remains around 50%. Remaining solid waste is disposed of in dumpsites or recycled. In this scenario, it is assumed that the recovered methane gas is flared and only part of the healthcare waste (1.5 Gg in 2020 and 1.9 Gg in 2040) is being incinerated. It is estimated that this scenario should achieve 80% of disposal in SWDS by 2020 and 70% by 2040, as shown in Table 27 and reflected in Figure 26. The remaining proportion of waste is reused/composted/recycled. This scenario assumes methane recovery from landfilling activities through flaring or electricity generation equivalent to 18 Gg and 15 Gg in 2020 and 2040 respectively. This scenario is the most pessimistic among the three considered scenarios whereby no mitigation actions are taken and the government is not successful in implementing the strategy.

Table 27: BAU - estimated percentage of waste reaching SWDS

Year	Population	Percentage of waste into SWDS	Methane recovery (Gg)
2020	5,912,587	80%	18
2040	8,202,103	70%	15

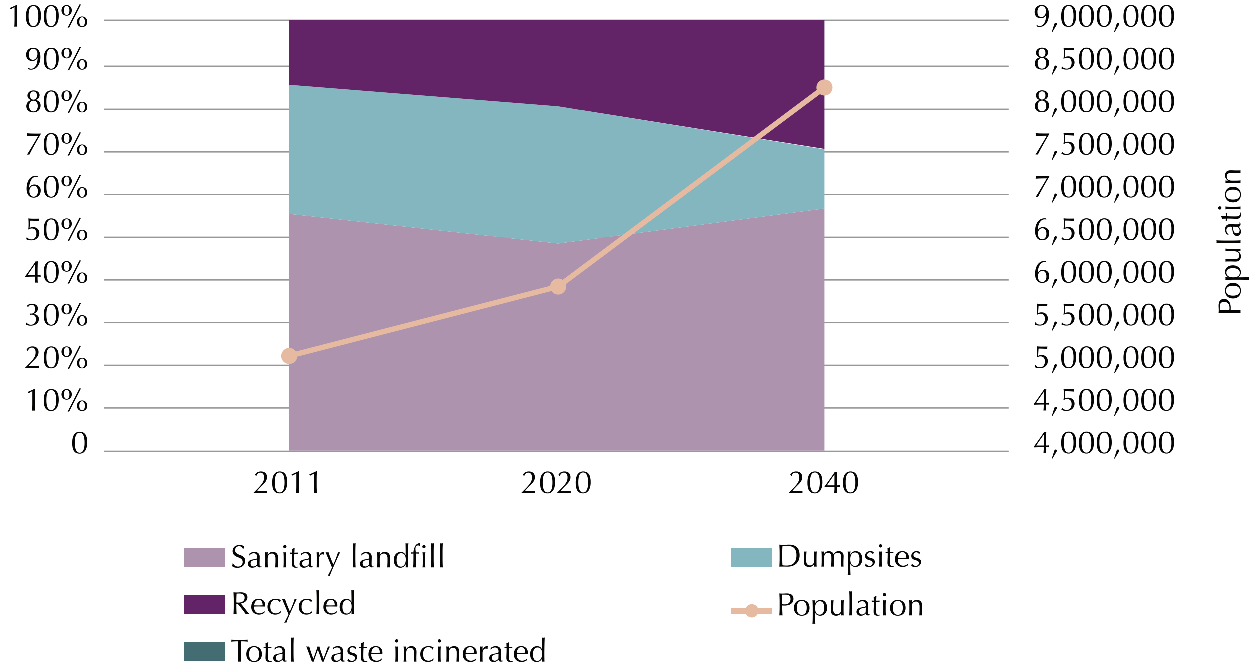


Figure 26: BAU - solid waste management practices through 2040

As reflected in Table 26 above, the BAU scenario assumes the continuation of the current wastewater management practices through 2040. Despite the population increase, no treatment of wastewater discharge will be implemented, thus discharge fractions in surface water and in septic tanks remain unchanged, i.e. 72% and 28%.

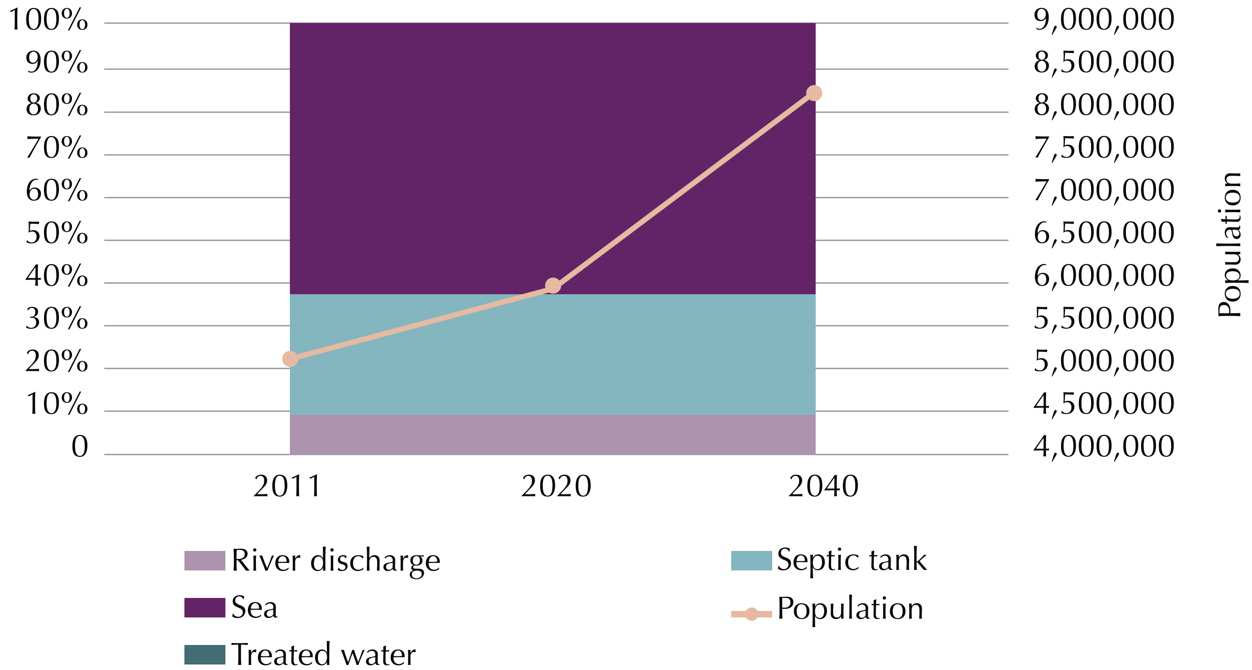


Figure 27: BAU - wastewater management practices through 2040

10.3.2. GHG emissions profile under the BAU scenario

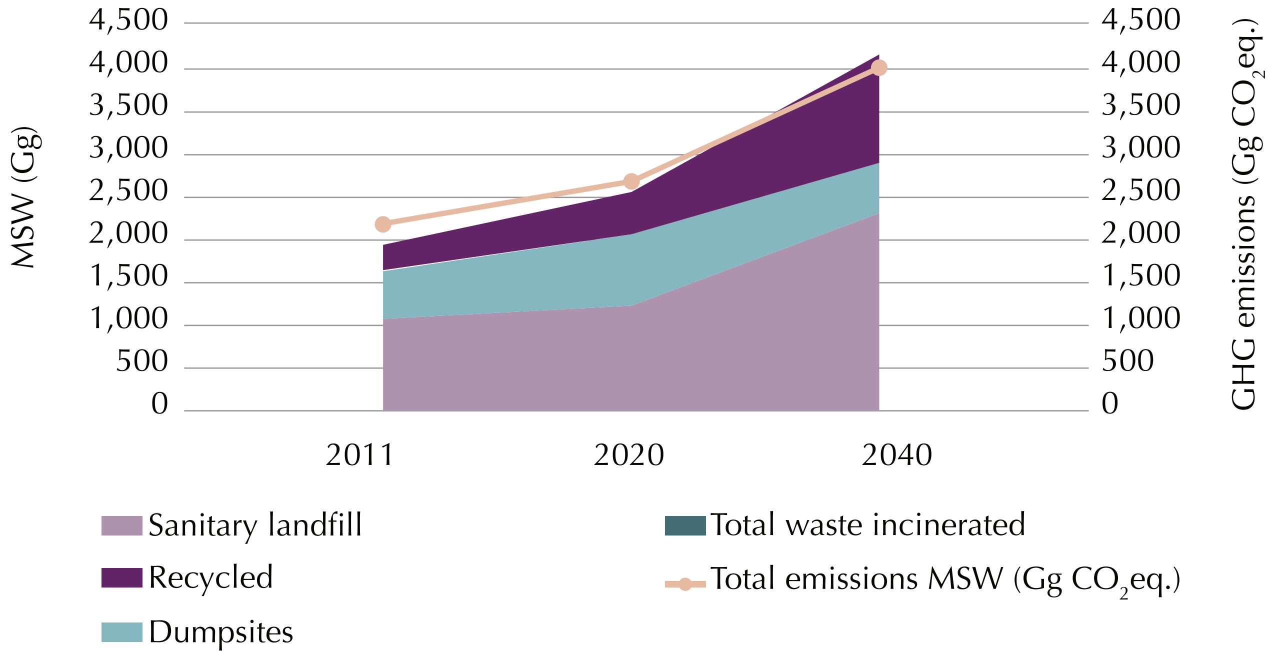


Figure 28: BAU - GHG emissions from solid waste management

Under the BAU scenario, and taking into account the increase in waste quantities over the years due to population growth among others, GHG emissions are expected to increase. Indeed, Figure 28 shows the increase in GHG emissions to around 3,000 Gg in 2040 from MSW, despite the increase in recycling from 15% in 2011 to 20% and 30% in 2020 and 2040, respectively.

