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

Korea Green Growth Trust Fund

WORLD BANK GROUP

IFC International Finance Corporation

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Photo: Curt Carnemark / World Bank

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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
EU	European Union
EUR	Euro
FCFA	West African CFA franc
GDP	Gross domestic product
GJ	Gigajoule
GoS	Government of Senegal
ha	Hectare
HDPE	High density polyethylene
IDB	Islamic Development Bank
IFC	International Finance Corporation
l	Liter
km	Kilometer
LDPE	Low density polyethylene
LHV	Lower heating value
m^2	Square meter
m^3	Cubic meter
MRF	Material recovery facility
MSW	Municipal solid waste
OPEX	Operational expenditure
ONAS	Office national de l'assainissement du Sénégal (National sanitation bureau)
PET	Polyethylene terephthalate
PNGD	Programme nationale de gestion des déchets (National program for waste management)
PP	Polypropylene
PPP	Private-public partnership
PVC	Polyvinyl chloride
RDF	Refuse-derived fuel
SSA	Sub-Saharan Africa
t	Metric ton
TDF	Tire-derived fuel
US$	US dollar
UCG	Unite de coordination de gestion des déchets (solid waste management coordination unit)
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 Senegal. The area around the city of Dakar is one of the prominent cement production clusters in West Africa, but also a major urban area, generating up to one million metric tons of waste each year. The main waste disposal site in the area, Mbeubeuss, is reaching its full capacity. Diverting the waste from the landfill, including conversion into fuel for cement plants, could be a sustainable solution.

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 aim to 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 Senegal.

MILAGROS RIVAS SAIZ

Global Head of Cross-Industry Advisory

Executive Summary

From August 2016 to April 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), agricultural residue, sewage sludge (produced from wastewater), used tires and tire-derived fuel (TDF), used oils, and other similar wastes, where applicable.

In Senegal, the assessment focused on the **Dakar area**, where both cement production and technical sourcing potential for AF are concentrated. At 7.9 million GJ/year, the technical sourcing potential amounts to **almost 50% of total energy demand**. Some cement companies are already using agricultural waste.

The assessment shows that, with the creation of an enabling environment for private sector participation, the cement sector can **substitute at least 25-30%** of its thermal energy demand with AF, **saving up to 10%**, approximately **US$6-7 million/year**, in total fuel costs. **RDF and TDF** show the greatest economic potential. Further expansion of the use of agricultural residue may be more challenging and costly, given the dispersion of agricultural production across the country. 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 10-15 years. Investment in material recovery facilities (MRF) to process MSW and tires to produce RDF and TDF respectively, will therefore be required, along with modifications to cement kilns.

Total **investment required by cement producers is estimated to be up to US$25 million**. This is based on approximately US$15 million in expenditure being required for kiln modifications (US$5 million for each of the three companies in the Dakar cluster) and a contribution of up to US$10 million towards MRF establishment (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). This investment will **pay back in 3-4 years**, depending on the sourcing model and fuel mix chosen by each of the players.

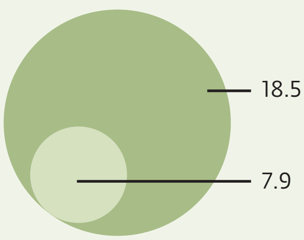
To support realization of this opportunity, cement producers need to secure AF supply at predictable prices that remain below the current price of coal (around US$100/t, or US$3.8/GJ in thermal equivalent). The establishment of an **efficient waste management system** is therefore critical, as proven 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. While Senegal does have a waste management policy in place, the policy framework does not promote private sector participation by setting targets or offering incentives for diversion of waste from landfills. Also, while secondary regulations supporting private sector involvement, such as those related to payments and contracting, may be in place, they are often not enforced.

The waste management system in Senegal is currently in transition: a coordinating agency responsible for waste management policy (at a national level) and operational management of waste in the Dakar area has been set up. One of the agency's priorities is the creation of a framework that fosters Private-Public Partnerships (PPPs) and private investment in the sector.

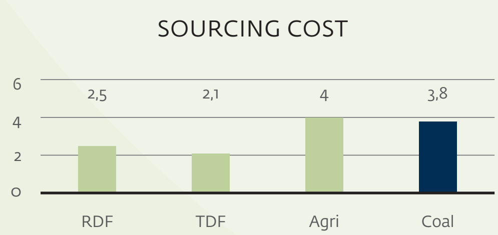
INVESTMENT US$ MILLION / PAYBACK (YEARS)

25 / 3-4



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

FIGURE 1. SUMMARY OF ALTERNATIVE FUEL OPPORTUNITIES FOR THE CEMENT SECTOR IN SENEGAL, US$/GJ



The following measures, implemented as part of Senegal's integrated solid waste management system, would encourage the use of AF by securing long-term supply and incentivizing investors to develop the required facilities:

(1) Clear definition of **waste ownership and responsibilities** for key waste streams, including treatment of waste tires as a stand-alone stream, separate from MSW, and enforcement of the obligation to collect and treat end-of-life tires;

(2) 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; and

(3) Establishment of a **transparent long-term contracting approach** for waste management services.

Implementation of 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 indirectly 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.

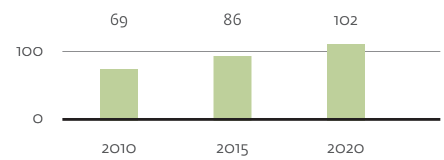


FIGURE 2. MUNICIPAL SOLID WASTE GENERATION IN NIGERIA, MILLION T/YEAR[1]

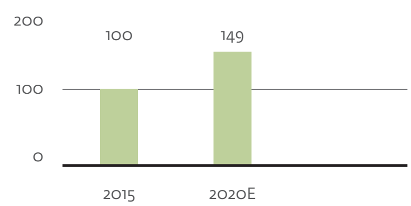


FIGURE 3. EXPECTED DEMAND FOR CEMENT IN SUB-SAHARAN AFRICA, MILLION T/YEAR[1]

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.

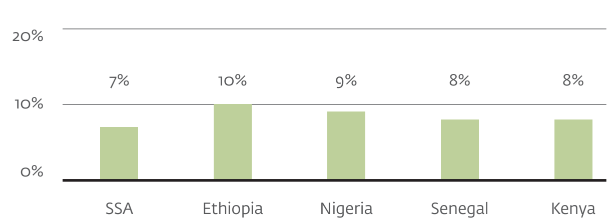


FIGURE 4. CEMENT CONSUMPTION GROWTH (2010-2015 CAGR)[1]

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

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.

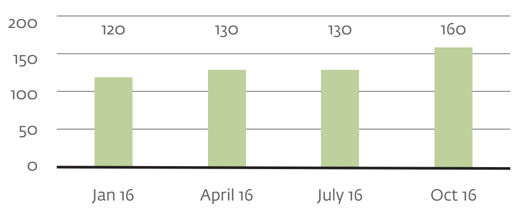


FIGURE 5. COAL PRICE IN ETHIOPIA, US$/T

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 Senegal.**[2] The study had the following objectives:

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

(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 Ethiopia, Kenya 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

