Republic of Kenya

National Climate Change Action Plan:

Mitigation

Chapter 9: Waste

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Lachlan Cameron (ECN)
Laura Würtenberger (ECN)
Seton Stiebert (IISD)

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Mitigation Team:

Deborah Murphy, Seton Stiebert, Dave Sawyer, Jason Dion, Scott McFatridge, International Institute for Sustainable Development

Laura Würtenberger, Lachlan Cameron, Raouf Saidi, Xander van Tilburg, Energy Research Centre of the Netherlands

Peter A. Minang, ASB Partnership for the Tropical Forest Margins at the World Agroforestry Centre

Tom Owino, ClimateCare

Peterson Olum

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For further information, please contact:

Deborah Murphy, IISD
Tel: +1-613-238-2296
Email: dmurphy@iisd.ca

Laura Würtenberger, ECN
Tel: +31 88 515 49 48
Email: wuertenberger@ecn.nl

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Abbreviations

BAU	business as usual
CDM	Clean Development Mechanism
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
GHG	greenhouse gas
IPCC	Intergovernmental Panel on Climate Change
MSW	municipal solid waste
Mt	million tonnes
MW	megawatt
NAMA	nationally appropriate mitigation action
NEMA	National Environment Management Authority
REDD+	reducing emissions from deforestation and forest degradation plus the role of conservation, sustainable management of forests and enhancement of forest carbon stocks
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	The United Nations Children's Fund

9.1 Introduction

This chapter is part of a larger analysis of low-carbon development options in Kenya, which covers the six mitigation sectors set out in Article 4.1 of the United Nations Framework Convention on Climate Change (UNFCCC): energy, transport, industry, waste, forestry and agriculture. The holistic, sectoral analysis aims to inform the Kenya Climate Change Action Plan and provides the evidence base for prioritizing low-carbon development options and developing proposals for Nationally Appropriate Mitigation Actions (NAMAs) and REDD+ actions.

The analysis includes a preliminary greenhouse gas (GHG) emissions inventory and reference case projecting GHG emissions to 2030 for the entire Kenyan economy and by sector. The analysis then demonstrates how low-carbon development options can bend down emissions from the proposed reference case in each sector. Recognizing Kenya's development priorities and plans, the analysis also considers how the various options can contribute to sustainable development. The overall work concludes with the identification of priority actions to enable low-carbon development.

This chapter analyses low-carbon development options in the waste sector in Kenya and is one of seven sectoral chapters developed as part of the overall low-carbon scenario analysis.

9.2 Waste Sector: Background

9.2.1 Sector context

Kenya is experiencing rapid growth in the generation of solid waste. In Nairobi, for example, municipal solid waste (MSW) volumes are predicted to grow from 3,000 to 3,200 tons a day in 2009 to 5,400 tons a day in 2020.[1] Appropriate systems for waste collection, management and disposal are a cornerstone for development as they significantly contribute to cleanliness and health in human settlements. Solid waste collection, management and disposal has improved over the past years, yet still poses a challenge in Kenya. According to the Kenya National Environment Management Authority (NEMA), only 40 percent of waste generated in urban centres is collected and disposed of at designated disposal sites.[2]

Most of the collected waste in Nairobi is transported to Dandora, the city's official waste disposal site. Dandora, one of Africa's largest waste depositories, is an unsanitary landfill[3] without containment technology, which leads to surface water and groundwater pollution, and negative impacts on health of nearby residents, especially children.[4] Similar situations can be observed on a smaller scale in urban centres across the country. In rural areas, waste is mainly burned or disposed of in an unregulated fashion.

The provision of adequate sanitary facilities in urban areas, especially sewage disposal, poses another challenge. A growing population leads to increases in the amount of wastewater that needs to be managed. Shortages in clean water in some parts of the country point to the need for adequate treatment of wastewater. A 2012 publication of the World Health Organization and UNICEF reports that access to sanitation facilities has been increasing over the past 20 years in Kenya; and 32 percent of the population had access to improved sanitation facilities in 2010.[5] However, only an estimated 12 percent of the population has sewerage coverage, and at a national level approximately five percent of sewerage is effectively treated.[6]

Both waste disposal and sewage treatment are relevant from a low-carbon perspective, because methane is generated in both processes. The organic waste material in a landfill, such as food residues, paper and biomass, is decomposed by microbes which generate a mixture of methane, carbon dioxide (CO_2) and traces of other gases.[7] This gaseous mixture is called landfill gas, which is especially produced in controlled landfills that have a large density of disposed waste that creates the anaerobic conditions under which methane is produced. Methane is a potent greenhouse gas that has a global warming potential of 25 times that of CO_2.[8] When following Intergovernmental Panel on Climate Change (IPCC) rules for calculating GHG emissions in an economy in the waste sector (which includes wastewater treatment), methane emissions from solid waste disposal on land generally represent the main source of GHG emissions in the sector.

In a wastewater treatment plant, methane is generated as organic matter in the wastewater is decomposed under anaerobic conditions by methane-forming microorganisms. Methane emissions from wastewater treatment plants are generally considered to be the second largest source of GHG emissions in the waste sector according to IPCC inventory rules.[9]

9.2.2 Structure

Various government ministries and agencies, as well as private sector players, are involved in the waste and wastewater treatment sector in Kenya. On the national level, the overall policy-making responsibility lies with the Ministry of Environment and Natural Resources (MEMR) for waste, and Ministry of Public Health and Sanitation for sanitation. NEMA is responsible for the overall enforcement of water quality and waste regulations.

