Environmental Policy Update 2012:
Development Strategies and Environmental Policy in East Africa

Chapter 6. Waste Management for Social and Environmental Benefits in Ethiopian Cities

Kelly Kneeland & Björn Knutson
Environmental Policy Update 2012: Waste Management for Social and Environmental Benefits in Ethiopian Cities

By Kelly Kneeland & Björn Knutson

Executive Summary

This report provides an analysis of the municipal waste management practices in urban centers of Ethiopia and the social, environmental and economic implications associated with the waste management process. As a developing country with population growth and urbanization rates that are currently exceeding economic growth, Ethiopia faces stresses on finite resources and environmental impacts related to inefficient energy and waste management.

The 1991 decentralization of Ethiopia’s government into semi-autonomous states aggravated the already disorganized systems of waste management, healthcare, and education. Though the federal and state governments have begun establishing policies to address these basic issues, there is a great need for improved implementation of formal waste management.

A literature review and case study analysis showed numerous factors hindering the implementation of sustainable waste management thus far. These factors include institutional weaknesses, high initial cost of implementation, lack of issue salience for the benefits of improved waste management, and a lack of skilled workers. Furthermore, Geographic Information Systems (GIS) analysis demonstrated lack of paved infrastructure necessary to support sustainable waste management practices. Finally, interviews highlighted potential for landfill gas recovery projects in Ethiopia.

Waste management practices differ among all urban centers of Ethiopia. However, even in the cities with the most developed systems, the opportunities for improved waste management are largely applicable to all of Ethiopia. During primary stages of waste management, opportunities include improved separation, collection, and transportation. At secondary stages, opportunities for improved management include formal recycling, composting, the establishment of sanitary landfills and landfill gas utilization technologies.

Specific policy recommendations could aid the transition to improve sustainable waste management in Ethiopia. First, formalization of primary and secondary waste management will reduce environmental, social and economic impacts. Next, there is a need for prioritized investments in efficient waste transportation vehicles, paved infrastructure, and education. Finally, the government could utilize Clean Development Mechanisms to promote landfill gas technologies. Together these recommendations could improve waste management throughout Ethiopia to reduce social and environmental impacts of pollution and climate change.
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Introduction

Ethiopia, like all developing nations in East Africa, currently faces waste management challenges related to over-accumulation on open land, water pollution, and overall public nuisances such as pests, diseases, and odors (Edwards, 2010). Municipal solid waste, which is any material discarded by the primary user in an urban area, contributes to about 70 percent of total waste generated in Ethiopia (Fikreyesus, 2011; Wakjira, 2007). Both biodegradable and non-biodegradable waste products can produce negative environmental, social and economic effects. Biodegradable pollutants are waste materials that can decompose naturally, but these pollutants can still become a problem when added to the environment faster than they can decompose (Filaba, 2008). Non-biodegradable pollutants are materials that either do not decompose or decompose very slowly. These pollutants become extremely difficult to remove once released into the environment (Filaba, 2008). Although the Ethiopian government has begun taking steps to address the environmental and social challenges associated with municipal waste, there remains a great deal of inefficiency in, and environmental degradation as a result of, current waste management systems (Regassa, Sundaraa, & Seboka, 2011a).

This chapter explores Ethiopia’s current and future options for waste management, highlighting the many environmental and social complexities associated with economic development and growing waste production. As Ethiopia’s population grows exponentially, the stresses on finite resources and the environmental impacts of increasing waste become more prominent (Regassa, Sundaraa, & Seboka, 2011b). Because Ethiopia’s Gross Domestic Product (GDP) has remained relatively constant in recent years, its rate of urban growth is accelerating faster than that of the economy (German Federal Ministry of Education and Research, 2012a). This creates a need for more efficient uses of limited resources. One of the most pressing environmental concerns in Ethiopia today is the lack of energy accessibility for household needs such as cooking and heating (International Energy Agency, 2012). This energy poverty, along with other intensifying social issues such as groundwater contamination and exposure to hazardous materials, underscores the need for sustainable development strategies. The consequences of improper waste disposal, resource depletion, and social inequality also relate to the growing effects of global climate change. In 2009, methane produced during waste landfilling accounted for 17% of global methane emissions (FDR EPA, 2011). An alternative waste disposal method to landfilling is waste-to-energy technology, which reduces greenhouse gas emissions and is financially viable due to the revenues from energy production (Sabiiti, 2011).
This chapter provides an overview of Ethiopia’s existing waste management practices and evaluates the social and environmental impacts of proposed projects to improve waste management systems in the country.

Specifically, this chapter asks:

- What are the social and environmental implications of waste management in established and emerging Ethiopian cities?
- What are options to improve the sustainability of waste collection and transportation in the capital city of Addis Ababa?
- What are possibilities for improving waste management in emerging Ethiopian cities to mitigate climate change?

Past studies examining waste management in the Addis Ababa municipality have found that existing waste management systems are outdated and that there is a great deal of potential for improving the sustainability and efficiency of waste collection, transport, processing, and disposal (Alem, 2007; Regassa et al., 2011a; Speck & Fh, 2011). Meanwhile, smaller but rapidly growing cities such as Mekele, Dire Dawa, and Jimma have relatively new waste management systems that take advantage of technologies such as pre-landfill sorting, composting, and methane venting from landfills (Fikreyesus, 2011). However, these studies also highlight the difficulties inherent in introducing new strategies to a poorly established municipality. This chapter investigates these challenges and provides policy recommendations that seek to reduce the environmental impacts of waste management.

This chapter includes four main sections. It begins by describing the history of waste management in Ethiopia, followed by a comparative case study analysis of current waste management practices in Addis Ababa and smaller Ethiopian cities. The chapter concludes with a discussion and policy recommendations to improve waste management practices and waste-to-energy conversion. As this research seeks to identify more sustainable options for waste management and waste-to-energy conversion in urban centers of Ethiopia, the target audience for this study includes Ethiopian policymakers and urban planners involved in the waste management process.

**Methods**

In order to determine the options for improved sustainable waste management and waste-to-energy technology, this research uses five methods. First, extensive literature review of the institutional context related to current practices provides potentials for improved sustainable waste management and waste-to-energy conversion practices in Addis Ababa and smaller emerging Ethiopian cities. Second, Geographical Information Systems (GIS) explore paved roads in Addis Ababa in relation to
the four planned waste transfer stations. This research completes case comparisons of Addis Ababa and smaller emerging urban centers identifying opportunities for improved waste management systems throughout the entire country. This chapter also analyzes the role for biogas technology in urban Ethiopian centers and the potential for international finance in support of these projects through an interview with an expert in the waste-to-energy field.

Background of Waste and Resource Management

The Federal Democratic Republic of Ethiopia first recognized citizens’ rights to live in a “clean and healthy environment” in 1994, with the provisions of Articles 44.1 and 44.4 of the Constitution (Alem, 2007). Ethiopia’s government first approved environmental policy provisions in 1997. These recognized the need to promote conditions for domestic solid waste disposal, community education of sustainable waste management, standards for sanitation technologies across all socioeconomic groups, and partnerships among the government, communities, and NGOs for an integrated sanitation system (Alem, 2007). In 2002, the government passed the Environmental Pollution Control Proclamation, establishing pollution monitoring and environmental quality standards for air, water and soil (Unifruit Ethiopia, 2011). Ethiopia established the most recent and concrete federal law related to waste management in 2007 as the Solid Waste Proclamation, mandating safe, designated waste sanitation areas for people and the environment, as well as household separation of recyclables and community-level waste management plans (Federal Democratic Republic of Ethiopia, 2007). Although this proclamation also requires any person transporting or treating municipal solid waste to obtain a permit from the Environmental Protection Agency, its implementation has lacked enforcement in many individual communities (Federal Democratic Republic of Ethiopia, 2007; Fikreyesus, 2011; Regassa et al., 2011a).

Like in all urban centers, the evolution of Ethiopia’s formal government has significant effects on today’s state of waste management. Addis Ababa has the longest history of formal waste management in Ethiopia, with a landfill system dating back to 1964 when the Repi landfill was established (Mahiteme, Management, Sustainability, & Ababa, 2005). However, relatively little has been done in other urban areas, with the exception of a few recent developments (Fikreyesus, 2011). The cities of Dire Dawa, Mekele, and Adama established municipal landfills in 2007, 2008, and 2010, respectively (Fikreyesus, 2011). Unlike the Repi landfill, these secondary cities have developed improved environmental protection technologies in their landfills, such as the application of cover material, a secured perimeter, and a leachate management system.

