UNLOCKING VALUE:

Alternative Fuels For Egypt's Cement Industry

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IFC International Finance Corporation
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UNLOCKING VALUE

Alternative Fuels For Egypt's Cement Industry

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Abbreviations

AFR	Alternative Fuels and Raw Materials or “Alternative Fuels”
BAT	Best Available Technology
BAT-AEL	Best Available Techniques Associated Emission Levels
BAU	Business as Usual
BEP	Best Environmental Practice
BM	Business Model
BPD	Bypass dust
BREF	European Commission Reference Document on Best Available Techniques
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expenditures
CAPMAS	Central Agency for Public Mobilization and Statistics
CEM	Cement Market
CF	Clinker Factor
CKD	Cement Kiln Dust
CPCB	Central Pollution Control Board
CSI	Cement Sustainability Initiative
DSS	Dried Sewage Sludge
EC	European Community
EEAA	Egyptian Environmental Affairs Agency
EGP	Egyptian Pound (1 EGP = 7.8 $, Central Bank of Egypt on November 2015)
EGPC	Egyptian General Petroleum Corporation
EIA	US Energy Information Administration
EII	Energy Intensive Industries
EIPPCB	European Integrated Pollution Prevention and Control Bureau
ELV	Emission Limit Value
EMR	Emission Monitoring and Reporting
ENCPC	Egypt National Cleaner Production Center
EPA	Environmental Protection Agency
EU	European Union
FICEM	Federación Interamericana del Cemento
Gcal	Giga Calories, 1Gcal = 1,000,000 kcal
GDP	Gross Domestic Product
GHGs	Greenhouse Gases
GJ	Giga Joule (1 Gcal = 4.184 GJ)
GNR	Getting the Number Right
HCWW	Holding Company for Water and Wastewater
HFO	Heavy Fuel Oil
kg	Kilogram
LCA	Life Cycle Analysis
LSF	Lime Saturation Factor

mg	Milligram
MJ	Mega Joule
MMBTU	One Million British Thermal Units
MRV	Monitoring, Reporting and Verification
MSW	Municipal Solid Waste
mtpa	million tons per annum
NGO	Non-Governmental Organization
OH&S	Operational Health and Safety
OPC	Ordinary Portland Cement
OPEX	Operational Expenditures
POPs	Persistent Organic Pollutants
ppb	Parts per Billion
RDF	Refuse Derived Fuels
SWM	Solid Waste Management
t	Ton
TDF	Tire Derived Fuel
TOC	Total Organic Carbon
TSR	Thermal Substitution Rate
UNEP	United Nations Environment Program
VOC	Volatile Organic Compounds
WBCSD	World Business Council for Sustainable Development
WMRA	Waste Management Regulatory Authority
WWTP	Wastewater Treatment Plant

Elements and Compounds

Al_2O_3	Aluminum oxide
As	Arsenic
CaO	Calcium oxide
Cd	Cadmium
CI	Chloride
CO	Carbon monoxide
CO_2	Carbon dioxide
Co	Cobalt
Cr	Chromium
Cu	Copper
Fe_2O_3	Iron oxide
HCI	Gaseous chlorine
Hg	Mercury
K_2O	Potassium oxide
N	Nitrogen
Na_2O	Sodium oxide
Ni	Nickel
NOx	Nitrogen oxides
P_2O_5	Phosphorous pentoxide
Pb	Lead
Sb	Antimony
Se	Selenium
SiO_2	Silicate
Sn	Tin
SO_2	Sulfur dioxide
SO_3	Sulfite
Te	Tellurium
TiO_2	Titanium dioxide
Tl	Thallium
V	Vanadium

Glossary

AFR	Throughout the document, the term AFR will be used as "Alternative Fuels and Raw Materials" because some wastes can be used for simultaneous energy and material recovery. The recovery of raw material is replacing the material needed to produce clinker and has nothing to do with the blended cement.
Burnability	A parameter that is used to show whether the burner flame profile, when AFRs are burned, is identical to that when only conventional fuels are used. In certain cases, the burnability has to be studied in depth because it can have a negative effect on the clinker quality. Burnability can improve the clinker quality if better conventional fuels are used.
Bypass dust	Discarded dust from the bypass system dedusting unit of suspension preheater, precalciner and grate preheater kilns, normally consisting of kiln feed material which is fully calcined or at least calcined to a high degree.
Clinker	Intermediate product in cement manufacturing and the main substance in cement. Clinker is the result of calcination of limestone in the kiln and subsequent reactions caused through burning.
Cement	It is made by grinding clinker and adding gypsum (calcium sulphates) and possibly additional cementitious (such as blast furnace slag, coal fly ash, natural pozzolanas, etc.) or inert materials (limestone).
Co-processing	The use of waste as raw material, or as a source of energy, or both to replace natural mineral resources (material recycling) and fossil fuels such as coal, petroleum and gas (energy recovery) in industrial processes, mainly in energy intensive industries.
Decarbonation	The chemical decomposition of limestone which liberates CO_2.
Fuel CO_2	CO_2 emission from burning fuel and not from decarbonation.
MSW	All types of municipal solid waste generated by households and commercial establishments.
MTOE	Million tons oil equivalent is a unit of energy defined as the amount of energy released by burning one ton of crude oil.
Pre-processing	Encompasses all activities needed to transform waste into an acceptable AFR for cement kiln co-processing.
RDF	Refuse derived fuel: solid fuel prepared from the energy rich fraction of municipal solid waste after the removal of recyclables.
SWM	Solid waste management refers to the supervised handling of waste material from generation at the source through the recovery processes to disposal.
Tipping (or Gate) Fee	The charge levied upon a given quantity of waste received at a waste processing facility.
Volatility	The tendency of a substance to vaporize and is directly related to a substance's vapor pressure. A highly volatile fuel is more likely to form a flammable or explosive mixture with air than a non-volatile fuel. The rotary cement kiln would be fired with low-volatile fuels such as petcoke, low-volatile bituminous coal, and anthracite. On the other hand, high volatile-low calorific value AFR have limited use in the kiln primary firing system due to their relatively low combustion temperatures; they are used more in the precalciner firing. It is difficult to obtain complete combustion of low-volatile fuels in precalciners, which often requires design and operational modifications to the precalciner.

Foreword

Since its founding six decades ago, IFC has served as a bridge between private investment and the global development agenda. With a portfolio of $52 billion in over 100 countries, IFC is now the world's largest development finance institution focused on the private sector. It is bringing to bear the transformative power of markets on some of the developing world's most pressing challenges – from energy access to food security, infrastructure to health care, and education to financial inclusion. IFC's role in bringing together private investment and development remains urgent and essential. One of our key priorities is to increase climate-related investment from 16 percent in fiscal year 2015 to 20 percent of our committed portfolio by 2020.

Without immediate intervention to reduce greenhouse gases emissions, an additional 100 million people could fall into extreme poverty by 2030 as a result of climate change. Following the Paris agreement of 2015, where nearly 200 nations and scores of CEOs pledged to reduce their carbon footprint, IFC is in an unprecedented position to help clients capture the opportunities and mitigate the risks of climate change. Our objective is to boost climate-related investments and support the use of energy efficient technologies. To do that, IFC will maximize its impact by reducing greenhouse gas emissions from its investments, building client resilience to climate change, and engaging in thought leadership and standard-setting.