The primary responsibility for the practical implementation of waste collection, disposal and management systems and sewerage systems lies with City Councils. These responsibilities may change in the future, as under Kenya's new constitution the current system of local governance is eliminated and the new county governments are expected to create new local governance structures.[10]

The Kenya Investment Authority supports City Councils in encouraging private sector participation in the waste sector.[11]

9.2.3 Policy

The waste sector is regulated at the national level by the "Environmental Management and Co-ordination (Waste Management) Regulations" of 2006.[12] City-level planning documents play a central role in the planning and implementation of waste and wastewater management systems. The City of Nairobi, with support of United Nations Environment Programme (UNEP), has been working on an Integrated Waste Management Plan.[13]

There is little or no experience with low-carbon (or in this case low-methane) technologies in the waste sector within the current regulatory and policy framework. The promotion of such technologies requires consideration of how to best manage the rights to collect and utilise gas from landfill or wastewater.

9.2.4 Summary

Waste management and expansion of sewage coverage have improved in Kenya, yet the provision of comprehensive coverage of such services still poses a challenge. There are opportunities to improve: the collection of waste, the fraction of waste that reaches managed landfills, landfill management and waste water treatment practices. Moving in this direction would allow the implementation of complimentary approaches to methane management, which would reduce Kenya's GHG emissions. Few or no measures are in place to address methane emissions from the waste sector, but there is good opportunity for landfill gas utilisation and to a lesser extent wastewater methane utilisation.

The level of GHG emissions from the Kenyan waste sector is low compared to other sectors. This chapter is therefore less extensive than the analysis undertaken in larger sectors such as electricity generation or forestry. The report focuses on the one option with the largest expected potential for short-term GHG emission reductions.

9.3 Development Priorities of the Government of Kenya

Vision 2030 recognizes that development will affect pollution levels and generate larger quantities of waste with a different composition than at present. Waste management forms part of the short-term "strategic thrusts" in the environment pillar of Vision 2030, and specific strategies and projects focus on industrial and municipal waste management.[14] Solid waste management systems are planned for at least five municipalities and in the proposed economic zones to ensure a clean, healthy and secure environment. Regulations on the use of plastic bags and other hazardous products also form another goal under this strategic thrust.

Several Pollution and Solid Waste Management strategies have been identified to deliver on short- and long-term goals:

- Develop and enforce mechanisms targeting pollution and solid waste management regulations;
- Public-private partnerships for municipal waste;
- Reduce importation of oil with high sulphur content;
- Establish a national air quality monitoring system; and
- Apply market-oriented instruments to regulate the use of plastic bags.

The development of a national waste management system is Vision 2030 flagship project, which includes relocation of the Dandora landfill site and the establishment of a solid waste management system for the City of Nairobi on a public-private partnership basis. This project is expected to set a trend to be followed by other municipalities.

9.4 Reference Case

This section briefly discusses the methodology, data and assumptions that were used to generate the GHG emissions baseline for the waste sector between the years 2000 and 2030. This is followed by a discussion of data availability and quality. Finally, emissions are projected out to 2030 to create the reference case against which to measure abatement potential. Figure 9.2 illustrates the methodology used to develop the reference case and low-carbon scenario (discussed in Section 9.5).

9.4.1 Emissions baseline methodology

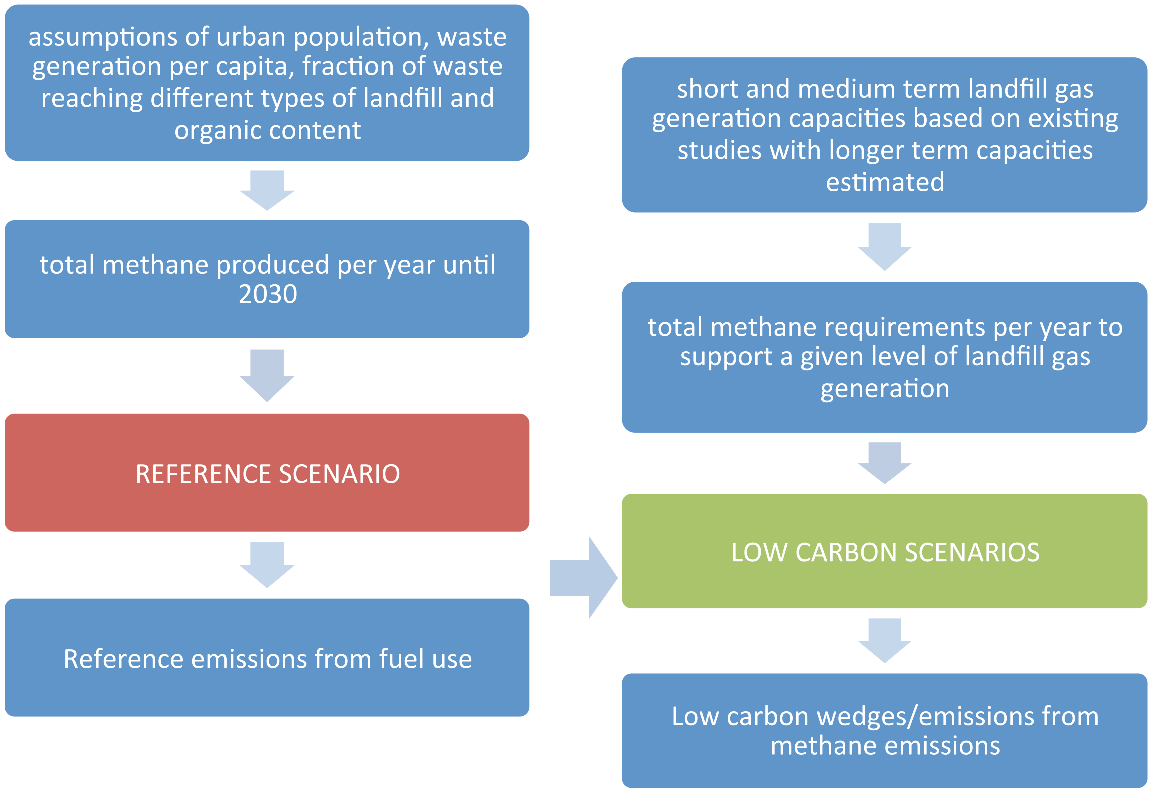
The emissions baseline for the waste sector was developed using 2006 IPCC Guidelines.[15] A Tier 2 approach was used to estimate emissions from solid waste disposal sites, and a Tier 1 approach used for wastewater and sludge treatment.