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1 Initial attempts to analyze efficient waste transportation routes using the government’s road data in Addis Ababa for the sustainable collection and separation analysis were unsuccessful due to inconsistency in the data.
Environmental Policy Update 2012

The Process of Waste Management

The sustainability of municipal waste involves efficiency measures at all steps of the process. Efficient waste management begins in the household. The initial disposal of waste determines the ways in which it can be utilized and processed further downstream (Tadesse, 2009). Separating waste into categories allows for the recycling and reuse of valuable materials without a trip to a landfill (Tadesse, Ruijs, & Hagos, 2008). The collection phase involves “not only the gathering or picking up of solid wastes from the various sources, but also the hauling of these wastes to the location where the contents of the collection vehicles are emptied” (Tchobanoglous, 2003). In Ethiopia, as in many developing countries, residents bring their waste to communal bins shared among neighborhoods (Wakjira 2007). This process affects the impacts of waste on the surrounding environment and people, and also contributes to individual incomes (Regassa et al., 2011a).

Transportation is also part of the collection process, as well as the later phases of waste management. Sustainable vehicle transportation is important in reducing gasoline consumption and exhaust emissions, both of which contribute to global climate change (Tchobanoglous, 2003). Finally, sustainable waste management involves the reuse, recycling, composting, or disposal of the products, all of which contribute to environmental and social impacts of the surrounding community (Hailu et al., 2008). There exists potential for a closed loop cycle of resources. Recycling involves “the recovery of materials for melting them, repulping them and reincorporating them as raw materials” (Wakjira, 2007). Compost entails converting decomposing organic waste to a rich peat product that can be used to increase soil fertility (Wakjira, 2007).

Energy Usage

Although many federal guidelines have recognized the need to reuse and recycle municipal waste for increased efficiency, the Ethiopian government has not formally mentioned provisions for waste-to-energy conversion. Today, less than ten percent of populations in 21 sub-Saharan African countries have access to electricity (Mshandete & Parawira, 2009). Without electricity, populations must find alternative fuel sources to meet their lighting, cooking, and heating needs. In Ethiopia, wood has been the main source of cooking fuel since the Axumite civilization (ca. 1000 B.C.-1000 A.D.), which has resulted in vast rates of deforestation and the loss of ecosystem services (Gebreegziabher, Mekonnen, Kassie, & Köhlin, 2010). Today, average wood consumption per capita is estimated to be 3kg per day (Sishuh personal communication, October 24, 2012).

One of the opportunities available for conversion of municipal waste-to-energy is the utilization of methane gas, which escapes into the atmosphere during the process of organic waste decomposition in the absence of oxygen (Mshandete & Parawira, 2009). This “biogas” is composed of 50-80% methane, 20-50% carbon dioxide, and small amounts of hydrogen, carbon monoxide, and nitrogen (U.S. Department of Energy, 2012). The technology itself is not new to Ethiopia. Approximately 1,000 biogas plants have been established in Ethiopia since 1979 (Boers & Eshete, n.d.). However,
anaerobic digestion of agricultural residue, rather than municipal solid waste, powers these biogas plants. Additionally, Ethiopia has vastly underutilized biogas technology due to poor management and lack of skilled workers (Boers & Eshete, n.d.).

**Federal Institutions**

*Ministry of Works and Urban Development*

The federal government developed the Ministry of Works and Urban Development (MoWUD) in 2005, which implements the Urban Development Policy (Fikreyesus, 2011). This policy aims to integrate all national urban policies, including the National Policy Framework for Grading and Defining Urban Centres, the Federal Urban Planning Law and Building Code, the Federal Housing Policy, the Federal Urban Planning Manual/Guideline, the Federal Urban Land Lease Policy, and the Federal Urban Capacity Building Strategies (United Nations Human Settlements Programme, 2008a). Additionally, this policy reaffirms regions as chief municipal authority over the federal government (United Nations Human Settlements Programme, 2008b). The Ministry of Works and Urban Development has the institutional authority to facilitate infrastructure development in municipalities; however, the Environmental Protection Authority (EPA) in Ethiopia takes authority over the vision for greenhouse gas reduction (United Nations Human Settlements Programme, 2008b).

*Ethiopian Environmental Protection Agency (EPA)*

In 2004, the Ethiopian EPA established two reports on guidelines for municipal waste management and composting. The municipal waste guidelines discuss environmental impacts, waste minimization, and options for collection and recovery (Ethiopian Environmental Protection Agency, 2004). The composting guidelines include definitions, types of composting processes such as anaerobic and aerobic, and situations in which composting practices are suitable options (The Federal Environmental Protection Authority, 2004). Recently, the Ethiopian EPA established an Environmental Management Program of the Plan for Accelerated Sustainable Development to Eradicate Poverty. This plan aims to improve public awareness of the current waste management system, evaluate and reduce waste pollution, enhance the possibilities for methane recovery in waste management, and increase stakeholder involvement in the process of waste management (FDR EPA, 2011). While the EPA guidelines are fairly comprehensive, there are no specific policies linked to these recommendations, and the desired effects have not been fulfilled.

The EPA’s largest responsibility is to ensure that all administrative levels and sectors are implementing formal environmental policies and laws (Fikreyesus, 2011). In order to ensure that these standards are carried out, the EPA has created environmental units within each regional state responsible for implementation. Called Units of Climate Resilient Green Economy (CGRE), these regional groups consider climate adaptation and greenhouse gas mitigation strategies in daily activity
(Fikreysus, 2011). Thus, this group holds responsibility for ensuring that the methane produced from landfill waste is not emitted into the atmosphere.

**Results**

Due to today’s globalizing economy and changing climate, it is important to understand the implications of policies across local, national and international scales regarding waste management, energy use and clean energy development. The decentralization of government in recent history has reduced the total available capital for many municipalities, which relatively increases the cost of waste management (Fikreysus, 2011). Consequently, improved understanding of the economic, social, and environmental aspects of current waste management systems will advance the sustainability of these systems.

**Current Waste Management Practices in Addis Ababa**

Addis Ababa, founded in 1887, is the capital city of Ethiopia and home to almost a quarter of all urban dwellers in the country (German Federal Ministry of Education and Research, 2012a). The Ministry of Health introduced the first Ethiopian sanitation service in 1958, providing guidelines for the construction of wells, drains, and garbage and sewer systems (Alem, 2007). In 1991 the country reorganized into a decentralized government comprised of nine semi-autonomous regional states. This conversion aggravated urban poverty and the decay of waste management, healthcare, and education (Alem, 2007). In response to these governmental weaknesses, “Addis Ababa became a chartered city with significant self-government rights” in 1997 (Alem, 2007). Governmental responsibilities were decentralized once more in 2003 when Proclamation Number 2 designated solid waste services to authorities at the sub-city and Kebele levels. This law also established the Sanitation, Beautification and Park Development Agency to design policies and regulations for solid waste management services (Alem, 2007). As the largest city in Ethiopia, Addis Ababa is especially subject to waste management challenges related to a growing population. Due to migration from rural areas, the city suffers a high rate of population growth, with a current population estimate of 4 million and a population projection of 12 million by 2024 (Speck & Fh, 2011).

A recent study on the history of municipal solid waste in Addis Ababa concluded that waste production has increased by 3.79% annually since 1993 (Regassa et al., 2011b). In 2010, Addis Ababa generated an estimated 0.4kg/capita of waste per day, with more than 200,000 metric tonnes collected each year (United Nations, 2010). Currently, 60% of the waste generated in the city is organic, while 15% is regarded as recyclable (Figure 1).
Addis Ababa established Repi, the only landfill in the city, in 1964. Repi is located in the Southwestern part of the city (Mahiteme et al., 2005). There are many problems associated with this landfill and its proximity to the center of the city, which is only approximately 13 miles away. These problems are a result of the lack of landfill coverage, poor rainwater drainage, limited fencing, no odor control, and an inaccurate measurement of daily waste weight (United Nations, 2010). Addis Ababa’s current waste management system first collects waste at bins placed throughout neighborhoods (Figure 2), then collects and transports this waste to the landfill. Since its establishment, Repi has emitted greenhouse gases (GHGs) into the atmosphere, resulting in odors which have affected both the local and global climate (Horn of Africa Regional Environment Centre and Network, 2012a). Although there is currently no legislation mandating landfill gas collection in Ethiopia, the Horn of Africa Regional Environmental Center (HoAREC), the EPA, and the United Nations Development Program have teamed together to complete a landfill gas collection and conversion system for the city (Horn of Africa Regional Environment Centre and Network, 2012a). By 2013, the project plans to close the Repi landfill as a collection facility and convert it to a landfill gas utilization facility. A new Addis Ababa landfill site planned for the outskirts of Sendafa will employ new and improved landfill management strategies. Additionally, four transfer waste bins placed in the corners of the city will improve separation and collection efficiency. Finally, this project is registered under the Gold Standard Foundation, which ensures socio-economic sustainability for all formal and informal stakeholders in the waste management process (Horn of Africa Regional Environment Centre and Network, 2012a).
A recent study on solid waste management in Addis Ababa lacked any findings on a comprehensive and city-wide solid waste management plan for the city (Alem, 2007). Although the city holds no power in raising its own revenue, a few sources of city-level income contribute to waste issues management. Five percent of each household water bill contributes to sanitation services. Additionally, the sale of Chat, which is a mildly intoxicating leaf that produces large quantities of waste from stem disposal, generates tax revenue (Alem, 2007).