With only a forecast of 1.5 tonnes and 1.9 tonnes of HCW incinerated in 2020 and 2040, CO_2 emissions are negligible compared with CH_4 emissions (1.25 Gg and 1.59 Gg of CO_2 emitted in 2020 and 2040, respectively). Consequently, the breakdown of the GHG emissions indicates that methane corresponds to the totality of GHGs emitted under the BAU.

Although GHG emissions from wastewater are by far less important than those from solid waste management, emissions increase between 2011 and 2040 mainly due to population growth. The BAU scenario assumes that wastewater is not treated and that the discharge rates remain unchanged throughout the years as shown in Figure 29.

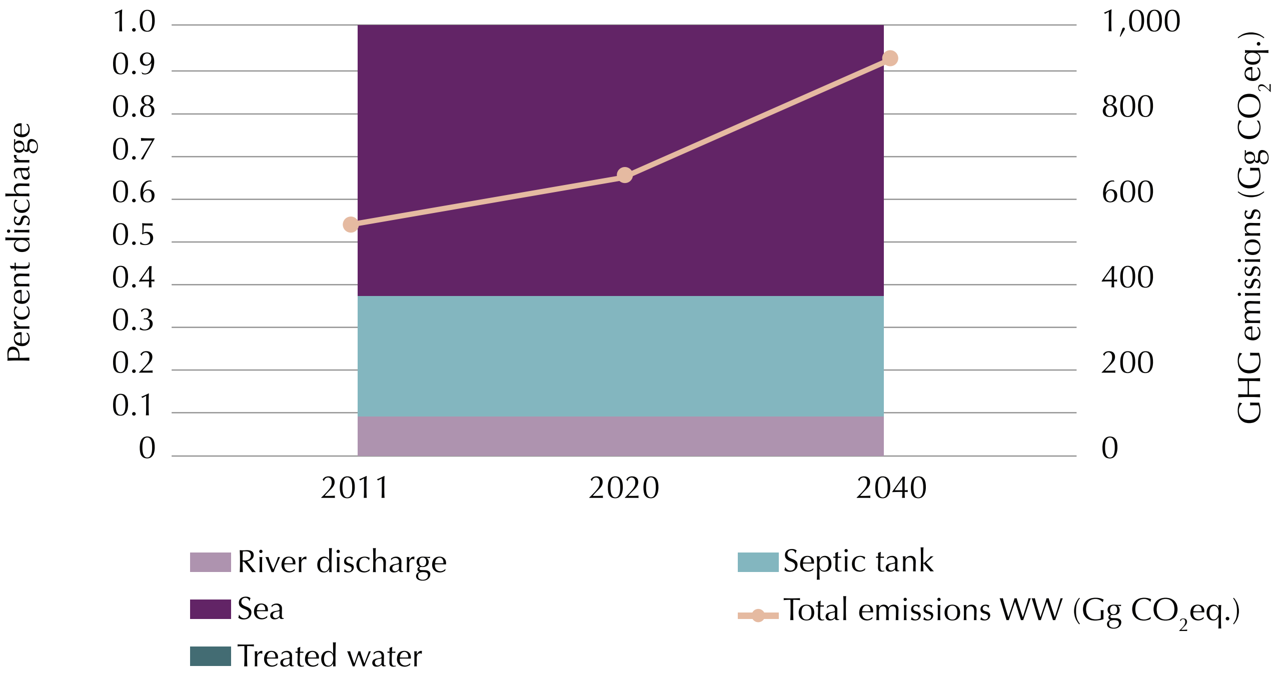


Figure 29: BAU - GHG emissions from wastewater

Total GHG emissions from the wastewater sector amount to around 547 Gg in 2011, 635 Gg, and 928 Gg for the years 2020 and 2040, respectively. A breakdown of emissions is presented in Figure 30.

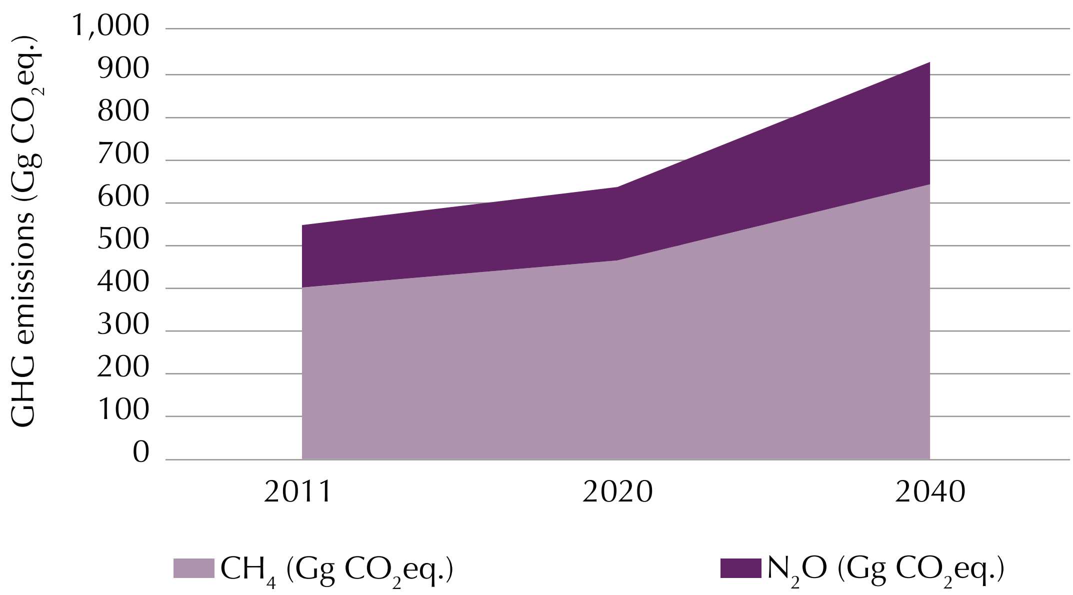


Figure 30: BAU emissions breakdown from wastewater

The results of the BAU are shown in Table 28 and Figure 31.

Table 28: Summary results of GHG emissions (Gg CO_2eq.) under the BAU scenario

	Solid waste related emissions	Wastewater related emissions	Total GHG emissions
2020	2,697.08	635.44	3,332.52
2040	4,039.52	927.53	4,967.05

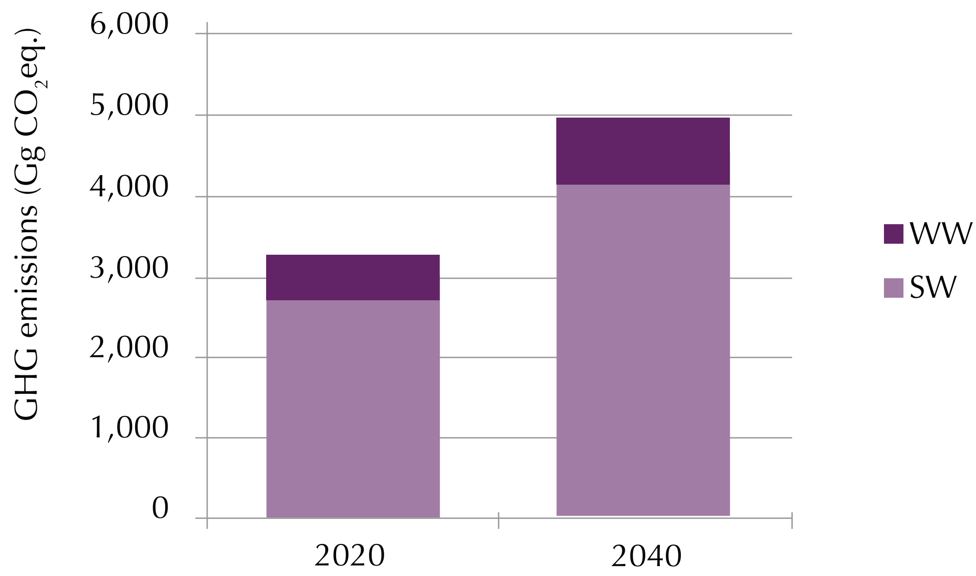


Figure 31: Summary results of GHG emissions of BAU

10.4. Mitigation option 1 (scenario 1)

10.4.1. Description of scenario 1

This scenario considers that the WtE technology will be used in Lebanon by 2020 in 2 locations, Beirut and Mount Lebanon, specifically as shown in Figure 32. Outside these 2 governorates, landfilling and uncontrolled dumping will still be practiced. Recycling rates will increase at the national level.

