Use of Alternative Fuels in the Cement Sector in Ethiopia: Opportunities, Challenges and Solutions

Korea Green Growth Trust Fund

WORLD BANK GROUP
IFC International Finance Corporation

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List of Acronyms and Abbreviations

AF	Alternative fuels
CO_2	Carbon dioxide
C&D	Construction and demolition
CAGR	Compound annual growth rate
CAPEX	Capital expenditure
CRGE	Climate resilient green economy
EU	European Union
EUR	Euro
GJ	Gigajoule
ha	Hectare
IFC	International Finance Corporation
l	Liter
km	Kilometer
LDPE	Low density polyethylene
LHV	Lower heating value
m^3	Cubic meter
MRF	Material recovery facility
MSMEs	Medium, small and micro enterprises
MSW	Municipal solid waste
OPEX	Operational expenditure
PET	Polyethylene terephthalate
PJ	*Prosopis juliflora*
PP	Polypropylene
PPP	Private-public partnership
PVC	Polyvinyl chloride
RDF	Refuse-derived fuel
SSA	Sub-Saharan Africa
SWM	Sikud waste management
t	Metric ton
TDF	Tire-derived fuel
US$	US dollar
WTE	Waste-to-energy
WWTP	Wastewater treatment plant

Acknowledgments

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Foreword

Rapid urbanization in emerging markets has created new challenges for economic development and poverty reduction. The need for more buildings, transport and other infrastructure has boosted demand for construction materials and especially cement, making it the centerpiece of the urban development agenda. In Sub-Saharan Africa, consumption of cement is expected to continue to grow over the coming decade.

To meet this demand, over a dozen new kilns were launched in Africa in recent years. At the same time, increasing output poses challenges for cement producers, who invest significantly in sourcing energy and fuel, primarily coal or natural gas. An alternative approach is to improve efficiency and implement new technologies – such as waste heat recovery and renewable energy – and utilize alternative fuels, which are already used by major players in the cement sector globally.

In IFC, a member of the World Bank Group, we have an investment portfolio in cement and construction materials of over $4.2 billion, and vast global experience in developing innovative solutions and leveraging best practices. For instance, we identify waste heat recovery opportunities as well as international best practices in the use of alternative fuels at cement plants.

In 2016, IFC launched an initiative to help increase the use of alternative fuels in the cement sector in Africa, with a focus on several countries, including Ethiopia. In this country, major cement producers are already using agricultural residue to offset coal which has become increasingly expensive. The capital, Addis Ababa, is a major urban area, generating over a million metric tons of waste each year. Growth of waste quantities resulted in overfilling of disposal sites, followed by a tragic landslide incident at the Koshe landfill earlier this year. The issue is recognized by the government, which is already looking at waste-to-energy solutions. Further, *Prosopis juliflora*, an invasive alien tree species that occupies more than one million hectares in one of the provinces, represents significant fuel potential. Harvesting prosopis could also free up agricultural land and create much needed jobs.

This report summarizes the outcomes of the assessment of alternative fuel opportunities in the country, with a focus on sourcing energy from municipal, commercial and similar waste, tires, sewage sludge and agricultural residue. It outlines the total potential as well as possible project models, involving linkages between the cement and waste management sectors. IFC has also assessed market barriers and offered measures that will increase the uptake of the use of alternative fuels.

We hope that this report will provide useful information to policymakers, cement producers, waste management companies, as well as investors and project developers to realize the untapped potential for the use of alternative fuels in the cement sector in Ethiopia.

MILAGROS RIVAS SAIZ

Global Head of Cross-Industry Advisory

Executive Summary

From August 2016 to March 2017, in collaboration with the Korea Green Growth Partnership, IFC conducted an assessment of opportunities to **increase the use of alternative fuels** (AF) in Sub-Saharan Africa (SSA). The assessment focused on countries with the highest demand for cement in the region: Kenya, Senegal, Nigeria and Ethiopia.

The assessment identified **cement production clusters** with high potential for substituting conventional fuels (primarily coal and natural gas) by co-processing these with fuels derived from waste streams. The assessment quantified opportunities for fuel substitution based on AF availability and the economic potential for fuel substitution. It also identified barriers to fuel substitution and measures for addressing these barriers. The AF considered in the assessment included refuse-derived fuel (RDF) produced from municipal solid waste (MSW), wood biomass and agricultural residue, sewage sludge (produced from wastewater), used tires and tire-derived fuel (TDF), used oils, and other similar wastes, where applicable.

In Ethiopia, the assessment focused on the **Addis Ababa metropolitan area** (including areas that are within 50 km of the city boundaries), where **two thirds of cement production** and a high proportion of waste generation is located. Agricultural wastes, especially sesame husks, are already used as fuel by some of the producers. These producers are exploring opportunities to increase substitution. To achieve higher substitution rates, however, they will need to secure a consistent supply of AF at predictable prices that are lower than the current price of coal (around US$6.2/GJ in thermal equivalent).

The assessment shows that, with the creation of an enabling environment for private sector participation, cement companies could develop the infrastructure to source AF at a cost much lower than that of coal. **Biomass, RDF and TDF** represent the highest thermal energy potential. Cement players are emphasizing the use of *Prosopis juliflora* (PJ), an invasive species that currently occupies over 1.2 million ha of land in the Afar region. While assessed technical potential is tremendous, there may be risks associated with sourcing of PJ. These risks call for diversification of the fuel supply, including the use of RDF/TDF. Sewage sludge is not currently produced at required volumes, and infrastructure for producing bulk volumes of dry sludge is only planned to be developed in the next 3-5 years.

Total **investment required by cement producers is estimated to be up to US$40 million**. This is based on up to around US$20 million for cement kiln upgrades (US$5 million for each of the four companies in the Addis Ababa cluster), a US$10 million contribution towards establishment of a MRF that produces RDF and TDF (assuming that the cement sector contributes up to 50% of total required investment of US$20 million, in order to secure supply and control prices), and a US$10 million investment in a PJ processing facility. This investment will **pay back in 3-4 years**.

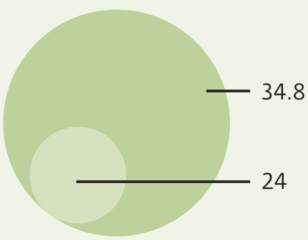
To support realization of this opportunity, cement producers need to secure AF supply at predictable prices that remain below the current price of coal (around US$6.2/GJ in thermal equivalent). The establishment of an **efficient waste management system** is therefore critical, as proven by global experience. This is, however, hampered by the current poor state of basic waste collection and transport infrastructure, and a **lack of incentives for private participation** in waste management projects.

Globally, while cement producers tend to co-invest in AF production facilities, they are typically reluctant to invest in or support basic waste management infrastructure – this is a non-core business that imposes additional risks on operations. Presently, waste management services in Ethiopia, including those in the Addis Ababa area, are dominated by municipal companies. Private companies operate on a very small scale and there is no system of incentives for diversion of waste from landfills.

Furthermore, there are community engagement issues around new disposal site projects in the Addis Ababa area, limiting overall waste disposal capacity. At the same time, certain projects under implementation, such as the waste-to-energy (WTE) project at the Repi disposal site, show that the government is committed to reducing the quantities of waste being landfilled.

CAPEX US$ MILLION / PAYBACK (YEARS)

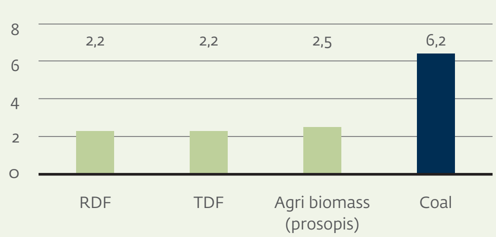
40 / 3-4



THERMAL ENERGY DEMAND AND TECHNICAL AF POTENTIAL, MILLION GJ/YEAR

FIGURE 1. SUMMARY OF ALTERNATIVE FUEL OPPORTUNITIES FOR THE CEMENT SECTOR IN THE ADDIS ABABA AREA IN ETHIOPIA, ASSUMING REMOVAL OF BARRIERS FOR THE PRIVATE SECTOR

SOURCING COST



The following measures, implemented as part of the integrated solid waste management (SWM) system, would encourage the use of AF by securing long-term supply and incentivizing investors to build the needed facilities:

(1) Establishment of a waste quantities **measurement and metering system at all stages of waste handling** which would enable **payments for waste management services to be linked to the volumes** of waste processed;

(2) Establishment of a **Private-Public Partnership** (PPP) **framework and a system of incentives** which would encourage private operators to enter the Ethiopian market and engage in waste recovery projects; and

(3) Improvement of the **technical capacity and awareness of municipal waste management operators and government agencies** responsible for waste management, in order to empower them to make informed decisions on upgrading waste handling infrastructure.

Implementation of concepts such as Extended Producer Responsibility is also essential. This is one of the key mechanisms for ensuring that the total cost of waste is covered by payments from 'polluters', including indirect payments through the cost of goods. Implementation will contribute towards creating a favorable environment for investors, including local and international private sector waste management service providers, financial institutions and cement companies.

1. Background and Objectives

In the past decade, countries in Sub-Saharan Africa (SSA) have been going through **economic and social changes** that are reshaping development and growth patterns and creating new challenges and opportunities for various stakeholders, including the private sector, governments, and society as a whole.

Rapid urbanization has led to significant growth of industrial and household consumption, which in turn has triggered **rapid growth in waste volumes**, including municipal solid waste (MSW), wastewater, hazardous and chemical wastes, and industrial waste.

National and local governments are faced with the challenge of creating modern urban infrastructure that supports sustainable growth of cities by reducing their environmental footprints. In Nigeria, for example, the total amount of MSW generated is expected to reach more than 100 million t/year by 2020, almost double the recorded volumes in 2010.

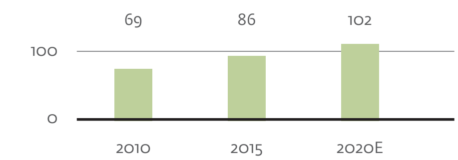


FIGURE 2. MUNICIPAL SOLID WASTE GENERATION IN NIGERIA, MILLION T/YEAR[1]

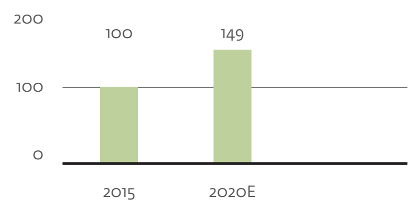


FIGURE 3. EXPECTED DEMAND FOR CEMENT IN SUB-SAHARAN AFRICA, MILLION T/YEAR[1]

Another urbanization trend is the rapid growth in demand for new residential and commercial property and, therefore, increased demand for construction materials, including cement. From 2015 to 2020, the **demand for cement in SSA is expected to increase by almost 50%**, calling for new cement kilns to be built. On average, since 2010, compound annual growth (CAGR) of cement consumption in the region has been approximately 7%, with certain countries, including Ethiopia, Nigeria, Kenya and Senegal, showing even higher growth rates.

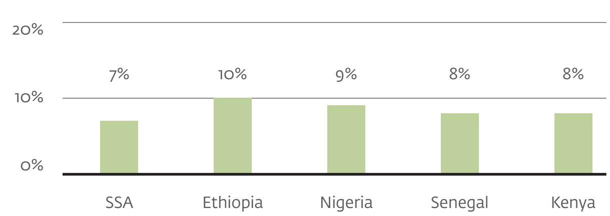


FIGURE 4. CEMENT CONSUMPTION GROWTH (2010-2015 CAGR)[1]

[1] Source: CW Group, 2015, Cleaner Cement Sector Africa: Context Study.

Photo: Simone D. McCourtie / World Bank

Production of clinker and cement is **highly energy intensive**; thermal energy and fuel contributes up to 40% of total production costs. Availability of primary fuel is often a major challenge in markets where demand for cement is growing rapidly, as is the case in SSA. Typically, coal and natural gas is used as the primary fuel for cement kilns. Many countries rely on imports of these fuels; these are often associated with a high cost of transportation, customs, duties and surcharges, currency exchange risks and insecurity of supply. Ethiopia, for example, imports coal from South Africa; the prices have been volatile in recent years and have been subject to upward pressure due to growing transportation costs and surcharges at the port of Djibouti.