Today, both formal and informal institutions play a role in determining the levels of sustainability and efficiency in Addis Ababa’s solid waste management system (Alem, 2007; German Federal Ministry of Education and Research, 2012a; HoAREC, 2012b; Regassa et al., 2011a). Additionally, there are specific points in each phase of waste management where sustainability can be improved. A 2011 study found five main inefficiencies in Addis Ababa’s current waste management system. These inefficiencies included poor infrastructure making most of the city inaccessible, lack of planned transportation routes and schedules, infrequent collection of collection containers, poor
truck maintenance, and poor waste reduction, recycling, and composting programs (Fikreyesus, 2011).

**Informal Institutions**

Informal workers sort the municipal solid waste of Addis Ababa in two different phases. At the first level, households sort out materials considered as valuables such as plastic, glass, and bottles for reuse. Additionally, door-to-door individuals buy or barter these valuable materials (Alem, 2007). Bartered material eventually ends up in the hands of middlemen, many of whom own small shops in Merkato - Addis Ketema Sub-City. One 2009 study found that between 2,200 and 2,700 resellers of valuable materials were counted upon entering the market (German Federal Ministry of Education and Research, 2012a). Because of its informal nature, the process of manual sorting through mixed household waste results in health risks. Workers are exposed to the risk of dermal injuries due to hypodermic needles, exposure to organic dusts, and physical strains due to the handling of heavy loads during the door-to-door collection, weighing and transferal (German Federal Ministry of Education and Research, 2012a).

At the second stage, collectors such as street boys and scavengers at both the collection centers and the landfill are responsible for the majority of the larger recyclable materials in the waste such as metal, wood, tires, electric products and shoes (United Nations, 2010). This material gets heavy very quickly, and many of these middlemen are often underweight due to both heavy labor and malnutrition. They also frequently report serious back problems (German Federal Ministry of Education and Research, 2012a). The landfill site sees about 200 to 300 waste pickers each day, scavenging for materials such as wood, metals, and even food (United Nations, 2010).

One quarter of municipal solid wastes generated in Addis Ababa go uncollected and dumped in unauthorized areas such as fields, ditches, sewers, and streets (Regassa et al., 2011a). A study in 2004 found that disposing of household waste into a river system is also a common practice. This is especially common in the Akaki Kality sub-city where the Akaki River seemed to be the sink for any waste. About 75% of study participants in this area admitted to burning organic waste together with the other solid waste in pits prepared for that specific purpose (Regassa et al., 2011a). While burning waste has the potential to produce usable outputs, “incineration on developing countries has historically been inefficient: incinerators built in Africa, Asia and Latin America did not function as promised. The moisture content of wastes was so high that fuel had to be added to maintain combustion, which increased costs significantly” (Wakjira, 2007).

Another study on informal dumping of waste found that residents are indeed willing to dispose of waste in old buckets or synthetic sacks when they are sure of getting services. Otherwise, many admitted to throwing wastes into rivers or a place already polluted, because communal containers are kept too far away from their homes (Alem, 2007). A 2007 study in Addis found that although the city has planned for all households to have a container within 200 meters of vicinity, only 48% the
households are located within this service area (Wakija, 2007). Additionally, many claim that the government does not properly collect and empty containers when full, causing the areas around them to become littered and foul smelling, thus encouraging illegal dumping (Edwards, 2010).

**Formal Institutions**

*Private Sector*

The private sector of waste management in Addis Ababa is responsible for the primary collection of municipal waste from individual households to the collection points throughout the city (Alem, 2007). This level of waste management includes roughly 750 enterprises, including NGOs, small companies, and individuals, often of a poor or younger status (Regassa et al., 2011a). Equipped with less than a dozen vehicles and simple tools such as pushcarts and shovels, these small-scale enterprises charge households about $0.33 to $0.56 USD for bi-weekly collection of household waste (Alem, 2007). Administrators at the Woreda (sub-city) level are responsible for collecting these fees and paying the private groups for pre-collection (Fikreyesus, 2011).

*Kebele*

The Kebele level of government is the smallest division in Addis Ababa, which is comprised of about 240 total Kebeles (Alem, 2007). A 2004 regulation gives responsibility to the City-level Sanitation Beautification and Park Development Agency to educate the community on sanitation, play an intermediary role between the community and Kebele Administration, monitor illegal disposal of wastes, facilitate removal, and find solutions to sanitary problems. However, there is little organized management in waste above the Kebele level (Alem, 2007). Instead, the local Cleaning and Beautification Department within each Kebele organization takes responsibility for the secondary waste management collection and transportation from collection sites to the Addis Ababa landfill (Regassa et al., 2011a).

The municipality currently collects 85% of the waste from containers and dumps it in the open landfill site (Fikreyesus, 2011). However, a much lower percentage of actual trips are currently conducted in relation to the city’s planned number of trips to the landfill from collection sites. In 2010, the municipality achieved an average target of 58% of total planned transportation trips (Fikreyesus, 2011). These performance rates vary among sub-cities (Table 1). Municipalities less central to the city infrastructure tend to plan fewer trips from collection sites (Nelson, 2012).
Table 1. Number of waste transportation trips by municipality vehicles in 2010.

<table>
<thead>
<tr>
<th>Sub-city</th>
<th>Number of Planned Trips</th>
<th>Percentage of Completed Trips</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nefa Selk</td>
<td>19,440</td>
<td>85.25</td>
</tr>
<tr>
<td>Bole</td>
<td>20,160</td>
<td>70.17</td>
</tr>
<tr>
<td>Akaki</td>
<td>12,600</td>
<td>69.25</td>
</tr>
<tr>
<td>Kirkos</td>
<td>21,600</td>
<td>60.27</td>
</tr>
<tr>
<td>Yeka</td>
<td>28,800</td>
<td>56.36</td>
</tr>
<tr>
<td>Addis Ketema</td>
<td>16,200</td>
<td>55.51</td>
</tr>
<tr>
<td>Gulely</td>
<td>20,160</td>
<td>54.59</td>
</tr>
<tr>
<td>Ldeta</td>
<td>28,800</td>
<td>54.48</td>
</tr>
<tr>
<td>Kolfy</td>
<td>25,200</td>
<td>46.97</td>
</tr>
<tr>
<td>Arada</td>
<td>25,200</td>
<td>40.27</td>
</tr>
</tbody>
</table>

(FikreYESUS, 2011)

The greatest inefficiencies in collection rates are associated with frequent breakdown of transportation vehicles (Alem, 2007; Edwards, 2010; German Federal Ministry of Education and Research, 2012a). Additionally, as shown in Figure 3, many of the sub-cities listed with lower rates of completed transportation trips are located in the areas densest in paved roads. One study found that “lack of proper access roads and the terrain of many urban areas that make some neighbourhoods, particularly the most densely populated areas, inaccessible for waste collection” (Edwards, 2010). This suggests challenges are related to both efficient planning and adequate infrastructure.

Although the Filidoro and Koche transfer stations are located closer to the paved infrastructure, the remaining two stations are not located on a paved road. Additionally, Bole Arabasa is located in a portion of the city containing no paved roads whatsoever, thus this trip is increasingly inefficient due to the difficulties associated with transportation on dirt roads and pedestrian walkways.
IGNIS

Income Generation & Climate Protection by Valorising Municipal Solid Wastes in a Sustainable Way in Emerging Mega-Cities (IGNIS) is a multilateral institution sponsored by the German Federal Ministry of Education and Research. IGNIS partners with multiple organizations from Germany have also piloted this program, including AT-Verband / AT-Association, the Institute for Sanitary Engineering, Water Quality and Waste Management, the Institute for Future Energy Systems, and the Federal Institute for Occupational Safety and Health (German Federal Ministry of Education and Research, 2012a). Founded in 2008, this project has established pilot projects in the city of Addis Ababa in order to complete studies concluding that “municipal solid waste will contribute to job creation and will have positive effects on greenhouse gases and other emissions” (German Federal Ministry of Education and Research, 2012a). Projects include composting of organic waste, a youth group biolatrine, occupational safety improvement of waste collectors, paper recycling, charcoal production from waste by a women’s group, organic glove production for women with fistula, plastic recycling, metal recycling, and erosion prevention (Speck & Fh, 2010, 2011; German Federal Ministry of Education and Research, 2012).
A few of the sustainable waste management studies by IGNIS have already resulted in successful projects in Addis Ababa. In a preliminary study, IGNIS concluded a successful and sustainable establishment of a biogas facility with $16\text{m}^3$ fermenter capacities (German Federal Ministry of Education and Research, 2012). The Addis Ababa Institute for Technology (AAIT) installed and operates this project. Another preliminary study on charcoal brick production found that garden waste can be introduced as an input into carbonization in replacement of tree cuttings. This process reduces emissions, empowers the women’s group that it exclusively employs, and educates all stakeholders involved about the issue of deforestation (German Federal Ministry of Education and Research, 2012b). Finally, the small-scale paper recycling project has not only reduced waste products, but also reduced the amount of new raw material needed to produce paper. Additionally, workers involved benefit from this employment. This study found that the salary of the small-scale paper recycling operator is five times greater than that of his previous occupation (Sabiiti, 2011).