In the Middle East and North Africa, IFC will focus on addressing the root causes of the region's instability and its biggest long-term development challenge: a dearth of jobs and opportunity. IFC is looking to identify new clients in the fields of power, entrepreneurship, and access to finance.

At the intersection of these priorities lie innovative opportunities such as those presented in this report. Egypt's cement industry is a pillar of growth and crucial to the country's economic recovery. But growth has been hampered by a complicated energy picture. As such, our regional Resource Efficiency Advisory team spearheaded this pioneering national study. The report identifies viable and low-carbon energy sources that would help cement producers satisfy their growing energy demand. For the first time, we have mapped, quantified, and analyzed co-processing in Egypt. We have also identified the current and future appetite for alternative fuels, highlighted impediments to market growth, and recommended potential solutions throughout the supply chain.

We discussed our research with a range of industry players, many of whom were reluctant to previously come together. In these sessions, participants spoke about the challenges in making the switch to alternative fuels. There is no doubt that embracing these new technologies will take time and money, but the rewards far outstrip the hardships. We hope this study makes that point clear, and encourages producers, officials, and other stakeholders to find greener ways to help Egypt's cement industry grow.

Mouayed Makhlouf

IFC Regional Director
Middle East and North Africa

Preface

Egypt's cement sector is an important economic player, but it is also one that can play a decisive role in helping the Arab world's most populous nation meet climate change targets. In Egypt's Third National Communication to UNFCCC released in March 2016, it was reported that the cement industry alone contributes 40 percent (16.7 million tCO_{2e}) of the country's total industrial sector greenhouse gases emissions in 2005. At the 2015 Paris Climate Summit, Egypt committed to several actions to reduce emissions, which included development of locally-appropriate low-carbon energy systems such as incentivizing renewable energy technologies and switching to alternative and cleaner fuels. Other commitments also covered developing a national monitoring, reporting and verification system and adopting wider energy efficiency, especially in the production of cement, iron, steel, among other industries.

The private sector is expected to play a prominent role in mitigating climate change, whether through finance, technological innovations or partnerships with public entities. Today, the business community is ready to embrace that role than at any point in the past, making their own commitments to decrease their carbon footprints, adopt renewable energy, and engage in sustainable resource management.

A key lever of achieving lower-carbon growth in the cement sector is the adoption of non-fossil based fuels. Not only is wider uptake of alternative fuels of immense untapped potential for Egypt's cement sector, it is also a critical tool to help manage energy insecurity in the aftermath of diverting state-subsidized natural gas and heavy fuel oil away from the cement industry.

IFC, a member of the World Bank Group and the largest global development institution focused exclusively on the private sector, commissioned, funded and facilitated the production of this study to assess the current status of alternative fuel usage across the sector and identify obstacles and solutions to encourage the development of a sustainable, commercial waste-to-energy market in Egypt. The report is the culmination of nearly two years of original, first-of-its kind research that has mapped waste sources and identified the potential for co-processing across the cement sector. CEMENTIS GmbH (Anne Dekeukelaere, Laurent Grimmeissen, Jean-Pierre Degré and Stéphane Poellaer) and EcoConserv (Tarek Genena, Omneya Nour Eddin, Eduardo Lopez, Fakhry Abdelkhalik, and Maysra Shams Eldin) provided considerable expertise and drafted the initial findings of this study.

The report relied on an extensive stakeholder engagement effort. Dialogue with different stakeholders was initiated to understand their levels of involvement and their roles in promoting the use of AFR, as well as to elicit views and concerns on the potential for further usage. A primary objective in the various workshops was to dispel misinformation, a barrier preventing cement industry players from finding a point of consensus with other stakeholders. IFC's research team (Dalia Sakr, Dina Zayed and Bryanne Tait) would like to extend its gratitude to all parties interviewed for the purposes of data collection, as well as to individuals who gave their time and support during multiple rounds of dialogue.

Those include but are not limited to: Egypt's Chamber of Building Materials and the Cement Association, especially: Eng. Medhat Stefanos, Mr. Bruno Carré, and Mr. Adel Draz; Cement Companies: Amreyah Cement Company, Arabian Cement Company, ASEC Cement, Assiut Cement Company (CEMEX Egypt), El Sewedy Cement Company, Lafarge Cement Egypt, National Cement Company, Suez Cement Company, and Titan Cement Company; Egypt's Ministry of Trade and Industry and its relevant agencies: Egyptian National Cleaner Production Center and the Industrial Development Authority, and the Egyptian Organization for Standardization and Quality, Egypt's Environmental Affairs Agency and its relevant departments: the Central Department for Waste & Hazardous Waste, the Waste Management Regulatory Authority, the Department of Air Quality, the Department of Industrial Pollution, the Central Department for Impact Assessment and the Department for Regional Offices; the Ministry of Local Development; Former Ministry of Urban Renewal and Informal Settlements; Egypt's Ministry of Agriculture; The Holding Company for Water and Wastewater Treatment; ECARU; Nahdet Misr; EcoCem; Reliance Egypt; Polyeco; Spirit of Youth Association; The Egyptian National Competitiveness Center; National Solid Waste Management Program (NSWMP); the Egyptian Center for Economic Studies; and the following individuals consulted to understand tire manufacturing and recycling: Eng. Ahmed Fahmy, Head of Solid Waste Management Department, Gharbia Governorate; Eng. Eman Mohamed, EHS Department Manager, Prelli; Maghrby Shaheen, Meet El Haroun; Sherif Mohamed, Meet El Haroun; Mr. Shaalan Mohamed, Manager of Haanna Masr company (tire recyclers), Ismaillia Governorate.

In addition to commissioning and guiding the production of this study, IFC contributed with its international experience-gained through the financing of more than 180 projects in the cement sector in about 60 countries, in the last 55 years. IFC's present portfolio includes 30 investments and 10 advisory projects in cement, in 26 countries. IFC has already invested more than $4 billion in the sector globally.

The production of this study was made possible through the generous support of the Government of Italy, the Korea Green Growth Partnership, DANIDA, and the Earth Fund Platform. The production of this study greatly benefited from the guidance and contributions of Benjamin Stewart, Clara Ivanescu, Elizabeth Burden, Alexander Sharabaroff, Jeremy Levin, Michel Folliet, Asimina Papapanou, Nada Shousha, Dalia Wahba, Yana Gorbatenko, Sivaram Krishnamoorthy, John Kellenberg, Riham Mustafa, and Mohamed Essa.

Executive Summary

The Egyptian cement industry is the world's 12th largest and a vital economic force supporting the construction and building sector that accounts for nearly five percent of Egypt's Gross Domestic Product (GDP).[1] Today the energy-hungry industry is at a cross-roads: due to fuel shortages, the cement sector is being forced to diversify its energy mix.