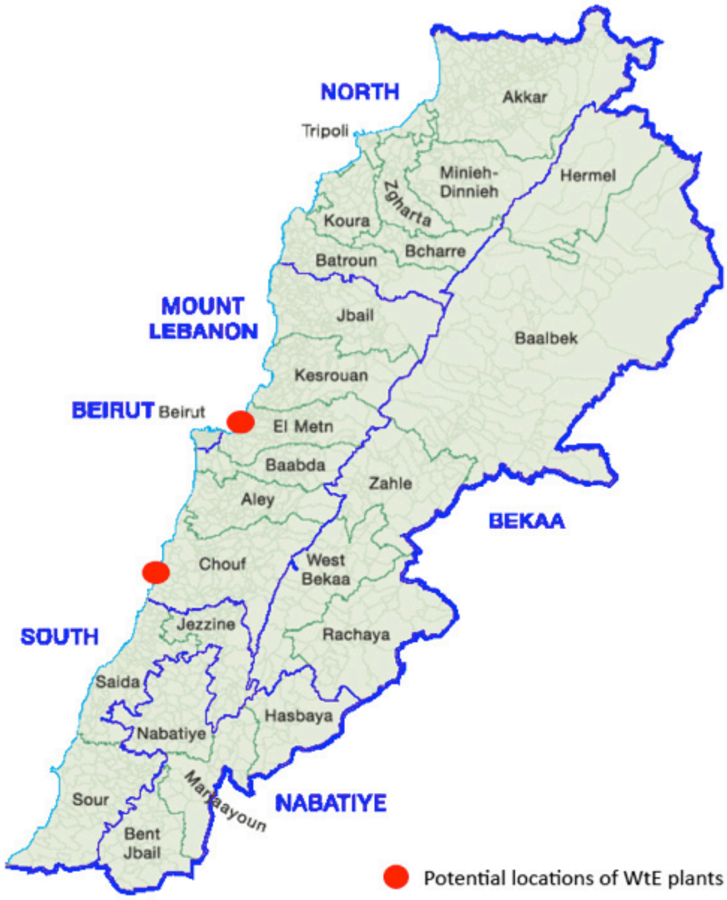


Figure 32: Potential location of WtE facilities in mitigation scenario 1

Scenario 1 expects the adoption of the WtE technology alternative to be executed in phases. The amount of waste incinerated is expected to be around 30% and 40% in 2020 and 2040, respectively as shown in Table 29.

Figure 33 presents schematically the trend in adopting WtE as an alternative to disposal. It is also to be noted that recycling rates are identical to those in the BAU scenario, increasing from 15% in 2011 to 20% and 30% for 2020 and 2040, respectively. Similarly to the BAU, methane recovery is anticipated in smaller amounts since part of the waste is expected to be incinerated.

Table 29: Scenario 1 - estimated percentage of waste disposed in SWDS and incinerated

Year	Population	Percentage of waste for disposal	Percentage of waste for incineration	Methane recovery (Gg)
2020	5,912,587	50%	30%	14
2040	8,202,103	30%	40%	11

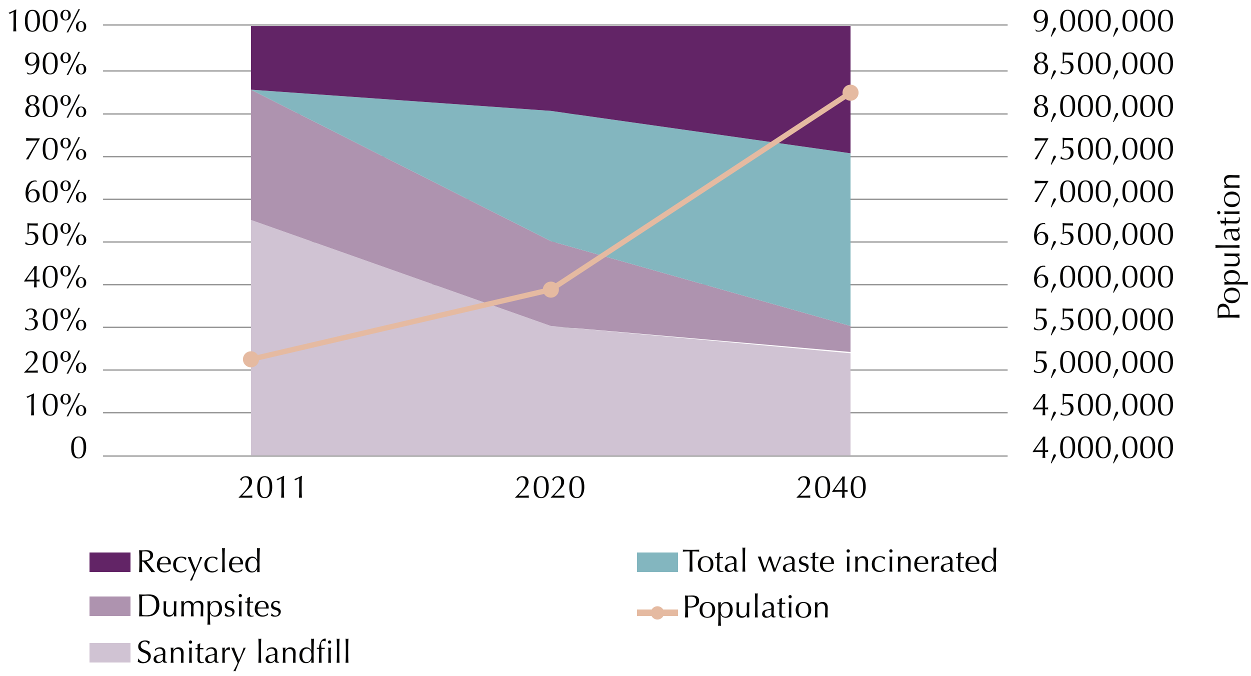


Figure 33: Scenario 1 - solid waste management options through 2040

With respect to developments on the wastewater management front, scenario 1 assumes improved wastewater treatment services reaching 35% in 2020 and 51% in 2040. This implicitly reduces discharges in surface waters and in the sea, without any implication on household connections and use of septic tanks as reflected in Table 26 above.

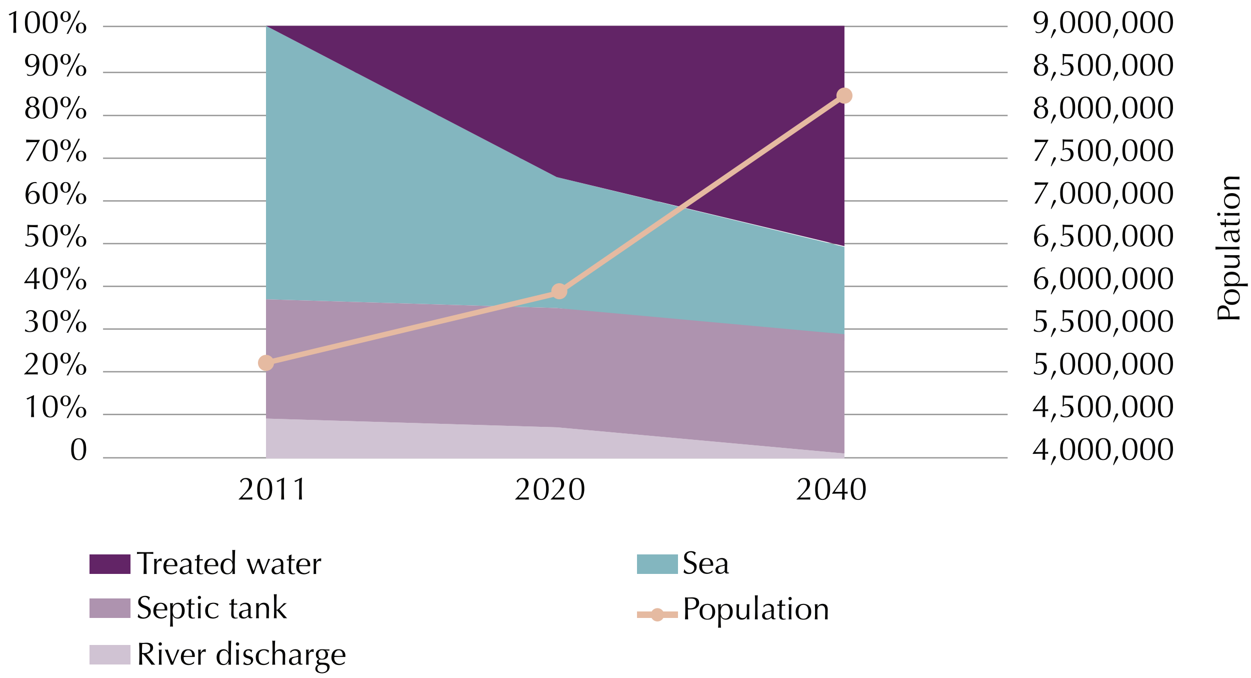


Figure 34: Scenario 1 - wastewater management options through 2040

10.4.2. Emission reduction potential from scenario 1

Taking into account the introduction of WtE as a mitigation measure along with other measures as stated in scenario 1 for reducing GHG emissions from solid waste, the emissions profile for 2020 and 2040 indicates that by 2020 a potential emission reduction of 22% is calculated as compared to the BAU whereas by 2040, a potential emission reduction of 32% is calculated compared to the BAU.