**Horn of Africa Regional Environmental Centre and Network**

The Horn of Africa Regional Environmental Centre and Network (HoAREC) is a non-governmental institution under Addis Ababa University, with a mission to “improve environmental governance and management in the Horn of Africa Region, encompassing Ethiopia, Sudan, Djibouti, Kenya, Somalia and Eritrea” (HoAREC, 2012b). Promoting more than 40 local member organizations, the network facilitates cooperation to “enhance environmental governance and management, contribute to sustainable development, and improve livelihoods within the region” (HoAREC, 2012b).

HoAREC plans to complete the Repi conversion project by 2013 (HoAREC, 2012a). Through a GIS analysis of the provided road data in Addis Ababa, there is currently a lack of adequate paved road infrastructure to allow for the most efficient transportation of waste from the primary collection containers to the planned transfer stations, and finally to their determined sites (Figure 3).

**Opportunities for Improved Sustainable Waste Management in Addis Ababa**

**Landfill Gas Utilization**

In addition to national laws governing the waste management system in Ethiopia, a number of international institutions are currently involved in the improvement of sustainable waste and energy capture management. As shown in Table 2, the United Nations and the Global Methane Initiative are both working to improve clean energy use as an alternative to environmentally degrading exploitation of limited natural resources.
Table 2. Institutions promoting GHG reductions & landfill gas utilization.

<table>
<thead>
<tr>
<th>Scale of Influence</th>
<th>Institution</th>
<th>Partners</th>
<th>Development Initiatives</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>International</strong></td>
<td>United Nations&lt;sup&gt;1&lt;/sup&gt;</td>
<td>Horn of Africa Regional Environment Centre and Network, Addis Ababa City Administration</td>
<td>The Kyoto Protocol and the ensuing Clean Development Mechanisms (CDM)</td>
</tr>
<tr>
<td><strong>International</strong></td>
<td>Global Methane Initiative&lt;sup&gt;2&lt;/sup&gt;</td>
<td>38 Governments, the European Commission, Asian Development Bank, Inter-American Development Bank</td>
<td>Global Methane Initiative</td>
</tr>
<tr>
<td><strong>National</strong></td>
<td>4REnergy&lt;sup&gt;3&lt;/sup&gt;</td>
<td>Ethiopian Environmental Protection Agency, HoAREC</td>
<td>Repi landfill gas flaring project</td>
</tr>
<tr>
<td><strong>International</strong></td>
<td>HoAREC</td>
<td>Ethiopian Environmental Protection Agency, 4REnergy</td>
<td></td>
</tr>
</tbody>
</table>

(Sources listed in Appendix 6A.)

**United Nations**

The United Nations established the Kyoto Protocol in 1997 as part of the United National Framework Convention on Climate Change to limit global greenhouse gas emissions. The protocol includes three options called “flexible mechanisms” available for Annex I countries to help achieve their emissions reduction goals. One of these flexible mechanisms is the Clean Development Mechanism (CDM), which allows countries to invest in emissions reduction projects in developing countries and consequently earn certified emissions reduction (CER) credits. Countries possessing CER credits can then sell them to other Annex I countries, who can then count them towards their reduction commitments. Since 2004, CDM projects have resulted in the mitigation of 1 billion tonnes of CO2 equivalents in developing countries (UNFCCC, 2012). While there is significant potential for CDM projects in Ethiopia, currently there is only one registered CDM project in the country, which focuses on forestry management (UNDP, 2012). The capture of methane released from urban landfills could not only be beneficial in terms of reducing greenhouse gas emissions, but also by reducing dependence on forests for fuel. Although the current Kyoto Protocol commitments expire at the end of 2012, parties have committed to another period ending in 2017 or 2020 (UNFCCC, 2012).
Global Methane Initiative

The Global Methane Initiative is a multi-lateral institution, formerly known as the Methane to Market Partnership, that seeks to reduce global methane emissions and expand the scope of clean energy technology. Currently, there are 40 member countries involved in this initiative, including Ethiopia. As Ethiopia is the only member country in East Africa, there is great potential for Ethiopia to establish itself as a leader in climate change mitigation and biogas technology (Global Methane Initiative, 2012).

4R Energy

4R Energy is a private institution that is focused on creating a new business environment centered on alternative energy, specifically biogas. 4R Energy, the Ethiopian EPA, and the Horn of Africa Regional Environmental Center (HoAREC) have formed partnerships to reduce the rate of deforestation, fight poverty by creating new jobs, increase energy accessibility, and make waste valuable (Sishuh, personal communication, October 24, 2012).

The Repi landfill will be the first in Ethiopia to implement a methane gas utilization system. Initially, HoAREC and the Ethiopian Electric Power Corporation (EEPCO) planned to install a system that would produce 1.7 megawatts of electricity through a landfill gas capture conversion process (HoAREC, 2012). This project would have provided enough electricity to supply 8,000 homes in Addis Ababa and significantly reduce greenhouse gas emissions. Through cooperation with the United Nations Development Program, HoAREC planned to register this project as a Clean Development Mechanism, which would have delivered a source of revenue for the Addis Ababa administration (HoAREC, 2012). However, due to high initial costs of establishing the landfill gas capture system, HoAREC and EEPCO altered the construction plans and are currently working to complete a landfill gas flaring system instead (Sishuh personal communication, October 24, 2012).

As Figure 4 illustrates, this project has the potential over the next 17 years to reduce carbon emissions by 1,784,862 tonnes and destroy 84,993 tonnes of methane (Fikreyesus, 2011).
A more recent study by 4REnergy estimated that upon the 2013 onset of flaring, 187,369 tonnes of carbon emissions and 8,935 tonnes of methane will be mitigated per year.

Recycling

Although many informal levels recycle municipal waste throughout Addis Ababa, studies have concluded that the establishment of a formal recycling system could significantly contribute to economic sustainability. In addition to reducing environmental pollution, extraction of limited resources, and the amount of waste needing management, a formal recycling system would create employment for thousands of people and contribute to 0.5% of the total GDP in Ethiopia (Fikadu, 2008).

Current Waste Management Practices in Emerging Cities

Waste management in Addis Ababa is fundamentally different from other emerging cities of Ethiopia. There has been no form of waste management in emerging cities until very recently.
A few of these new municipalities, as seen in Figure 5, were designed to decrease human exposure to unsanitary conditions and environmentally degrading practices. Yet, as Table 3 illustrates, the collection and management of waste in most of the municipalities is still quite inefficient.

![Waste Generation Rates in 8 Ethiopian Cities](image)

Figure 5. Waste generation rates in growing Ethiopian cities.

Two exceptions, Mekele and Dire Dawa, have recently experienced promising results for improved waste management and waste-to-energy conversion through biogas capture from landfills using both technical and institutional strategies (Fikreyesus, 2011). International financing, such as the Clean Development Mechanisms, could support the transition to sustainable waste management in these emerging cities, similar to the Addis Ababa municipality. Although most emerging cities have not developed formal waste management systems comparable to that of Addis Ababa, it is important to recognize what has been established thus far so that all systems can develop more sustainably.
Table 3. Ethiopian municipalities and waste generation, 2010.