In 2012, in the face of frequent electricity blackouts, the Egyptian Government diverted natural gas from heavy industrial users towards power production, effectively leaving most of the 25 operating cement companies with only a fraction of the gas needed to continue their operations. By 2013, domestic cement production had fallen by 50 percent. With no end to fuel shortages in sight, the industry lobbied to switch from natural gas to other fossil fuel-based alternatives, such as coal and petcoke.

Yet, switching to coal entirely comes with a price. In 2015, about 49 million tons of clinker were produced with a thermal energy appetite of 46 million gigacalories (GCal). By 2025, that figure is expected to grow to 72 million tons of clinker, demanding 68 million GCal. Assuming an average calorific value of 7,000 kcal/kg for coal, the cement industry's total energy demand in 2025 would require about 9.7 million tons of coal per year. That is enough to fill a train 1860 kilometers long, roughly twice the distance between Cairo and Aswan. The associated greenhouse gases (GHGs) emissions would be 27 million tons of CO_2 per year, more than the total annual emissions from countries the size of Tunisia, Croatia or Estonia.

On the other hand, integrating alternative fuels into the energy mix can help ensure a lower carbon transition that is commercially viable and economically attractive.

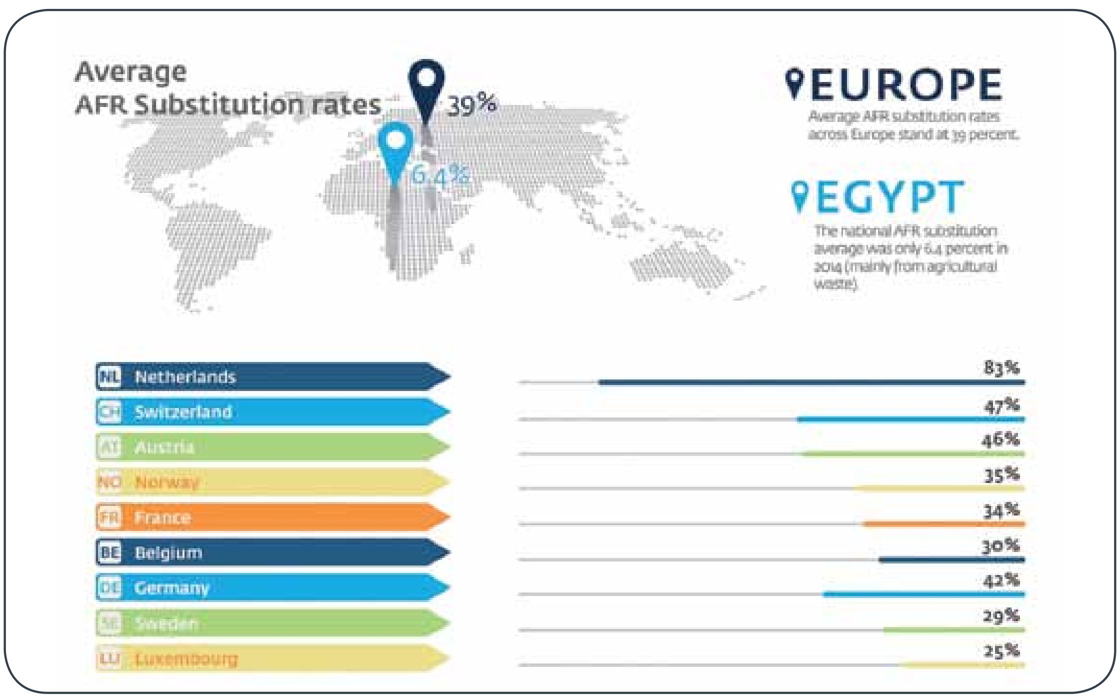


Figure 1: Comparison between Average AFR Substitution Rates in Europe and Egypt
(Source: WBCSD, 2013 and Cement Egypt Interviews, 2015)

1 The sector grew by nearly 10 percent in the past fiscal year, further expanding from a 7.4 percent growth rate in FY2014 (Bank Audi, 2016) "Egypt Economic Report: Between the Recovery of the Domestic Economy and the Burden of External Sector Challenges." February 24, 2016. Retrieved online at: http://www.bankaudi.com.eg/Library/Assets/EgyptEconomicReport-2016-English-040615.pdf.

The technological and financial viability of transforming waste streams into thermal energy for the cement industry is well-established internationally. The use of processed waste, known as Alternative Fuels and Raw Materials (AFR), instead of and in addition to traditional fuels like coal or natural gas, is a common best practice in Europe (See Figure 1), where the average substitution rate of AFR for the cement industry is almost 39 percent. Egypt's substitution rate, by contrast, was only 6.4 percent in 2014, despite severe energy shortages and declining fuel subsidies.

In order to seek out viable and low carbon energy sources to help fill the energy demand gap, IFC has carried out this study. The research has mapped, quantified, and analyzed the price competitiveness of four alternative streams of waste fuels across the country: refuse derived fuel (RDF) from municipal solid waste, dried sewage sludge (DSS) from wastewater treatment plants, agricultural waste, and tire derived fuel (TDF) from scrap tires. The study has identified the current status of co-processing in Egypt, analyzed the potential appetite for AFR, highlighted impediments to market growth, and recommended potential solutions throughout the waste supply chain to ensure a sustainable market solution tailored to the Egyptian context, which may lead to investment opportunities for players within the AFR value chain.

The study concludes that Egypt produces enough solid waste to satisfy the cement sector's entire thermal needs. In fact, achieving a 20 percent thermal substitution rate in year 2025 would recover an annual four million tons of waste, which would have been landfilled, dumped or burned. When processed at scale, AFR per GCal can be up to 40 percent cheaper than coal. At a conservative substitution rate of 20 percent, the AFR market represents an opportunity of $200-250 million annually.

Market Drivers

While the current use of AFR is limited in Egypt, the market is poised for rapid growth. Of the 14 cement plants interviewed for this report, 86 percent now use, or have active plans to incorporate, up to 30 percent AFR within the next five to ten years. **Reaching that figure could reduce CO_2 emissions by 5.9 million tons of CO_2 per year and save the industry $77 million by 2025.**

Multinational cement firms own and operate 64 percent of the installed capacity in Egypt. Most are members of the World Business Council for Sustainable Development Cement Sustainability Initiative (WBCSD-CSI). As part of that initiative, the majority of the 14 CSI corporate members have set GHGs emissions reduction targets, including AFR substitution. In addition, cement companies are motivated to use AFR in order to reduce their thermal energy costs and improve their competitiveness.

The use of coal, which is not available domestically, puts pressure on Egypt's hard currency reserves at a time when the country is struggling with foreign capital liquidity. Civil society stakeholders also point to another crucial drawback to switching to coal; environmental and health externalities associated with not only the combustion of coal, but also its importation.