Methodologies along with the specific data and assumptions to estimate emissions from each of these sources are described in detail in Chapter 2, Preliminary Greenhouse Gas Emissions Inventory.

9.4.2 Data availability and quality

There is considerable uncertainty about the amount of waste sent to solid waste disposal sites in Kenya where significant methane emissions are likely to be generated. Reasonable statistics are available for the largest dumpsite, the Dandora site in Nairobi, but there are many unofficial dumpsites across the country where wastes may be deposited in unmanaged shallow disposal sites, usually with a depth of less than five metres. The estimates of total waste deposited in solid waste disposal sites is likely to have the highest uncertainty of all parameters in the preliminary GHG inventory.

Figure 9.1: Approach for determining mitigation potentials of low-carbon development options in the waste sector

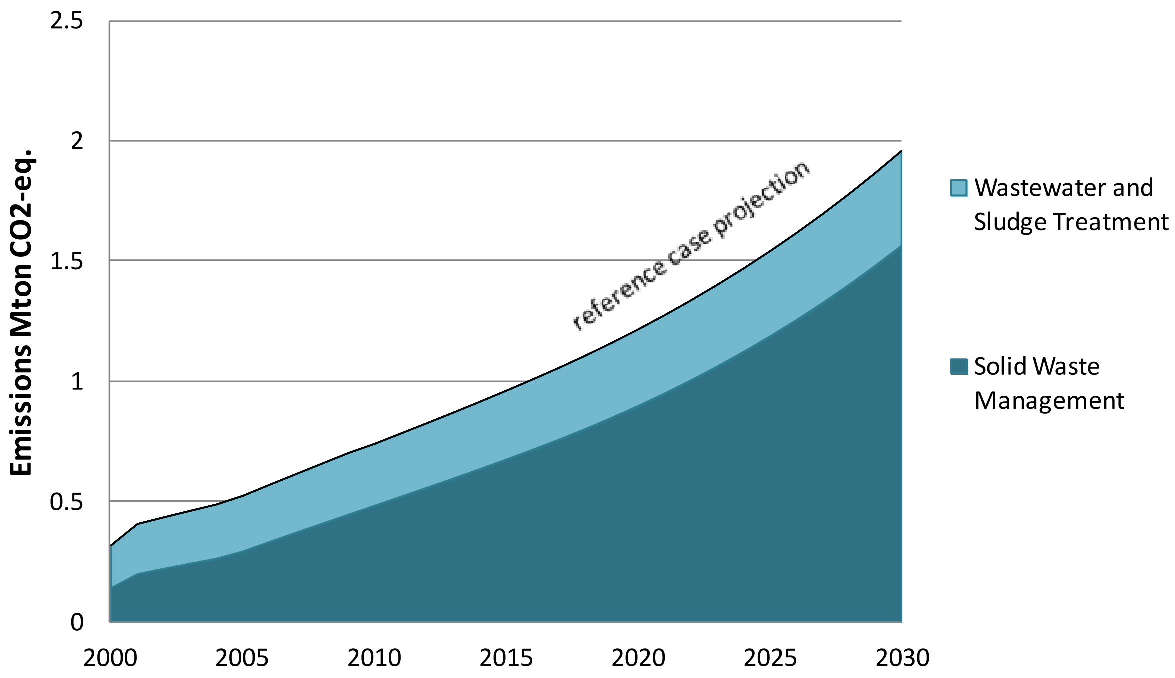


Uncertainties in estimates of wastewater emissions are primarily related to the methane production capacity and the Biological Oxygen Demand per person, that can both exceed ± 30 percent.[16] The emissions baseline presented quantifies methane emissions from human wastes. Estimates of methane generated from industrial wastewater and from nitrous oxide emissions from wastewater are not included in this analysis because they were not included in Kenya's first national communication inventory and there was insufficient information to generate an estimate.[17]

9.4.3 Greenhouse gas emissions reference case

The emissions baseline for the waste sector is summarized in Figure 9.2. Total emissions are expected to grow from 0.8 million tonnes (Mt) in 2010 to 2.0 Mt in 2030 representing an annual growth rate of 4.9 percent. Solid waste disposal emissions are rising faster than population growth because of the lag time in emission releases of wastes that have been deposited in the past. Solid waste disposal emissions account for approximately 75 percent of waste sector emissions for the 2010 to 2030 time period.

Figure 9.2: Total reference case emissions from waste sector ($MtCO_2e$)



9.5 Low-carbon Scenario Analysis

The low-carbon scenario analysis consisted of identifying low-carbon development options, and calculating the mitigation potential against the reference case. The resulting wedge analysis demonstrates the emission reduction potential by low-carbon technology in the sector.