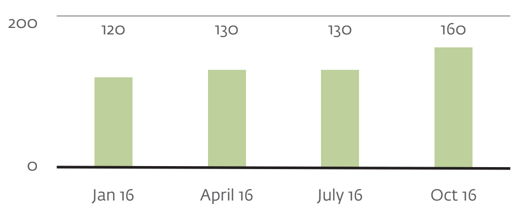


FIGURE 5. COAL PRICE IN ETHIOPIA, US$/T

Given this situation, most major cement producers are looking for **cheaper reliable alternatives**. In Ethiopia, agricultural residues are increasingly being used as fuel for cement kilns. In other countries, including Kenya and Senegal, there have also been some positive experiences in the use of alternative fuels (AF). At the same time, **substitution rates typically do not exceed 15-20%**, which is relatively low, based on best practices in the European Union (EU) or the United States (US). Some of the waste streams that can become sources of fuel, such as MSW, sewage sludge, waste tires, oils, and other commercial or industrial waste, seem to be underexploited when compared to global best practices. This may indicate that there are **certain barriers that prevent cement companies** and other stakeholders from implementing AF projects.

In response to these challenges, IFC conducted a study to identify opportunities for and barriers to the use of AF in the cement sector in SSA, focusing on the **countries with significant demand for cement, including Ethiopia.**[2] The study had the following objectives:

(1) **Assess technical and economic potential** for fuel substitution in key cement production cluster(s) in Ethiopia;

(2) **Assess the overall market environment and identify barriers** for implementation of AF projects, including policy, administrative, financial and technical aspects, and propose solutions that would enable private sector players, including cement companies, to invest in infrastructure to increase fuel substitution rates and make sourcing of AF economically feasible, thereby reducing cement companies' environmental footprints and contributing to sustainable development of the country.

[2] Other countries included in the assessment are Kenya, Senegal and Nigeria. These countries are covered in separate reports.

2. Approach and Methodology

The potential for fuel substitution by AF was informed by the following activities:

(1) **Assessment of technical potential for sourcing AF** based on quantities of waste available (generated and collected, or technically feasible to collect) in the key cement production clusters;

(2) **Analysis of waste management practices, regulatory framework, and other factors** that would affect accessibility and the cost of sourcing key AF streams, in order to identify barriers to full utilization of AF potential, and development of solutions;

(3) **Assessment of the cost of sourcing AF** under different scenarios involving assumptions on available infrastructure, secondary regulations, and stakeholder participation; and

(4) **Preliminary assessment of economic feasibility of AF projects**, based on required capital expenditure (CAPEX) by cement companies and cost differential between AF and traditional fuels.

The assessment draws on studies, reports and other data available from market stakeholders and the World Bank, as well as interviews conducted with 15 stakeholders, including cement producers, environmental and waste management authorities, and private waste management operators. Data included in the assessment was collected up to 31 March 2017.

It is worth noting that the economic potential for the use of alternative fuels was assessed primarily from the standpoint of the cement sector. The assessment identifies **costs and benefits for the cement industry** (as well as associated waste management players). For each specific project or opportunity, further analysis should be performed to assess financial implications for the public sector, including the impact of various incentives and support measures. Such further analysis may include a comparison of costs and benefits of operating or upgrading a disposal site, as opposed to supporting construction of material recovery/RDF production facilities, in order to justify specific incentive schemes.

To assess the potential for AF projects, the following **assumptions** were made:

(1) Based on waste composition data, assumptions were made as to the physical properties of key waste streams, their calorific value and amount of available fuel (such as RDF or TDF) – see Annex 1 for details;

(2) It was assumed that certain modifications would be performed on the cement kilns in order to maximize fuel substitution rate and burn AF (as specified in Annex 1);

(3) Key stages of waste conversion into fuel would include collection, transportation, processing and then delivery to the cement kiln. Detailed assumptions on each of the technical and economic parameters regarding processing facilities and logistics, based on available data and IFC's experience in the sector, are available in Annexes 2-4;

(4) For the purpose of the assessment, the total sourcing cost was estimated for each AF stream reviewed. Under the baseline scenario, the total sourcing cost includes a sum of the costs incurred at all stages of waste-to-fuel conversion listed under item (3) above. The cost includes fixed and variable operating expenditure (OPEX) as well as CAPEX depreciation over the period of the economic life of the facilities and infrastructure (excluding pre-existing facilities). Where appropriate, the cost of sourcing is adjusted for waste management service fees and payments, as well as revenue from recyclables. Details on the cost structure and assumptions are provided in Annexes 2-4; and

(5) For certain types of waste, some of the sourcing cost components were excluded for the purpose of the assessment. For the assessment of MSW/RDF costs, two scenarios have been considered, as indicated in Table 1 below, to reflect various possible scenarios of the market environment, capacity of sector players and regulatory barriers, based on the data in Annexes 2 and 3.

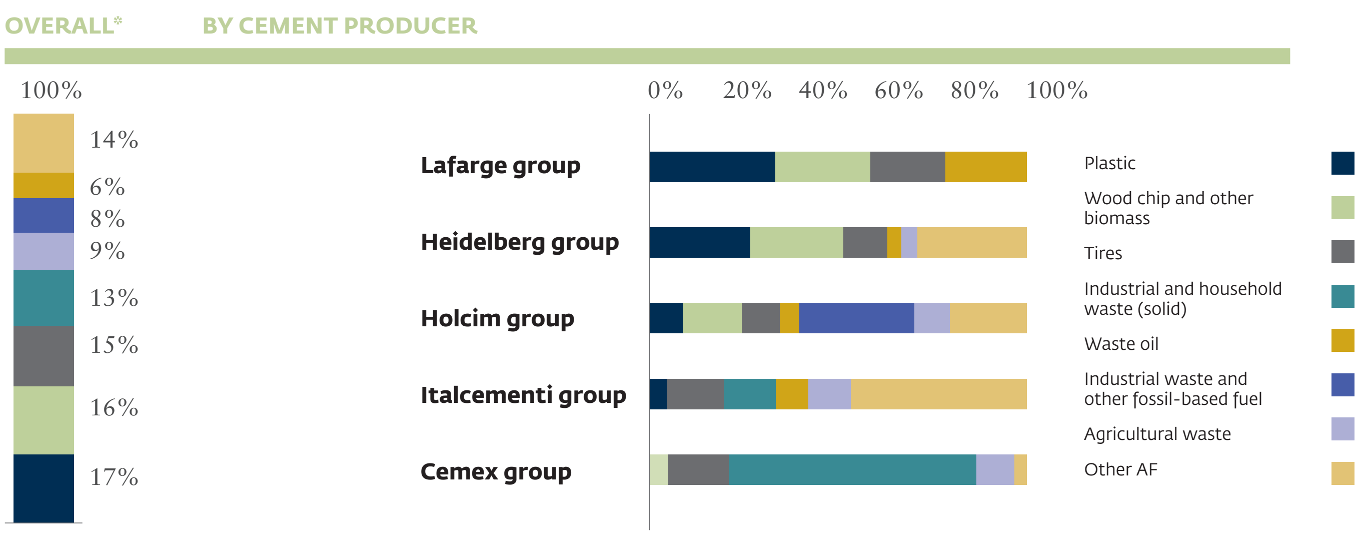
TABLE 1. SOURCING SCENARIOS FOR MUNICIPAL SOLID WASTE / REFUSE-DERIVED FUEL

Cost Item	**Option 1**	**Option 2**
Cost of primary collection and transportation of MSW	Excluded	Included (with the exception of the cost currently covered by waste management fees and addition of the depreciation of CAPEX required to maintain infrastructure)
Cost of MSW processing at a comprehensive MRF	Included (proportional to the volume of waste converted into RDF)	Included (full)
Cost of RDF delivery to the cement plant	Included	Included
Cement sector participation in MRF CAPEX	50% + adjustment of the sourcing cost for the revenue from recyclables	50%
Cement sector participation in collection and transportation infrastructure CAPEX	None	50%

3. The Use of Alternative Fuels in the Cement Sector: Drivers and Global Practices

Cement production is highly energy intensive – energy costs make up approximately 60% of total production costs. Thermal energy costs, in particular, are significant, representing **40% of production costs**.[3] Thermal energy needs vary from 3.2 to 4.2 GJ/t of clinker produced, depending on the process used.[4] Dry process systems are the most efficient, using less than 3.8GJ/t.[5] Modern cement plants tend to use from 3.3 to 3.5 GJ/t of clinker produced.

The cement industry is therefore focusing on **reducing thermal fuel costs by substituting** conventional thermal fuels **with lower cost AF** arising from waste streams. Key waste streams that can be used as AF are plastic, biomass, tires, and solid industrial and household waste. These streams make up approximately 60% of AF used by major global cement producers.



*Overall proportions are estimated based on relative production of cement and clinker of producers

FIGURE 6. WASTE USED AS AF BY SELECTED MAJOR CEMENT PRODUCERS[6]

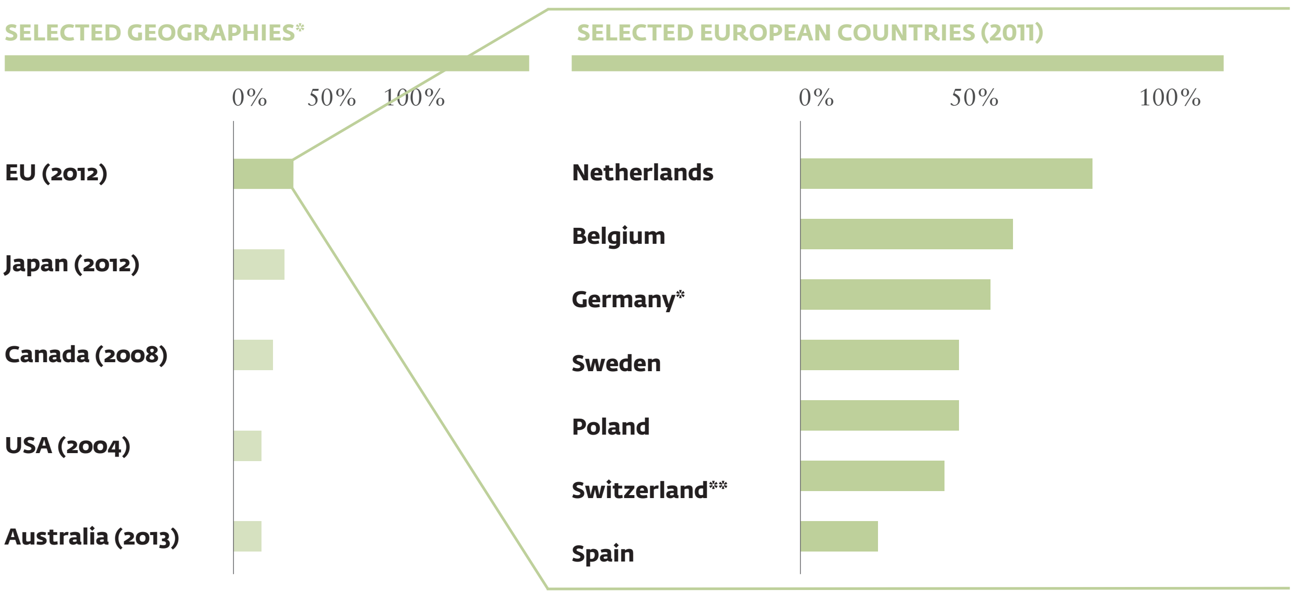
[3] Electricity needs vary from 90 to 120kWh/t of cement produced.

[4] Wet processes involve grinding raw materials in water to form a slurry, which is fed either directly into the kiln or to a slurry drier. Semi-wet processes involve dewatering raw slurry in filter presses; the filter cake is pelletized and fed to either a grate preheater or a filter cake drier. Semi-dry processes involve pelletizing raw material with water and feeding the mix into a grate preheater or to a long kiln. Dry processes involve grinding and drying raw materials to form a flowable powder, which is fed into the preheater or precalciner.

[5] Source: http://hub.globalccsinstitute.com/publications/co2-capture-cement-industry/24-cement-plant-descriptions

[6] Sources: Rahman, Rasul, Khan and Sharma, 2014, Recent development on the uses of alternative fuels in cement manufacturing process; Holcim, Annual Report 2011 Holcim Ltd, 2012; Securities and Exchange Commission, Italcementi Group, Annual report, 2015; Heidelberg Cement, Annual Report 2015; GBL Annual Report 2013.

Globally, most large producers' plants have achieved a **substitution rate of 10-30%**, with some plants reaching 100% substitution.[7] European countries have advanced significantly, averaging 18% and reaching as high as 85% substitution.