The government, determined to meet national climate emissions targets and to respond to public concerns after a heated debate, reacted. In April of 2015, the Executive Regulations of the law on Environment have been amended to allow and regulate the use of coal. Under this amendment, each cement firm applying for a coal operational license must commit to mitigate the difference between assumed greenhouse gases (GHGs) emissions from the theoretical consumption of 100 percent coal and a hypothetical baseline of 100 percent heavy fuel oil (HFO) within two years of the license's issuance.[2] With this new reality, cement firms need to invest in GHGs emissions-cutting initiatives to renew their operational licenses, but each firm is free to determine the method most appropriate for its circumstances. The use of AFR has been encouraged by the government of Egypt as one of the possible GHGs mitigation options. This will be a key regulatory demand driver for a strong AFR market in Egypt. The coal license mitigation target could be fully achieved if the sector reached a TSR of 30 percent by 2025, which would require approximately 20.4 million GCal of AFR.

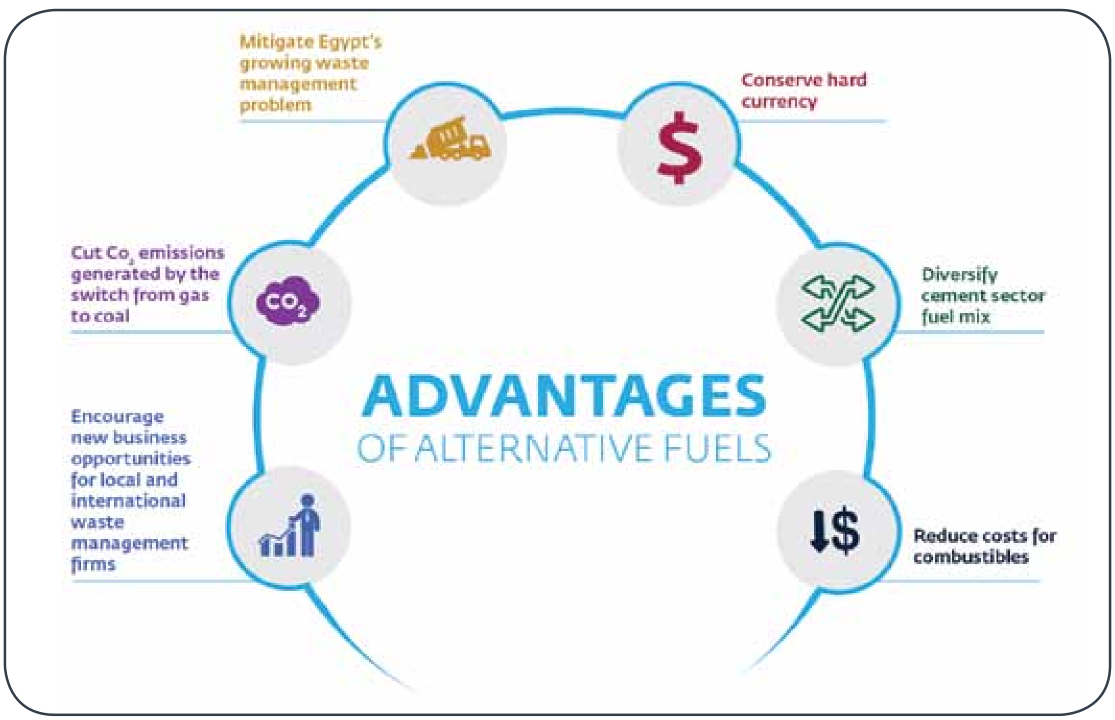


Figure 2: Advantages of Alternative Fuels for Egypt

2 Each firm must provide its current specific thermal consumption, which is capped at 4,000 MJ/kg (equivalent to 956 kCal/kg). This is above the national average of 945 kCal/kg. Authorities then calculate the total energy required to produce at nominal cement capacity and issue allowances for the respective volume of coal. HFO was used for this baseline to avoid penalizing those who were totally or partially using natural gas before the new regulations. This formula is valid for all plants, regardless of their real fuel mix.

Adopting alternative fuels may help the cement industry in not only meeting these regulatory requirements, but in saving money. AFR is a locally available resource with immense growth prospects: a steadily growing population base generates a continuous flow of waste. Furthermore, key governmental entities and the current regulatory frameworks are receptive to the incorporation of AFR as a means to confront the challenge of emissions, and the growing public health threat of waste. AFR usage will have fewer negative externalities. It will conserve valuable fossil fuels, reduce pressure on foreign currency reserves and allow for safe disposal of waste that would otherwise be landfilled or illegally, openly dumped.

In summary, these are five drivers supporting AFR growth in Egypt: a) local fossil fuel shortages constraining cement production, b) competitiveness amid rising fuel costs, c) a severe shortage of foreign currency reserves hindering imports of clinker and coal, d) CO_2 mitigation requirements and licensing mandates, and e) corporate and/or company-set AFR substitution targets.

These drivers have created an increased appetite and significant unmet demand, which could lead to a five-fold increase in current consumption levels of AFR, if the supply of waste is secured.

Estimated Available AFR Supply

Of the four waste streams evaluated as part of this study, agricultural waste is by far the largest in volume, at an annual estimate of 10.7 million tons. RDF from MSW, closely follows, at two to five million tons, with DSS offering another one million tons. Tires are a distant fourth, due primarily to competition from the tire retread and reuse industry. The study concludes that current waste volumes in Egypt from this first three sources offer between 46-72 million GCal of potential fuel that goes untapped each year. **Combined, the three waste streams contain enough technically viable fuel potential to supply nearly 1.6 times the 46 million GCal of the Egyptian cement industry's 2015 energy needs.** Table 1 summarizes available quantities, prices and chemical properties for each of the proposed waste stream.

Waste Stream	Quantities Available for AFR[1] (tons/year)	Calorific Value (GCal/ton)	Advantages	Disadvantages
RDF	2 to 5 million (year 2012)	3.1 – 3.8	• Plentiful supply • Costs tend to be low if MSW is secured unprocessed	• Low collection efficiency • Illegal dumping practices • Underdeveloped and in some cases, non-existent MSW treatment facilities
Agricultural waste	10.7 million (year 2012)	3.6 - 4.3	• Plentiful supply • Good calorific value	• Geographic dispersion • Many small farmers to deal with • Seasonal supply
DSS	982,992 (year 2013)	2.5 – 6.9	• Good calorific value • Consistent chemical characteristics	• Handling and transport of hazardous waste • Investment for drying required
TDF	Limited amounts[2]	6.0 - 8.4	• High calorific value	• Current legal environment offers permitting challenges • Other industries use tires • Competing over a small supply
46 to 72 million GCal annually				

[1] Includes remaining volumes after competing uses are assumed, except for DSS, where 100 percent utilization of generated sewage sludge is used, due to unavailability of data on current safe disposal practices.

[2] about 32,000 tons/year of scrap tires were substituted by cement companies in Egypt in 2014.

Table 1: Potential AFR Quantities from the Four Waste Streams

AFR Financial Viability and Commercial Potential

The entry of coal into the Egyptian energy landscape can be expected to create fierce competition for other fuel sources, but there is still a market for waste-based alternative fuels in Egypt and a potential appetite for investing in co-processing solutions. But in order for AFR to be competitive, the price difference between traditional fuels and alternative fuels must be taken into account. AFR prices are dictated by factors that include: the amortization of the equipment installed at the cement plant to co-process with either fuel; the operational cost of co-processing (also covers handling and maintenance); the cost of procuring the AFR; and the cost of potential negative impacts of the AFR on the kiln process and equipment.