9.5.1 Choice of abatement options

The identification of low-carbon options for further analysis followed a participatory multi-step approach that is described in Chapter 1. Few viable options were identified in the waste sector and one option was analysed: Landfill gas methane capture (and electricity generation). This option and the results were presented at a local validation meeting in May 2012 for review by and input from Kenyan experts. Box 9.1 discusses options that were suggested by Kenyan experts and the rationale for not including in the low-carbon scenario.

9.5.2 Calculation of abatement potentials

The abatement potential of this option is calculated in a similar way to the reference case, using the same bottom-up assumptions on the volume of MSW collected, the percentage of waste that reaches landfills that could be suitable for methane collection and utilisation,[18] as well as the organic content of this waste (which to a large degree determines the methane production potential). The starting point for estimating the total reduction in methane emissions due to landfill gas collection and destruction (in this case by burning for electricity generation) is a 2010 study of biogas potentials in Kenya.[19] This study considers Nairobi and estimates a range of electricity (and cogeneration) potentials depending on feasible cost levels. It also provides estimates of the volume of methane required for this generation.

Box 9.1: Low-carbon options in the electricity sector not considered in the analysis

Waste technologies proposed at local validation meetings but excluded after further analysis are described below.

Landfill gas flaring is very similar to the landfill gas methane capture option, but the captured methane is simply burnt to avoid its release to the atmosphere. It is a second-best option – because no electricity is produced – and not considered further in the low-carbon scenario. Its mitigation potential would be similar to that calculated for landfill gas generation if modern high efficiency flare technology is used; with older candle flares up to 10 percent of the methane may be released un-burnt.

Wastewater treatment is a potentially feasible solution that could be considered in a future analysis. A 2010 study on agro-industrial wastewaters suggests that the potential for methane capture and utilisation is relatively low because the methane potentials per cubic metre of wastewater are much lower than solid substrates due to the low content in organic material and high water content.[20]

Waste-to-energy generation is often better suited to areas with a scarcity of space for landfill (because of the lower costs of using landfill) and waste with a lower moisture and higher energy content (less likely in Kenya because of a high organic waste content).[21] Although incineration can still prove beneficial under these conditions, there is a significant overlap with the option of electricity generation from landfill gas without appropriate waste separation practices, which are not currently found in Kenya.

Anaerobic Composting involves a two-stage process of anaerobic digestion and composting. It can treat organic waste to recover energy in the form of biogas, and compost in the form of a liquid residual. Both would reduce methane emissions and may produce a soil conditioner. In addition, the biogas can generate electricity via gas engines. However, it needs a feed stream of source-separated organic wastes, typically in the form of animal manure (which is not readily collected in Kenya) or municipal organic wastes (which are not collected in Kenya). Agricultural residues are considered as a cogeneration option in Chapter 8, Industrial Processes.

These figures provide a starting point for the assumed landfill gas generation potentials in the low-carbon scenario in the short and medium term. Total installed capacities are conservatively assumed in the more distant future (2025 and 2030) based on a moderate increase in the percentage of waste that is collected and disposed of in appropriately managed landfills. The methane requirements to support this level of generation over time are then estimated and deducted from total Kenyan methane emissions from MSW in a given year.

It should also be noted that in addition to methane, the decomposition of organic material in MSW produces CO_2. The methane produced and released to the atmosphere contributes to global warming and the emissions need to be estimated and reported. However, the CO_2 produced originates from biogenic sources (such as food, garden, paper and wood waste) and thus the emissions need not be considered in national inventories.[22]

Finally, only the mitigation potential of avoided methane is calculated. The displaced electricity mitigation potential (a result of less coal and diesel use) is shown on the electricity wedges, meaning the mitigation potential is split over two sectors. In making this split it is assumed that the organic component of MSW (which generates the methane) is domestically produced and is renewable as it is biogenic. This is in accordance with protocols for determining emissions reductions from renewable generation facilities.[23,24]

9.5.3 Calculation of abatement costs

The marginal abatement costs, are calculated using the total abatement potential (from both displaced electricity and captured methane summed together). More detail is provided in Chapter 5, Electricity Generation.

9.5.4 Data availability and uncertainties

With regard to data availability for mitigation options, the situation is similar to the data problems experienced in establishing the waste sector baseline.

Limited reliable data is available on rates of waste generation, composition and management practices in Nairobi. In regards to landfill gas generation specifically, the main source of data was a 2010 study that focussed on Nairobi.[25] There were no useful sources of estimates across the rest of the country. It was assumed that the characteristics of waste management and landfill observed in Nairobi could be extrapolated across the remainder of the country (based on urban population numbers) in the absence of specific data.

9.6 Low-carbon Development Options

Landfill gas methane capture (and electricity generation) is the one low-carbon development options analysed in the waste sector. The MSW created by a population is a significant management problem for any country from a social, environment and economic perspective. From a climate change perspective, methane is produced as the organic content in MSW slowly degrades anaerobically (that is, without exposure to oxygen). The degree to which this occurs is strongly dependent on conditions in the site where the MSW is disposed.