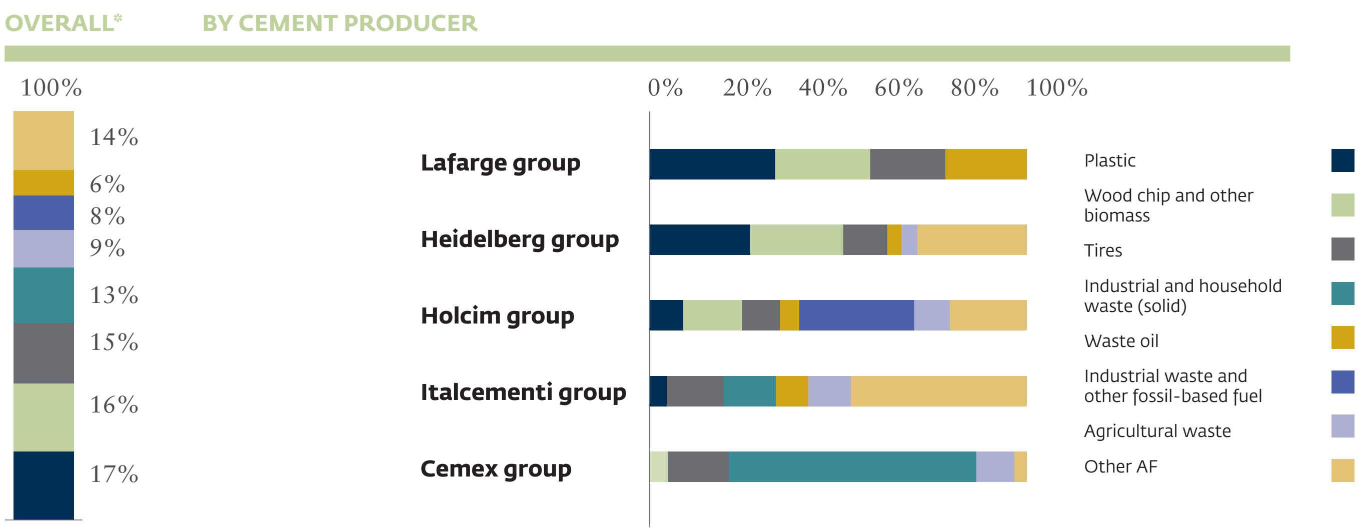
Cost Item	Option 1	Option 2
Cost of primary collection and transportation of MSW	Excluded	Included (with the exception of the cost currently covered by waste management fees and addition of the depreciation of CAPEX required to maintain infrastructure)
Cost of MSW processing at a comprehensive MRF	Included (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%

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.

Photo: Alex Baluyut / World Bank



*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]

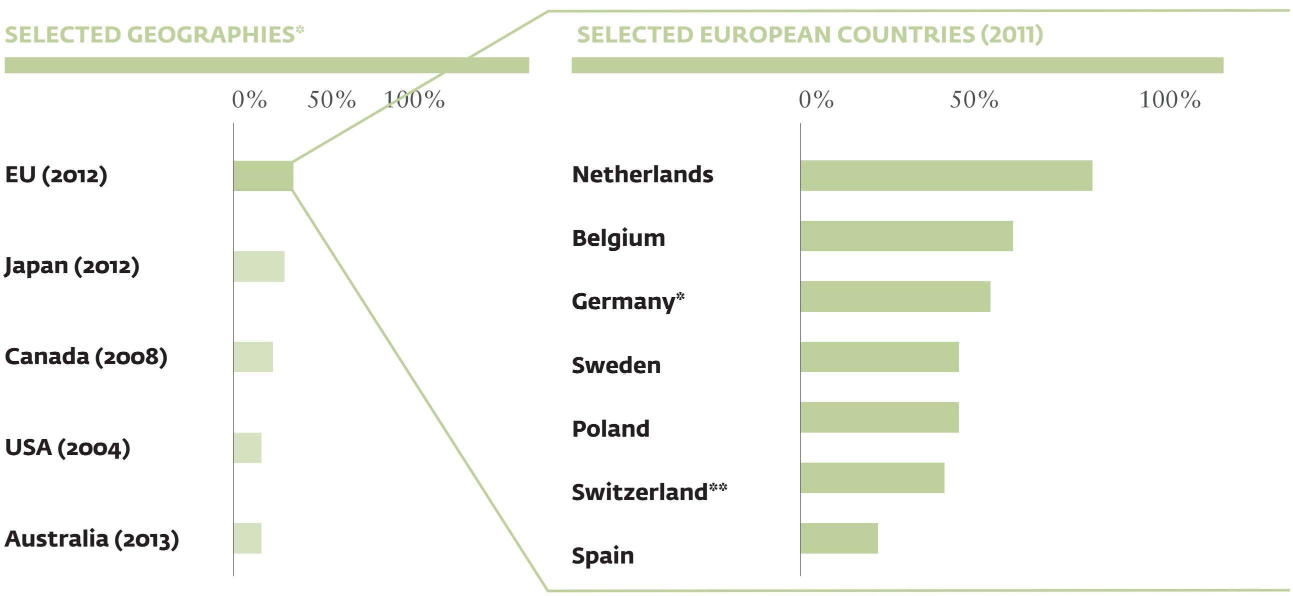
[3] Electricity needs vary from 90 to 120kWh/t of cement produced.

[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 Senegal: Overview and Energy Demand Forecast

Senegal's cement industry utilizes approximately 18.5 million GJ/year in thermal energy, served predominantly by coal. The price of coal is stable at US$100/t (or US$3.8/GJ thermal equivalent). Cement production is dominated by three major players (Sococim, Dangote and Ciments du Sahel) and is concentrated within a 50 km radius of Dakar.

The Senegalese cement industry serves the third largest cement market in Sub-Saharan West Africa – Senegal utilized 3.1 million t in 2015, compared to 23.2 million t in Nigeria and 5.5 million t in Ghana.[12] It is not known whether there are plans for major expansions or installations of new kilns before 2020.

Senegal's cement sector is dominated by three major regional players: Dangote, Sococim (Vicat Group) and Ciments du Sahel. At 100% capacity, the total clinker output is estimated at 5.1 million t/year and the thermal energy demand is therefore estimated at 18.5 million GJ/year.[13]

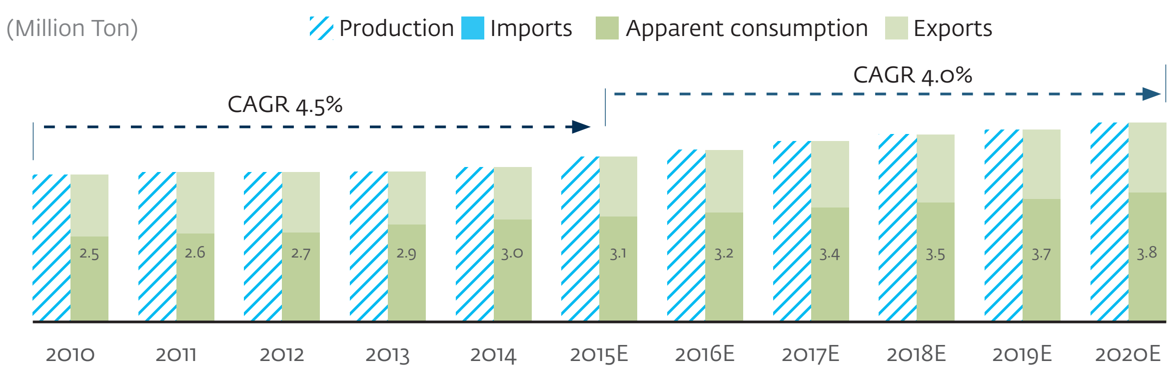
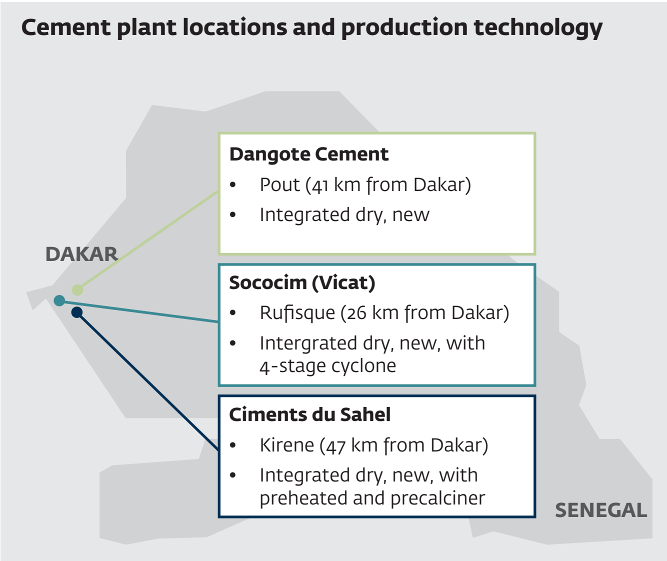


FIGURE 8. CEMENT PRODUCTION AND CONSUMPTION IN SENEGAL[14]

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

[13] Source: Dangote Cement, Annual Report 2015.