* Data is for 2010
** Includes only Holcim, data is for 2012

FIGURE 7. AF SUBSTITUTION RATES IN SELECTED REGIONS AND COUNTRIES[8]

Poland's fuel substitution rate has grown rapidly, from a negligible contribution in 1998 to over 60% in 2016. Some plants have achieved a rate of 85%. AF co-processing capacity, primarily for RDF, of 1.5 million t/year has been installed; this capacity is expected to grow to approximately 2 million t/year.[9]

[7] Source: Wurs and Prey, Alternative fuels in the cement industry, University of Vienna, http://www.coprocem.org/documents/alternative-fuels-in-cement-industry.pdf

[8] Source: Rahman, Rasul, Khan and Sharma, 2014, Recent development on the uses of alternative fuels in cement manufacturing process.

[9] This capacity draws on municipal waste production of 15-20 million t/y.

Factors contributing to Poland's rapid AF substitution growth

Poland's strong growth in AF substitution, to over 60% in 2016, was supported by a range of factors, as set out below.

- **Successive increases in landfill tax:**
  - Adoption of a tax in 1998 prompted greater interest in AF (previously substitution had focused on hazardous wastes, which were forbidden to be disposed of at landfill sites);
  - Landfill taxes were extended to municipal wastes in 2001; and
  - The tax was increased significantly in 2008 from 4 EUR/t to approximately 17 EUR/t, with a 100% increase to be implemented between 2008 and 2018.
- **Expanded supply of RDF** due to overproduction in Germany following a ban on disposing of recyclable and organic waste at landfill sites in 2005; this drove the substitution rate in Poland to 20%.
- **Clear responsibilities** for **waste collection** by landfill operators and **municipal waste management** by municipalities, supported by adoption of relevant EU Directives (Waste Management, Waste Incineration, and Landfill Directives).
- **Allocation of legal responsibility to manage used tires to tire manufacturers** under the Extended Producers' Responsibility principle – in response, tire manufacturers created a shared company to subsidize and organize tire collection and management.
- **Investment in RDF handling facilities** by all cement companies at their plants – Polish cement companies were willing to duplicate the AF experience of international cement groups, in order to reduce operating costs.
- **Investment in shredding lines for RDF preparation** by the waste management sector (typically local entrepreneurs supported by international companies or investment funds), supported by:
  - High potential demand for RDF from the cement sector, at up to 1 million t/year in source MSW volume equivalent;
  - Mid- to long-term contracts with the cement industry;
  - Subsidies provided by EU and local government funds (partly through an allocation of the landfill tax); and
  - Shared investment by both cement plants and RDF preparation plants in some cases.

AF substitution rates have also been increasing in other regions, including emerging markets. In **Egypt**, Italcementi's Katameya plant has reached **8.3% substitution** in two years, saving 115,000 t of CO_2. Fossil fuels were replaced with biomass (such as chopped wood and cotton stalks) and high-quality RDF produced by a waste pre-treatment facility using material diverted from landfills.[10] In **Mexico**, CEMEX's Tepeaca plant uses **800 t** of commercial and industrial residues per day supplied by Mexico City's waste management facilities. In 2016, CEMEX was planning to invest in RDF facilities to increase capacity to 1,600 t per day.[11]

An important lesson from global best practices for the use of AF is that fuel substitution is driven not only by fuel prices and access to fuel for cement kilns, but also to a great extent by the **waste management sector** which is the main source of AF. In many markets, **strong incentives exist to divert waste from disposal sites and maximize recovery**, including as energy and fuels. Those incentives include different types of **fees and surcharges** (such as gate fees) applied to various forms of waste and wastewater treatment. Furthermore, in certain cases, there is a complete ban on disposing of certain types of waste. Strengthening of the waste management sector is often accompanied by implementing mechanisms such as **Extended Producer Responsibility**, which engages producers of goods such as electronics, cars and car parts, and packaging in the sector, and incentivizes them to invest in basic waste collection and transportation infrastructure, as well as waste recycling and waste-to-energy projects. Globally, these are the types of mechanisms that engage private investors and project developers in this sector, while cement companies **act as long-term off-takers of fuel** and may be reluctant to invest in basic infrastructure, as this is outside their scope of business. There are, however, cases where **cement companies co-invest specifically in the production of fuels** (such as RDF and TDF), on a standalone basis or as part of a comprehensive material recovery facility (MRF). This allows cement companies to secure long-term supply of fuel as well as obtain **more control of the prices and the value chain**.

Therefore, the **development of integrated solid waste management systems in African cities would be the major factor fostering the use of AF**. However, experience from emerging markets also shows that, in the medium term, it may be possible to create a market environment and **structure projects specifically in the AF space** with more proactive participation of the cement sector. Such scenarios and opportunities are explored in the remainder of this report.

[10] Source: Italcementi Annual Report 2015.

[11] Source: CEMEX, 2015 Sustainable Development Report.

4. The Cement Sector in Ethiopia: Overview and Energy Demand Forecast

The cement cluster in the Addis Ababa area, which represents two-thirds of production, utilizes approximately 24 million GJ/year in thermal energy, served predominantly by coal. The price of coal is is currently at US$160-180/t (or US$6.2/GJ thermal equivalent) and increasing.

The Ethiopian cement industry serves one of the largest markets in SSA – Ethiopia produced 10 million t in 2017, nearly matching demand. New kilns are planned to be commissioned, supporting further growth to an estimated 12 million t/year of clinker by 2020.

The largest players in the industry are Mugher Cement, Derba Midroc Cement, Messebo Cement, Dangote Cement and National Cement. Another player, Habesha Cement, has recently launched production with capacity of up to 1.5 million t/year. The Addis Ababa area represents the biggest cement production cluster, where four out of six key players, Mugher, Derba Midroc, Dangote and Habesha Cement are located, with an **expected thermal demand of 24 million GJ/year by 2020.** Other players are dispersed across the country.

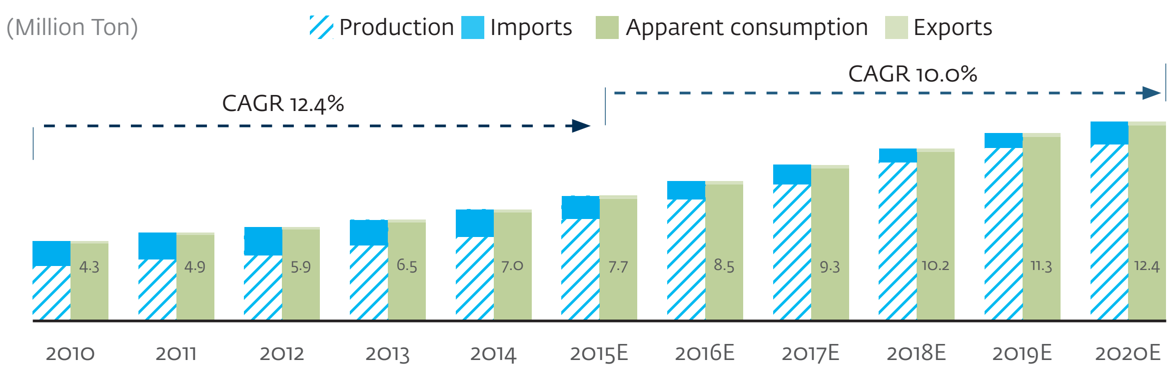


FIGURE 8. CEMENT PRODUCTION AND CONSUMPTION IN ETHIOPIA[12]

[12] Source: CW Group, 2015, Cleaner Cement Sector Africa: Context Study.

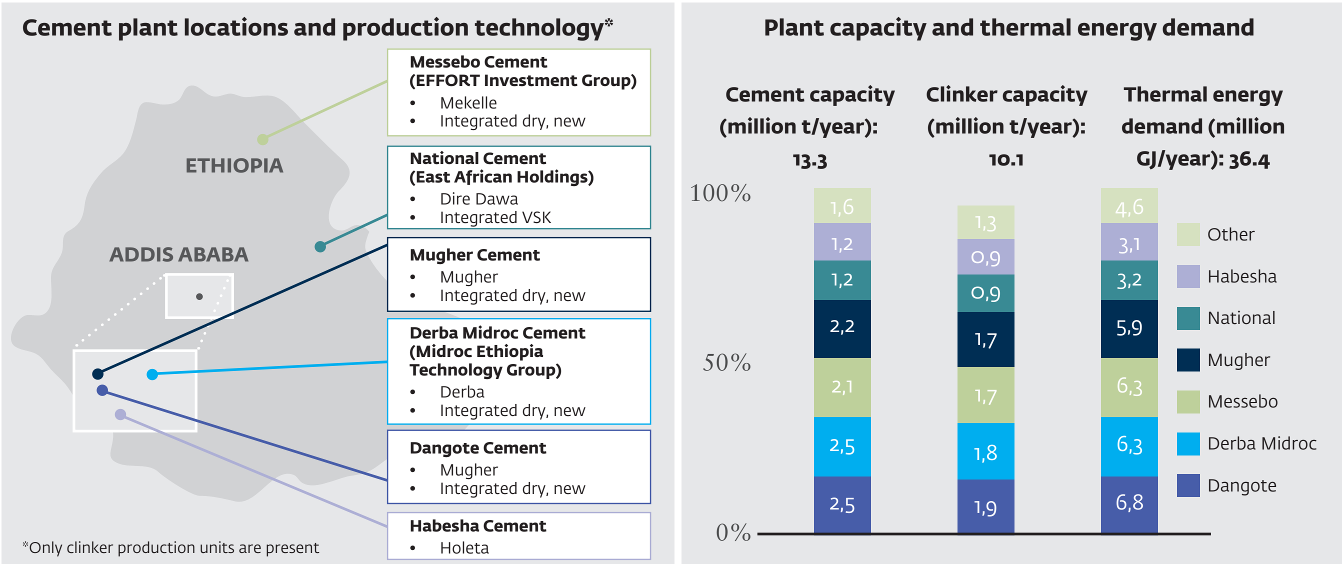


FIGURE 9. CEMENT PLANT LOCATIONS, CAPACITY AND ENERGY DEMAND IN ETHIOPIA AS OF MARCH 2017[13]

The cement industry has good technical potential for AF substitution: the plants use dry process, cyclone preheater technology and currently most are capable of achieving a substitution rate of 20-25% (with a maximum theoretical replacement of 30%); this could be increased to 50% and above with installation of appropriate AF equipment.[14]

Currently, the cement industry uses predominantly coal for its thermal energy needs. Most of the coal is imported from South Africa. The resulting cost at the plant has been steadily increasing and was within the range of US$160-180/t, which translates to at least **US$6.2/GJ** in thermal equivalent. Some players reported a price of up to US$200/t in 2016, translating to US$7.8/GJ.
A more conservative estimate of US$6.2/GJ will be used for further analysis.

Certain cement producers are using agricultural wastes and all major cement companies aim to increase use of AF to substitute coal. The use of tires, waste oils and other industrial wastes is limited and MSW/RDF is not used at all.

All major players are seeking to offset costly coal with alternatives. National Cement is piloting use of sesame husks and rice husks. Messebo Cement has already made the modifications necessary to use sesame husks as fuel on a large scale. The equipment and machinery installed is designed for 40% heat replacement with the prospect to rise to 60%.[15] Further sourcing of agricultural residues may, however, be associated with additional cost and potentially increased risk of access to fuel. A detailed analysis of the AF sourcing potential is provided in the next section. Further analysis will be focused on the Addis Ababa area, which shows the highest thermal energy demand, along with the greatest untapped potential fuel substitution.

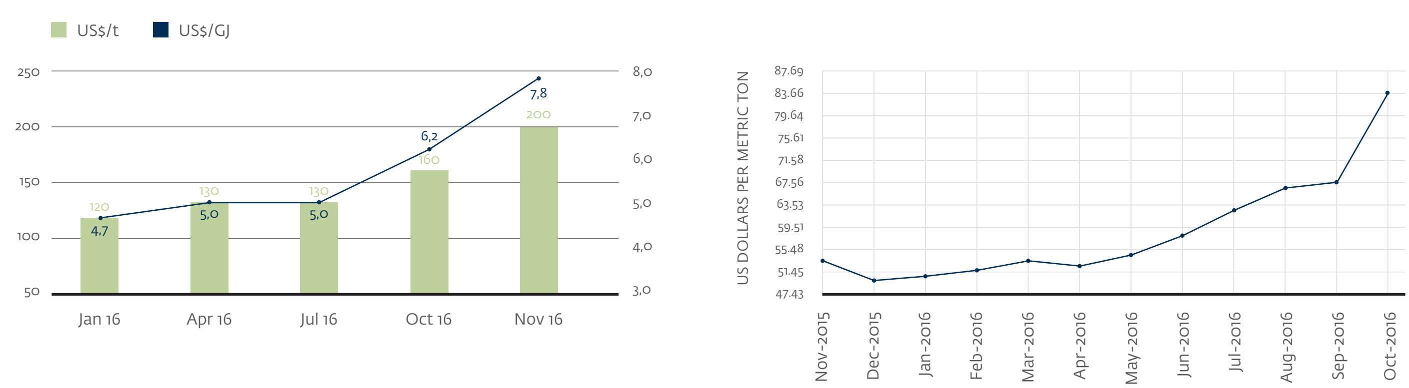


FIGURE 10. COAL PRICE TREND IN ETHIOPIA

[13] Source: CW Group, 2015, Cleaner Cement Sector Africa: Context Study; Interviews with sector players, 2016.