<table>
<thead>
<tr>
<th>City</th>
<th>Region</th>
<th>Population</th>
<th>Municipal Solid Waste Generation</th>
<th>Municipal Solid Waste Collection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Addis Ababa</td>
<td>Addis Ababa</td>
<td>2,979,100</td>
<td>1,132 tonnes/day</td>
<td>70% collected</td>
</tr>
<tr>
<td>Mekele</td>
<td>Tigray</td>
<td>261,200</td>
<td>78 tonnes/day</td>
<td>82% collected</td>
</tr>
<tr>
<td>Dire Dawa</td>
<td>Dire Dawa</td>
<td>256,800</td>
<td>77 tonnes/day</td>
<td>48% collected</td>
</tr>
<tr>
<td>Jimma</td>
<td>Oromia</td>
<td>120,960</td>
<td>87 tonnes/day</td>
<td>30% collected</td>
</tr>
<tr>
<td>Nazret (Adama)</td>
<td>Oromia</td>
<td>260,600</td>
<td>59 tonnes/day</td>
<td>48% collected</td>
</tr>
<tr>
<td>Bahir Dar</td>
<td>Amara</td>
<td>170,300</td>
<td>27 tonnes/day</td>
<td>58% collected</td>
</tr>
<tr>
<td>Awasa</td>
<td>SNNPR</td>
<td>200,400</td>
<td>46 tonnes/day</td>
<td>44% collected</td>
</tr>
<tr>
<td>Harer</td>
<td>Harari</td>
<td>108,200</td>
<td>32 tonnes/day</td>
<td>45% collected</td>
</tr>
</tbody>
</table>

(Central Statistical Agency of Ethiopia, 2010; Fikreyesus, 2011; Getahun et al., 2011)

The city of Jimma faces waste management challenges primarily related to socioeconomic barriers. Only 25% of the city currently utilizes the municipal waste collection containers (Getahun et al., 2011). While citizens of higher income can afford private or municipal waste collection, most citizens can only afford to burn or dump household waste in an open area (Getahun et al., 2011). An analysis of waste composition in Jimma reveals ideal levels of moisture content in waste, creating a large potential for compost of organic material (Getahun et al., 2011).

Mekele is another Ethiopian city that has recently increased solid waste generation but lacks management to accommodate the growing rates of waste. The municipality currently offers poor disposal services throughout the city, with a total of 58 collection containers (Tadesse et al., 2008). Final collectors dispose of waste in two open dumping sites about 10km outside of the city (Tadesse et al., 2008).

The city of Dire Dawa currently collects and disposes only half of all solid waste produced (United Nations Human Settlements Programme, 2008a). Additionally, the city owns only one waste collection vehicle. Unlike Addis Ababa, where the private sector has communication ties with the government, Dire Dawa’s municipality manages all waste without the consultation of private groups (United Nations Human Settlements Programme, 2008a). There is also no attempt to sort or recycle wastes apart from common scavengers. With low water tables, Dire Dawa is especially vulnerable to ground and surface water pollution (United Nations Human Settlements Programme, 2008a).

It is increasingly apparent that local institutions, the Ethiopian federal government, non-governmental organizations, and international organizations dedicate themselves to sustainable waste management in Ethiopia. As Table 4 illustrates, a number of projects are underway to convert or construct sanitary landfills in the cities of Addis Ababa, Dire Dawa, Mekele, and Adama. Since 2009, sanitary landfill projects have been established in each of these municipalities (HoAREC, 2012).
Table 4. Technologies utilized by municipalities, 2010.

<table>
<thead>
<tr>
<th>City</th>
<th>Year Landfill Established</th>
<th>Sanitary Landfill</th>
<th>Secured Perimeter</th>
<th>Pre-landfill Sorting</th>
<th>Landfill Gas Management</th>
<th>Leachate Managed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Addis Ababa</td>
<td>1964</td>
<td>Currently In Construction</td>
<td></td>
<td>(Flaring System Proposed)</td>
<td>Currently In Construction</td>
<td></td>
</tr>
<tr>
<td>Dire Dawa</td>
<td>2007</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>Venting System (Flaring System Proposed)</td>
<td>✓</td>
</tr>
<tr>
<td>Mekele</td>
<td>2008</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>Venting System</td>
<td>✓</td>
</tr>
<tr>
<td>Adama</td>
<td>2010</td>
<td>✓</td>
<td></td>
<td></td>
<td>Venting System</td>
<td></td>
</tr>
</tbody>
</table>

(Fikreyesus, 2011 & HoAREC, 2012)

Sanitary landfills include the following characteristics:
- Leachate management
- Landfill gas management
- Soil cover applications
- Environmental monitoring systems

Maintaining a multifaceted leachate management system prevents leachate, which is a composition of water, decomposed waste, and bacteria, from percolating through the soil and contaminating ground and surface waters (Fikreyesus, 2011 & Graf, 1999). Additionally, after collectors dispose of waste into sanitary landfill, at least 6 inches of soil are applied as a cover layer after each day of operation (Tchobanoglous, 2003). This soil cover offers a number of benefits such as reducing fire hazards and odors and controlling the venting of methane (Graf, 2007). A secured perimeter tends to reduce the spread of diseases and can improve public health, as it does not allow pests and other vectors to enter or exit the landfill (Fikreyesus, 2011).

The Dire Dawa, Mekele, and Adama landfills all employ venting systems to reduce the pressures from decomposition and methane accumulation below the surface layers (Tchobanoglous, 2003). Additionally, the Dire Dawa and Addis Ababa municipalities have proposed to implement landfill gas flaring technologies, which destroy methane before it is released into the atmosphere (Fikreyesus, 2011).
Opportunities for Improved Sustainable Waste Management in Ethiopia

There is currently a disparity in waste management practices between urban locations. However, along with recycling, landfill gas utilization, and sanitary landfills, which are already being implemented throughout Ethiopia, there are a number of additional practices that could be uniformly utilized in all areas of Ethiopia. These include composting, education, and international financing.

Composting

Although this research found no evidence of formal institutions currently composting organic waste in Addis Ababa, there exists potential for composting material in sustainable waste management. City-level compost initiatives usually involve technology-intensive designs offering a better product quality, but they are generally more costly in most developing countries. Thus, the intermediate, community-level composting initiatives are most applicable to conditions in East Africa. These initiatives generally require more physical labor and offer flexibility to adapt to changes in the economy (Oberlin & Szántó, 2011). A 2011 study found “no overview published so far on the viability of community-level composting activities in East African municipalities” (Oberlin & Szántó, 2011). Composting could contribute to food security, as it can enhance crop production through organic fertilizers, in an area where per capita production continues to decrease while the population grows. Organic compost produces an environmentally safe material composed of nitrogen, phosphorus, potassium important for improving nutrient status of soils in urban agriculture (Sabiiti, 2011).

Education

Addis Ababa residents’ knowledge of the social, environmental, and economic aspects of sustainable waste management contributes greatly to the overall efficiency of the waste management system. One of the largest problems related to sustainable waste management at the community level throughout Ethiopia continues to be lack of promotion and education about waste reduction, recycling, recovery, composting and energy generation (Edwards, 2010). A 2011 study in Ethiopia found that “municipal waste containers were least utilized by the illiterate families and most utilized by families with education level of grade 12 and above. This is because of the impact of education on behavior of individuals and its association with employment, income, and increased awareness on environmental protection” (Getahun et al., 2011). The EPA’s report on Environmental Management Programme of the Plan for Accelerated Sustainable Development to Eradicate Poverty cites one of the main problems in sustainable environmental management as limitation in awareness about sustainable use of resources (FDR EPA, 2011). Finally, many residents simply do not understand the economics of waste: in a 2008 survey of attitudes toward solid waste in Ethiopia, about 58% of respondents believed that solid wastes were completely useless (Tadesse et al., 2008). Lack of awareness for these issues has hindered the implementation of improved waste management thus far.
International Financing

Aside from the initial cost of constructing landfill gas capture systems, the current CDM methodology standards are a barrier to implementation. As there is no pipeline for landfill gas distribution, bottling projects are the most environmentally and economically beneficial options for utilizing landfill gas. However, today there are no pre-approved methodologies for large-scale landfill gas recovery projects that exceed 60,000 tonnes (Sishuh personal communication, October 24, 2012). Thus, landfill gas flaring projects have been promoted instead, which do not capture the energy or revenues that bottling projects have shown potential for.

In addition to the United Nation’s Clean Development Mechanisms, there have been other recent financing options to incentivize sustainable waste management. The French Development Bank has primarily funded the improvement of solid waste management, while the World Bank has focused efforts to improve water quality through the construction of waste water treatment plants (Sishuh personal communication, October 24, 2012). The African Development bank is taking a comprehensive approach by granting funds for improved collection and utilization of waste in Addis Ababa, as well as emerging cities such as Dire Dawa, Awasa, Mekele, and Bahir Dar (Sishuh personal communication, October 24, 2012).

Discussion

Currently there are many social, environmental, and economic issues associated with waste management that require attention in Ethiopia. There is opportunity for all stages of waste management to become more efficient. Although Addis Ababa has the most developed waste management system in Ethiopia today, there are still flaws in the current system. The lack of a city-wide waste management plan in Addis Ababa suggests that much inefficiency in the system is due to poor communication and poorly established authority boundaries between sub-city and Keble levels. Since Addis Ababa is still struggling with these institutional issues, all emerging cities are subject to the same challenges.

While there is no formalized recycling waste in urban centers in Ethiopia, there are opportunities to establish a sustainable recycling system. With more efficient sorting and collection processes, the government has the ability to not only profit economically from a formal recycling system, but also reduce landfill waste and the need for natural resource extraction. The preliminary economic and environmental success of a small paper recycling system through IGNIS suggests that a larger system could be successful in urban locations.