Indeed, with the introduction of waste incineration, CO_2 is generated while CH_4 emissions are decreasing as compared to the BAU scenario. At the same time, N_2O is generated in smaller proportions since a higher proportion of wastewater is treated in scenario 1 as compared to the BAU scenario.

As reflected in Figure 35 through Figure 37, the reduction of CH_4 emissions is the main reason behind the drop of overall GHG emissions while CO_2 emissions have increased for the same years.

The potential emission reductions of mitigation scenario 1 are shown in Table 30 and Figure 35.

Table 30: Summary results of GHG emissions (Gg CO_2eq.) under mitigation scenario 1

	Emissions from solid waste	Emissions from wastewater	Total GHG emissions	Total GHG emissions from BAU	Percent reduction from BAU
2020	2,157.74	450.42	2,608.15	3,332.52	22%
2040	2,778.39	596.97	3,375.37	4,967.05	32%

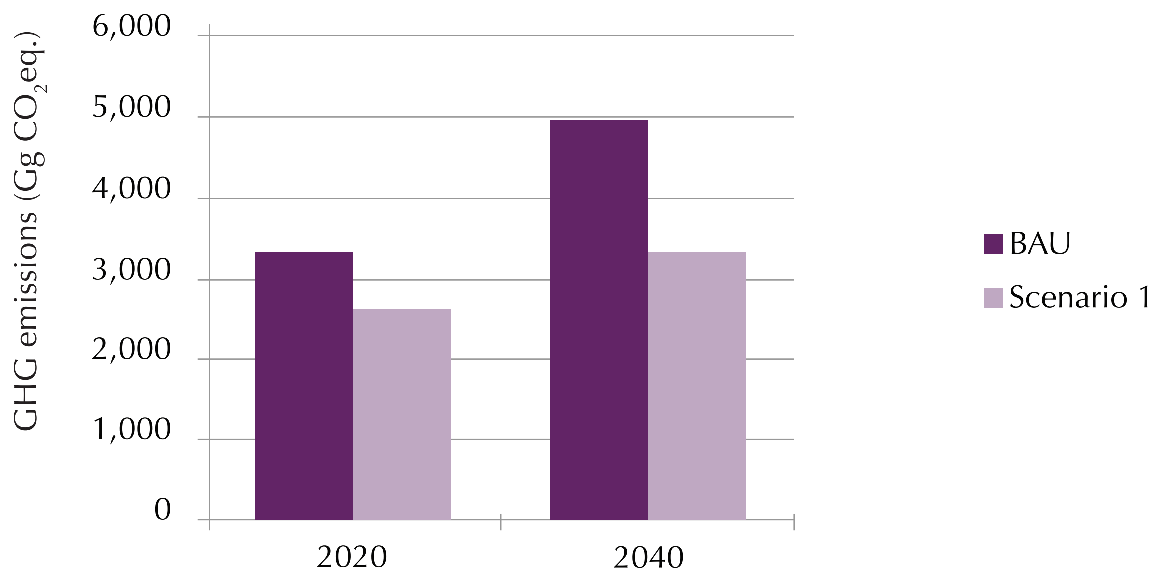


Figure 35: Summary of GHG emissions results of scenario 1

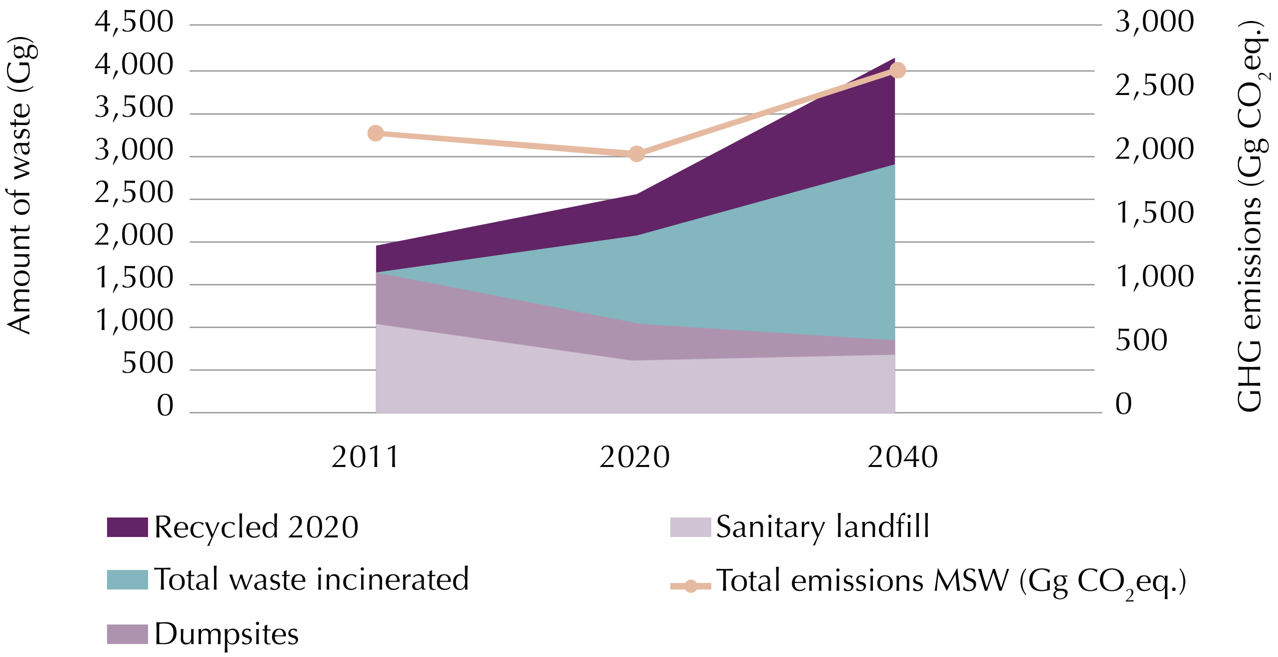


Figure 36: Scenario 1 - GHG emissions from solid waste

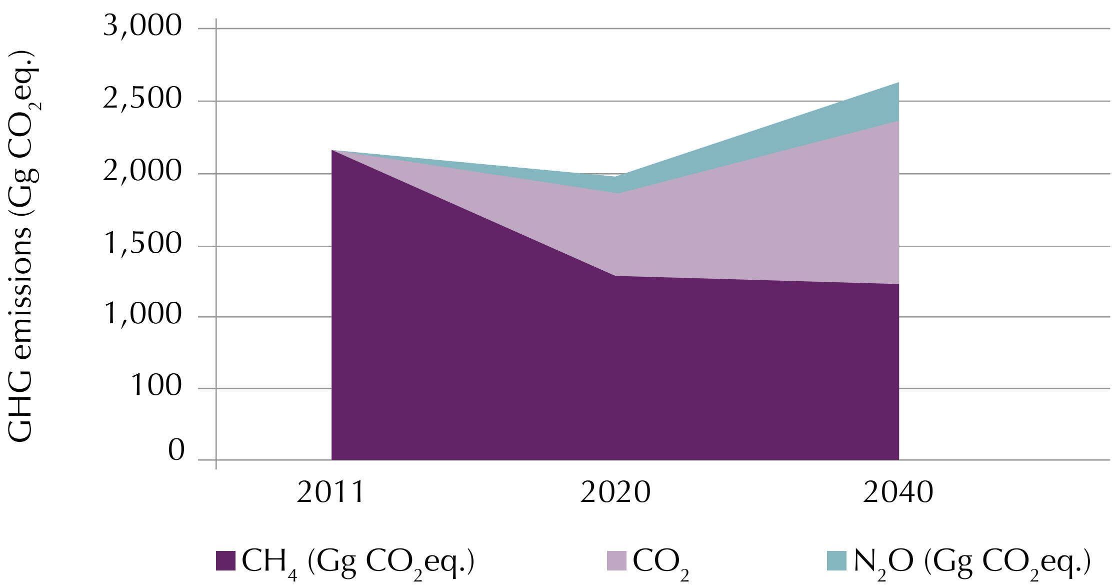


Figure 37: Scenario 1 - emissions breakdown from solid waste

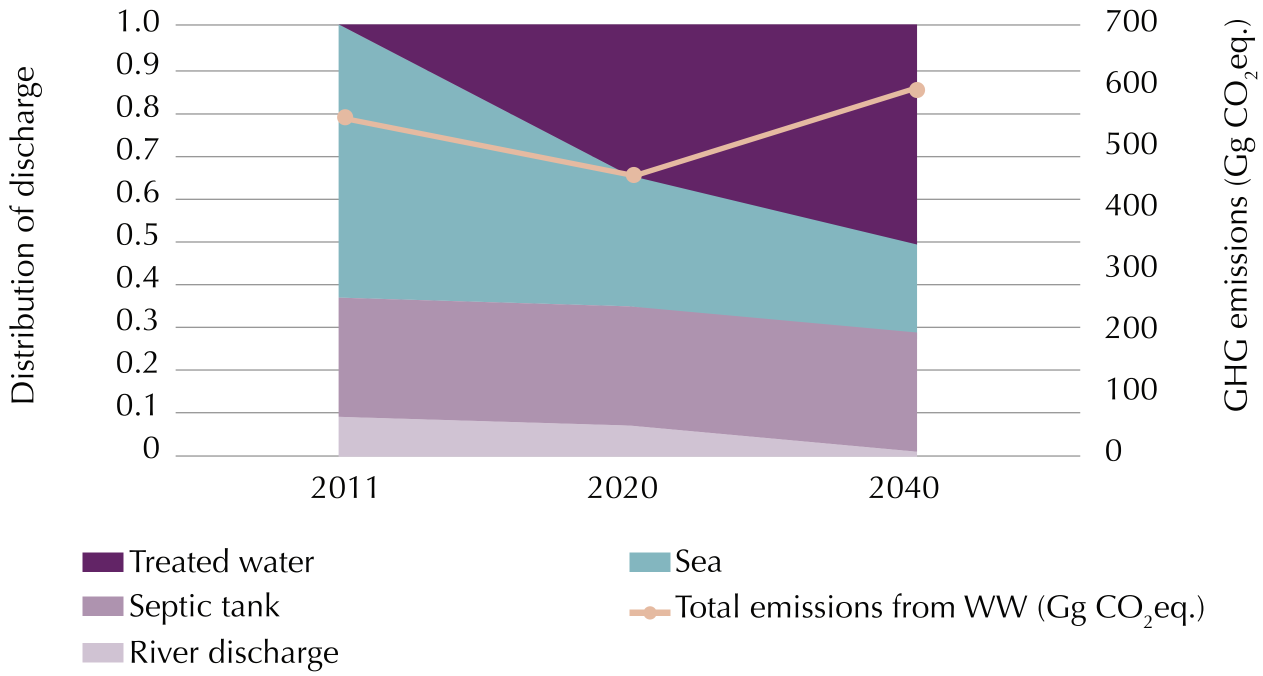


Figure 38: Scenario 1 - GHG emissions from wastewater

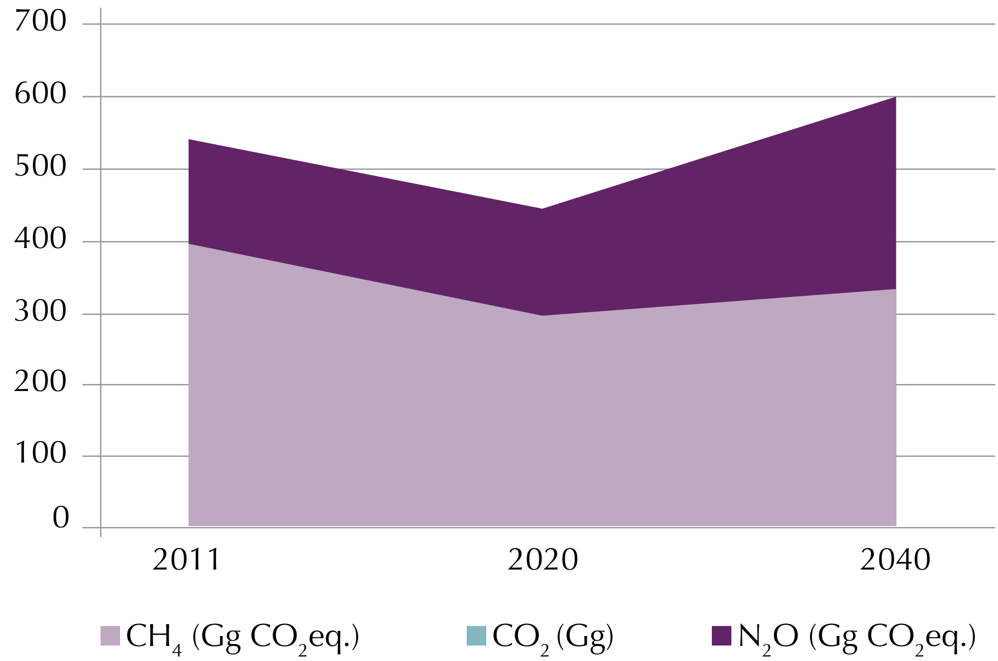


Figure 39: Scenario 1 - emissions breakdown from wastewater

10.5. Mitigation option 2 (scenario 2)

10.5.1. Description of scenario 2