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



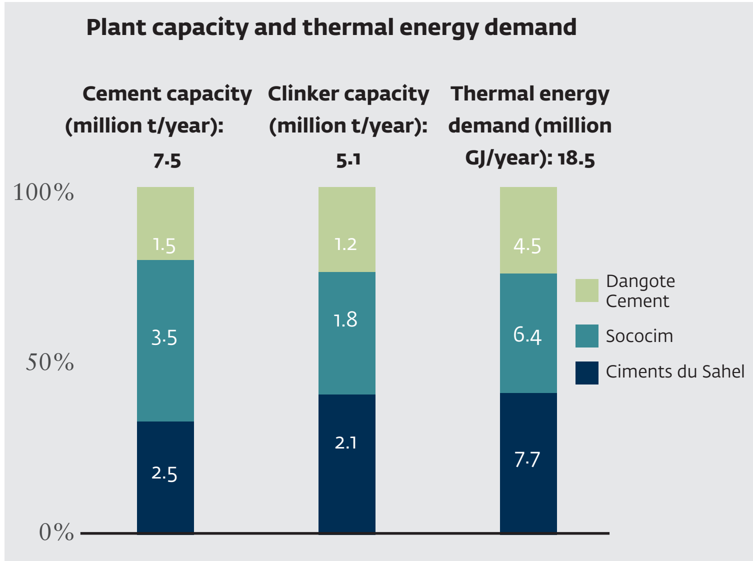


FIGURE 9. CEMENT PLANT LOCATIONS, CAPACITY AND ENERGY DEMAND[15]

The cement industry has good technical potential for AF substitution. The cement plants are concentrated around Dakar, in close proximity to the major metropolitan area, which is where waste generation is concentrated. Furthermore, the cement plants use dry process, cyclone preheater technology and are currently capable of achieving a substitution rate of 20-25% (with a maximum theoretical replacement of 30%); this could be increased to 50% with installation of appropriate AF equipment.[16]

Currently, however, the cement industry uses predominantly coal for its thermal energy needs. Most of the coal is imported from Southern Africa (including South Africa and Mozambique). The resulting cost at the plant is US$100/t, which translates into US$3.8/GJ of thermal equivalent. According to cement companies, the price has been stable over the past few years and there have not been any major fluctuations.

The three cement companies in Senegal already use peanut shells from processing facilities as AF; however, the use of tires, waste oils and other industrial wastes is limited and MSW/RDF is not used at all.

In an effort to lower the cost of sourcing thermal energy, cement plants are undertaking some initiatives to co-process AF with conventional fuels. At certain kilns, the fuel substitution rate reaches up to 25%, due to the use of biomass residues, used oils and tires.[17] The major source of AF is peanut shells, making up to 68% of the total AF volume. While husks are sourced from agricultural enterprises located up to 400 km away from the Dakar area, transport costs are kept low, as the cement trucks are also used to deliver the peanut shells. A detailed analysis of the AF sourcing potential is provided in the next section.

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

[16] 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).

[17] Interview with the cement sector players, 2016.

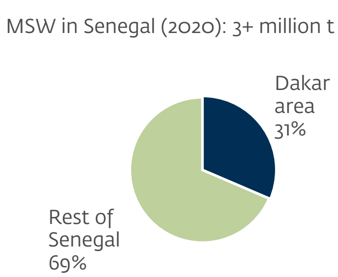
5. Technical Potential for the Use of Alternative Fuels

RDF from MSW, agricultural residue and waste tires available in the Dakar area show the highest technical potential for sourcing as AF, at 7.9 million/GJ in thermal energy. This amounts to almost half of cement companies' forecasted thermal energy demand.

5.1 MUNICIPAL SOLID WASTE

The generation of municipal solid waste has been growing steadily. 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 Senegal, MSW generation is estimated at 2.8 million t/year, based on a rate of 0.52 kg/capita/day.[18] At the same time, urban population is growing rapidly and, by 2020, the total quantity of waste (measured at collection) could reach or exceed 3 million t/year. Waste volumes vary from state to state – states with a more urban character generate more waste than those with a rural character. Dakar, the major metropolitan area, accounts for approximately one-third of that amount at 0.8-0.9 million t/year with a 60-70% collection rate, according to the local waste management agency.[19] When calculated on the basis of population and average generation, this figure is much lower, at around 500,000 t/year. This discrepancy highlights the difficulty of assessing MSW volumes in locations with high population growth and with a significant influx of daily workers. It also underlines the need for more precise measurement of waste quantities.



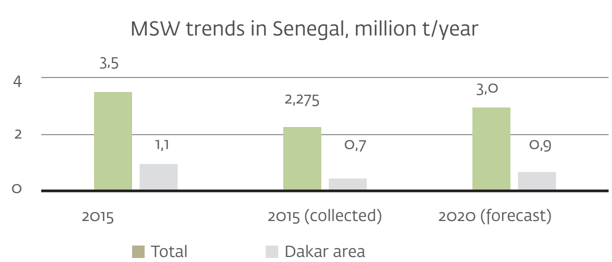


FIGURE 10. FORECAST OF AVAILABLE MUNICIPAL SOLID WASTE

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

[19] Interview with UCG.

Photo: © Aisha Faquir / World Bank

MSW is composed primarily of organic waste. Composition varies broadly across locations. In Thiès, for example, MSW is reported to contain approximately 11% organic matter and at least 9% plastics.[20]