Just as the solid waste system in Ethiopia can improve with recycling, it can also improve with the reuse of organic waste through composting. The current composition of waste in Addis Ababa today suggests ideal conditions for this strategy. Additionally, this process could improve food
security in an environmentally sustainable manner, contributing to both social and economic progress in Ethiopia today.

The pre-sorting process of waste involves inefficiencies related to human health and the environment. As no governmental institutions are involved in this step, regulation is difficult. Scavengers, who make their living from the pre-sorting process, often suffer from exposure to hazardous waste materials. Additionally, the informality of the pre-sorting process leads to inefficiencies in recycling and composting both economy and environmentally. Moreover, the simple dumping of waste into open areas or bodies of water significantly contributes to environmental degradation (Sishuh personal communication, October 24, 2012).

The collection process of waste management is also socially, economically, and environmentally inefficient. The Addis Ababa government is involved in the secondary collection of waste; however, informal and private institutions must be better recognized and regulated during primary collection. Waste collectors are exposed to health issues such as respiratory illnesses and heavy loads; thus, there exists a need for improved safety standards and efficient collection tools. Informal dumping and pollution on streets due to infrequent collection of bins suggests a need for better planned and more frequent waste collection.

Transportation is one of the largest barriers to sustainable waste management systems in Ethiopia today. Through a GIS analysis and extensive literature review, it is clear that many areas lack adequate infrastructure to support waste transportation vehicles. Upgraded transportation vehicles would reduce the human health impacts related to current waste management systems. Additionally, more efficient use of vehicles would reduce the economic costs of sustainable waste management and the environmental impacts associated with infrequent collection of waste and exhaust emissions related to inefficient transportation trips.

The need for greater awareness and education is relevant in all steps of the waste management process, as residents will not be inclined to make changes to their actions without proper understanding of the need to do so. Although government and private institutions can increase sustainable waste management practices, non-governmental organizations could have the largest impact in educating citizens about sustainable waste management practices.

Manipulating the final byproducts of waste management could minimize social and environmental consequences while maximizing economic benefits. Landfill gas technology is essentially a renewable resource as waste is constantly produced. This alternative energy source reduces methane emissions and displaces the use of wood, charcoal, and kerosene (Sishuh personal communication, October 24, 2012). Although it is currently not technically feasible in Ethiopia, compressed landfill gas could eventually be bottled and transported to households and businesses. This is the best strategy for utilizing landfill gas in Ethiopia, because there is no pipeline to distribute this gas from landfills to consumers (Sishuh personal communication, October 24, 2012).
While there is currently no national legislation requiring city-wide waste management plans or waste-to-energy utilization, a few city administrations are taking steps to make improvements on a local scale. Unfortunately, a number of institutional and financial challenges have hindered the implementation of national sustainable waste management practices. The decentralization of Ethiopian governments reduced the total available capital for many municipalities, which increased the relative cost of waste management and reprioritized city administration goals. Furthermore, it is difficult for the private sector to gain loans within Ethiopia for renewable energy projects due to a high level of default risk associated with these projects (Fikrevesus, 2011). It is evident that the institutional structure within Ethiopia could benefit from international financing. The recent investments in both Addis Ababa and emerging cities are promising for future development of sustainable waste management projects.

**Policy Recommendations**

Our research suggests that the following policy recommendations could aid the transition to improve sustainable waste management. First, our findings show a need for formalized primary and secondary waste management, as this would reduce human exposure to hazardous materials, internalize economic benefits, and reduce social and environmental impacts of pollution. Next, there is a need for prioritization of investments in efficient waste transportation vehicles, paved infrastructure through the Bole Arabasa and Akaki waste transfer stations in Addis Ababa, and education about the benefits of sustainable waste management. Finally, the government could utilize the United Nations Clean Development Mechanisms, which may require the redefinition of current CDM methodologies to be more accommodating of landfill gas bottling projects. Together these recommendations could improve waste management throughout Ethiopia to reduce social and environmental impacts of pollution and climate change.
Works Cited


The Federal Environmental Protection Authority. (2004). *Draft Guidelines on Composting Environmental Protection Authority and the Environmental Units of Competent Sectoral Agencies* (pp. 1–5).


Chapter 6 Appendices

Appendix 6A

Table 2 Sources:


Appendix 6B

E-mail Communication, Benjamin G. Sishuh, Project Manager, 4R Energy PLC
21 October, 2012

My name is Bjorn Knutson. My colleague Kelly Kneeland and I are working with Professor Travis Reynolds of the Colby College Environmental Studies Program to study the environmental, social, and economic impacts of the current waste management practices in Ethiopia. Our hope is to identify how national policies and private associations might increase the benefits and decrease the negative effects of unsustainable waste management in Ethiopia.

We are interested in learning more about the potential for renewable energy production from waste in Ethiopia, specifically within growing urban municipalities. Would it be possible for me discuss the topics listed below with someone from your organization by telephone.

Any information you have regarding the above topics would be much appreciated.

Areas of Biogas Potential
(1) What are the most rapidly growing urban areas in Ethiopia?
(1a) Which of these areas, in your opinion, have the "best" waste management systems, and which have the "worst"?
(2) On what scale is biogas technology used in Ethiopia?
(3) Is landfill gas capture a technique that could be used in Ethiopia? Which cities/towns have the greatest potential for successful landfill gas capture?

Barriers to Biogas Implementation
(4) Are there institutional factors that are hindering the implementation of biogas technology?
(4a) If so, what are the most significant?
(5) Are there technical factors that are hindering the implementation of biogas technology?
(5a) If so, what are the most significant?

International Support for Biogas
(6) Are you familiar with the United Nations Clean Development Mechanism (CDM)?
(6a) Could you please tell me what you know about this?
(7) Does 4REnergy work with any international institutions to influence biogas projects in Ethiopia?

24 October, 2012

My name is Benjamin G. Sishuh, I am the projects manager at the 4R Energy PLC here in Addis Ababa, Ethiopia.

First I would like to express my appreciation in your interest contacting 4RE to understand more about the environmental, social and economical impact challenges from waste-to-energy projects specifically in the Bio-Methane production in Ethiopia. We hope this information might be useful to show you the bigger picture for your research.
The roadmap for energy sector in Ethiopia is yet to develop in many folds in order to satisfy the socio-economic development needs of the country. The sector constitutes the traditional energy sub-sector which supplies over 90% of the energy requirements and the modern energy subsector that currently provides less than a tenth of the total energy supply but growing at an unprecedented rate, especially regarding the hydropower development. One area of a considerable energy source is municipal solid and liquid wastes, the management of which remains one of the biggest problems for wastes could cause serious health and environmental hazards, and make cities unfit for living. Major cities in Ethiopia specially the city of Addis Ababa has a huge problem in this regard although some encouragements from the City administration in new solid waste collection designs, expansion of the sewage networks and wastewater treatment plants projects in recent years.

In Addis Ababa alone, the generated wastewater by the dwellers of Addis Ababa, vast amount is released to the various streams and rivers without being treated. Currently, barely about 5% of this wastewater is treated by the only wastewater treatment plant (WWTP) in the country, which is located in Addis Ababa at Kaliti. Moreover, no energy is recovered or utilized by Kaliti WWTP from the organics with which the wastewater is loaded although part of the treatment ponds are generating marsh gas (methane) and releasing it to the atmosphere.

In addition currently the City Administration is closing Repi municipal solid waste landfill site (Koshe) and is undertaking landfill gas (LFG) recovery project. The implementation activities of the LFG recovery project are contracted to a Finish and local NGO’s and currently nearing the completion. It is intended to register as a CDM project and obtain carbon credits for emission reductions by simply flaring the LFG.

Noting the potential of upgrading the Bio-Methane or LFG to a high value gas in order to provide cooking fuel that would replace liquefied petroleum gas (LPG) and benefit the city dwellers of Addis Ababa on one hand, and considering the city could obtain additional benefits from the sale of the recovered Biomethane CNG on the other,

4RE - has shown interest to engage in the business of waste-to-energy production of Biomethane, Bio-Fertilizer and upgrading the LFG to high value cooking fuel to provide alternative fuel to the consumer. Thus, waste-to-energy project would be more advantageous from both the environment, socio-economic perspective and the CDM (carbon credit) benefits.

Currently, there is no national gas distribution or delivery network infrastructure in the country, kerosene and liquefied petroleum gas (LPG) are the two major modern cooking fuels used in Ethiopia. There is also a plan to increase the Ethanol production for cooking fuel purpose. As Both LPG and kerosene are non-renewable fuels imported from abroad. Their annual imports in 2011 have reached about 9,000 tonnes and 555,000 tonnes, respectively. The demand for these fuels especially that of LPG, is growing at a fast rate, over 11% per annum on supply trend and close to 9% on per capita consumption basis. It is projected that, if the current trend continues, the annual demand for LPG and kerosene would reach about 16,000 tonnes and 700,000 tonnes in five years (by 2016/17), respectively.