An economic viability analysis of the four waste streams demonstrates that AFR is commercially competitive with coal. The cost competitiveness of each fuel varies, depending on preparation and processing costs, the price of other fuels and the cost of transport. IFC's initial analysis shows that for 2015, average AFR pricing was between 5 and 40 percent less expensive per GCal than coal at the burner point. That price difference also reflects pre-processing, handling, transportation, and co-processing costs.

The necessary capital investment by a cement plant for co-processing AFR in the kiln ranges from $1 million for agricultural wastes (fine materials) to $4 million for MSW. However, most cement plants needed to make capital investments to burn coal, investments which ranged much higher than that for AFR. For each coal line, the figure varied from $15 to $25 million (excluding land prices).[3] The total CAPEX requirements for co-processing varies for each cement plant, depending upon its existing production processes and equipment. Thus, sector-wide estimates are difficult to assess. However, the payback periods for investments required for AFR co-processing are expected to be less than five years.

As for pre-processing, which may be led by cement plants or by a third party service provider, the estimated capital investment ranges from $0.6 million for TDF to $5 million for RDF. Figures depend on the waste type, but also the size and complexity of the pre-processing platform. For most AFR types, significant economies of scale exist, particularly for labor intensive preparation of MSW. DSS, for instance, also requires technologically-intensive preparation. As discussed, operating costs vary. But, in general RDF is considered the most expensive waste to prepare, whereas TDF is the least expensive since it requires only shredding.

To reach a TSR of 20 percent by 2025, total investments for pre-processing are estimated at $114 million and may potentially be as much as $320 million. This represents a significant opportunity to attract investors and financial institutions. Based on the findings of the study, the economic feasibility of AFR pre-processing projects (with the exception of TDF) could result in an internal rate of return (IRR) above 15 percent, and a payback period of three to five years.

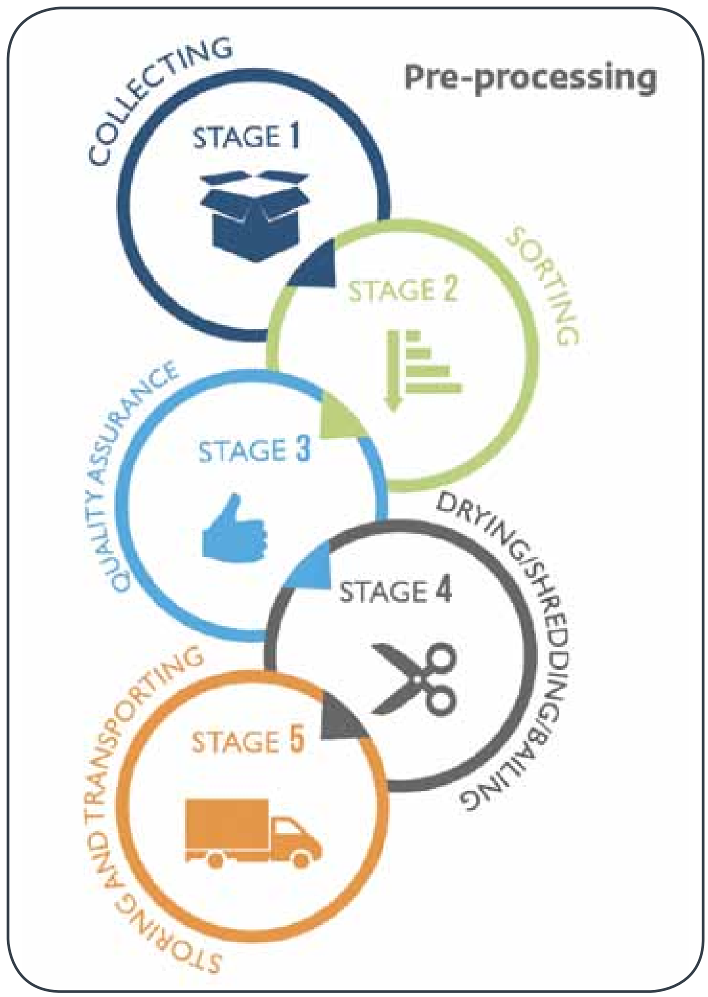


Figure 3: The Main Stages of AFR Pre-Processing

3 Estimate for a cement plant producing three million tons of clinker per year and using approximately 400,000 tons of coal.

ESTIMATED AVAILABLE AFR SUPPLY

Alternative Fuel Streams

- **RDF** Refuse Derived Fuel
- **DSS** Dried Sewage Sludge
- **Agricultural Waste**
- **TDF** Tire Derived Fuel

01 **Agricultural Waste**
AFR Availability = 10.7 Million Tons

02 **RDF**
AFR Availability = 2 - 5 Million Tons

03 **DSS**
AFR Availability = 1 Million Tons

04 **TDF**
Limited Amounts

Volumes from these sources offer between 46 to 72 million GCal of potential fuel that goes untapped each year

MARKET DRIVERS

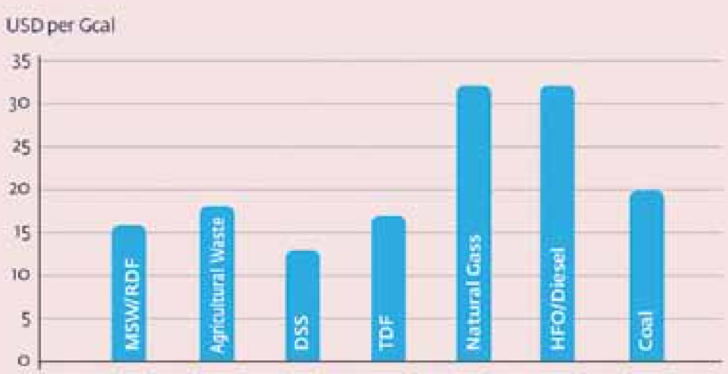
- In 2014, cement companies achieved on average 6.4% TSR equivalent to approxima[1]ely 2.9 million GCal per year of AFR.
- 86% of the 14 cement plants interviewed now use or have active plans to incorporate up to 30% AFR within the next 5 to 10 years.

Key Drivers

- Local fossil fuel shortages and limited foreign currency reserves
- Competitiveness amid rising fuel costs
- CO2 mitigation requirements, environmental regulations and licensing needs
- Corporate / company-wide AFR subsittution targets

AFR FINANCIAL VIABILITY AND COMMERCIAL POTENTIAL

- In 2015, average AFR prices were between 5 and 40 percent less expensive per GCal than coal at the burner point. This price included pre-processing, transportation and handling, and co-processing.
- The total investment required to reach TSR of 20 percent by 2025 is estimated at USD 114 million and may reach a potential USD 320 million.