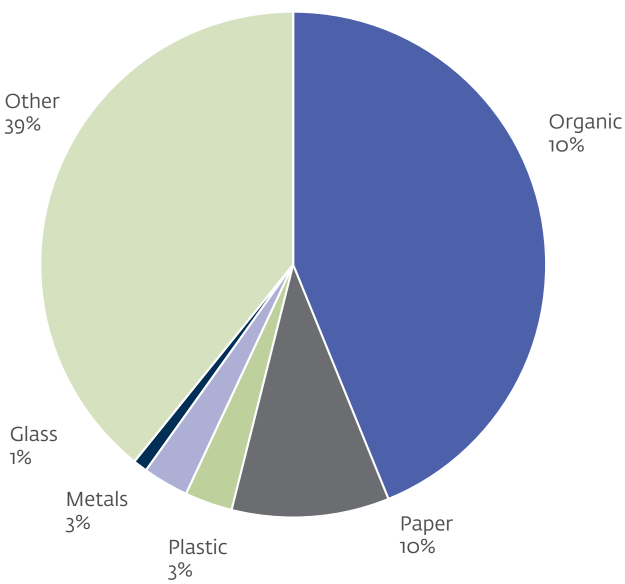


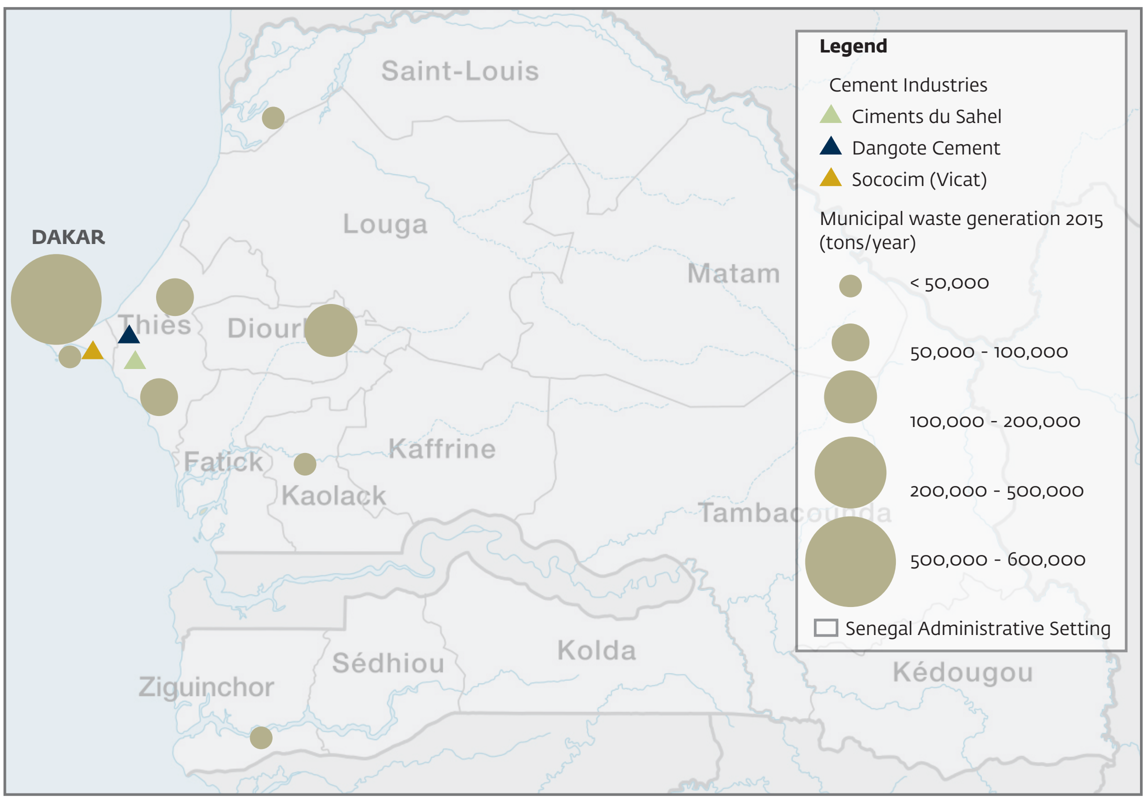
FIGURE 11. SENEGAL'S MUNICIPAL SOLID WASTE COMPOSITION (DAKAR AREA)[21]

For the purpose of the assessment, it is assumed that the total amount of municipal and similar solid waste available in the Dakar area by 2020 at the current rate of collection will be **up to 900,000 t/year**. Based on the assumed waste composition, this translates into the potential for generating up to **350,000 t/year of RDF and 5.5 million GJ/year of thermal energy**, which is up to **30% of the total forecasted thermal energy demand in the cement sector**. Further assessment focuses on the Dakar area as the largest cement production cluster, which also corresponds with the largest potential source of AF.

[20] Interview with UCG.

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

Accessibility of MSW is affected by the management of waste streams, from collection to disposal. Many areas in Senegal are either under-served or not served at all by waste management systems. Collection systems may not exist in some towns; where collection systems do exist, collected waste tends to be dumped in an uncontrolled manner along roads, in drain systems, or on the outskirts of settlements. Many settlements lack engineered landfills, and mixed streams of municipal, commercial and industrial waste are disposed of at informal dumpsites. This situation is exacerbated by inadequate policies, financial and operational constraints, and lack of awareness amongst citizens of good waste management practices.[22]



Agence Nationale de la Statistique et de la Démographie Sénégal

FIGURE 12. MUNICIPAL SOLID WASTE GENERATION IN MAJOR CITIES IN SENEGAL[23, 24, 25]

[22] Source: 2011, Regional evaluation of the SWM situation in target countries (report as part of the project "Integrated Waste Management in Western Africa").

[23] Source: http://www.citypopulation.de/Senegal.html

[24] Source: 2014, Study on the characterization of waste in Senegal (provided by UCG).

[25] In the absence of official data, waste quantities were estimated on the basis of population, using the most recent census (2013) and estimated population growth rates for each administrative region.

Formal collection services are generally better developed in larger cities. Collection rates are estimated at approximately 50% in most cities and at least 60% in Dakar and Thiès.[26] In Dakar, Unite de Coordination de Gestion des Déchets (UCG) is the government agency responsible for waste management operations, including MSW collection. It procures services from 22 private contractors, which deploy 250 trucks and 350 push-carts, covering approximately 1,400 km. These contractors are responsible for transferring waste to dumpsites. In other cities and towns, waste collection is managed by the municipalities, using either municipal agencies or private contractors. Waste is collected door-to-door by trucks, or, in areas that are inaccessible to trucks, by push-carts. It is not uncommon to see informal waste collectors using vehicles such as push-carts for door-to-door collection services in some cities.

The use of waste transfer stations is not common practice in Senegal. Waste is most commonly transferred by collectors directly to waste disposal sites. In Dakar, push-cart operators are reported to transfer collected waste to intermediate containers prior to final transfer to dumpsites.

Most waste management actors report a lack of formal MSW sorting or treatment infrastructure. Limited MSW sorting is, however, conducted by private firms and the informal sector. For example, IDEX, a private firm, was previously involved in waste collection and is currently active in recycling paper, plastics, aluminum cans and wood residues (to produce briquettes). IDEX receives waste from collectors or dumpsites, and sells recyclables either domestically to local entrepreneurs or to other countries (including Tunisia and China). Sorting by the informal sector ranges from sorting of waste collected from households to salvaging materials such

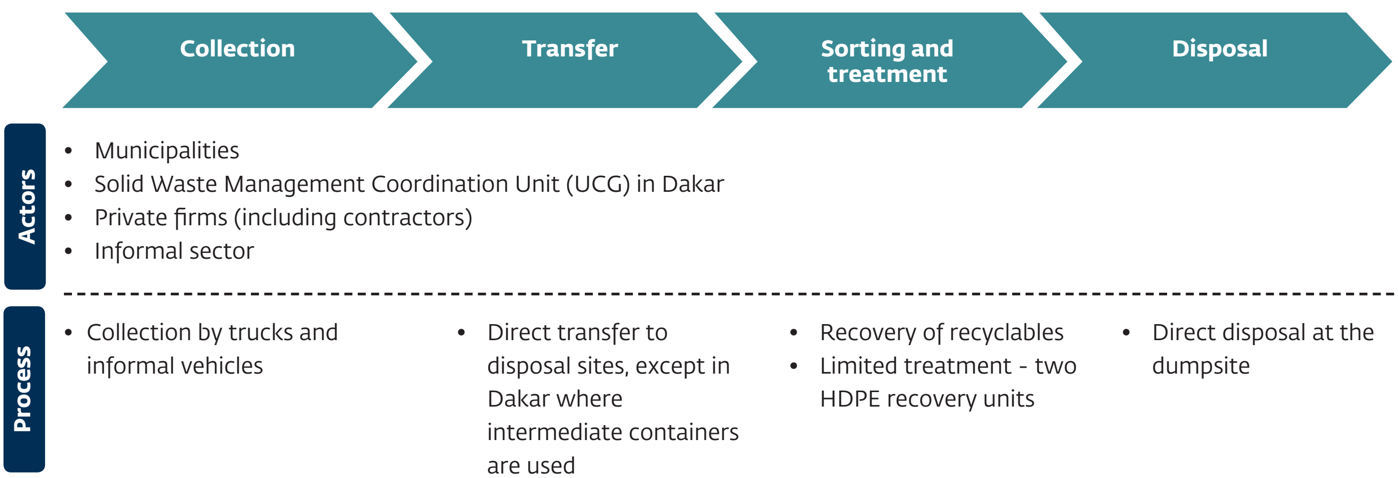


FIGURE 13. MUNICIPAL SOLID WASTE MANAGEMENT IN SENEGAL

[26] Interview with a waste collection company, 2016.

as plastics, paper, electric and electronic waste, glass and metals from landfill sites. Although there are no statistics on waste quantities that are segregated, it is estimated that in Dakar approximately 1,500 t (mostly plastics) are recovered per month.