The heating value of bio-methane is very high, higher than kerosene and very close to natural gas and LPG. The burning properties are also similar to the two gaseous fuels. It burns with clean blue flame like natural gas and LPG. Moreover, unlike the two fuels, it is renewable and carbon neutral. Bio-methane can be compressed, filled in gas bottles like LPG and distributed to households and other end users. Thus, in view of the ever growing demand for modern cooking fuels, bottled bio-methane or bio-CNG, as sometimes referred to, has a big potential to replace LPG and kerosene in the Ethiopian market with an expected fast growing market share.

Biomethane use, replacing conventional fuels like kerosene or firewood, allows for the conservation of environment. Therefore, it increases its own value by the value of i.e. forest saved or planted. Biogas is able to substitute almost the complete consumption of firewood in urban and rural households in Ethiopia.
The main socio-economic benefits of the present project include foreign exchange saving by reducing import of cooking fuels such as LPG and kerosene. It is estimated from few Addis Ababa waste-to-energy projects (USD 40-60 million) in foreign exchange could be saved over the few years of the project life. The project also helps the Addis Ababa City Administration to earn carbon credits. Although difficult to measure, the social benefits due to the project could be quite high since the project reduces environmental pollution while generating wealth from waste. Reduction of dependency on foreign sources of energy, and creation of jobs are also the other socio-economic benefits of the project.

Biomethane can have significant health benefits; the availability and the affordability of biomethane can have effects on nutritional patterns. With easy access to energy, the number of warm meals served may increase. Whole grain and beans may be cooked longer, increasing their digestibility, especially for children. Water may be boiled more regularly, thus reducing waterborne diseases. Since biogas burns clean, homes do not fill with smoke and ash.

Women and children experience less bronchial problems and can expect to live longer.( decrees of respiratory illnesses from indoor air pollution).

• Homes are also more hygienic.
• Cooking with gas takes less time than with wood or charcoal or any other commonly used modern fuel.
• It is easier to cook with gas stove.

Estimating an average per capita consumption of 3 kg of wood per day for energy (cooking, heating and boiling water) in rural areas, the daily per capita demand of energy equals about 13 kWh which could be covered by about 2 m3 of biogas*. A biogas plant therefore directly saves forest. Annually, each biogas plant can save more than four ton's of firewood and 32 liters of kerosene.

The production of Biomethane from farm or household and utilization of municipal waste in general can make a substantial contribution for a country like Ethiopia. First, biogas could increasingly replace firewood as a source of energy. Second, biogas systems yield more and better fertilizer. As a result, more fodder becomes available for domestic animals and can lessen the danger of soil erosion attributable to overgrazing.

Areas of Biogas Potential
(1) What are the most rapidly growing urban areas in Ethiopia?
According to the national data the rapidly growing cities are; Addis Ababa, Bahir Dar, Hawassa, and DireDawa, however, there are 100’s of smaller cities across Ethiopia where the population is growing in a faster rate.

(1a) Which of these areas, in your opinion, have the "best" waste management systems, and which have the "worst"?
At present waste management practices are becoming priorities for the government, the demand is also increasing accordingly with the urbanization plan and population growth. The future waste management design project plan can dramatically change the waste management system practices in major cities in Ethiopia; in the meantime I have not seen best waste management systems yet in the country, however, Addis Ababa ranks better followed by DireDawa and Mekele. In my opinion the “worst” is Baher Dar, Haawassa and Nazareth.

(2) On what scale is biogas technology used in Ethiopia?
Small Scale, farm, households and few remote rural schools,

(3) Is landfill gas capture a technique that could be used in Ethiopia? Which cities/towns have the greatest potential for successful landfill gas capture?
Yes, As mentioned above, the only successful extraction Landfill gas implementation project is taking place is in the city of Addis Ababa.

Barriers to Biogas Implementation
(4) Are there institutional factors that are hindering the implementation of biogas technology?
Yes

(4a) If so, what are the most significant?
Since biogas technology was introduced in Ethiopia in the 1960’s it is easy to say it’s rather new technology for the country, it lacks strong national biogas strategy policy, creating environmental socio-economical awareness for renewable energy, lack of funds for the development of large scale waste-to-energy projects, not prioritizing environmental and socio economic issues.

(5) Are there technical factors that are hindering the implementation of biogas technology?
Yes

(5a) If so, what are the most significant?
Lack of R&D, minimum technical knowhow, no adequate technical transfer and service maintenance after implementation of the technology, there are very few individuals and NGO’s who are involved in the construction of bio-digesters business or consultation. Thus, the development of biogas technology has never evolved to the scale where the energy demands are enormous.

International Support for Biogas
(6) Are you familiar with the United Nations Clean Development Mechanism (CDM)?
YES

(6a) Could you please tell me what you know about this?
Organization under UNFCCC responsible for approving CDM projects around the world, The Clean Development Mechanism (CDM) requires application of a baseline and monitoring methodology in order to determine the amount of Certified Emission Reductions (CERs) generated by a mitigation project in a project host country.

(7) Does 4REnergy work with any international institutions to influence biogas projects in Ethiopia?
Not at this time, but we’re interested in partnering with international institution or organization with long term experience and good reputation.

We hope this provided information should be sufficient for you inquiry.

24 October, 2012

Thank you very much for all the information you provided me and my colleague with, it has already been extremely helpful. We appreciate you replying so quickly and thoroughly. We plan to use this information immediately to continue our analysis of the waste management practices in Ethiopia. We will be sure to keep in touch with you regarding our analysis, and will let you know if we have any additional questions.

Again, we deeply appreciate your contributions to our research. Best of luck with your influential work with 4REnergy.

26 October, 2012

There were few things that were bothering me for not explaining few additional issues.

If you don’t mind me asking, who do you report your final analysis and does your analysis help to change or enhance UNFCCC methodologies regarding large scale LFG project for the development of new methodologies for developing countries?
Reason for my questions; 4RE had an opportunity for utilization of Addis Ababa’s largest landfill site recently. To begin with, the project started as a simple CDM project by flaring the LFG to earn CER, at the later stage the city administration has decided the project should have a room to incorporated other LFG utilization options. Prior from contacting 4RE, the city had offer the extracted LFG to EEPICO to produce 1.7 MW electric power (you can find out more about the project http://www.hoarec.org/index.php/programmes/energy/active-projects/repi-landfill, because of the high initial investment cost for the project, EPPCO was not interested. So the opportunity came to 4RE to utilize the extracted LFG by upgrading the gas for bottling and distribution. 4RE was and still is interested in implementing the project, however, we could not find suitable methodology to incorporate upgraded LFG as compressed natural gas (CNG) for bottling for a large scale landfill project. the issues we’re facing:

The ACM0001 Flaring or Use of landfill gas (clearly indicates)
· Typical project(s)
· Capture of landfill gas (LFG) and its flaring and/or use to produce energy and/or use to supply consumers through natural gas distribution network.
· Type of GHG emissions mitigation action
· GHG destruction. Destruction of methane emissions and displacement of a more-gHg-intensive service.
· Important conditions under which the methodology is applicable
· Captured landfill gas is flared, and/or;
· Captured landfill gas is used to produce energy, and or;
· Captured gas is used to supply consumers through natural gas distribution network.
· Important parameters

Monitored:
· Amount of landfill gas captured;
· Methane fraction in the landfill gas;
· If applicable: electricity generation using landfill gas.
· BASELINE SCENARIO
· LFG from the landfill site is released to the atmosphere
· PROJECT SCENARIO
· LFG from the landfill site is captured and flared; and/or used to produce energy (e.g. electricity/ thermal energy); and/or used to supply consumers through natural gas distribution network.

Even though 4RE main objectives are to grow its business and benefit its shareholders, our main vision is to bring a new business environment model to provide the society with a new social and economical benefit, to provide an alternative energy to the new market, to fight deforestation by substituting waste-to-energy projects, fighting poverty by creating new jobs and making waste valuable which helps to create a cleaner city etc.. The landfill gas upgrading and bottling project could have created more jobs, produced new market for alternative energy and so on. The benefits were enormous but unfortunately this project was aborted and the LFG will be flared rather have been utilized.