[14] AF substitution potential depends on a range of factors, including waste availability, sourcing cost, and distance from the cement plants; each case must be assessed separately (see Section 2 of the report and Annexes 2-4).

[15] Source: http://www.messebocement.com/Biomass.aspx

5. Technical Potential for the Use of Alternative Fuels

RDF from MSW generated in the Addis Ababa area, biomass (specifically PJ) and waste tires show the highest technical potential for sourcing as AF, at 35 million/GJ in thermal energy. This exceeds thermal energy demand of cement companies located in the Addis Ababa area. It is estimated that MSW available in the Addis Ababa area by 2020 will translate to up to 240,000 t/year of RDF and 3.8 million GJ/year of thermal energy. PJ is estimated to represent up to 30 million GJ/year in technical thermal potential (assuming that up to 10% of PJ residue can be immediately accessed). A further 1 million GJ/year is estimated to be available from waste tires.

5.1 MUNICIPAL SOLID WASTE

The generation of municipal solid waste has been growing steadily, particularly in Addis Ababa. As in many countries in Africa, however, estimating quantities of available waste is challenging due to the absence of reliable statistics and sub-optimal collection rates, especially outside major cities and in rural areas.

Across Ethiopia, based on an average estimated generation of 0.30 kg per capita per day and projected population size of up to 110 million by 2020, the total amount of generated MSW is expected to be approximately **12 million t/year.**[16] The Addis Ababa area is the largest source of MSW. Although there are uncertainties and gaps in statistics available from authorities, it is reasonable to assume that in 2015, an estimated 1.1 million t MSW was generated with a 60-70% collection rate. Since 2006, the recorded quantity has nearly doubled, following rapid urban growth. Assuming this trend continues in the future, at a constant collection rate, the available amount of waste would exceed 1 million t/year by 2020.

Households, institutions, commercial centers, factories, hotels, health facilities and public areas are the main sources of waste. In Addis Ababa, it is reported that 76% of MSW is generated by households, the remainder is generated by organizations or in public areas.[17]

[16] Source: World Bank, 2012, What a Waste, A Global Review of Solid Waste Management.

[17] Interview with Addis Ababa City Administration Cleansing Management Agency, 2016.

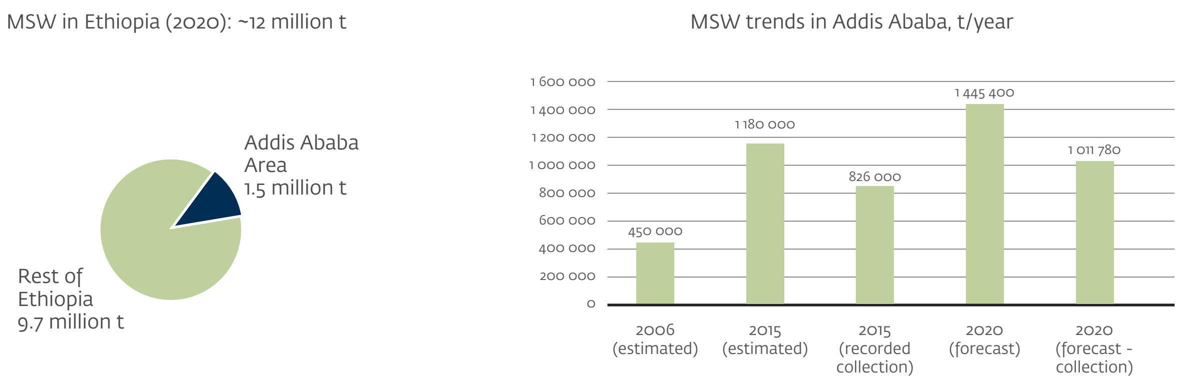


FIGURE 11. FORECAST OF AVAILABLE WASTE QUANTITIES[18]

MSW generated in Addis Ababa is composed primarily of organic waste. Waste in other Ethiopian towns and cities is likely to have an even higher level of organic waste.

A WTE plant currently under construction at Repi, the primary disposal site serving Addis Ababa, is expected to utilize approximately 360,000 tons/year, based on its planned peak electricity output of 25MW (an additional processing line of 25MW capacity may be installed in future). With this site fully in operation, over 600,000 t/year of waste will remain untreated.

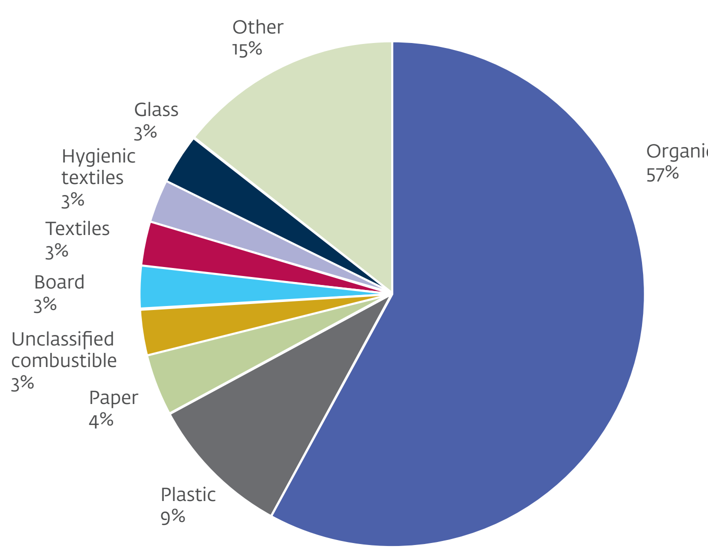
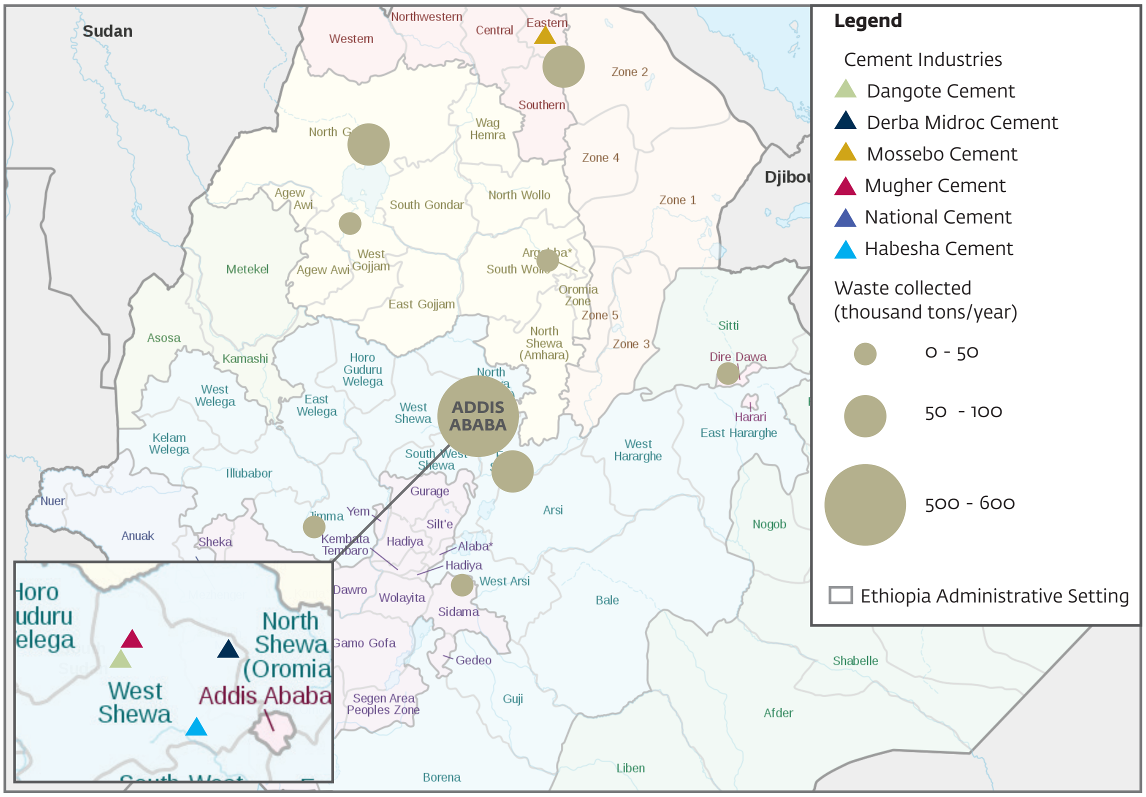


FIGURE 12. WASTE COMPOSITION IN ADDIS ABABA

[18] Interview with Addis Ababa City Administration Cleansing Management Agency, 2016.



https://commons.wikimedia.org/wiki/File:Map_of_zones_of_Ethiopia.svg

FIGURE 13. WASTE COLLECTED IN MAJOR URBAN AREAS IN ETHIOPIA 2015, MILLION T/YEAR

MSW availability is affected by management of waste streams, from collection to disposal. Waste collection systems do not exist in many areas, or are inadequate for serving the intended customers. Waste is dumped along roads, drainage systems or any other available space. In the absence of engineered landfills in most cities, waste is generally dumped in an uncontrolled manner on the outskirts of towns and cities. The situation is exacerbated by inadequate enforcement of waste management policies, financial and operational constraints, and lack of awareness of good waste management practices amongst citizens.

Waste collection practices and efficiencies vary widely. Collection efficiencies reach 70% in Addis Ababa and Mekelle, but are estimated to be much lower in other towns and cities. It is common practice, however, for primary collection of household waste to be conducted by individuals or small or micro enterprises, referred to as associations. The pre-collected waste is placed in containers, which are then collected by municipalities and transferred to dumpsites or landfills for final disposal.

In Addis Ababa, solid waste collection services are divided into primary and secondary collection. Primary collection and transport to intermediate garbage containers (skip points) are outsourced to small and micro enterprises and private companies (with private companies focusing on collection from organizations).[20] Small and micro enterprises involved in waste collection are organized by the government and involve 6,400 people. Methods used for primary collection include door-to-door, curbside collection and block collection systems. Door-to-door collection, the most common method, involves collecting waste from households using push-carts. Curbside collection, the second most commonly practiced method, involves households depositing their waste using baskets, plastic bags, etc. into containers of varying sizes placed by Addis Ababa City Administration Cleansing Management Agency near street corners. Garbage containers for block collection are provided by private companies to hotels, hospitals, enterprises and other governmental and non-governmental organizations. Street sweeping is carried out by the Addis Ababa City Administration Cleansing Management Agency.[21] Secondary collection, i.e. the collection from skip points for final disposal at dumpsites, is performed by Addis Ababa City Administration Cleansing Management Agency and a few private contractors.