Some limited pre-treatment of plastics is conducted by two units at Thiès (PROPLAST) and Kaolack. These two units specialize in the recovery, milling and granulation of High Density Polyethylene (HDPE), which is then sold for transformation. They are estimated to have a combined processing capacity of up to 20 t/year of HDPE.[27] Small-scale composting of the organic fraction of waste is being initiated as part of the National Strategy for Waste Management. Pilot projects are planned in Joal and Podor, with capacity of 10 t/year of waste.

Waste disposal is characterized by uncontrolled disposal of mixed waste to numerous unofficial dumpsites. In Dakar, Mbeubeuss is the largest dumpsite, covering approximately 100 ha. All three cement plants in the Dakar area are located within 50 km of Mbeubeuss dumpsite. Mbeubeuss was established in 1968 and receives mixed waste streams from the broader Dakar area. The site poses serious environmental and sanitary problems due to a lack of appropriate infrastructure (i.e. leachate and biogas collection), the waste types and quantities received, and the site's close proximity to residential areas. Plans for a new landfill site in Sindia were proposed over a decade ago. These were, however, suspended due to unfavorable local reactions. Besides Mbeubeuss, a number of other dumpsites serve Dakar: surveys conducted from 2004 to 2005 identified more than 425 small unofficial dumpsites, sized from 5 m^2 to 15 m^2.[28]

The cost of waste collection is partly covered by the waste tax (established at state level but collected by municipalities). The waste tax is reported to cover only 15% of collection costs, with the rest subsidized by the state budget.[29] No gate fee is applied for waste disposal. The management cost of Mbeubeuss, estimated at 40 million FCFA/month (or US$70,000),[30] is covered by the municipal budget. In the absence of a functioning environmental monitoring and law enforcement framework, the application of a gate fee would constitute an environmental and health risk as it would increase illegal waste dumping.

[27] Source: World Bank, 2016, Gestion des Déchets Solides Municipaux au Sénégal.

[28] Source: Amadou Bélal Diawara, 2010, Les déchets solides à Dakar – Environnement, sociétés et gestion urbaine, Thèse de doctorat, Université Bordeaux III Michel de Montaigne.

[29] Interview with the Municipality of Dakar, 2016.

[30] Interview with UCG, 2016.

While there is some private sector participation in the sector, this remains limited. A key challenge is financing of initiatives. Private actors are awarded contracts of a limited duration (in general contracts of only one year are given), and contracts may be silently extended after expiration. The services are generally underpaid (7,500 FCFA/t or US$12/t on average as reported by service providers, as compared to the estimated cost of 9,000 FCFA/t or US$15/t of waste collected and delivered to landfill) and have been the cause of disputes. This issue is a significant barrier to further development of waste recovery practices that limits private sector waste operators' and cement companies' engagement in AF projects – it will be explored further in the next section.

Photo: Daniella Van Leggelo-Padilla / World Bank

5.2 AGRICULTURAL RESIDUE

The agricultural sector is essential for Senegal's economy – it represents 17% of Gross Domestic Product (GDP) and employs approximately 75% of the workforce. The theoretical energy potential from exploitation of only rice, maize and coconut residues has been calculated at over 10 million GJ.[31] Agricultural production, however, is spread across the country (in particular as production is primarily rain-fed and based on small farms). Therefore, while large quantities of agricultural residues are available, the use of residue as AF is constrained by transport costs. Approximately 50% of residues is burned or otherwise exploited on site. Significant potential may exist for onsite energy production of agricultural biomass (largely crop residues).

Peanuts, cotton, gum arabic and sugarcane are the primary cash crops and millet, maize, sorghum and rice are the main food crops. Peanut production is approximately 700,000 t/year,[32] covering 40% of cultivated land or 770,000 ha.[33] Both of Senegal's large oil mills use peanut shells for energy, which would represent strong competition to increased use by the cement sector. SUNEOR (ex SONACOS) purchases 400,000 t/year of peanuts and uses the shells as fuel in boilers. NOVASEN purchases 40,000 t/year and uses the resulting 20,000 t/year of shells to produce domestic fuel as a charcoal substitute, following the establishment in 2005 of a joint venture with CARBO (CARBOSEN).[34] Small hulling companies process the remaining peanuts.

Rice production, primarily in the Senegal River valley, is approximately 215,000 t/year. Approximately 30% of production is machined in large rice mills, representing a potential 13,000 t/year of recoverable rice husks.[35] The remaining 70% is consumed by the producers or machined by small hulling companies. Rice husks are not currently exploited as an AF.

Millet, sorghum and maize production, covering an area of approximately 1.1 million ha, represents an average potential of 4.5 million t/year of dry biomass.[36] The residues of these crops remain in the field after harvest, where they are used for animal feed. Their availability is, however, highly dependent on crop seasonality and collection and transport conditions.

In total, up to **5.2 million t/year of dry agricultural biomass** may be available for sourcing, much of it within the 100 km radius from the Dakar area. However, interviews with stakeholders indicate that some of the cheaper sourcing options (such as peanut shells from processing plants) appear to be heavily utilized already. Further sourcing may require additional investment in transportation and processing infrastructure and therefore increased cost. Currently, cement players arrange for bulk collection and deliveries from the designated collection points along the main cement transportation routes, as agreed with agricultural companies. Assuming this sourcing model applies to other agricultural residues, it can be estimated that around **10% of all biomass could be technically available for cement plants, translating into 3-4 million GJ/year thermal energy**.

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31 Source: A macro analysis of crop residue and animal wastes as a potential energy source in Africa, Cooper C.J., Laing C.A., Journal of Energy in Southern Africa, 2007.

32 Peanut exports, once the economic engine of Senegal, dropped from 80% of total exports in the 1960s to 12%, in part because of competition with other oils, reduced yields and increased foreign trade barriers.

33 Source: http://www.new-ag.info/en/country/profile.php?a=530

34, 35, 36 Source: Ministry of Energy and Biofuels (2010 data).

Photo: Matluba Mukhamedova / World Bank

5.3 WASTEWATER AND SEWAGE SLUDGE

Senegal's sewerage system covers parts of major municipalities, such as Dakar. Dakar's sewerage system covers up to 25% of wastewater, while septic tanks increase coverage to 70-80%. Most of the wastewater is discharged into the environment with limited processing or treatment. However, the government is actively developing wastewater treatment infrastructure, including sludge production facilities (although infrastructure for processing significant volumes is likely to be developed over 10-15 years).

Senegal has nine wastewater treatment plants (WWTP): four are located in Dakar (Cambérène, Niayes of Pikine, SHS Guédiawaye and Rufisque) and five are located in cities in the regions of Thiès, Saly, Louga, St Louis and Kaolack. During 2010, these plants received 14,743,000 m^3 of wastewater, of which 76% was treated. Of the treated wastewater, 3% was reused. In smaller cities, individual septic tanks are commonly used for wastewater treatment.

The Government of Senegal (GoS), with support from the World Bank, developed three pilot stations for sludge production. These stations are located in Cambérène, in the Niayes area and Rufisque.