Country like Ethiopia or many African countries without Natural Gas Distribution Network, modern waste management practices and high investment cost on infrastructure can cause many countries to face similar issues regarding CDM methodology. In one hand carbon financing can be one area where the developing countries should be able to benefit from, in another because of certain methodology requirements and understanding the needs for different gas or energy delivery mechanisms such as Ethiopia, it’s difficult to apply for CDM. Our argument regarding this issue even for a small company like 4RE to develop a new methodology for such purpose is challenging to invest a huge amount of cost for PDD development. We could have seen many renewable energy projects in Ethiopia, however, one area that your research or analyses could help us arguing, that, it is essential for such methodologies to be developed, UNFCCC CDM methodologies need to be more flexible or accommodative for such projects in the developing
countries, from the local energy needs to the distribution mechanism perspective. This is one of the key issues for developing a sound environmental and socio economic policies that I think I need to explain to you and your colleagues.

5 November, 2012

I apologize for the delayed response. I report my final analysis to the Colby College Environmental Studies program and the Horn of Africa Environmental Collaborative (HoA-REC). This report is an analysis of the current waste management practices and the potentials for improving waste management practices in emerging Ethiopian cities with a focus on Addis Ababa.

Thank you for all the information you have provided me with thus far; it has been very helpful!

I am attempting to compare Addis Ababa to other emerging cities. You had mentioned that Dire Dawa and Mekele along with Addis Ababa are in your opinion the "best" managed municipalities and that Baher Dar, Haawassa and Nazareth are the "worst." If you have any specific information on any of these smaller emerging municipalities that would greatly contribute to my research and analysis of the potentials for improving waste management and the social and environmental benefits associated with these improvements.

8 November, 2012

I had one more follow up question. What exactly did you mean by saying that the UNFCCC CDM methodologies must be "more flexible" for projects like the landfill gas capture project at the Addis Ababa landfill?

9 November, 2012

To your previous questions regarding “best” and “worst” cities in Ethiopia; first the question is unclear, because of, “best” or “worst” based on to what standards?

Thus, based on 4RE’s independent analysis at current waste management condition within Ethiopia, the top best cities we’re referring to have acceptable or reasonable waste collection and management system requirements than the cities categorized in the “worst” list, due to priorities, in sizes of population growth, environmental issues, health etc..implementing adequate or acceptable solid and wastewater (liquid) waste management systems.

On other hand, for the specific information HoAREC works with different municipalities within Ethiopia and can supplement your specific questions.

Regarding UNFCCC methodologies; “not knowing then who you’re reporting too “ as I’ve mentioned on my previous email, our previous assumption If your analysis resulting to enhance or help UNFCCC’s CDM methodologies on large scale LFG projects.

First of all its not only landfill gas capturing or extraction methods, our main challenge are “Utilization methods”. if you have chance to look in to the UNFCCC methodologies, the acceptable CDM methodologies for utilizing the captured gas from a large LFG CDM project are limited to the fact, that a new methodology have to be developed for gas upgrading and bottling for distribution as additional CDM project.

For a poor countries like Ethiopia where there is no natural gas distribution network, due to high investment cost to produce electricity from LFG and it does not benefit the society by simply flaring the gas. Thus in discussing the Environmental, Social and Economical benefits, I tried to explain by example where some of the challenges are. This is
the reason I’ve mentioned UNFCCC methodologies should be flexible for poor countries like Ethiopia. It is more likely 4RE will develop such methodology.

Current UNFCCC CDM methodology for large scale landfill gas project.
· A) Captured landfill gas is flared, and/or;
· B) Captured landfill gas is used to produce energy, and or;
· C) Captured gas is used to supply consumers through natural gas distribution network.

11 November, 2012

Thank you for that information. I have looked at the information that both you and HoAREC provide on the waste-to-energy project at the Addis Ababa landfill and am a bit confused with exactly what is happening currently at the Addis Ababa landfill. I understand that initially the EEPCO was planning to establish a LFG recovery plan to produce electricity (1.7 mw) but the initial investment costs were too great. 4REnergy would like to find a way to utilize the LFG by bottling it on a large scale however, has not been able to do so thus far. So I am wondering what actually is happening now with the LFG project because you have said it is nearing completion right now? Is it simply a flaring project to destroy methane that does not utilize any methane for energy? And which institution is completing this project?

Are there other international financing options besides CDMs? I have found information suggesting that the World Bank Urban Development Project plans to grant Addis Ababa, Dire Dawa, and 17 other urban municipalities with funding for development, which includes waste management improvement. Do you know anything about this? I am trying to understand this fully in order to report accurate findings.

12 November, 2012

If you can, It’s better we talk over the phone in order to clear the confusion. The best time to call is between 8:am and 10:am US time.

Appendix 6C

Phone Interview Benjamin G. Sishuh, Project Manager, 4R Energy PLC
12 November 2012, 9:15 AM

What was the process of the Repi landfill conversion project?

HoAREC came to 4REnergy with the landfill gas recovery project
4REnergy is the only company to utilize waste
Offers more incentives and profits for gas as 4REnergy would buy the gas

Why did 4REnergy not continue with the landfill gas utilization project?

The project failed due to the Current CDM methodologies
Must use pre-approved CDM Methodologies, however, currently there are none for large-scale landfill gas recovery projects over 60,000 tonnes.
Because the conversion project was already approved as a large scale flaring project, it cannot be redefines as a landfill gas recovery project.
If the project were smaller (under 60,000 tonnes) it could possibly be adapted to a recovery project
4REnergy is still interested in landfill gas recovery project at the Addis Ababa landfill, however we would have to develop these methodologies and propose them to the United Nations before we could begin a recovery project
What is the current status of the Repi landfill conversion project?

It is already registered as a CDM flaring project
Flares approximately 15,000 meters cubes per hour
It would be better if 4REnergy could utilize this gas rather than flaring it.
Provide more jobs and money for the municipality
Alternative energy source that would displace the use of wood, charcoal, and kerosene, which is both environmentally and socially harmful

What are the opportunities for other emerging cities in Ethiopia to improve waste management?

Many areas for engagement for business.
As there is no pipeline for landfill gas to be sent to, bottling landfill gas is the best option in Ethiopia.
International finance could significantly improve waste management in Ethiopia.
French development back is providing funds for improvements in solid waste.
World Bank fund waste water treatment and networking area.
African Development Bank plans to fund projects to improve the collection and utilization of waste.
In Bahir Dar, the population is exploding and waste is not managed. Bahir Dar is near a lake and waste and sewage is dumped straight into the lake, which causes fish to die. The impacts could be catastrophic in the future.

Appendix 6D

E-mail Communication, Nels Nelson, Project Manager, Horn of Africa Regional Environment Centre and Network
31 October, 2012

I just wanted to check in to let you know how things are going regarding our senior capstone research for sustainable waste management in Ethiopia. We have completed a great deal of literature review and are on track to complete our reports within the next month! I am planning to complete a good amount of GIS analysis this week on efficient transportation routes in Addis. I wanted to double check on the process you would like me to complete for this analysis - am I calculating efficient routes based on four pre-determined collection sites in the city, or would you like me to try to determine the most feasible sites based on this analysis?
I have a picture of a map of the city with the four locations of these new collection sites; however, I was wondering if you knew the exact latitude and longitude of these locations for my GIS analysis. Please let me know if I am correct in this understanding of the analysis, and if you might have more specific coordinate information on these locations!

31 October, 2012

Are the sites not included in ArcGIS files I gave you? As for the collection, please use the existing containers for the current (mixed waste) pick-up. If possible, you could calculate (using estimated population density, waste generation rate per capita, and waste composition characterization) the optimal spacing of organic waste bins and plastic waste bins and then place those in the city, preferably adjacent to existing pick-up locations.

Per capita generation rate: 0.25 kg/capita/day (Solid Waste Management Status Report of Addis Ababa: The Way Forward. City Government of Addis Ababa Sanitation, Beautification and Parks Development Agency, July 2003). This figure could reasonably be increased to 0.3 kg, as the data was from almost 10 years ago. Attached there are two documents - if you look at the Repi feasibility study you will find a waste composition analysis.
Thank you Nels! These are great resources and I look forward to sending you our final findings. The GIS information that you gave me includes all of the individual collection containers around the city (there are 1074 "Genda Plates" in the layer). If I understood correctly, there are plans to create four new secondary collection sites at the corners of the city. I found a few recent articles that said these sites will be located in Bole, Akaki, Kolfe, and Koshe, with the new biogas site location in Sendafa. Is this correct? If so, I have not found any specific coordinate information on the four collection sites in these areas. If I cannot find specifics, I can use more generalized information of the. Am I correct with this information?

1 November, 2012

The new landfill will be at sendafa, perhaps with biogas, but the city is leaning towards biogas at akaki as the transfer station is adjacent to a sewerage treatment facility. As for the the transfer station at koshe, it will be on the west part of the landfill site on the ring road. The other two sites are correct but I do not have coordinates so you'll have to estimate from the jpg maps I gave to you along with the data. The transfer stations will be places where waste is sorted and redirected to treatment destinations. Plastic waste will be some to private companies. Organic waste will probably be brought to the akaki site for treatment, and mixed waste will be put onto larger trucks and moved to sendafa.