Although methane is a GHG with a relatively high global warming potential and contributes to climate change, it is also a potential source of energy if it can be captured. This capture and use of methane from MSW to generate electricity is done in many countries, developed and developing, across the world, but would be a new technology for Kenya. Dandora, the largest landfill site in Kenya, has been the subject of an unsuccessful attempt to develop a landfill gas generation project and has also been considered as a potential CDM project.[26]

A recent study by German International Cooperation (GIZ) considered data on theoretical potentials from 13 selected groups of biomass available from the agro-industrial business in Kenya as well as for MSW in Nairobi.[27] MSW was found to have the largest potential for electricity generation (and equally for cogeneration should this technology be chosen) ranging from 11 to 64 megawatts (MW), depending on permissible cost assumptions, with a mean value of 37.5 MW. This potential was calculated based only on the amount of MSW generated in Nairobi, about 996,450 tons per year. Nairobi was chosen because there was not much literature on MSW in other cities in Kenya.[28] This means that a higher potential could be expected: 1) if more cities were considered; 2) as urban populations grow, and 3) as MSW practices increase the percentage of MSW that reaches landfills (currently roughly 60 percent but with only an estimated 18 percent reaching disposal sites of depth greater than five metres or with high water levels).[29]

The results of the analysis are covered in five categories:

- Scenarios;
- Mitigation potentials;
- Costs;
- Development benefits;
- Climate resilience; and
- Feasibility of implementation.

9.6.1 Scenarios

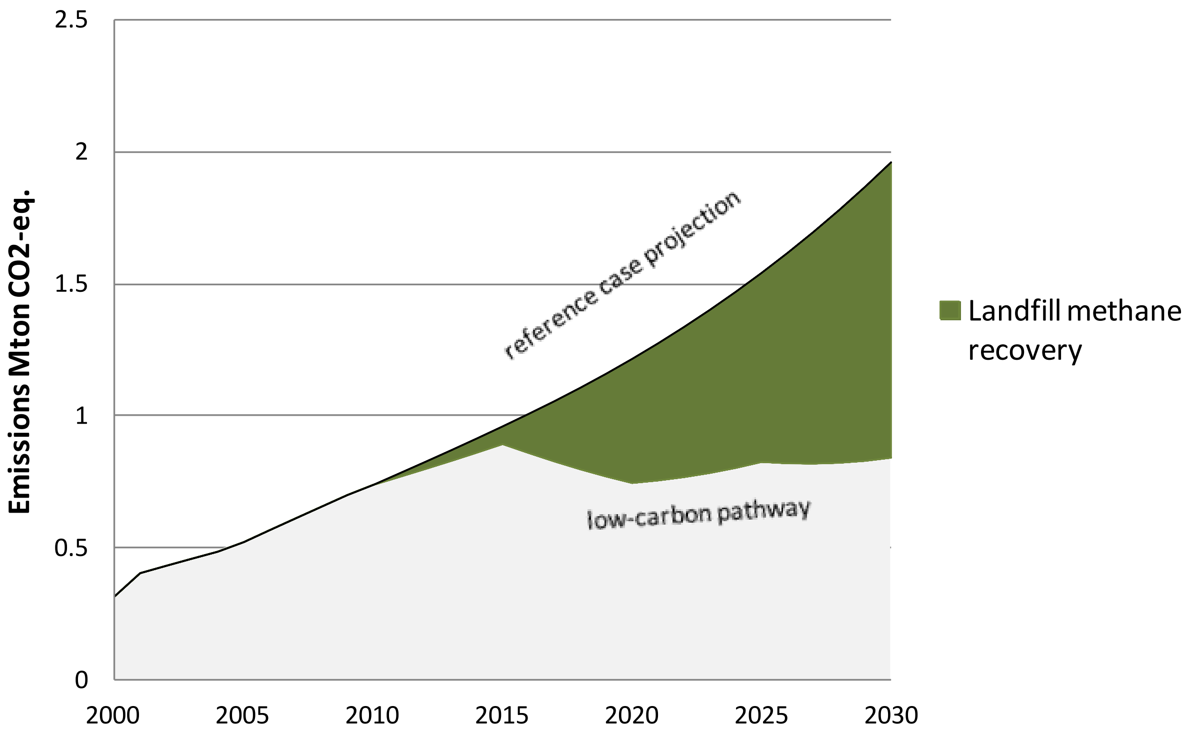
The low-carbon scenario for the amount of methane that could be captured is directly based on the installed capacity of landfill gas generation assumed in Chapter 5, Electricity Generation.[30] The installed capacities are based on conservative assumptions from a prior study that found that 11 to 64 MW of MSW biogas electricity could be installed in Nairobi alone, based on 2009 waste levels.[31] The low-carbon scenario assumes a mean value of 37.5 MW can be realistically deployed in 2020 and the maximum value of 64 MW in 2025. For 2030 it is assumed that the current maximum MSW methane potential in Nairobi has approximately doubled (covering the whole of Kenya). The final capacities of landfill gas generation can be seen in the factsheet in Annex 1.

9.6.2 Mitigation potentials

Figure 9.3 shows the low carbon mitigation wedge in the waste sector (including both solid waste and wastewater methane emissions). As discussed in Section 9.5 on the methodology for the low-carbon assessment, the results are based on a bottom-up calculation of emissions. Mitigation potentials for each five-year period out until 2030 are provided in the factsheet in Annex 1.

Figure 9.3 only considers the mitigation potential from methane emissions avoidance (approximately 1.1 kilotonnes CO_2eq in 2030). Any mitigation potential from displaced electricity is calculated in Chapter 5, Electricity Generation. The potential from methane emissions avoidance is found to be roughly twice as large the potential from electricity displacement.

Figure 9.3: Low-carbon development option mitigation wedge in the waste sector



9.6.3 Costs

The costs are reported as marginal abatement costs and are the same as those presented in the electricity sector chapter. These are calculated to be US$ -4.90 per tCO_2 in 2020 and – US$ -12.40 per tCO_2 in 2030. The change over time is due to different assumptions in learning rates between landfill gas generation and conventional generation technologies against which the various renewable energy technologies are compared.