TABLE 2. CAPACITY AND TECHNOLOGY OF WASTEWATER TREATMENT PLANTS IN SENEGAL[37, 38]

Plant	Technology	Capacity (m^3/day)
Cambérène	Activated sludge	19,200
Rufisque	Impoundment	2,856
Saly	Impoundment	1,020
Niayes	Activated sludge	875
Kaolack	Impoundment	600
Louga	Aerated lagoon	600
Saint-Louis	Impoundment	600
SHS	Activated sludge	595
Thiès	Activated sludge and impoundment	300

[37] Source: National Sanitation Office of Senegal, ONAS, 2013.
[38] ibid.

Sludge production in the Dakar region was estimated to be more than 170,000 m^3 in 2005. Cambérène, located in Dakar, is the largest plant, with an average of 3,300 t/year of sludge extracted.[39] The plant was expanded in 2007, to serve a 200,000 population equivalent with a daily flow of 19,200 m^3/day. A project was initiated in 2016, with funding from the Islamic Development Bank (IDB), to increase Cambérène's capacity to 91,000 m^3/day and cover three of the four sanitation zones of Dakar (it covered only one zone in 2016). Rufisque is the second largest treatment plant in Dakar. It uses the lagoon technique and has a capacity of 45,400 population equivalent and an average daily flow of 2,856 m^3/day (in 2010). Sludge is also extracted from domestic septic tanks and transported by truck to the existing stations of Dakar (or disposed of locally in open pit areas).

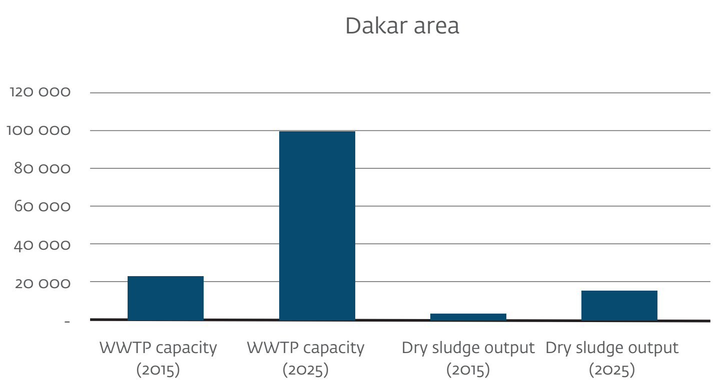


FIGURE 14. WASTEWATER TREATMENT AND SLUDGE PRODUCTION IN THE DAKAR AREA – CURRENT AND EXPECTED CAPACITY AND OUTPUT BY 2025, M^3/DAY

As shown above, the total amount of sludge that is expected to be available in the Dakar area in the medium term (3-5 years), does not demonstrate significant potential for use as AF. If the World Bank-supported initiatives are successful, however, the rate of conversion of wastewater treatment into sludge could be boosted to 60%. Sewage sludge is reported, however, to be exploited locally for biogas generation or as soil fertilizer; its relevance as an AF is therefore further limited.[40]

5.4 WASTE TIRES

Although there are no reliable country-wide statistics or formal collection systems, 100,000 t/year of waste tires is estimated to be available in the Dakar area.[41] Waste tires are most commonly available in urban areas, and are collected and disposed of at dumpsites together with MSW. A small proportion is collected by the informal sector and recycled for other uses (e.g. shoes) or burned to recover the wires.

Some of the private companies engaged in the tire import and distribution business are initiating a project to manage waste tires, beginning with their own substantial stock. Plans include supporting reuse, recycling (i.e. production of granules that can be used in tar) or shredding for co-processing at cement plants. Estimates suggest that this would use up to **30-40% of waste tires**, in which case **up to 2.4 million GJ/year of thermal energy potential** could be available in the form of TDF.

5.5 USED OILS

Although there are no formal statistics, it is estimated that 20,000-24,000 t/year of used oils are available.[42] There is no formal collection system for waste oil. Used oil is disposed of in canals or collected by the informal sector during replacement of engine oil of vehicles and other machinery, and forwarded to regeneration facilities.[43] Presently, accessibility and potential for use as AF of used oils is not considered to be substantial on a national scale, though it may be possible to incorporate them as part of AF streams for specific projects.

[39] Source: http://www.iwawaterwiki.org/xwiki/bin/view/Articles/Senegal#HOverviewofHomeSanitation
[40] Interview with ONAS, 2016.
[41] Interview with a tire supply company 2016.
[42] Interview with a cement company, 2016.
[43] Interview with the Municipality of Dakar, 2016.

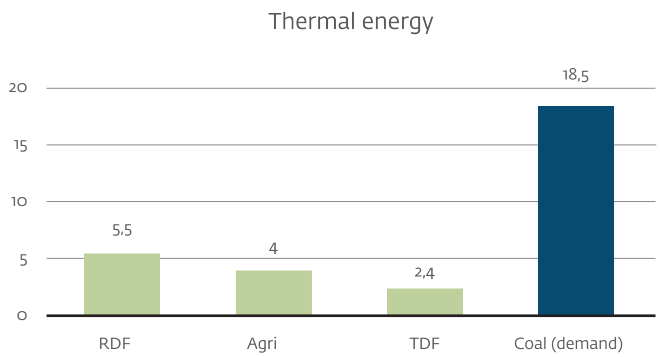
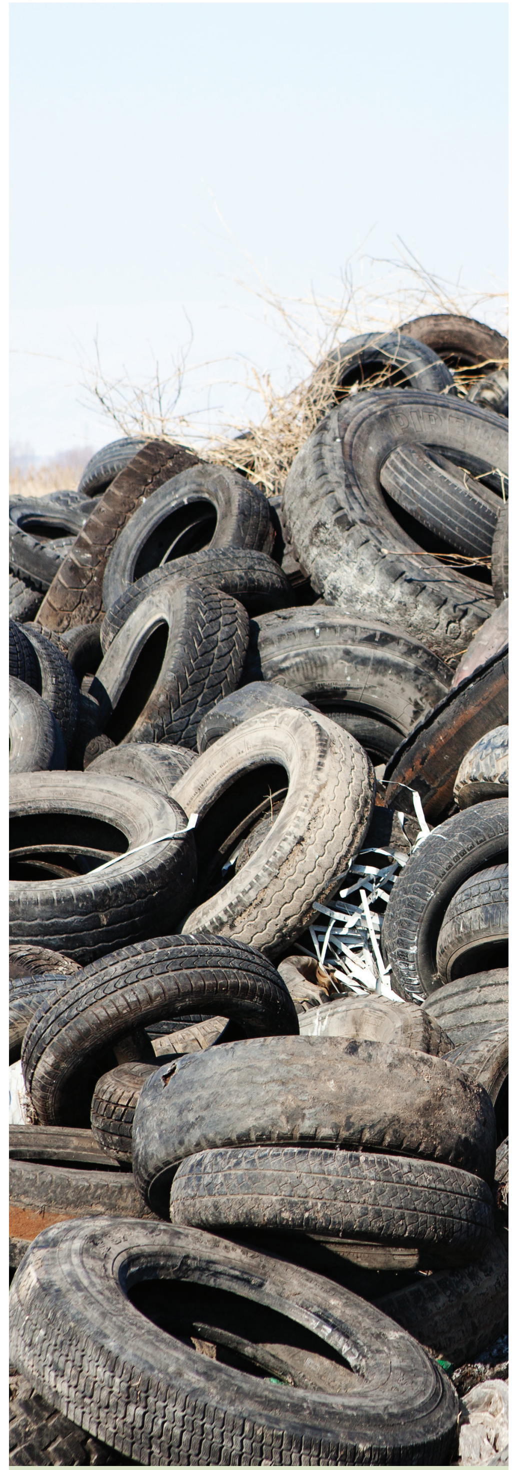


FIGURE 15. TECHNICAL POTENTIAL FOR SOURCING ALTERNATIVE FUELS – SUMMARY FOR SENEGAL, MILLION GJ/YEAR

5.6 SUMMARY OF POTENTIAL

The assessment suggests that major technical opportunities for the use of AF may be associated with MSW in the Dakar area, which has significant thermal energy potential, amounting to almost 30% of the forecasted thermal energy demand in the cement sector. Agricultural residue, already being exploited by some major players, represents further potential. However, there are competing alternative uses which may represent sourcing risks. Tires and TDF may also represent significant potential, once collection systems have been put in place and/or upgraded (see Sections 6 and 7).