Scenario 2 considers that the WtE technology will be used in Lebanon by 2020 in 4 locations, i.e. in Beirut and Mount Lebanon in addition to 2 other coastal cities as shown in Figure 40. Outside these 4 locations, in the rest of the country, landfilling and uncontrolled dumping will still be practiced. Recycling rates will increase at the national level. Similarly to scenario 1, methane recovery is anticipated in smaller amounts since a bigger portion of the waste is expected to be incinerated.

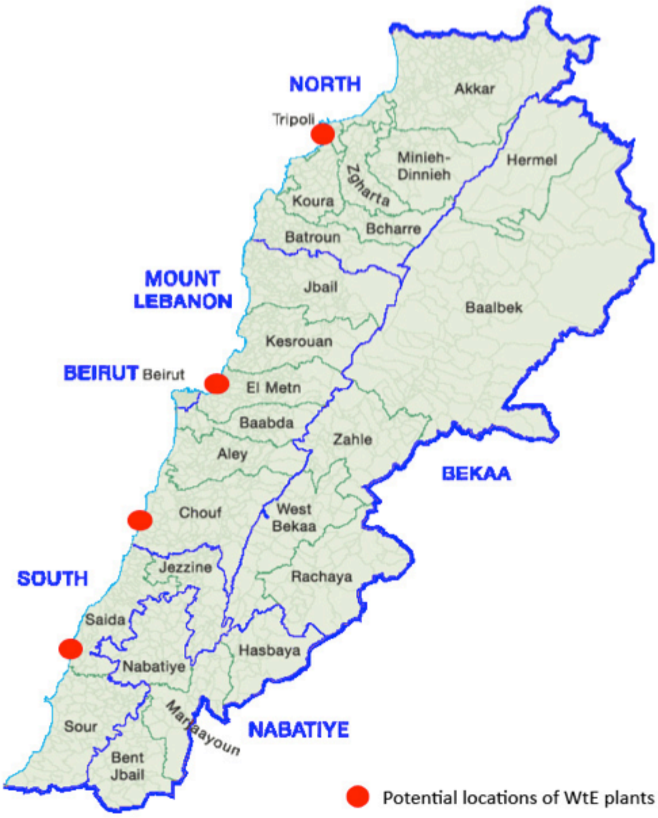


Figure 40: Potential location of WtE facilities in scenario 2

The adoption of the WtE technology alternative is expected to be executed in phases and therefore the amount of waste incinerated in 2020 is around 40% and 50% in 2040. Table 31 presents the percentages of waste disposed in SWDS or in incinerators for the years 2020 and 2040. The increase in adoption of the WtE alternative is clearly depicted in blue in Figure 41 reaching a percentage of 50% in 2040.

Table 31: Scenario 2 - estimated percentages of waste disposed in SWDS or incinerated

Year	Population	Percentage of waste into SWDS	Percentage of waste going to incinerator	Methane recovery (Gg)
2020	5,912,587	40%	40%	11
2040	8,202,103	20%	50%	7

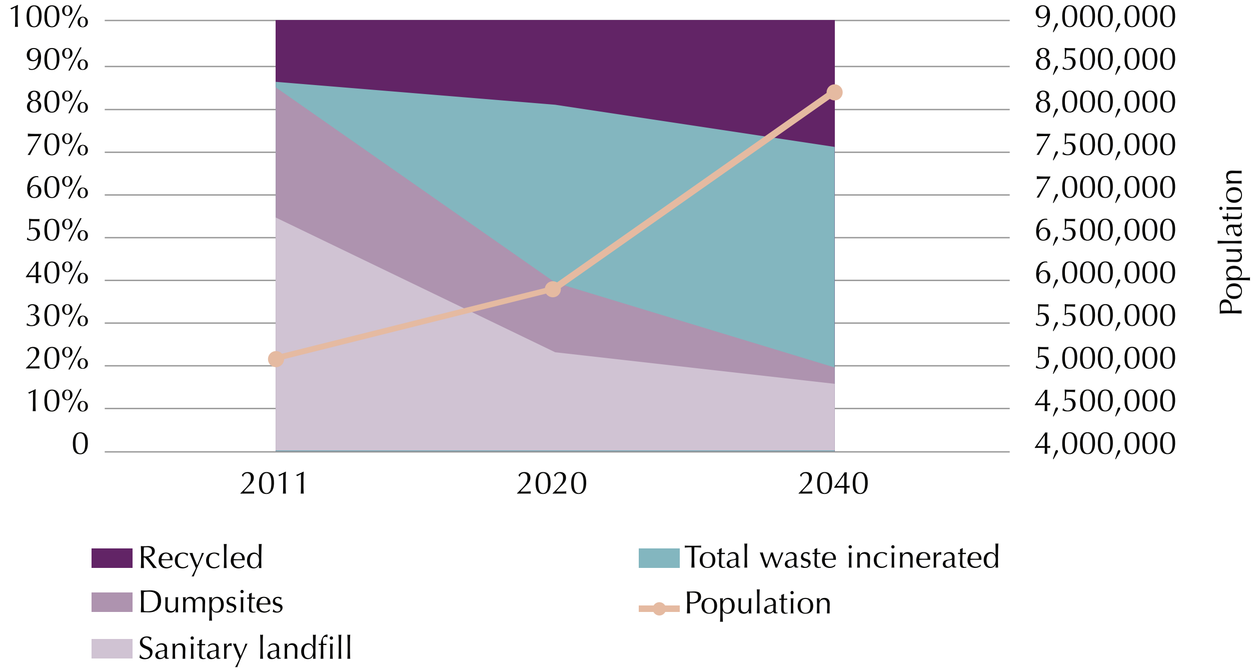


Figure 41: Scenario 2 - solid waste management options through 2040

With respect to developments on the wastewater management front, scenario 2 assumes significant improvements of wastewater treatment services reaching 51% in 2020 and 74% in 2040. This scenario also implies improved wastewater collection rates and therefore decreased discharges in septic tanks and in surface waters as reflected in Table 26 above.