Figure 14. Primary waste collection using push-carts in Addis Ababa[19]

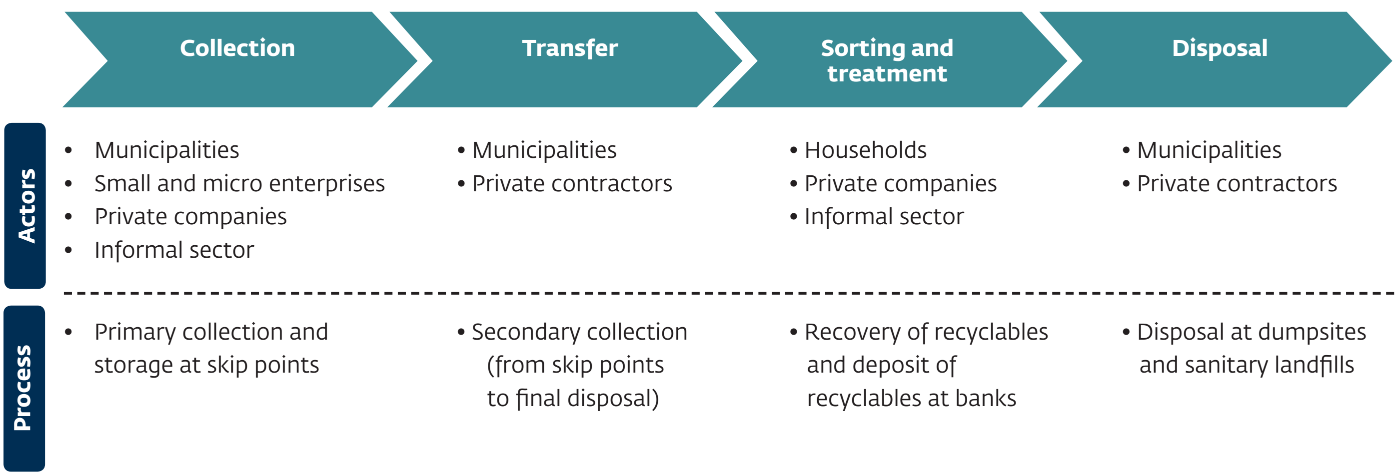


FIGURE 15. MSW MANAGEMENT IN ETHIOPIA

[19] Source: Addis Ababa City Administration, 2010, Overview of Addis Ababa City Solid Waste Management System.

[20] Interview with Addis Ababa City Administration Cleansing Management Agency, 2016.

[21] Source: Desta, Worku and Fetene, 2014, Assessment of the contemporary MSW Management in Urban Environment: The case of Addis Ababa, Ethiopia, Journal of Environmental Science and Technology 7 (2).

Ethiopia does not use waste transfer stations. Instead it uses skip points, or, in cities that lack skip points, collected waste is stored on the roadsides until it is transported to dumpsites.

Figure 16. Skip points to support secondary waste collection in Addis Ababa[23]

Figure 17. Repi dumpsite in Addis Ababa[26]

In Addis Ababa, waste is collected at skip points using 8 m^3 garbage bins, before being transported to the final disposal site. The Addis Ababa City Administration Cleansing Management Agency has 19 solid waste compactors of 80 m^3 capacity, additional solid waste compactors of 24 m^3 capacity, and 111 skip-mounting trucks for lifting 8 m^3 garbage bins.[22] The agency is planning to replace the skip trucks with 40 m^3 compactors to reduce transport costs.

While the Addis Ababa City Administration Cleansing Management Agency is encouraging separation of waste at source, most sorting is conducted by the informal sector on collection, at skip points, or at dumpsites. The individuals and small and micro enterprises involved in sorting then sell the recyclables (plastic bottles, metals, aluminum etc.) to middlemen, brokers, or formal or informal recycling companies. From January to November 2016, approximately 611,600 m^3 (161,500 t) of solid waste had been processed by small and micro enterprises, generating an income of 8 million Birr (US$350,000) from sale of the recyclables.[24]

In Addis Ababa, most solid waste is disposed of at Repi dumpsite.[25] Repi is associated with many environmental, social and operational problems: it has exceeded its capacity, is surrounded by residential areas, and has no leachate collection or treatment system, no rainwater drain, no fence and no waste weighing system. Over 300 informal waste pickers sort remaining valuable items such as unbroken glass bottles and scrap metals.

A new sanitary, engineered landfill was constructed in Sendafa (35 km from Addis Ababa) in order to replace Repi. The launch of the new landfill site is, however, being delayed due to challenging consultation with local communities.

For the purpose of the assessment, it is assumed that the total amount of municipal and similar solid waste available in the Addis Ababa area by 2020 at the current rate of collection will be up to 700,000 t/year (excluding the amount consumed by the WTE facility). Based on the assumed waste composition, this

[22] Interview with Addis Ababa City Administration Cleansing Management Agency, 2016.
[23] Source: Addis Ababa City Administration, 2010, Overview of Addis Ababa City Solid Waste Management System.
[24] Interview with Addis Ababa City Administration Cleansing Management Agency, 2016.
[25] Interview with Dibora Garbage Collecting Service, 2016.
[26] Source: Addis Ababa City Administration, 2010, Overview of Addis Ababa City Solid Waste Management System.

Photo: A'Melody Lee / World Bank

translates into the potential for generating up to 240,000 t/year of RDF and 3.8 million GJ/year of thermal energy, which is up to 20% of the total forecasted thermal energy demand in the cement sector.

5.2 WOOD BIOMASS AND AGRICULTURAL RESIDUE

Wood biomass and agricultural residue offer promising sources of AF. Ethiopia's agricultural sector is well developed – it is the largest producer of coffee in SSA, and amongst the largest producers of wheat and maize in the region. Residue from maize, wheat, and sorghum together represent a technical potential of 27 million t/year. Currently, this agricultural residue is used primarily by rural households for cooking (as available given crop seasonality). However, the most biomass-to-fuel potential is represented by PJ, an invasive species occupying around 1.2 million ha in the Afar region.[27, 28] The total amount of biomass from PJ is estimated at 21 million t/year (based on an estimated yield of 17.8 tons/ha) and much of it would be available within 100-200 km from the Addis Ababa cement cluster.

Much analysis has been conducted on the use of PJ as a fuel source. The calorific value of PJ is estimated at 4,200-4,500 kcal/kg of biomass (or up to 17GJ/t), indicating a total energy potential of over 300 million GJ/year. Harvesting of PJ would also result in significant benefits. PJ is an invasive species that causes severe environmental degradation, and harvesting it would support greater biodiversity and enable crop and livestock production by local communities using cleared space. Negotiations have been in progress to secure access to the PJ-invaded areas, in order to bring in harvesting equipment and processing facilities to produce fuel for the cement companies.

As at May 2017, however, no projects had been implemented on a large scale. Given the attractiveness of PJ, this assessment focuses on PJ as the primary source of AF derived from wood biomass or agricultural residue.

While agricultural residue is available across the country, the largest quantities are available from PJ in the Afar region.

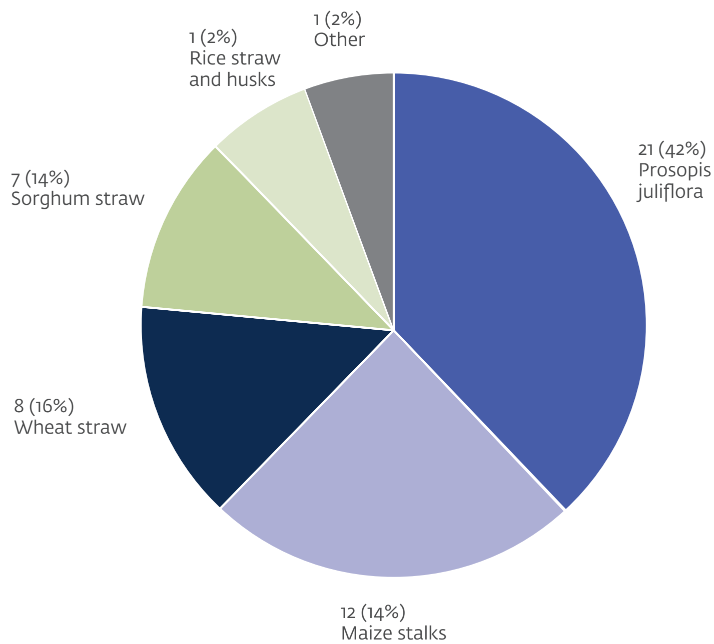


FIGURE 18: ESTIMATED AGRICULTURAL RESIDUES, MILLION T/YEAR

[27] Source: Joint Ethiopian Electric Power and NCSC / East African Mining Corporation PLC report regarding the Prosopis juliflora harvesting areas in Afar region.

[28] Source: Afar Regional Government Pastoral Agriculture Bureau.

Photo: © Simone D. McCourtie / World Bank

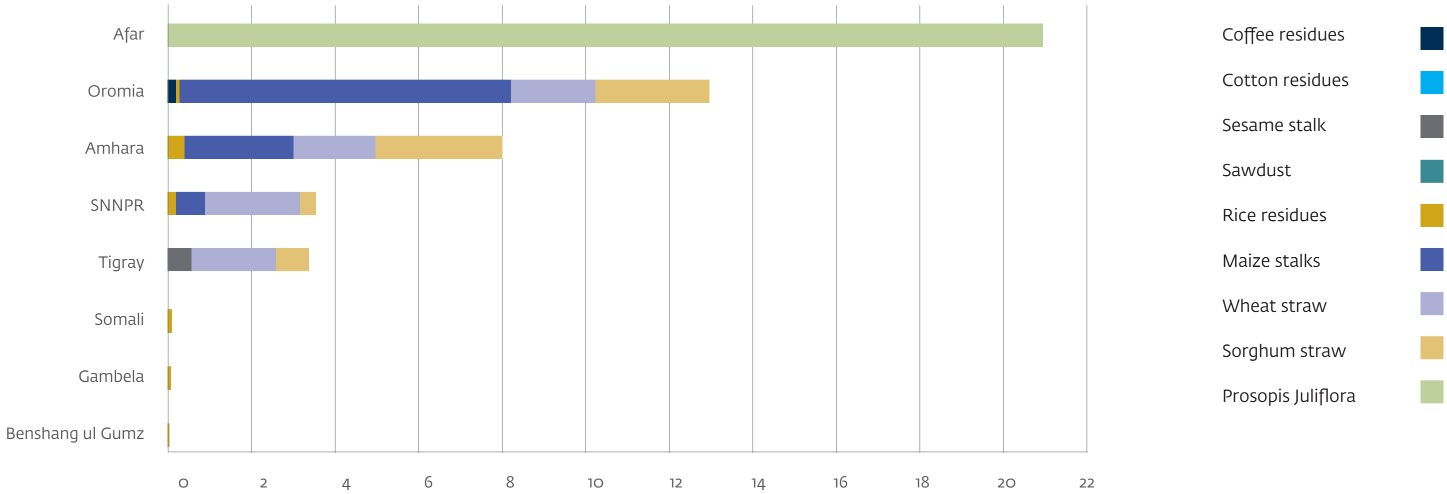
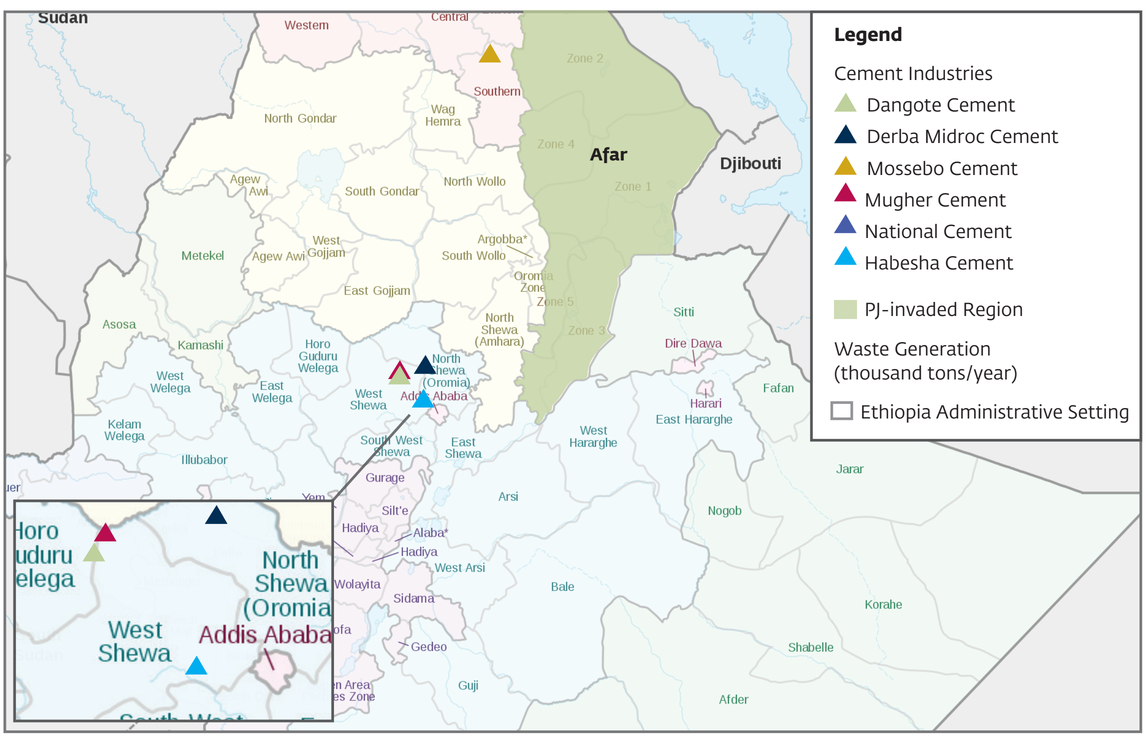


FIGURE 19. AGRICULTURAL RESIDUE PRODUCTION BY REGION AND CROP



https://commons.wikimedia.org/wiki/File:Map_of_zones_of_Ethiopia.svg

FIGURE 20. LOCATION OF THE PJ-INVADED REGION

Utilization of PJ (as well as other residue), although very promising, may be associated with a number of risks and challenges, potentially increasing the cost of sourcing and preventing access to some of the residue:

1. Accessibility and costs for most crop residues is defined by seasonality and alternative uses (including use by nearby communities) and cement delivery logistics: most crop growing regions are outside a 100 km range of the Addis Ababa cluster, so a limited amount of residue would be accessible by cement trucks; alternative logistics would dramatically increase the cost of sourcing;

2. Harvesting of PJ is predicated on access to land: ‘harvesting concessions’ from the local government along with agreements with local communities and farmers to hand over part of the cleared land, may take time and require additional costs to be borne by cement companies.