BUSINESS MODELS

Outsourcing (No Integration)

Partial Integration

Full Integration

Agricultural Waste
RDF
TDF
DSS

Business Model Selection Criteria

- Degree of AFR Quality Control
- Scale of Investment
- Complexity of Operations

AFR Substitution Scenarios

The TSR at each cement plant varies widely, depending on the sophistication and co-processing equipment available at each individual cement plant. Most cement plants in Egypt are quite modern, and thus could theoretically accept TSR up to 30 percent without significant kiln modifications and related investments. Though achieving a limited TSR of 5-15 percent is relatively easy, the path to a higher TSR (> 20 to 30 percent), is long and requires technical knowledge that needs to be encouraged and developed.

Growth rates in the average thermal substitution rates will follow a gradual learning curve. Cement producers will need to make capital modifications, acquire needed knowledge and to train their employees. International producers possess this technical knowledge at the corporate level, and are thus well-placed to lead the market to higher TSR levels.

As demonstrated earlier, with the exception of tires, all waste streams are available in sufficient quantities to partially supply the cement industry's thermal energy needs. Assuming the absence of natural gas from the fuel mix, various thermal substitution rates by volume are presented in Table 2 below, which illustrates that a 20 percent TSR by the year 2025 is a realistic scenario. A 30 percent TSR is also technically achievable, but only with the implementation of significant regulatory interventions.

	Fuel	TSR%	Energy (Million Gcal per year)	CO_2 Reductions (mtpa)	Annual Fuel Spending[1] (Million USD)	Savings per Year (Million USD)
Scenario 1: Best Case	AFR	30%	20.4	5.8	326	77
	coal	70%	47.6		943	
Scenario 2: Business as Usual	AFR	20%	13.6	3.9	217	51
	coal	80%	54.4		1,077	
Scenario 3: Worst Case	AFR	13%	8.8	2.5	141	33
	coal	87%	59.2		1,172	

1) Assumption that average cost of AFR is 56 USD/ton (16 USD/Gcal) at the burner for calorific value of 3.5 Gcal/ton. Cost of coal of 118.8 USD/ton coal (19.8 USD/Gcal) at the burner for calorific value of coal at 7,000 kcal/kg.

Table 2: Three Scenarios of AFR Substitution Percentage

Reaching the Business As Usual (BAU) 20 percent TSR target by 2025 means an additional 13.6 percent in AFR substitution beyond the current 6.4 percent TSR levels of 2014. However, in order to reach this BAU scenario, **cement plants must look to a combination of the various waste streams. No single waste stream could meet the demand on its own. In addition, a diversified AFR fuel base would reduce potential supply reliability concerns.**

In order to reach 20 percent TSR by 2025, cement plants would need to spend around $217 million annually on procuring AFR. This could help the cement industry save $51 million annually. It would also replace about 1.9 million tons of coal in 2025 and avoid 3.9 million tons of CO_2 emissions.

AFR Supply Chain

A key challenge is the lack of an established supply chain to collect, process and deliver waste to cement plants at the required quality and with a mutually accepted price. In order for AFR to grow, commercially and sustainably, strong partnerships between waste suppliers, waste management operators, and the cement industry must be forged.

International experience shows that there are different levels of AFR pre-processing integration in the cement sector. In general, there are three levels of integration in AFR upstream activities: i) outsourcing (no integration), ii) partial integration, and iii) full integration. The cement plant would select the model most relevant by evaluating the degree of AFR quality control it requires, the scale of investment a firm can afford, and the complexity of operations it can tolerate. The appropriate business model will vary depending on the type of waste stream and the cement company's risk appetite.

However, whatever the type of waste, market players must come to clear and fair commercial arrangements ensuring a **secured AFR supply and return on investment, a fair pricing mechanism, and acceptable quality standards, and economic and regulatory incentives/disincentives.**

The majority of the cement companies, interviewed as part of this study, plan to increase AFR thermal substitution rates, but the cement companies increasingly envisage entering into pre-processing as a consequence of the high prices of AFR provided by the existing waste management companies in Egypt, unless competitive options can be offered. This represents a potential opportunity to third party waste processing players to bring their expertise forward.

Challenges and Recommendations

Alternative fuels for the cement industry represent an immediate and attractive opportunity in Egypt. Nonetheless, there are several issues that should be considered carefully and addressed prior to an investment decision, in order to ensure a long term and more sustainable market for AFR in Egypt. These issues include the following, along with options for mitigation:

Logistics and transportation costs. Transportation costs can significantly impact the profit margins of an otherwise viable financial model. Waste streams like MSW and DSS are overwhelmingly concentrated in urban areas. Others, particularly agricultural waste, are geographically distributed and may lack central collection and processing points.

> **Mitigation:** In order to help address this issue, IFC has created a map which indicates the locations of a) cement plants throughout Egypt, b) the distribution of various types of crops in Egypt c) various sources of AFR and d) locations of the existing waste processing/composting sites, which may be considered as potential future pre-processing locations. The map could be accessed at this link: http://arcg.is/1ToAspz

Qualified investors. Waste markets remain fragmented and dominated by informal players, most of which lack the technological knowledge and financing to supply a cement company with AFR on a long-term basis at required quality specifications.

> **Mitigation:** This study aims to equip investors in the waste management or cement industry with initial information with which to investigate the potential of investments in the pre-processing stage of AFR. The findings of this study indicate that the investment opportunity can be an attractive one, if the complexities inherent in the various waste streams are managed today.

Agreement on quality and secured supply. Almost all potential AFR requires pre-processing to guarantee a more homogenous waste product with characteristics that comply with the technical specifications of cement production. The cost and complexity involved in pre-processing varies for each type of waste. Feedback from the cement producers surveyed for the purposes of this study has indicated that both availability and quality of AFR is of unreliable or of lower quality than required.

> **Mitigation:** As will be further elaborated in this report, IFC recommends that the cement companies contractually agree with AFR suppliers on various standard terms such as a) minimum volume off-take, b) pricing, and c) quality characteristics and technical specifications of the AFR supplied. The more the cement industry can harmonize its requirements from a quality and characteristic perspective, the greater the economies of scale.

Support from local governments. Cooperation from the government is vital to ensure the security of supply and off-take agreements, particularly for MSW. If price and volume are fixed under a longer-term supply contract to allow for investment cost recovery and minimum returns on investment, waste management firms can obtain financing and qualified players may be willing to become involved.

Mitigation: Local governments are encouraged to see AFR processing companies as an opportunity to help solve the waste problem, particularly in urban areas where waste endangers public health. Furthermore, investing in AFR will help minimize public expenditure costs and reduce the environmental impact of dumping and landfilling. Nevertheless, a viable AFR sector is not an opportunity for wind-fall profits. Local governments are encouraged to support potential investors by selecting AFR pre-processing sites and making them available for development.

Enforcement of regulations and an efficient waste management chain. Extensive bans exist to prevent waste dumping and other disposal methods. But, a lack of enforcement impacts the availability of AFR supply, as well as the financial margins of co-processing. Existing facilities are currently treating less than 10 percent of generated MSW, which reduces the AFR volumes available to interested investors.

Mitigation: After adequate rehabilitation, operation and maintenance of existing pre-processing facilities, and the establishment of new ones, illegal dumpers may find it is just as economical, if not in fact cheaper, to deposit their collected waste with an AFR pre-processing plant even with a tipping fee. AFR represents a potential market-based solution to this serious environmental problem.