These costs assume that landfill has been managed in a way that lends itself to methane capture and landfill gas generation, whereas sites like Dandora have not been prepared for methane capture and may have higher costs to adapt. That being said, there are also technologies advocated for the region that may allow a relatively simple adaptation of the dumpsite for capture.[32] The starting point for costs in this study (11.5 US¢ per kilowatt hour in 2012) is also very conservative compared to costs in other studies of landfill gas generation in developing countries which suggest costs as low as 6.5 US¢ per kilowatt hour.[33]

While marginal abatement costs give an indication of the cost-effectiveness of different low-carbon options, their results should be interpreted with a high-level of caution. Results are highly dependent on the assumptions underlying the levelised cost of electricity and do not give an indication on the capital intensity of the options. The latter is especially relevant for many renewable energy sources, which require high upfront costs but no fuel costs. As a consequence, access to capital is an important barrier for many renewable energy options. Finally, marginal abatement cost curves say nothing about the development benefits of various options, and thus can only provide one input into a more comprehensive process of selecting mitigation options to pursue.

9.6.4 Development benefits

Development benefits have been qualitatively described within the study and validated with stakeholders at expert meetings and individual interviews.

Table 1 shows an overview of development benefits of the low-carbon options in the waste sector (in addition, see the fact sheet in Annex 1).

Table 1: Overview of development benefits of low-carbon development options in the waste sector

Legend: High Positive; Positive; Neutral / Minor impact; Negative; Uncertain	Climate			Development		Environmental impact
	Abatement potential ($MtCO_2$)	Abatement costs (USD/tCO_2)	Adaptation impact	Energy security	Improved waste management	
Landfill methane capture	1.1	-12.4	Positive	Positive	High Positive	Positive

A study on sustainable development contributions that could be delivered by landfill gas capture and combustion projects in developing countries implemented under the Clean Development Mechanism (CDM) identified the following:[34]

- Improved groundwater quality as the management of the site could be combined with leachate collection and disposal action.

- Improvement of local air and safety (fewer emissions of sulphur oxide, nitrogen oxide and particulates) through burning less coal for electricity generation and reduction of landfill gas released into the air.
- Reduced risk of dangerous methane gas concentrations in landfills and reduced exposure of residential areas to odour.
- Small increase in local employment.
- In some cases, additional payment by the project sponsor to support community programmes for stakeholders, including support for people living nearby the sites and who are affected by the project.[35]

The process of designing, constructing and operating landfill gas capture plants could create jobs, however the technology used and local content are important factors in determining the local economic impact.

9.6.5 Climate resilience impacts of low-carbon options

Landfill gas methane capture is considered, by and large, resilient to climate change because it would experience very small impacts in comparison an alternative of generating electricity from hydropower. Water levels and temperature may have a small impact on methane production rates, however too little is known about these aspects and landfill conditions in Kenya to say anything conclusive.

9.6.6 Feasibility of implementation

The feasibility of landfill gas capture and use in Kenya is limited by the following barriers:

- Lack of legislation: Currently no regulations enforcing landfill gas extraction with or without utilization.
- Unfavourable financial performance: The financial performance of several CDM projects in the field of landfill gas capture and use is often insufficient to attract enough investment funding from financial institutes (because the project is unattractive compared to the interest rates provided by local banks). In the case of the CDM, projects are financially supported through the sale of carbon credits based on the avoidance of methane emissions.
- Waste management practices are variable across the country and within cities. Some areas are much better served (due to financial and capacity constraints) than others.
- A lack of technology familiarity and awareness, as well as and lack of availability of equipment.
- Potentially a lack of social acceptance. For example, Dandora is a source of livelihood for as many as 6,000 people. This can be a key factor for determining the success of waste projects.
- Type of landfill: a key barrier is the amount of MSW that currently reaches deeper landfill (for example the IPCC define this as greater than five 5 metres or where there is a high water table; Dandora landfill in Nairobi is of this type). Only about 18 percent of total urban MSW currently reaches this type of landfill. To improve generation potential out to 2030 (and support the capacities that are shown in this study) needs to increase to something like 50 percent by 2030. Such an increase should be aligned with the development goals of the government, making the increase a safe assumption.[36]

9.7 Potential Policy Measures and Instruments

The evidence suggests that favourable policies can have a significant effect on landfill gas utilisation and corresponding GHG mitigation.[37] The driver behind landfill gas capture (and subsequent electricity generation) in developed countries is usually regulation. In developing countries, the decision to capture and use landfill gas is generally financially motivated.[38]

These incentives have often been through the sale of carbon credits, in particular through the CDM. More than 75 projects are registered for the capture of landfill gas for flaring or electricity generation. However, in instances where a government wishes to encourage domestic action independently of the CDM, then local generation incentives can be used, such as feed-in tariffs, subsidies or tax incentives. These options are discussed in more detail in the policy section of Chapter 5, Electricity Generation. Chapter 5 also includes more details of the types of supporting policies that can be used to enable landfill gas generation facilities. These include: 1) interconnection standards (to provide independent power producers with the ability to get connected in a timely and transparent way and sell electricity back to the grid); 2) awareness and capacity building campaigns; and 3) improvements in data monitoring and availability in regards to waste.

Specifically for the waste sector it is important to: 1) improve rates of waste collection and disposal to regulated landfills;[39] 2) create a regulatory framework that allows for the rights to landfill gas to be licensed to developers for capture and use; and 3) plan future landfills so that landfill gas can be economically captured and utilised. This could be a challenge under the new county governance model, but some cities are proceeding with landfill plans. For example, Kisumu City plans to establish a sanitary landfill that will incorporate waste recycling and methane capture. Capacity building and awareness raising about improved waste treatment processes and associated policy could help counties and cities with their waste management plans.