For the purpose of this assessment, it is assumed that up to 10% of the PJ residue can be immediately accessed via cement supply routes (i.e. by cement trucks that would deliver the fuel to the plants), resulting in **up to 30 million GJ/year technical thermal potential** being available.

5.3 WASTEWATER AND SEWAGE SLUDGE

Addis Ababa is the only city with a centralized sewerage network, however, the **network covers only 13% of the city**. The rest of the population relies on septic tanks,[29] which are evacuated by 50 to 60 government and 40 to 45 private trucks of varying capacity (3, 7.5, 8, 10, 12 and 16 m^3). Wastewater is collected in a number of catchments (open lagoons), three Waste Water Treatment Plants (WWTP), and a number of smaller plants that are either in operation or are under construction.

Sewage collected at catchment areas is estimated at 8.2 million tons/day. The sludge is left to be digested anaerobically. The lagoons are emptied and dried sludge removed on a staggered basis every 10 years.

The WWTPs have capacities of up to 12,500 m^3/day. All of the plants use biological waste stabilization pond technology. The Kality plant has a design treatment capacity of 7,500 m^3/day and will be upgraded to 100,000 m^3/day at an estimated cost of US$15 million (expected by 2025). The plant in Chefe has a potential treatment capacity of 12,500 m^3/day. These quantities suggest a thermal energy potential of up to 2-3 million GJ/year from dry sludge. These quantities, however, are unlikely to be available in the next 5-7 years or beyond, as significant expansion of the sewerage network will be required to produce sludge at full planned capacity.

TABLE 2. CATCHMENT SITES AND QUANTITY OF DISPOSED SEWAGE

Catchment Area	Quantity (t/day)
Kality	3,200,000
Decentralized (outside Addis Ababa)	2,853,000
Easter	1,500,000
Akaki	675,000
Total	**8,228,000**

[29] Interview with Addis Ababa City Water and Sewerage Authority, 2016.

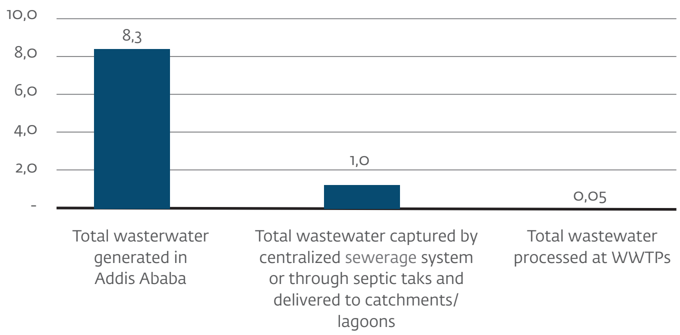


FIGURE 21. WASTEWATER TREATMENT VOLUMES IN ADDIS ABABA (2015), MILLION M[3]

Based on the available data, sewage sludge will not be considered as a technically feasible source of AF in the medium term for the purpose of the assessment.

5.4 WASTE TIRES

Though no reliable country-wide data is available and no formal collection system is in place, **an estimated 30,000-35,000 t/year** of tires is estimated to be available in the Addis Ababa area. Waste tires are most commonly recycled by formal and informal micro-entrepreneurs; limited amounts are disposed of at dumpsites together with MSW.

Once an integrated waste management system has been established, it may become feasible to establish formal waste tire collection and processing infrastructure (including joint processing facilities with MSW). This would make tires a viable source of AF, at **an estimated 1 million GJ/year**.

5.5 SUMMARY OF POTENTIAL

The assessment suggests that major technical opportunities for the use of alternative fuels are associated with the use of PJ and MSW concentrated in the Addis Ababa area. Tires and TDF may also represent potential once a collection system has been put in place. The total technical thermal energy potential for the Addis Ababa area is estimated at 35 million GJ/year.

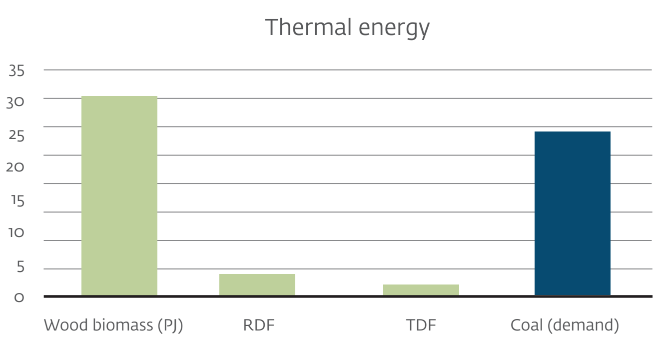
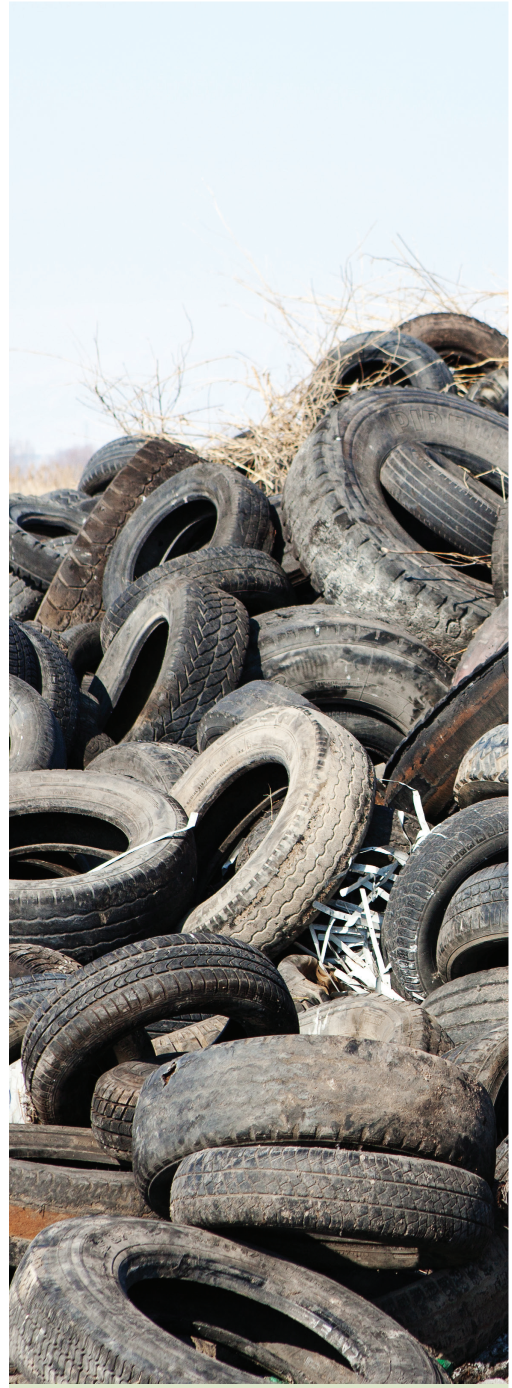


FIGURE 22. TECHNICAL POTENTIAL FOR SOURCING ALTERNATIVE FUELS – SUMMARY FOR THE ADDIS ABABA AREA, MILLION GJ/YEAR



The market environment, regulatory framework and barriers that prevent the full utilization of this potential, especially for RDF and agricultural residue, as well as the cost of sourcing these fuels under different scenarios, are explored further in Sections 6 and 7 of this report.

6. Waste Management and Alternative Fuels: Policies, Practices and Barriers

An environmental and waste management legislation framework exists in Ethiopia, however, **incentives are inadequate** or are **not enforced in way that encourages greater private sector** participation in the waste management space. Payments from 'polluters' only partially cover costs and tend not to be linked to waste quantities. This low level of cost recovery limits the ability of private sector players to invest in their capacity. As such, the introduction of **measures such as the 'polluter pays' principle**, and **Extended Producer Responsibility** will be critical for attracting private investment into the sector.

Ethiopia's waste management policy is based on the Solid Waste Management and Environmental Pollution Control Proclamations, and the Environmental Policy. Development of the sector is hindered, however, by a lack of enforcement of the existing policy and regulations, limited management capacity, lack of coordination between municipalities and other stakeholders, and limited involvement of formal private sector players. Very poor working conditions and low efficiency of informal sector players are further concerns.

Ethiopia's Constitution is an important source of environmental law. Ethiopia's environmental policy is based on Articles 92.1 and 92.2:

- Article 92.1: "Government shall endeavour to ensure that all Ethiopians live in a clean and healthy environment"
- Article 92.2: "Government and citizens shall have the duty to protect the environment"[30]

The primary national policy on waste management is the Solid Waste Management Proclamation (513/2007), issued in 2007. Its main objective is to enhance capacity for prevention of possible adverse effects from waste and creation of economically and socially beneficial assets from waste.

The Proclamation covers the following topics relating to SWM: responsibilities, waste management planning, collection & storage, transportation, treatment, disposal, incineration, recycling, and management of hazardous waste. The Solid Waste Management Proclamation supplements the Environmental Pollution Control Proclamation (300/2002), which places an obligation on all urban governments to devise and implement safe and effective mechanisms to handle, transport, and store municipal waste. It also states that any transport or treatment of municipal waste can be done only with a permit from the Ethiopian Environmental Protection Agency.

Waste management governance – a snapshot

The Government of Ethiopia established the Ministry of Environment and Climate Change (formerly the Environmental Protection Authority) in 2013. It is mandated with coordination of the implementation of the Ethiopian Climate Resilient Green Economy (CRGE) Strategy, covering environmental management and forestry. More specifically, the Ministry:

- Drafts environmental policies, regulations, directives and standards.
- Coordinates various environmental protection stakeholders.
- Oversees and controls the disposal of municipal and industrial waste and by-products.
- Approves licences for various manufacturing and service industries based on relevant environmental declarations.

[30] Source: Environmental Policy Review 2011: Waste Management in Ethiopia.

TABLE 3. MAIN ARTICLES OF THE SOLID WASTE MANAGEMENT PROCLAMATION AND THE ENVIRONMENTAL POLLUTION CONTROL PROCLAMATION

SWM activity	Proclamation	Description
Management of municipal waste	Environmental Pollution Control Proclamation	All urban administrations shall ensure the collection, transportation, and, as appropriate, the recycling, treatment or safe disposal of municipal waste through the institution of an integrated municipal waste management system.
Management of household solid waste	Solid Waste Management Proclamation	Each household shall ensure that recyclable solid wastes are segregated from those that are destined for final disposal and are taken to the collection site designated for such wastes. Urban administrations shall ensure that adequate household solid waste collection facilities are in place. It is prohibited to dispose of litter on streets, waterways, parks, bus stops, train stations, sports fields, water bodies in urban areas or in other public places while litter bins are available.
Collection / recycling of glass containers and tin cans	Solid Waste Management Proclamation	The manufacturer or importer of glass containers or tin cans shall develop and implement a system that enables it, on its own or through other persons, to collect and recycle used glass containers or tin cans.
Collection and disposal of food-related solid waste	Solid Waste Management Proclamation	Food industries and restaurants shall collect, store and dispose of the food-related solid wastes they generate in an environmentally sound manner. Restaurants shall design and implement SWM systems in accordance with directives issued by the concerned

SWM activity	Proclamation	Description
Transportation	Solid Waste Management Proclamation	Urban administrations shall set the standards to determine the skills of drivers and equipment operators and prevent overloads of solid waste.
Disposal	Solid Waste Management Proclamation	Each urban administration shall, in conformity with the relevant federal environmental standard, ensure that solid waste disposal sites are constructed and properly used. The owner of any solid waste disposal site shall, regardless of fault, be liable for any damage caused to the environment, human health or property in the course of its operation and after its closure.
Management of hazardous waste	Solid Waste Management Proclamation	The generation, keeping, storage, transportation, treatment or disposal of any hazardous waste without a permit from the Authority or the relevant regional environmental agency is prohibited. Any person engaged in the collection, recycling, transportation, treatment or disposal of any hazardous waste shall take appropriate precaution to prevent any damage to the environment or to human health or well-being.
Permitting	Solid Waste Management Proclamation	Any person should obtain a permit from the concerned body of an urban administration prior to his engagement in the collection, transportation, use or disposal of solid waste.