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.



Waste tires are most commonly available in urban areas, and are collected and disposed of at dumpsites together with MSW. A small proportion is collected by the informal sector and recycled for other uses (e.g. shoes) or burned to recover the wires.

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

Senegal's **environmental protection and waste management framework is in transition** towards an integrated waste management system that prioritizes diversion of waste from disposal. A **dedicated coordination agency** has been created to support sector reform, enforce existing policies and deal with operational issues of waste management in the Dakar area. A number of **major infrastructure projects** are being planned or implemented to mitigate the environmental impact of waste. According to a plan developed by Office National de l'Assainissement du Sénégal (ONAS), however, it will take up to 10-15 years for new WWTPs to run at full capacity. A number of **important steps promoting waste recovery need to be taken to utilize the AF potential fully**, including establishing systems for transparent **long-term contracting, waste quantity measurement, and linking payments to volumes**.

The GoS introduced waste management policies in 1972, at which point it established a fee for waste collection. In 1974, the GoS issued Decree 74-338 defining and regulating waste management practices (including landfilling and waste treatment). The Constitution of Senegal, adopted in January 2001, reinforced waste management policy and regulations by introducing the concept of sustainable development. Article 8 stipulates that "every man is entitled to a healthy environment".

In 2001, the Code of Environment entered into force as the principal legal instrument governing waste management. The Code, along with associated decrees and orders, covers areas such as pollution of air, water and land, environmental impact assessments, and domestic, industrial, and chemical waste management. It specifies that:

- Waste must be disposed of or recycled in an environmentally sound manner, in order to remove or reduce its harmful effects on human health or natural resources, fauna and flora (Article 30);
- Waste generators must ensure elimination, recycling or proper disposal of waste by companies approved by the Minister of Environment and Sustainable Development. The local authorities may sign contracts with waste generators for proper disposal or recycling, and recycling must always be based on the standards in force in Senegal (Article 31);
- Municipalities should ensure the elimination of waste from households, in collaboration with national and regional services of the State, in accordance with the regulations in force (Article 32); and
- Elimination of waste includes collection, transport, storage and processing necessary for the recovery of valuable materials or energy, or disposal at appropriate places (Article 33).

The Ministry of Planning and Local Governance has established the Solid Waste Management Coordination Unit (UCG) to coordinate waste management reform at a national level and conduct waste management operations in the Dakar area. UCG has been given the following responsibilities:

- Development of a national strategy for sustainable and integrated waste management.
- Support for and capacity development of local authorities in sustainable waste management.
- Implementation of waste management programs, including waste recovery and treatment.

In addition, UCG is responsible for coordination of the national program for waste management (PNGD), which is supported by the GoS and the IDB. The program focuses on Dakar, Kaolack, Tivaouane and Touba, and comprises five components: (i) reform of the laws and regulations of the sector; (ii) implementation of programs and establishment of infrastructure for the management of solid waste in the Dakar area; (iii) technical and financial support to local communities; (iv) communication and capacity building; and (v) coordination and follow-up evaluation of the program. The program is expected to result in a new integrated solid waste management framework, which will prioritize waste recovery, and set recovery targets, including for waste-to-energy and fuel, and promote incentives for diverting waste from landfills.

Recent developments in waste management prove that the GoS is prioritizing the sustainable treatment of waste and wastewater. The GoS is making significant efforts to develop waste management infrastructure that will support the realization of the technical potential of RDF. At the same time, analysis suggests that, at the operational level, there are still challenges that limit the use of AF (along with other solutions for the recovery of waste).

One of the major challenges is the lack of a **link between payments within the waste management system and waste volumes**. A further challenge is the absence of a payment link between polluters (residential, commercial and industrial) **and waste management service providers**. This is best demonstrated by the indication, provided in the previous section, that payments for MSW collection cover around only 60% of the total estimated cost of collection and transportation of the waste-to-landfill sites. The government charges environmental tax that partially fills the gap, but available information suggests that some of the contractors may significantly underinvest in their infrastructure and capacity (e.g. truck purchases, maintenance and staff training). Full implementation of the 'polluter pays' principle and other mechanisms such as Extended Producer Responsibility will result in the sector becoming more attractive for private players, including cement companies.

In addition, despite the proactive efforts of the UCG, **the long-term contracting framework for waste management services has still not been established**. The UCG-coordinated framework exists in parallel with legacy contracts, creating disincentives for existing private players in the market and discouraging new players from entering the market. In terms of deal structures, PPP solutions may be a possible way to implement projects in the MSW space, including the establishment of RDF production facilities. While a general PPP framework exists in Senegal, there is a lack of specific experience in the waste management sector. The joint efforts of the GoS and the World Bank may help build capacity of stakeholders in this area.

The barriers that persist apply to all potential waste recovery projects. The impact of some of these barriers on the cost of sourcing key types of AF and economic feasibility of AF 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$25 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.

To **utilize viable AF fully**, cement players in the Dakar area will need to make **modifications to their kilns** to allow at least 25-30% substitution by RDF and TDF. Based on experience, IFC estimates that such modifications would require all three major players in the Dakar area to invest US$5 million each, **amounting to US$15 million**. A detailed breakdown of required upgrades is provided in Annex 1.

Special infrastructure for producing RDF and TDF needs to be developed. As indicated in Section 3, the global experience provides successful examples of integrating RDF/TDF production infrastructure in solid waste management frameworks that prioritize material recovery as a waste treatment method. Using this approach would require putting in place **comprehensive MRFs** that allow for separation of recyclables and compostable organic fractions and produce RDF from reject fraction. Building such facilities in the Dakar area with a capacity of 900,000 t/year of MSW to generate up to 350,000 t/year of RDF would require investing up to **US$20 million.**[44] The cost of facilities required to process 100,000 t/year of **waste tires** (cutting, shredding, and removal of metal content) is estimated at **US$1 million**. It might be feasible to co-locate RDF and TDF production, resulting in combined CAPEX of US$20 million.

For the purpose of this assessment, it is assumed that the cement sector would cover 50% of the investment in the required MRF in an equity form. This would afford cement players some control of the cost of the fuel and ensure security of fuel supply. Thus, the **total investment requirement** for the cement sector is estimated at **US$25 million**.

Securing waste supply and participation of the waste management sector is crucial for any AF sourcing business model. To achieve this, it is essential that waste management service providers are able to recover the cost of waste collection and transportation and invest in infrastructure. In the context of this assessment, this would point towards implementation of the **Option 1 scenario** described in Section 2, i.e. the cost of basic collection and transportation infrastructure will be fully covered by the waste management sector players (rather than passed on to other players).[45]

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

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

Based on the estimated cost of processing MSW into RDF and the cost of delivery of the fuel to major cement plants in the area, the **total cost of sourcing RDF can be estimated at US$2.5/GJ**, which is 35% cheaper than the current price of coal.

Persistence of the barriers described in Section 6 would point towards the **Option 2 scenario**. Under this scenario, cement companies in the Dakar area would co-finance **the entire RDF value chain**, including basic collection infrastructure and **full operational costs**, excluding the payments that waste management companies are currently receiving for their services. In the context of Senegal, this would represent the current situation where the sector operators lack access to finance for their infrastructure and are not incentivized to engage in waste recovery projects. In this case, **the total cost of sourcing RDF would be US$4.5/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.