9.8 Conclusion

Landfill gas methane capture, potentially in combination with electricity generation is a low-carbon development option that could lower GHG emissions by 1.1 Mt CO_2e in 2030, provide sustainable development benefits and business opportunities for the private sector involved in project development and operation. This analysis estimates that emissions from waste make up less than 1.5 percent of total GHG emissions in 2011 and would account for approximately two percent of GHG emissions in 2030 for our reference scenario. Although there are important benefits associated with improving waste management in Kenya, low-carbon considerations will likely be only a small driver for general improvements in waste management practices.

Annex 1: Low-Carbon Development Option Fact Sheets

Methane Avoidance from Landfill Gas

When solid municipal waste (MSW) is dumped in landfills, the organic component can degrade in the absence of oxygen; this is called anaerobic digestion. This process releases methane that typically escapes to the atmosphere and contributes to climate change. The methane can be captured (and can be used as a source of fuel to generate electricity and heat through combustion; see option for electricity generation from landfill gas in Chapter 5, Electricity Generation). In the waste sector, only the mitigation potential of avoided methane is calculated. The displaced electricity mitigation potential (because less coal and diesel is used) is shown as an electricity wedge in Chapter 5. The mitigation potential is split between the waste and electricity generation sectors. The marginal abatement cost, is however calculated using the total potential summed together.

Current situation: Feasibility study for the use of landfill gas (from MSW) in Nairobi, but no concrete plans for implementation. Initial studies suggest up to 64MW of generation capacity in Nairobi is feasible.[40]

Low carbon scenario: Moderate growth such that the existing capacity in Nairobi is exploited in 2020, growing to 100 MW across all of Kenya in 2030.

Development benefits and priorities

Development benefits:

- Improved management of landfill.
- Potential source of baseload electricity for reliable power supply.
- Significant additional GHG benefits from avoided emissions from alternate fossil fuel generation in the electricity generation sector. The abatement potential shown here for the waste sector only shows the reduction in methane.
- Improved energy security,
- Incentive to collect waste.

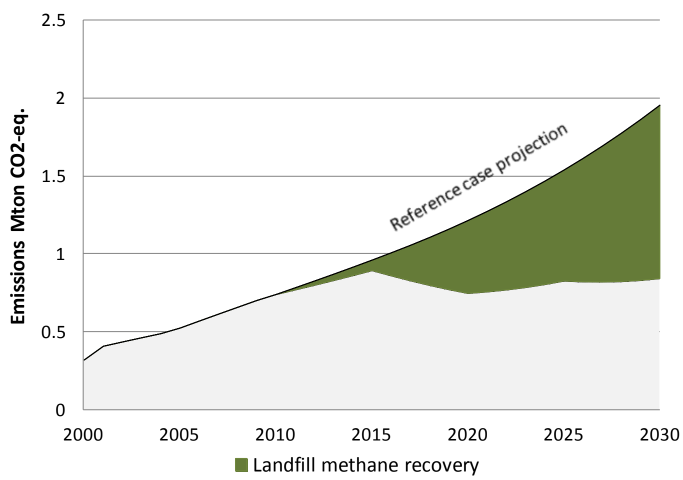
Alignment with GoK priorities: Vision 2030 recognizes that achieving its anticipated developments will affect pollution levels and generate larger quantities of waste. In response to this, as well as the current challenges in the waste sector, GoK has developed a number of specific strategies and projects focused on waste management considering both industrial and municipal waste.

Links to adaptation: May be very marginally affected by weather conditions (the moisture content of the waste is a key factor in determining methane production) but it can replace hydropower, which is more vulnerable to climate change.

Abatement potential and costs

Greenhouse gas abatement: The mitigation potential from landfill gas methane capture alone is estimated to be 1,116 ktCO_2e/year in 2030.

Costs: The unit costs of mitigation are found to be favourable and are expected to improve over time, from a marginal abatement cost of US$ -1 per tCO_2e today to US$ -12 per tCO_2e in 2030.



Scenario	2010	2015	2020	2025	2030
Methane used for generation - low carbon scenario (mil. m^3)	-	4.5	31.2	47.6	74.5
Abatement potential ($ktCO_2e$)	-	67	469	714	1,116

Feasibility of implementation

A key barrier is the amount of MSW that currently reaches deeper landfill, which is defined by the IPCC as >5m or where there is a high water table. Dandora landfill in Nairobi is this type. Currently about 18% of total urban MSW in Kenya reaches this type of landfill. This needs to increase to approximately 50% by 2030 to improve generation potential out to 2030 and support the capacities that are shown here. This increase is likely to be aligned with the development goals of the government, and therefore is a valid assumption. Moreover, any investment related to official landfills in Kenya will require the approval of the respective city council.