In addition to the proclamations, the Environmental Policy of Ethiopia, issued in 1997, refers to waste management either directly or indirectly:

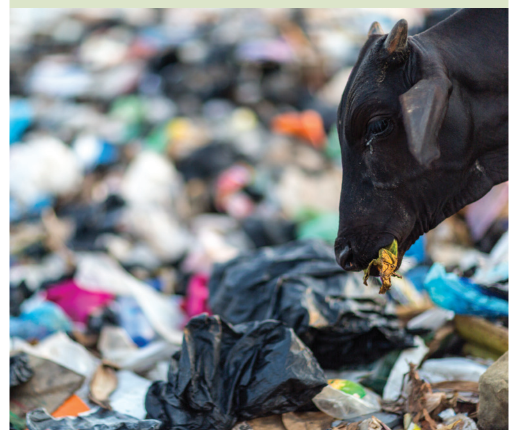
- Article 3.7 addresses issues related to human settlement, urban environment and environmental health;
- Article 3.8 addresses issues related to the control of hazardous materials and pollution from industrial waste; and
- Article 3.9 addresses atmospheric pollution and climate change.

Regional SWM legislation and regulation essentially follow national policy.[31] For example, in the Amhara region the regional law is the Basic Solid Waste Management Directive of Amhara Regional State Health Bureau 2009, which addresses issues of garbage classification, collection and storage, treatment, disposal, and recycling in the same manner as the national governmental policy.[32]

Waste management tariffs – a snapshot

- Waste collection charges in Addis Ababa are reported to be added to water bills:
  - MSW is charged at 20% of the water bill for households and 40% for organizations;
  - Wastewater collection and treatment service fees are included in drinking water accounts, at approximately 4-5% of water accounts in 2016 (an increase to 50% in the short-term is planned).
- Waste services in Mekelle are charged at varying rates from 2 birr/year for low-income households to 26 birr/year for high-income households (US$0.08-US$1).
- In Dire Dawa, collectors gather waste from households 2-3 times per week at a charge of 10 birr/month (US$0.4).
- A gate fee is charged at Repi dumpsite of 15 birr/ton of waste (US$0.6).

Although an environmental and waste management legislation framework exists in Ethiopia at the national and municipal levels, there is a lack of incentives for private sector participation in the waste management space, including waste recovery and AF projects.



[31] The Ethiopian legal system comprises a federal government and regional governments.

[32] Source: Environmental Policy Review 2011: Waste Management in Ethiopia.

Photo: © James Martone / World Bank

The current framework and enforcement practices create the following issues and challenges:

- In many cases, waste management services are provided as a social service: the cost is recovered on the basis of household incomes and/or other utility bills, rather than linked to the quantities of generated wastes (added to the fact that metering and measurement of waste volumes is not universally done and reporting has significant gaps);
- The payments recovered from 'polluters' contribute to around 30% of the total estimated cost of collection, transportation and treatment of waste. The rest is being subsidized by the government, often irregularly and incompletely, despite the fact that the budget for waste management services has been increasing over the past few years;
- Historically, the sector has been dominated by small-scale municipal companies and mini- and micro-entrepreneurs that are semi-formal or informal, especially at the primary collection level. The low level of cost recovery and cash flow gaps do not allow these players to invest in waste recovery or development of infrastructure, therefore, it has been traditionally done by the government (although on a limited scale).

As a result, in the current market environment, any potential AF project, especially in the RDF/TDF space, will require consolidation of waste streams and volumes and additional investment in basic waste management infrastructure, as well as guaranteed cost recovery to ensure uninterrupted supply of waste to the AF production facilities. In the case of the Repi WTE project, the government took on the roles of sector coordinator and sole investor. To engage private players in such projects (including AF), full implementation of the 'polluter pays' principle and other mechanisms such as Extended Producer Responsibility is essential. This will result in the sector becoming more attractive for private players, including cement companies. The impact of some of these barriers on the cost of sourcing key types of AF and economic feasibility of such projects is explored in the following section.

7. Economic Potential for the use of Alternative Fuels

Comparative assessment demonstrates that, if barriers for access to finance for basic waste collection and treatment infrastructure are removed and incentives for private sector players are created, the cost of sourcing of certain AF, such as RDF and TDF, at US$2.1-2.5/GJ, can be **35-50% lower than that of coal**. Full utilization of economically viable AF would offset 25-30% of thermal energy and **reduce total fuel costs by up to 10%** across the sector. **Total investment of up to US$30 million would be needed** (including AF production facilities and kiln modifications), **paying back in 3-4 years**. Expanding the use of agricultural residue beyond current levels may result in additional costs, and available volumes may be volatile due to fluctuations in crop production.

In the context of Ethiopia, and specifically in the Addis Ababa area, to utilize the RDF potential fully, material recovery facilities will need to be built. Assuming a total capacity of up to 1 million t/year of MSW, these facilities would be able to produce up to 240,000 t RDF per year and will require CAPEX of up to US$20 million, with TDF production requiring up to US$1 million more.[33]

Depending on how many kilns will be modified by each cement company, additional CAPEX of up to US$20 million will be required (if all kilns in the Addis Ababa are modified).

Implementation of the Option 1 scenario described in Section 2 would mean that the cost of basic collection and transportation infrastructure would be fully covered by the waste management sector players or other agencies (rather than passed on to other players).[34] Based on the estimated cost of processing MSW into RDF (proportional to the total amount of incoming MSW), as well as the cost of delivery of RDF to major cement plants in the area, the total cost of sourcing RDF can be estimated at US$2.2/GJ, which is around one third of the current cost of coal.

Under this scenario, the cement sector would cover 50% of MRF CAPEX, affording it some control of the cost of fuel and ensuring security of fuel supply. Thus, the total investment requirement for the cement sector is estimated at up to US$30 million, paying back in 3-4 years.

Implementation of the Option 2 scenario in the Addis Ababa area would mean that cement companies would invest in the entire consolidated MSW/RDF value chain, including basic collection infrastructure, and bear the full operational cost (excluding the payments that waste management companies are currently receiving for their services). This scenario represents Ethiopia's current situation where private sector operators lack access to finance for investing in infrastructure and are not incentivized to engage in waste recovery projects.

[33] See Annex 2 for detailed MRF characteristics and assumptions.

[34] See Section 2 and Annexes for details on the cost structure.

In this case, the total cost of sourcing RDF would be US$4.2/GJ, accompanied by the risks of waste supply security, since the waste collectors will not be able to recover the cost of building and operating proper collection and transportation infrastructure.

However, even with these additional costs and risks, AF projects would still be viable under this scenario, as RDF would be 30% cheaper than coal. Investment in establishing waste collection and transportation infrastructure is estimated at US$30 million. If cement companies (in cooperation with large-scale private waste management operators) took on 50% of this cost as well as 50% of MRF costs, the total investment amount would be up to US$45 million, paying back in 6-7 years due to fuel cost savings.

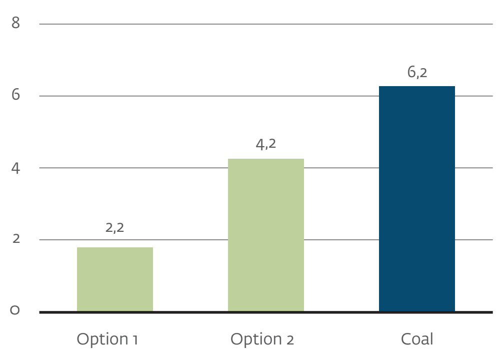


FIGURE 23. COMPARATIVE COST OF SOURCING REFUSE-DERIVED FUEL FOR CO-PROCESSING FOR THE CEMENT KILNS IN THE ADDIS ABABA AREA, US$/GJ

The cost of sourcing PJ is relatively low – as this type of fuel is accessible in bulk quantities and supply is highly concentrated, cement trucks can be used for transporting the biomass fuel to the kiln. Based on the processing cost alone, the estimated cost of sourcing PJ would be US$2.5/GJ, which is around 2.5 times lower than that of coal. A standalone PJ project would require CAPEX of an estimated US$10 million, paying back in around 3 years.

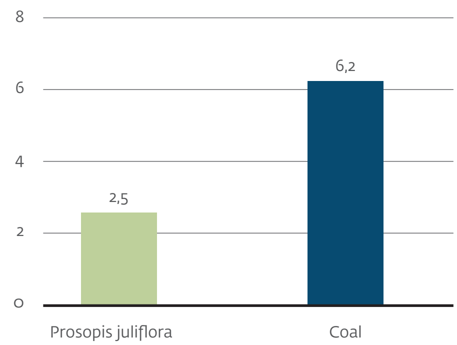


FIGURE 24. COMPARATIVE COST OF SOURCING PJ AS FUEL FOR CO-PROCESSING IN THE CEMENT KILNS IN THE ADDIS ABABA AREA, US$/GJ

Given the estimated quantities of tires, it makes economic sense to recycle tires and produce TDF at a combined facility, which is assumed to require US$20 million in capital investment for both RDF and TDF production. In the case of a standalone TDF facility, capital investment is estimated **at US$1 million**, while the **cost of sourcing of TDF would be US$2.2/GJ**, resulting in a **2-3 year payback period**. The main issue for unlocking TDF potential is, however, access to fuel, as the infrastructure for separate collection of tires is virtually non-existent. It can be assumed that establishing a RDF production framework will also boost TDF production.

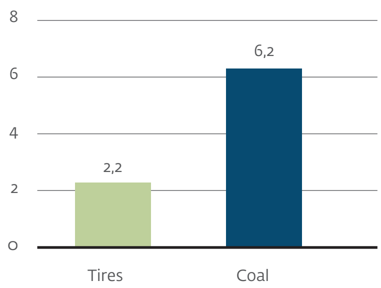


FIGURE 25. COST OF SOURCING OF TIRE-DERIVED FUEL FOR CO-PROCESSING IN THE CEMENT KILNS IN THE ADDIS ABABA AREA, US$/GJ

As presented below, sourcing costs for key types of AF – RDF, TDF and PJ – compare favorably with the cost of coal. Thus, under the Option 1 scenario for sourcing RDF (along with TDF and PJ), the total amount of investment required by cement companies would be US$40 million, paying back in 3-4 years, while under the Option 2 scenario, the CAPEX estimate is US$55 million, paying back in 6-7 years.

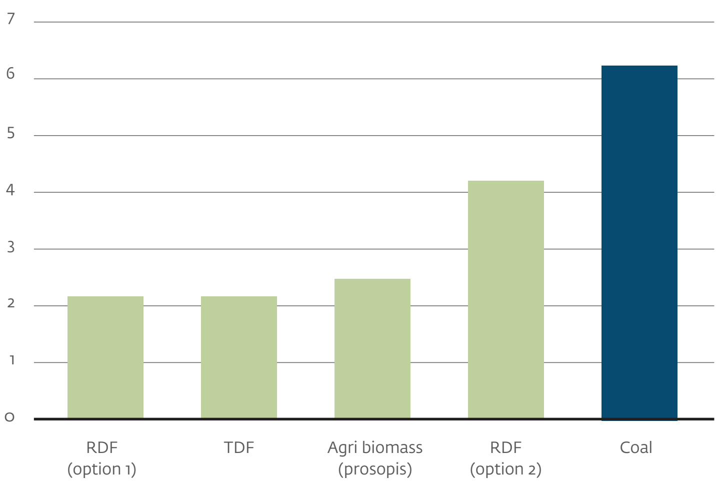


FIGURE 26. COMPARATIVE COST SOURCING ALTERNATIVE FUELS IN THE ADDIS ABABA AREA, US$/GJ

8. Summary and Conclusions

There is significant potential for sourcing AF for the cement sector in Ethiopia, specifically in the Addis Ababa area where four out of six major cement producers are located. Almost 35 million GJ could technically be sourced from waste-derived fuels, such as RDF, TDF and agricultural residue (specifically PJ). This exceeds the thermal energy demand in the Addis Ababa area, which is estimated to amount to 24 million GJ/year by 2020. The use of sewage sludge, typically a high-potential source of energy, is not feasible due to the current low capacity of the wastewater treatment system.