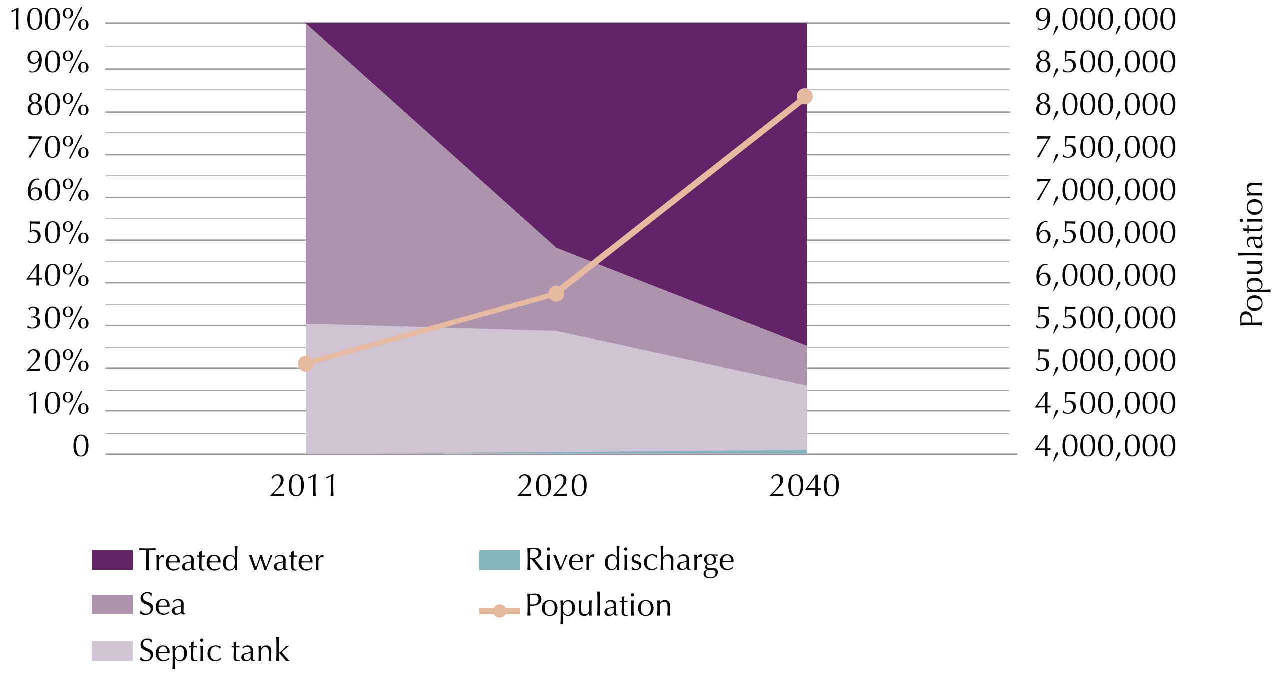


Figure 42: Scenario 2 - wastewater management options through 2040

10.5.2. Emission reduction potential from scenario 2

In scenario 2, GHG emissions generated from solid waste and wastewater are reduced by 29% in 2020 compared to the BAU, whereas by 2040, a potential emission reduction of 38% is calculated compared to the BAU.

In scenario 2, the reduction of waste incineration has substantially reduced CH_4 emissions as compared to the BAU scenario by 60% and 75% in 2020 and 2040, respectively. At the same time, CO_2 and N_2O emissions generated by incineration have increased, specifically CO_2 emissions that reached 1,170 Gg in 2040 as compared to 1.59 Gg under BAU.

Figure 44 and Figure 45 highlight the trend of GHG emissions throughout the years based on the implementation plan for solid waste.

The results of the scenario 2 are shown in Table 32 and Figure 45.

Table 32: Summary results of GHG emissions (Gg CO_2eq.) under mitigation scenario 2

	Emissions from solid waste treatment	Emissions from wastewater treatment	Total GHG emissions	Total GHG emissions under BAU	Percent reduction from BAU
2020	2,012.95	363.56	2,376.52	3,332.52	29%
2040	2,672.36	398.19	3,070.55	4,967.05	38%