Endnotes

[1] Von Blottnitz, H. 2011. *Integrated Solid Waste Management Plan for the City of Nairobi, Kenya*. Developed for the City Council of Nairobi on Assignment to the United Nations Environment Programme (UNEP). 1st Draft, 19 February 2010. Accessed at: http://www.unep.or.jp/ietc/GPWM/data/T3/IS_6_4_Nairobi_ISWMplan_draft1_19Feb.pdf.
[2] NEMA. 2012. *Waste management in Kenya*. Website. Accessed 13th June 2012 at: http://www.nema.go.ke/index.php?option=com_content&view=article&id=311:waste-management-in-kenya&catid=120&Itemid=659.
[3] Landfills are waste depositories run by a government agency that should adhere to relevant waste treatment laws and processing regulations. Dumps are informal, or illegal, sites for the disposal of waste and are unregulated.
[4] World Bank. 2011. *Nairobi Metropolitan Services Project – Project Information Document, Concept Stage*.
[5] World Health Organization and UNICEF. 2012. *Estimates for the use of improved sanitation facilities – Kenya*. Updated March 2012. Accessed at: http://www.wssinfo.org/fileadmin/user_upload/resources/KEN_san.pdf.
[6] Gakubia, R., Pokorski, U., and Onyango, P. 2010. "Upscaling Access to Sustainable Sanitation." Presentation at the *Follow-up Conference of the International Year of Sanitation (IYS)*, 26th January, Tokyo, Japan. Accessed at: http://www.waterforum.jp/eng/iys/agenda/doc/session1/12_Dr.UlrikePokorski.pdf
[7] UNEP. 2010. *Waste and Climate Change - Global Trends and Strategy Framework*. Accessed at: http://www.unep.or.jp/ietc/Publications/spc/Waste&ClimateChange/Waste&ClimateChange.pdf
[8] Assuming a time horizon of 100 years in accordance with IPCC 2007 rules.
[9] UNEP. 2010.
[10] World Bank. 2011.
[11] See for example: http://www.tradeinvestkenya.com/investment_opportunities/225060.htm.
[12] Available at: http://www.unep.org/urban_environment/PDFs/ISWM2_WasteManagementRegulations.pdf
[13] von Blottnitz, H. 2011.
[14] Government of Kenya. 2007. *Kenya Vision 2030: A Globally Competitive and Prosperous Kenya*. Nairobi: Government of Kenya.
[15] Intergovernmental Panel on Climate Change (IPCC). 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Hayama: Institute for Global Environmental Strategies on behalf of the IPCC.
[16] IPCC. 2006.
[17] MoE 2012. *National Energy Policy – third draft*. Nairobi: MoE.
[18] In this case based on the IPCC landfill categorisations; methane is considered from MSW landfills of greater than five metres depth or with high water levels.
[19] Fischer *et al*. 2010.
[20] Fischer, E., Schmidt, T., Hora, S., Geirsdorf, J., Stinner, W., and Scholwin, F. 2010. *Agro-Industrial Biogas in Kenya: Potentials, Estimates for Tariffs, Policy and Business Recommendations*. Berlin: German International Cooperation (GIZ).
[21] UNEP. 1996. *International Source Book on Environmentally Sound Technologies for Municipal Solid Waste Management*, IECT Technical Publication Series 6. Nairobi: Division of Technology, Industry and Economics, UNEP.
[22] Frøiland Jensen, J.E. and Pipatti, R. 2000. *CH4 Emissions from solid waste disposal*. Hayama: Institute for Global Environmental Strategies on behalf of the IPCC. Accessed at: http://www.ipcc-nggip.iges.or.jp/public/gp/bgp/5_1_CH4_Solid_Waste.pdf
[23] Chicago Climate Exchange, Inc. 2009. *Renewable Energy Systems Offset Project Protocol*, Chicago: Chicago Climate Exchange, Inc.
[24] Chicago Climate Exchange, Inc. 2009. *Landfill Methane Collection and Combustion Offset Project Protocol*. Chicago: Chicago Climate Exchange, Inc.
[25] Fischer *et al*. 2010.
[26] City Council of Nairobi. 2007. *Dandora – Feasibility study: Developing a new dumpsite of regional acclaim*. Nairobi: City Council of Nairobi.
[27] Fischer *et al*. 2010.

[28] UNEP. 2005. *Selection, Design and Implementation of Economic Instruments in the Solid Waste Management Sector in Kenya: The Case of Plastic Bags*. Geneva: Economics and Trade Branch, UNEP.
[29] UNEP. 2006. *City of Nairobi Environmental Outlook*. Accessed at: http://www.unep.org/DEWA/Africa/docs/en/NCEO_Report_FF_New_Text.pdf
[30] There is no landfill gas capture and flaring assumed. All methane is considered to be collected for electrify generation and that all the gas collected is used for power generation, not all the gas formed.
[30] In that study minimum and maximum values are calculated by low respectively high dry-matter content, organic matter content, biogas potential, methane content and conversion efficiency (combined heat and power) values.
[31] Fischer et al. 2010.
[32] The authors heard presentations from www.multriwell.com and www.trisoplast.com.
[33] Energy Sector Management Assistance Program. 2007. *Technical and Economic Assessment of Off-grid, Mini-grid and Grid Electrification Technologies*. Washington, D.C.: The World Bank.
[34] Netherlands Ministry of Foreign Affairs, 2007. *Clean and sustainable? An evaluation of the contribution of the Clean Development Mechanism to sustainable development in host countries*, IOB Evaluations, no. 307. The Hague: Netherlands Ministry of Foreign Affairs.
[35] In this respect, the direct use of landfill gas as an alternative fuel may be simpler than power generation.
[36] ClimateTechWiki. 2011. *Methane Capture at Landfills for Electricity and Heat*. Accessed at: http://climatetechwiki.org/technology/lfg_cap.
[37] International Energy Agency. 2009. *Turning a Liability into an Asset: the Importance of Policy in Fostering Landfill Gas Use Worldwide*. Paris: International Energy Agency.
[38] Spokas, K. 2007. "Methane: Signs of Progress along the Road," *Waste Management*, 27(4).
[39] This is a trade-off with GHG emissions, increasing landfill use will lead to increased methane emissions due to higher levels of anaerobic digestion, but it also increases the opportunities for methane capture and reduces the health problems associated with dumping.
[40] Fischer *et al.* 2010.