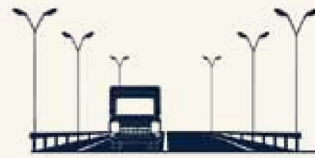
A Sustainable AFR Market in Egypt

IFC's analysis underscores the opportunity for the private sector to promote and invest in a commercially attractive market for alternative fuels in Egypt. If the supply chain for AFR can be unlocked by the private sector through developing and investing in pre-processing facilities and operations, investors will be rewarded with sustainable and long-term demand from the cement industry.

Alternative fuels are already less vulnerable to global price fluctuations than coal and less susceptible to supply volatility. Multiple forces in Egypt are pressing for greater reliance on alternative fuels and multiple stakeholders stand to benefit greatly from their adoption, not least of which are the multitude of small businesses that can become waste collection agents or pre-processing facilities along the cement production supply chain. There is a clear opportunity for the private sector to transform these waste streams into a financially sustainable business.

The challenges in making the switch to alternative fuels are significant. But the rewards far outstrip the hardships of reaching the goal.

CHALLENGES AND RECOMMENDATIONS



LOGISTICS AND TRANSPORTATION COSTS

Data is essential to fill gaps and help lift uncertainty. A new GIS tool created to support this study maps the locations of cement plants, the various sources of AFR and identifies existing waste processing sites. Information goes a long way in helping investors on both sides of the supply chain.

QUALIFIED INVESTORS

This study aims to equip investors in the waste management or cement industry with information with which to investigate the potential of investments in the pre-processing stage of AFR. The findings of this study indicate that the investment opportunity can be attractive, if the complexities inherent in each waste stream are managed.

AGREEMENT ON QUALITY AND SECURE SUPPLY

It is vital for cement firms to agree with AFR suppliers on various standard terms such as a) minimum volume off-take, b) pricing, and c) quality characteristics of the AFR supplied. The more the cement industry can harmonize its requirements from a quality and characteristic perspective and secure supply, the greater the economies of scale which can be achieved in AFR pre-processing.

SUPPORT FROM LOCAL GOVERNMENTS TO ATTRACT INVESTORS

Local governments are encouraged to see AFR processing companies as an opportunity to help solve the waste problem, particularly in urban areas where waste endangers public health. Municipalities across the country spend large percentages of their budgets on waste management. AFR businesses can help minimize costs and reduce the environmental impact of dumping and landfilling. But a viable AFR sector is not an opportunity for wind-fall profits. Local governments are also encouraged to support potential investors by selecting AF pre-processing sites and making them available for development. Their role in providing long-term supply contracts for MSW, where needed, is central.

ENFORCEMENT OF REGULATIONS AND EFFICIENT WASTE MANAGEMENT CHAIN

With the increased use of AFR in Egypt, after the improved waste collection and the adequate rehabilitation and maintenance of existing pre-processing facilities, and the establishment of new ones, illegal dumpers may find it is just as economical, if not in fact cheaper, to deposit their collected waste with an AFR pre-processing plant. Instead of transporting the waste to a distant and illegal location, AFR represents a potential market-based solution to this serious environmental problem.

Chapter 1: Introduction

1.1 Alternative Fuels as a Viable Option for Egypt's Cement Industry

The successful use of alternative fuels for the cement industry brings with it potentially significant public and private benefits. The use of AFR can reduce landfilling, lower carbon emissions by substituting the use of coal, reduce public costs for waste management, and potentially transform waste from a public nuisance into a privatized and lucrative solution. The benefits make the investment more than worth the effort.

By removing subsidies on natural gas, and allowing the import and use of coal and petcoke in the cement sector for the first time, Egyptian authorities have definitively changed the future fuel mix for the industry. As a consequence of these changes, it is expected that heavy fuel oil (HFO) and natural gas will no longer be part of the fuel mix. Yet, fuel costs will also remain permanently higher. Even as cement plants complete the equipment investments necessary to switch to coal and petcoke, this new reality has provoked strong interest among industrial and the Egyptian government to investigate the competitiveness and attractiveness of alternative fuels for cement production.

Alternative Fuels and Raw Materials (AFR) are any non-fossil based fuels that can replace part of the raw material needed for the production of cement, whether it is used for thermal energy or material recovery. These alternative fuels are derived from waste material, which is plentiful in Egypt. Waste material is also largely being disposed of in economically inefficient ways that are damaging to the environment and public health. At present, regulatory requirements governing the disposal of these wastes are not enforced or are nonexistent. But the creation of an infrastructure for channeling these wastes into productive use as fuel sources would yield advantages for the environment, and for the economy generally. The cost of producing cement in Egypt, the 12th largest producer in the world, would be reduced by tapping into a sustainably available source of fuel.

The main objective of this study will be to examine in detail the financial viability, economic competitiveness, technical feasibility and other benefits of AFR for the cement industry. This report will consider four types of AFR waste streams: a) refuse derived fuel (RDF) from municipal solid waste, b) dried sewage sludge (DSS) from wastewater treatment plants, c) agricultural waste, and d) tire derived fuel (TDF) from scrap tires. These waste streams have been selected since they meet three essential criteria defined after extensive consultation with relevant stakeholders. Those are: 1) suitability for use by the Egyptian cement industry; 2) abundance, relative availability of data, and proximity to cement producers; and 3) current mismanagement of associated waste streams, leading to negative environmental and health impacts.

Conclusions can be drawn largely on the price differential between AFR and conventional fuel, which may depend in large part on Egypt's energy and waste management policies. Expanded use of alternative fuels will be further stimulated by the introduction of an economic framework around waste disposal and recycling. A more detailed analysis of the existing regulatory framework, future policies needed and international best practices will also be elaborated upon.

This report will address the following questions:

- *What is the current status of AFR in Egypt and how will it be affected by the cement sector's move to import coal? Will the introduction of coal impact the use of AFR? What are the AFR substitution targets of Egypt's cement firms, and what is the overall potential demand for AFR?*
- *Under the assumption that coal will be deployed in cement plants at significant levels in the near term, what would be realistic for AFR use in the cement industry within the next five to ten years? What is the most likely future fuel mix for the cement industry?*

- *What specific waste streams (municipal waste, sewage sludge, agricultural waste and scrap tires) currently exist in Egypt which may contribute to an increase in AFR supply to cement plants? What are the supply chains for these four waste streams, and their viability for use as AFR, either standalone or in combination with other waste streams, in cement plants?*
- *How do pricing and other economic factors affect waste sourcing, preparation, processing and transporting?*
- *How does the location of the various sources and uses of AFR affect the viability of this source of fuel for cement plants?*
- *What are the opportunities for investors in the supply chain of AFR in providing the cement industry with much-needed reliable fuel sources?*

Based on the assessment of the energy situation in Egypt, the cement industry's thermal energy needs, and the current use of AFR, a realistic energy mix scenario will be developed. This will also involve a comparison of the energetic (calorific) value of the various energy sources, potential volumes available, and the cost structure.