All major cement producers in the Addis Ababa area are considering using AF and particularly PJ. The use of PJ may, however, require long-term engagement with the local communities and may be associated with additional sourcing risks (and potentially increased costs). To justify investment in AF projects, it is essential that the long-term supply of AF be secured at a predictable cost lower than the current cost of the major conventional source of energy, which is coal (at US$6.2/GJ).

The business case for increasing the use of AF is strong. The sourcing cost for selected AF is estimated at US$2.2-2.5/GJ, resulting in fuel cost savings that will support pay back of the required investment of US$40 million by the cement sector in 3-4 years. Some of the steps within that system that would directly support investment in AF include:

(1) Establishment of waste quantities measurement and metering system at all stages of waste handling, which would enable linking payments for waste management services to the volumes of processed waste;

(2) Consolidation of the existing waste management collection and transportation infrastructure currently operated by small-scale municipal companies and private medium, small and micro enterprises (MSMEs) and establishment of a PPP framework for private sector participation in this process; and

(3) Upgrade of technical capacity and knowledge of the waste management sector players, including government agencies, with a focus on possible deal structures, contracting and tendering practices.

With these measure implemented, the cost of AF sourcing and overall economics, especially for RDF, point to the Option 1 scenario. At the same time, the high cost of coal would even justify deeper engagement of the cement companies in the waste/AF supply chain, including building a consolidated collection and delivery infrastructure. The required amount of CAPEX would then be US$55 million, paying back in 6-7 years, according to the scenario modeled under Option 2. However, it needs to be noted that 'interim' scenarios are also possible, depending on factors relating to the stage of market development and parameters of each deal, including the following:

- Contracting and payment mechanism and processing of payments (directly from service consumers, through designated government agencies, etc.);
- Composition of investors in the waste management infrastructure and their expected rates of return;
- Specific incentives for waste recovery (including those introduced as clauses of a PPP agreement) such as direct subsidies to players, one-off or recurring fees and surcharges (gate fees or equivalents), co-investment in infrastructure or offsetting part of CAPEX, tax credits, cross-subsidizing of waste management costs; and
- Liabilities of the stakeholders engaged in the AF project, risk insurance and penalties, etc.

The actual sourcing cost is therefore likely to fall between the Option 1 scenario and the Option 2 scenario, under which cement players would cover the full costs of the RDF value chain.

Much will depend on the development of an enabling environment and supporting infrastructure in the sector. In Ethiopia, the government already has experience in investing in waste management infrastructure and implementing waste recovery projects, such as the Repi WTE facility, which is to be launched in 2017. Continuation of this work, coupled with the specific measures above would create an enabling environment and unlock potential for the increased use of AF within the next few years.

ANNEXES

Annex 1

Assumptions on the properties of source waste streams, pre-processing requirements and corresponding modifications to the cement kiln.

MUNICIPAL SOLID WASTE

- 12-16 Lower Heating Value (LHV) GJ/dry ton
- -0.4 CO_2 change

COLLECTION & TRANSPORT

Trash collection fleet

PROCESSING

Bag opening & sorting → Drying & shredding → Screening / sorting → Shredding & baling/ pelletizing

- Bag opening & sorting:
  - o Bag opening system
  - o Overhead electro-magnetic moving belt or rotating magnetic drums
- Drying & shredding:
  - o Blower of rotary aerobic digestion drum
  - o Primary shredder
- Screening / sorting:
  - o Infrared sensor
  - o Mechanical centrifuge
- Shredding & baling/ pelletizing:
  - o Secondary shredder
  - o Pelletizer

Typically up to **30% substitution**, can be fed to **kiln entry region**, calciner or **burner** [<30mm, 15% moisture and <12% when fed to burner, <0.8% chlorine, and <2,00mg/kg heavy metal]

TIRES

- 12-16 LHV GJ/dry ton
- -0.8 CO_2 change

TIRE MANAGEMENT & COLLECTION

PROCESSING

Chopping & shredding → Metal removal → Granulating

- o Tire shredder / shredder

Typically **10-20% substitution** when fed as 5-30mm pieces to **kiln entry region** or **calciner** [dry process]; 10% substitution when whole tires fed directly to kiln

CEMENT PLANT

Typical upgrades required

TYPICAL UPGRADES REQUIRED

- **Debaler:** Breaks up compacted wasted (RDF, agricultural waste, etc.) to loosen the material and render it into a loose fluff
- **Storage systems:** Store the AF in silos, hoppers or moving floor systems
- **Flow control rotor type weighing systems**, equipped with **dosing mechanisms**: Allow for accurate and consistent feed rate of AFs
- **Materials handling:** Handle AFs using mechanical (screw conveyors, belt type conveyors, disconveyors, elevators, etc.) and/or pneumatic transport systems
- **Pipe above the burner:** a pipe coated with castable refractory materials above the main burner
- **Flexible multi-fuel burner** – the AF must be fine, e.g. RDF in pellets and <12% moisture, sewage sludge in pellets <5mm
- **Calciner:** Allows for lower temperature combustion, thereby reducing Nox – typically required for high AF levels and low grade AFs
- **Analyzing system:** Ensures kiln efficiency by monitoring O_2 and CO levels (variations in AF moisture content may cause flame shape change or CO rise in the calciner)
- **3G flap system** (triple gate): Minimizes false air entry during AF feeding – required for solid AFs which are not pulverized and cannot be sent to the calciner pneumatically or via mechanical conveying systems

INDICATIVE COSTS* (EUR)

TOTAL	**4,255,000**
Feeding / trasport machinery	750,000
Foundations – civil works	550,000
Shredding systems and mills	500,000
Pre-calciner and calciner	500,000
Fuel storage & fire-fighting systems	400,000
Weigh feeders	150,000
Environmental protection equipment	150,000
In-situ analyzers	150,000
Moving machinery	150,000
Moving floors	120,000
Double valves – flaps	50,000
Pneumatic transport	35,000
Other (electromechanical fabrications, installation, control, debaler, etc.)	750,000

Typically up to **20% substitution**, can be fed to **kiln entry region** or **calciner** in 2-5mm pellets (semi-dry and dry process systems) or pneumatically to **burner**

Typically **20% substitution**, can be fed at the **main burner** if below 6mm, or **at kiln entry region** or **calciner**

SEWAGE SLUDGE

- 10.5-29 LHV GJ/dry ton
- -2.5 Δ CO_2 (ton/ton coal replaced)

COLLECTION THROUGH SEWAGE SYSTEM/TRUCKS

PROCESSING

Screening & treatment → Dewatering / drying → Pelletizing

AGRICULTURAL WASTE

- 14.4-19 LHV GJ/dry ton
- -2.5 Δ CO_2 (ton/ton coal replaced)

COLLECTION

PROCESSING

Drying → Shredding → Pelletizing

Notes:

Lower heating value (LHV) calculated based on reported higher heating value (HHV).
Change in CO_2 emissions assumes that biomass is carbon-neutral; negative values represent a net reduction in emissions.

Annex 2

Technical, operational and economic assumptions on waste management facilities involved in production of alternative fuels.

TYPE OF FACILITY	SET OF ASSUMPTIONS
MATERIAL RECOVERY OF MSW (MRF PRODUCING RDF)	› Located very close to or on a major dumpsite. › Capacity: up to 0.5 million t/year MSW. › The MRF will have the capacity to perform the following operations: - Receiving of waste. - Manual removal of large items. - Bags knife splitter. - Magnetic separation. - Primary shredding. - Second magnetic separation, trommel screen separation, air or ballistic separation. - Thermal drying to reduce moisture to 10%. - Secondary shredding to the required product fineness of 30 mm and possible pelletizing of product to 12 mm (if needed). - Drying will be performed using open chamber firing in a rotary drum as the gas available from the landfill is not adequate or available. › The operating hours of the facility are 8,000 hours/year. › Electricity consumption: 30 kWh/t of waste at an electricity price from the grid of 0.1 US$/kWh. › Cost of fuel for moving machinery (cars, pickups, forklifts and front loaders): 0.7 US$/t of MSW. › Operation and administration costs: US$3 million/year. › Maintenance costs: 20% of the operation and administration costs. › Insurance: US$0.5 million. › Total operating (OPEX) fixed costs: ~ US$4-5 million/year. › Total operating (OPEX) variable costs: ~ US$13 million/year. › CAPEX: up to US$10 million. › Economic life: 20 years.
SEWAGE SLUDGE TREATMENT PLANT	› Plant capacity (wet input): 30,000 t/year. › The moisture of wet sewage sludge is considered 60% (average) and the plant will have the ability to dry the sludge to 5% moisture content. › The operating hours of the plant are 8,000 hours/year. › Electricity consumption: 300 kWh/t of dry product at an electricity price from the grid of US$0.1/kWh. › Cost of fuel for moving machinery: US$0.7/t of wet sludge. › Total operating (OPEX) fixed costs: ~ US$1 million/year. › Total operating (OPEX) variable costs: ~ US$1.7 million/year. › CAPEX of the plant: US$8-10 million. › Economic life: 20 years.

TYPE OF FACILITY	SET OF ASSUMPTIONS
TIRE PROCESSING PLANT PRODUCING TIRE-DERIVED FUEL (TDF)	› Capacity: 30,000 tires per year. › End-of-life tires will be shredded to a size of 5-30 mm so as to be suitable for co-firing as AF by the cement industry. › The plant will have the ability to handle any size and type of tires. › From the large tires, the central steel cord will be removed, then will be cut and directed to the shredder. The small tires will be shredded directly in the primary shredder. Any oversize pieces of tires will be recycled for re-shredding. › The operating hours of the plant are 8,000 hours/year. › Electricity consumption: 50 kWh/t of tires at an electricity price from the grid of US$0.1 /kWh. › Total operating (OPEX) fixed costs: ~ US$0.5 million/year. › Total operating (OPEX) variable costs: ~ US$0.5 million/year. › CAPEX of the plant: ~ US$1 million/year. › Economic life: 20 years.
AGRICULTURAL RESIDUE PROCESSING FACILITY	› Capacity: 40,000 t/year. › Agricultural residues will be shredded to a size of 5-30 mm so as to be suitable for co-firing as AF by the cement industry. The plant will have the ability to handle any size and type of agricultural residues. › Sieving will be performed so that any slides of material not shredded will return for re-shredding. › Large trunks will be cut into sizes of up to 500 mm before being fed to the primary shredder. Straw, etc. will be fed directly to the shredder. › The operating hours of the plant are 8,000 hours/year. › Electricity consumption: 30 kWh/t of agricultural residues at an electricity price from the grid of US$0.1/kWh. › Total operating (OPEX) fixed costs: ~ US$0.5 million/year. › Total operating (OPEX) variable costs: ~ US$0.7 million/year. › CAPEX of the plant: ~ US$1 million. › Economic life: 20 years.

Sources: IFC, interviews with market players.

Annex 3

Technical, operational and economic assumptions on the collection and transportation of source wastes and AF.

FACTOR	ASSUMPTION
Number of loads per day for collection and transport to the processing facility (return trips)	25 km: 3 50 km: 3 100 km: 2 200 km: 1
Persons for collection (workers)	Tires: 3 MSW: 4 Sewage sludge: 1 Agricultural residue: 4
Cost of each worker (US$/day)	11 (up to 100 km) 14 (200 km)
Cost of the driver (US$/day)	14
Cost of truck (US$/day)	27.4
Truck fuel consumption (l/km)	0.2
Price of diesel	1
Truck load (t)	Tires: 4 MSW: 10 Sewage sludge: 15 Agricultural residue: 7

Sources: IFC, interviews with market players.

Annex 4

Composition and maximum selling price of recyclable materials.

RECYCLABLES	COMPOSITION (%)	MAXIMUM SELLING PRICE (US$/T)
Paper	7.0	40
Cardboard	6.0	50
Plastic bottles of Polyethylene Terephthalate (PET)	5.0	200
Glass	4.2	15
Recyclable construction and demolition (C&D) waste	3.2	80
Aluminum cans	3.0	200
Ferrous matter	2.5	100
Low Density Polyethylene (LDPE)/ Polypropylene (PP)	2.4	120
Non-ferrous metals	1.0	150
Polyvinyl Chloride (PVC)	0.8	80

Sources: IFC, interviews with market players.

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