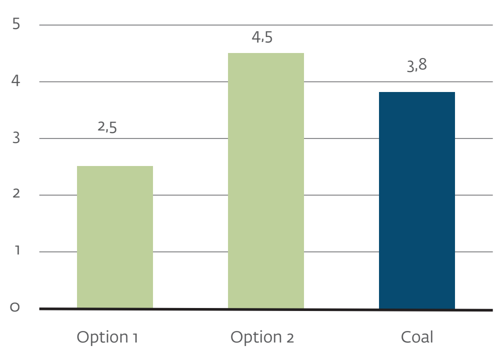


FIGURE 16. COMPARATIVE COST OF SOURCING RDF FOR CO-PROCESSING IN THE CEMENT KILNS IN THE DAKAR AREA, US$/GJ

The cost of sourcing of agricultural residue as fuel can be assessed separately for peanut shells (currently the most commonly used AF) and other potentially available dry residues (such as rice husks, sorghum and millet).

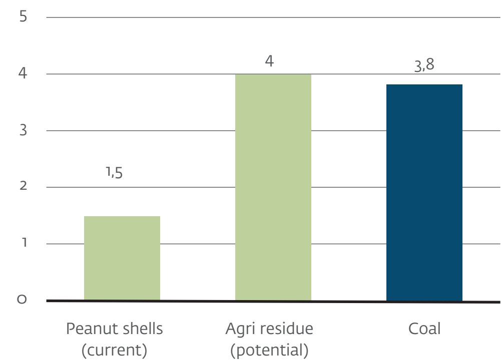


FIGURE 17. COMPARATIVE COST OF SOURCING OF AGRICULTURAL RESIDUES AS FUEL FOR CO-PROCESSING IN THE CEMENT KILNS IN THE DAKAR AREA, US$/GJ

The cost of sourcing peanut shells is relatively low, as this type of fuel is accessible in bulk quantities at processing facilities along cement delivery routes, allowing for use of backhaul capacity of cement trucks to transport biomass fuel to the kilns. Based on the processing cost alone, the **estimated cost of sourcing peanut shells would be just US$1.5/GJ**, approximately 2.5 times lower than that of coal.

However, the opportunities for further expansion of the use of peanut shells may be limited or incur additional cost. Sourcing of other agricultural residues assessed in Section 5 would likely be associated with additional transportation costs and higher processing costs. The total **sourcing cost for such residues would be up to US$4/GJ**, depending on the geographic areas for sourcing and physical properties of available waste. Though the required investment amount is small (less than US$1 million) a risk exists that the cost will exceed the current price of coal.

Similar to RDF, **TDF** may be produced by a standalone facility or by a comprehensive treatment complex. TDF has the benefits of low initial CAPEX (around US$1 million for the Dakar area), low processing costs and high calorific value per dollar invested. These result in a **total sourcing cost of US$2.1/GJ**. The main issue for unlocking the potential for sourcing TDF is access to waste tires, as infrastructure for separate collection of tires is very limited. It can be assumed that establishing a RDF production framework will also boost TDF production, as these facilities can be co-located.

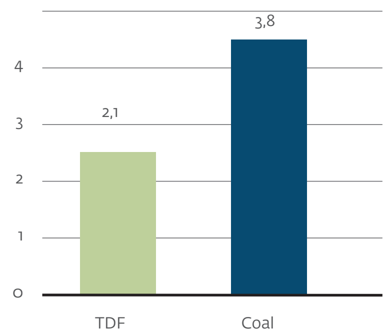


FIGURE 18. COST OF SOURCING OF TIRE-DERIVED FUEL FOR CO-PROCESSING IN THE CEMENT KILNS IN THE DAKAR AREA, US$/GJ

The costs of sourcing key AF types (excluding peanut shells which are already exploited) under a scenario which assumes removal of barriers to fuel access and full inclusion of private sector in infrastructure investment are compared below.

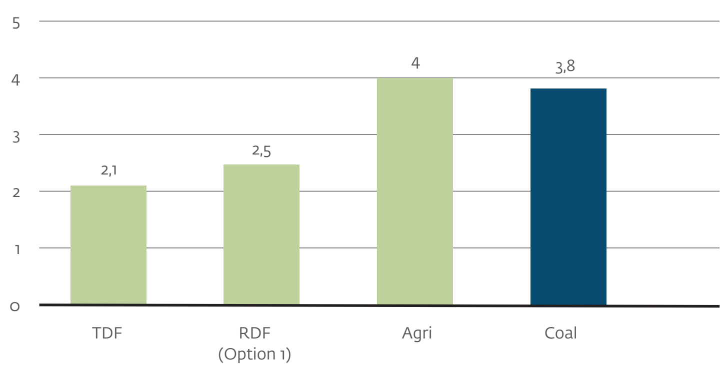


FIGURE 19. COMPARISON OF SOURCING COSTS FOR SELECTED ALTERNATIVE FUELS IN THE DAKAR AREA, US$/GJ

Based on the estimated sourcing cost, there is potential to **offset at least 25-30% of thermal energy** demand with AF, resulting in **fuel cost savings of US$6-7 million per year** (depending on types of fuels used).

At **US$25 million in CAPEX**, these savings allow for a **3-4 year payback period**. It needs to be noted that potential investments by individual players may result in shorter payback periods and would need to be assessed based on individual kiln characteristics and fuel mix.

8. Summary and Conclusions

There is significant potential for sourcing AF for the cement sector in Senegal, specifically in the Dakar area where major cement producers are concentrated. Of the total forecasted thermal energy demand of **18.5 million GJ/year, 7.9 million GJ could technically be sourced from waste-derived fuels**, such as RDF, TDF and agricultural residues, all of which are available in the Dakar area. The use of sewage sludge, though 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 Senegal are considering or already have experience using AF, mainly agricultural residues (specifically peanut shells). Some cement producers also burn small quantities of used oils, chemical wastes, and other industrial wastes. Further expansion of their fuel substitution capacity would require modifications to their kilns and, therefore, investment. To justify this investment, it is essential that the long-term supply of AF be secured at a predictable cost that is lower than that of the predominant conventional source of energy, which is coal (at US$3.8/GJ).

The business case for increasing the use of AF is strong, provided that certain waste management measures are implemented. The cost of sourcing RDF and TDF is estimated at **US$2.1-2.5/GJ** resulting in fuel cost savings that will support **pay back of the required investment of up to US$25 million by the cement sector in 3 to 4 years**. Key measures for supporting this investment include the following:

(1) Clear definition of **waste ownership and responsibilities** for key waste streams, including treatment of waste tires as a standalone stream, separate from MSW, and enforcement of the obligation to collect and treat end-of-life tires;

(2) 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 volumes** of waste processed;

(3) Establishment of a **transparent long-term contracting system** for waste management services; and

(4) **Upgrading of technical capacity and knowledge** of waste management sector players, including private firms and government agencies, focusing on possible deal structures, and contracting and tendering practices.

With these measures implemented, the economic potential of sourcing AF can be assessed under the Option 1 scenario, i.e. the cost of basic collection and transportation infrastructure will be fully covered by waste management sector players. 'Interim' scenarios, however, are also possible, depending on factors relating to the stage of market development and parameters of each deal, including the following:

- Ownership of waste collection, transportation and processing facilities;
- Contracting and payment mechanism, processing of payments (directly from service consumers, through designated government agencies, etc.);
- Composition of investors in 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 Senegal, the government has already been making significant efforts to build a more efficient waste management system. A dedicated waste management agency has been created to coordinate policy work nationwide as well as operational work and infrastructure upgrades in the Dakar area. Initiatives have been launched, including in partnership with the World Bank Group, to significantly improve wastewater treatment capacity in major cities and reduce environmental impact of waste disposal. This work, coupled with the specific measures outlined above, would create an enabling environment and unlock potential for key AF types 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)	5 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

Share in waste composition and maximum selling price of recyclable materials.

RECYCLABLES	SHARE IN WASTE 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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