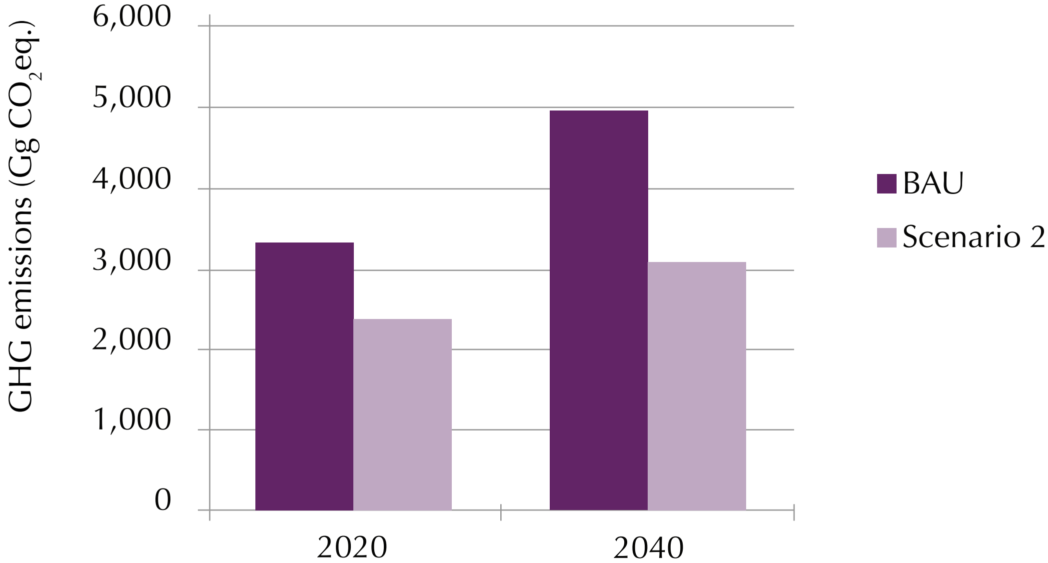


Figure 43: Summary of GHG emissions results of scenario 2

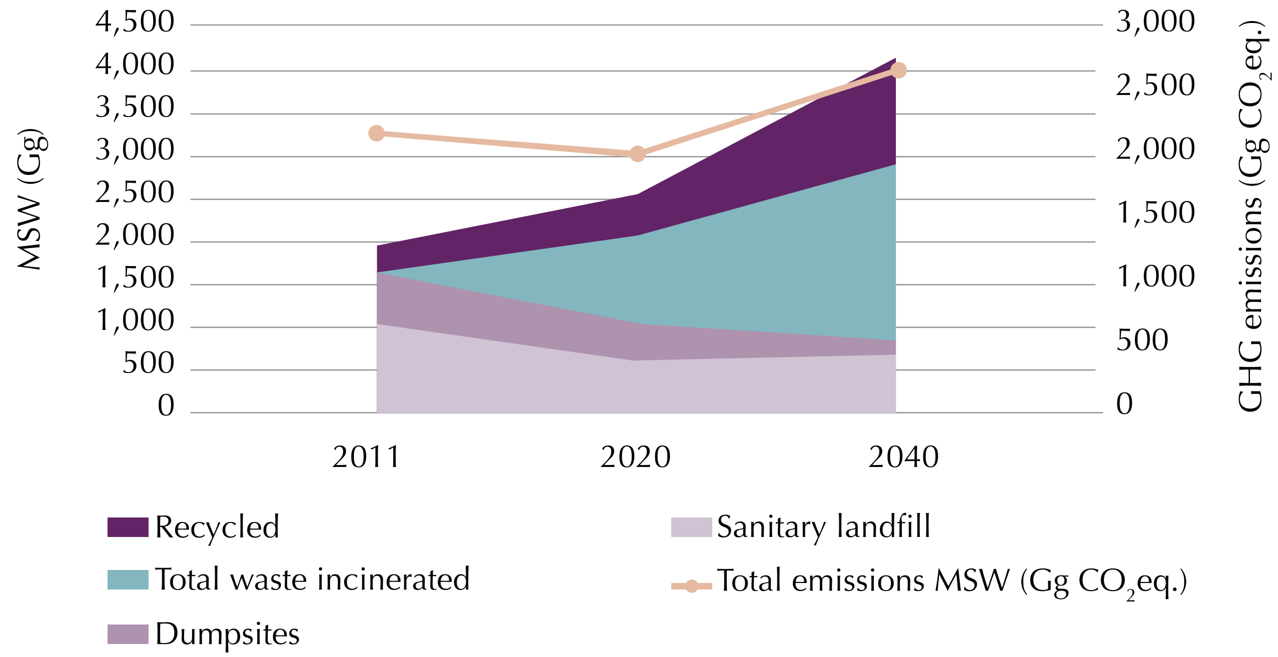


Figure 44: Scenario 2 - GHG emissions from solid waste

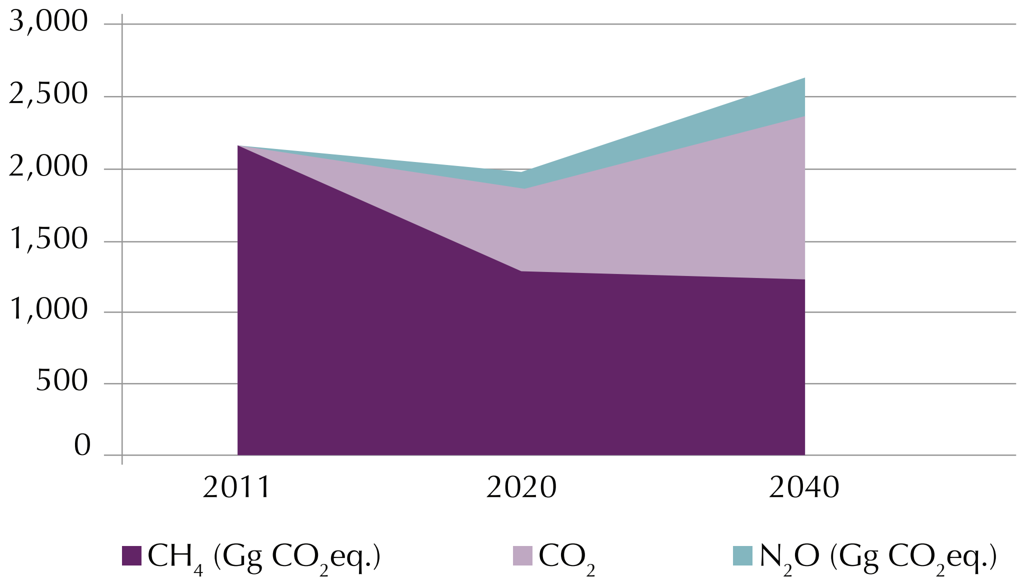


Figure 45: Scenario 2 - emissions breakdown from solid waste

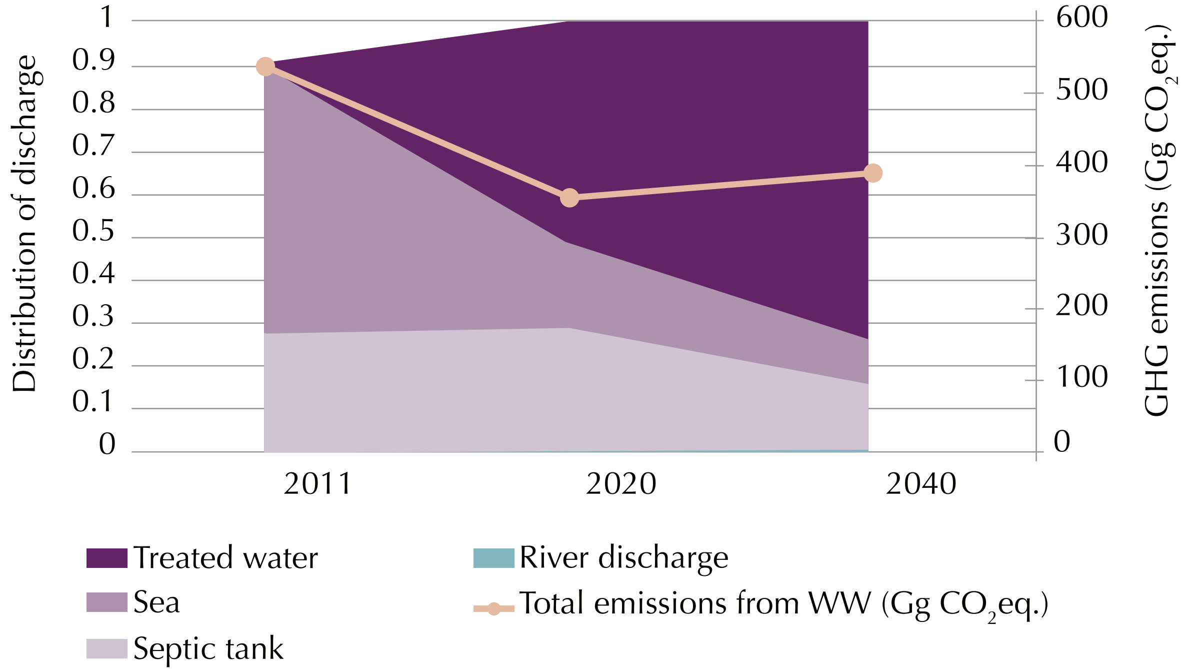


Figure 46: Scenario 2 - GHG emissions from wastewater

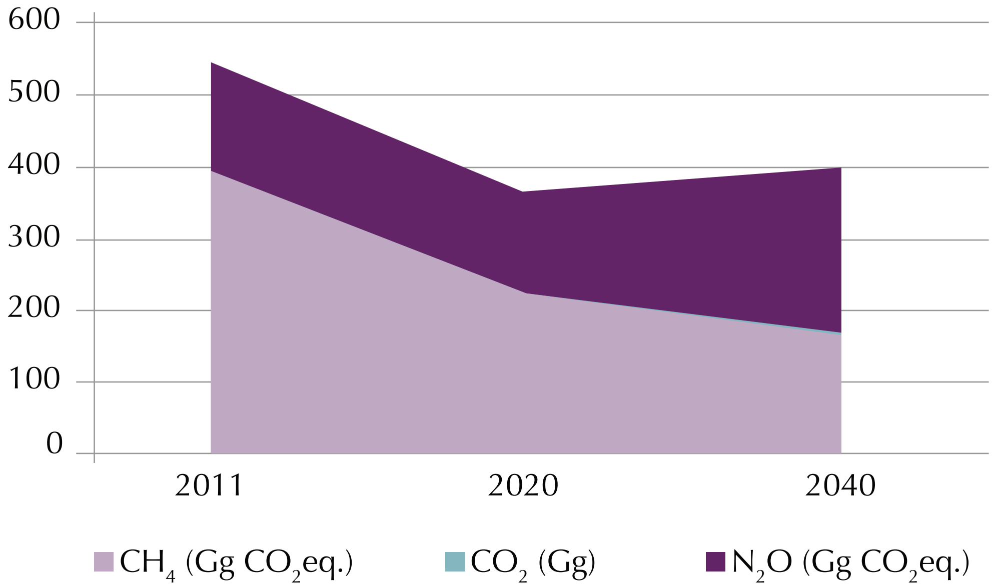


Figure 47: Scenario 2 - emissions breakdown from wastewater

11. Conclusion

The assessment of GHG reduction potential was based on policies and plans set by the GoL for the next decades. The actual implementation of these policies remains a function of a number of local factors, technical, financial and institutional which guide the progress to be made over the next years.

Based on a number of assumptions laid out in the present report, emissions were calculated for each development scenario as shown in Figure 48 and Figure 49 which present the actual emissions calculated for the years 1994-2011 and also emissions projected for the years 2020 and 2040 generated from each of the solid waste and wastewater sectors.

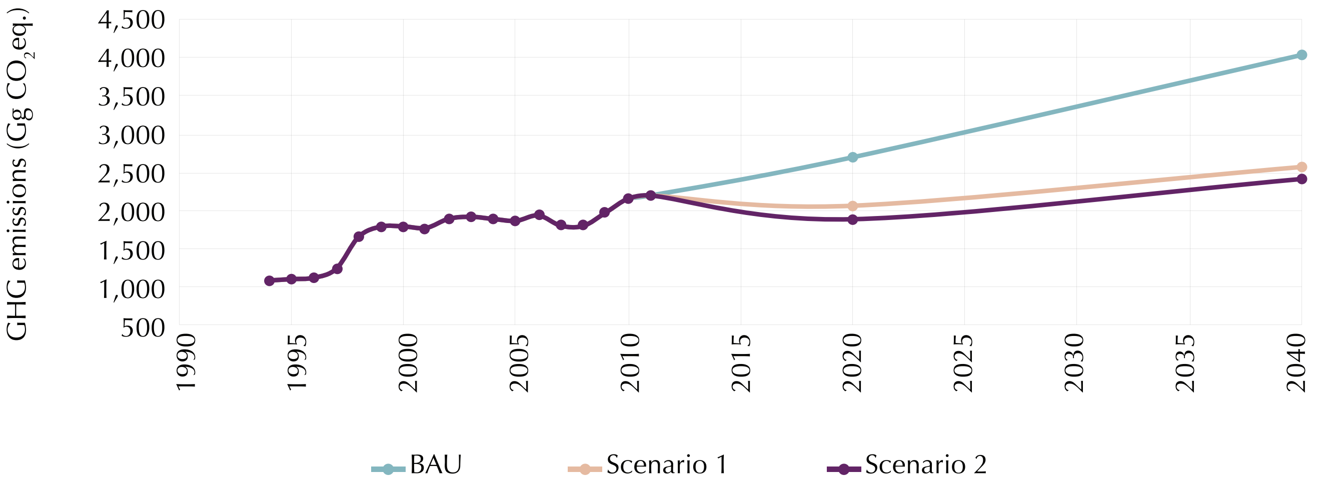


Figure 48: Estimated GHG emissions from solid waste per scenario

GHG emissions from solid waste are mainly impacted by the introduction of WtE technologies significantly reducing the generation of methane in scenario 2 as compared with the BAU scenario for the year 2040.

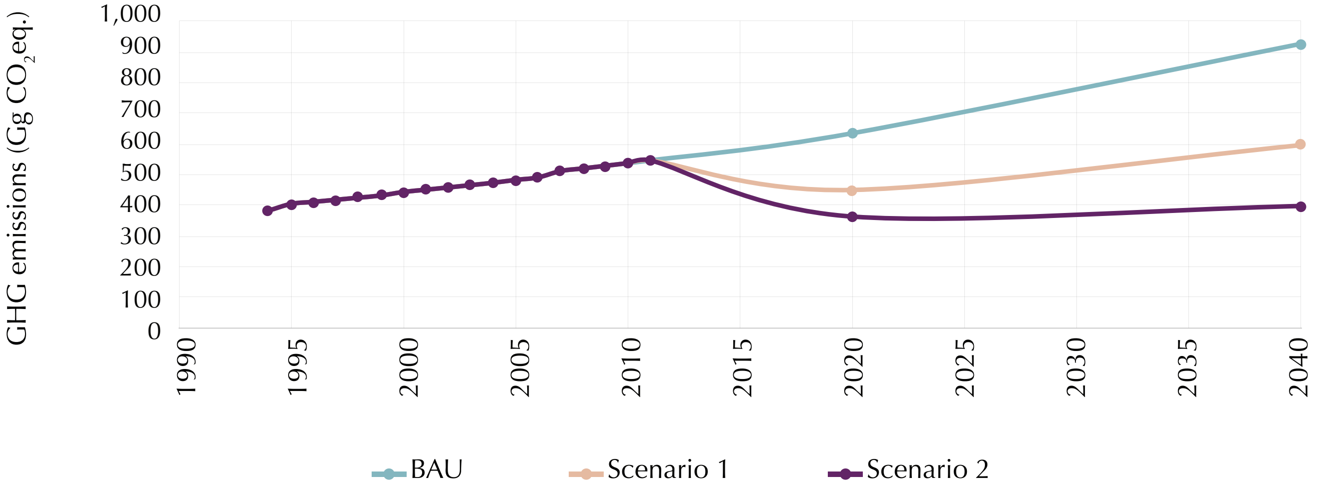


Figure 49: Estimated GHG emissions from wastewater per scenario

GHG emissions from wastewater are mainly impacted by the introduction of treatment technologies and improvement of collection services.

This report intended to provide various possible scenarios for mitigation options for solid waste and wastewater and the result is summarized in Figure 50.

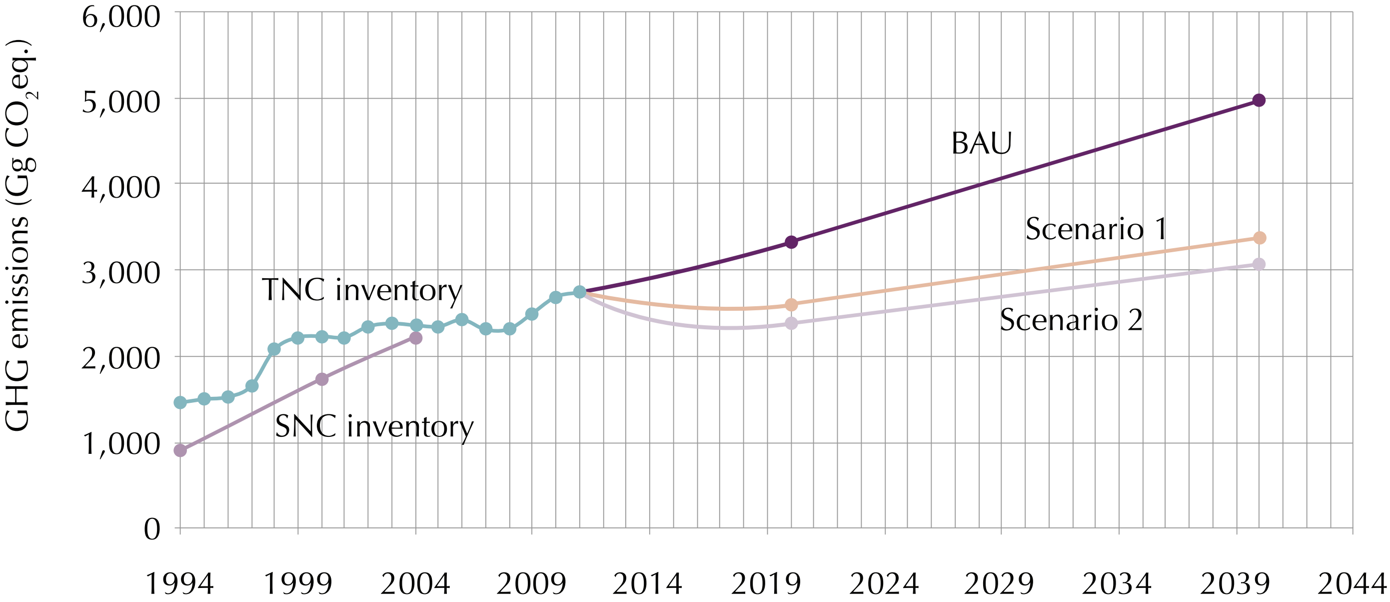


Figure 50: Summary of the GHG emissions inventory and mitigation scenarios

In conclusion, Figure 50 compares the TNC to the SNC since a recalculation was conducted in the TNC for the period 1994 until 2004 as described in the inventory report.

If no action is taken to mitigate against the increase of GHG emissions in the waste sector, emissions could reach around 4,000 Gg in 2040 expressed in CO_2eq. and it has the potential to be decreased to attain around 2,500 Gg CO_2eq. in the case where scenario 2 is adopted.

Figure 51 shows a comparison of total estimated GHG emissions between the BAU case and the two scenarios.

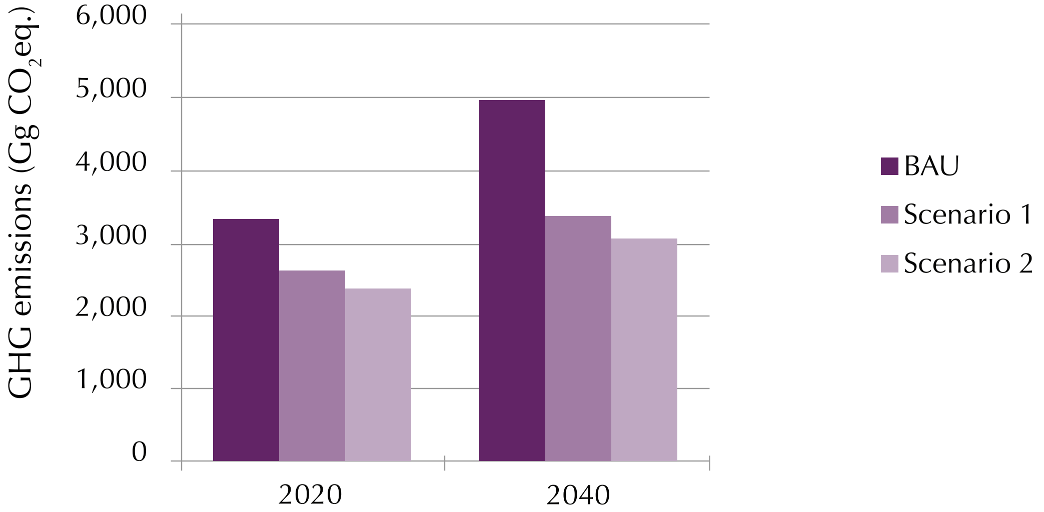


Figure 51: GHG emissions comparison of scenario 1 and scenario 2 with the BAU (CO_2eq. Gg/year)

Overall, various scenarios could be identified and studied. It is likely that most scenarios will fall between the BAU scenario and scenario 2 presented in this report.

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