Solutions will then be proposed to bridge the supply and demand gap between waste generators and cement plants, offering economic and financial analysis of different technical and business models. The recommendations for overcoming these challenges will include a variety of interventions, which would also require longer-term regulatory reforms.

This study aims to provide a reference for the cement industry, waste processing companies, and Egyptian authorities, helping them to understand and identify responsible and sustainable approaches to the selection and use of AFR in the cement industry in a transparent and sustainable manner.

1.2 Approach and Methodology

In order to answer the above questions, this study explores the current use of AFR in the cement industry in Egypt, identifies major bottlenecks for expansion of AFR use, and recommends business solutions. It explores the main constraints related to specific waste streams that can be used as potential AFR (municipal waste, sewage sludge, agricultural waste and scrap tires). Unlike in other markets, where data is readily available or can be extrapolated, this study relies on primary, original research to inform its conclusions. The scope and nature of the research is the first of its kind for Egypt.

The first component under the study assesses the baseline situation of AFR use among cement operators in Egypt. The four white cement producers were excluded from the 25 existing cement plants in Egypt, as AFR can contain elements (i.e. iron) that could degrade the color of the end-product, an outcome which would be undesirable for this market segment. Consequently, white cement producers are usually restricted to the use of non-polluted biomass waste. Of the remaining 21 plants, 14 were interviewed between March and May of 2015, representing 75 percent of the total Egyptian production capacity, equivalent to an annual production capacity of about 46.8 million tons of clinker. Ten of the 14 plants interviewed belong to multinational companies, and four are locally owned by Egyptian shareholders. Most interviews were carried out at the plants in order to ensure participation of key operational staff able to provide the required data.

Under this baseline survey the current status and planned use of AFR, as well as challenges faced by the cement sector for AFR use, were identified. The results of the survey will be shown throughout this study in the following three categories:

- Group 1: cement companies currently using AFR;
- Group 2: cement companies with AFR investment commitments or decisions to proceed with AFR; and
- Group 3: cement companies that have not yet taken any action regarding AFR use.

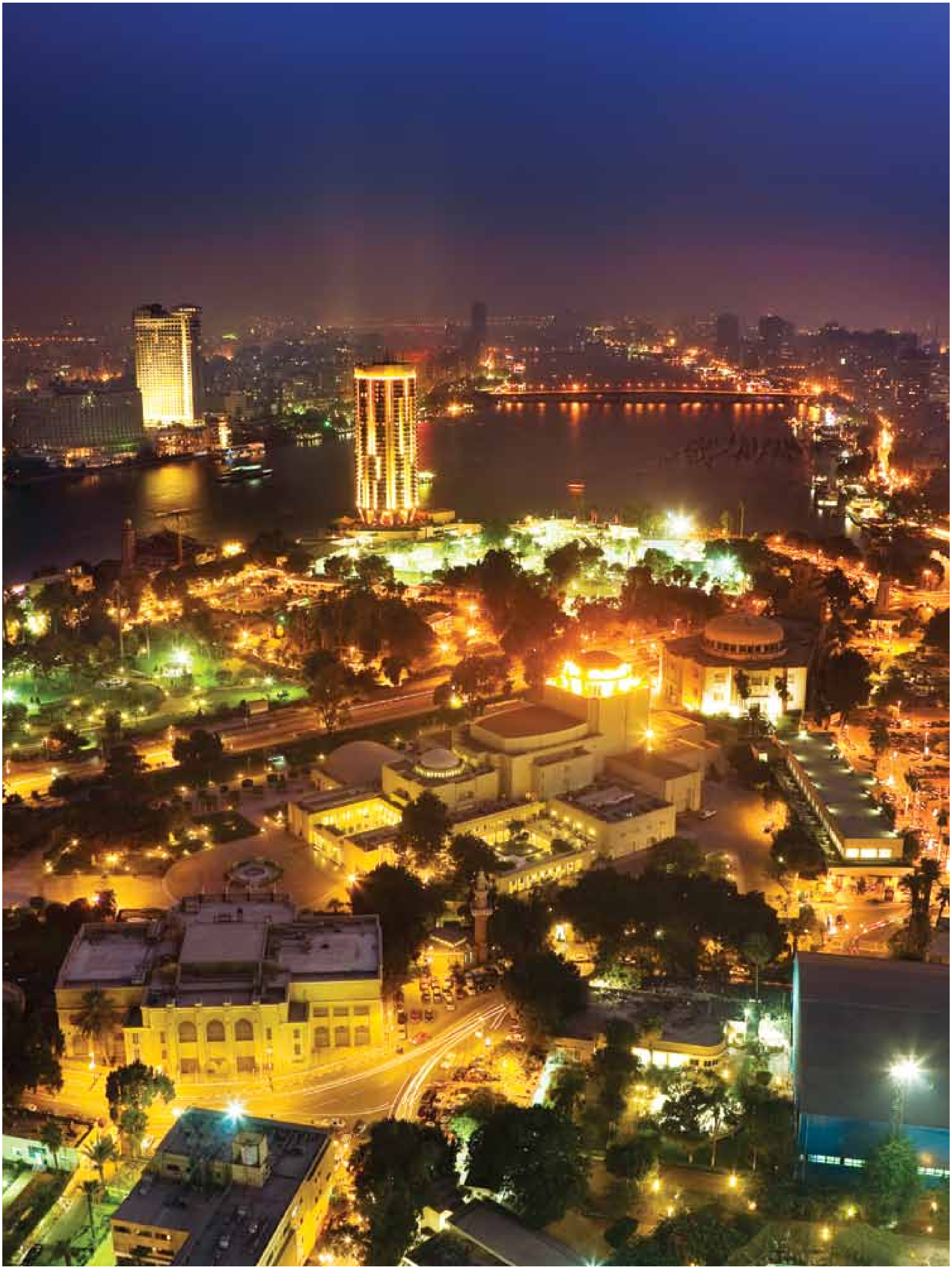
The second component of the study comprises an assessment of AFR sources, volumes, quality, locations, and pricing. Available data on different waste streams have been analyzed to discern gaps in the AFR value chain. The waste streams were selected based on feedback from multiple stakeholders in terms of viability and availability. But it may also be advisable for cement players to explore other business opportunities in the future, including but not limited to industrial waste, spent oils, spent solvents, and polluted soil.

The study relied extensively on dialogue with relevant stakeholders to shape its conclusions and recommendations. Data in the report was substantiated by participatory interviews, workshops, and a full stakeholder engagement process, which included the following groups:

- Private sector: cement firms and waste management companies (formal and informal) involved in collection and disposal;
- Government stakeholders: relevant ministries, affiliated organizations and select municipalities;
- NGOs: organizations working with waste collectors or taking part in collection themselves. This included representatives of Cairo's informal waste collectors, the "zabaleen".

An analysis of supply and demand was completed in order to identify sustainable investment opportunities in the AFR value chain, based on different business and operating environment scenarios. These included the current situation (i.e. without any regulatory modification), and what pre-requisites may be needed in order to realize higher AFR substitution opportunities.

Finally, this report refers to coal only for purposes of simplification. Though petcoke currently has a lower cost than coal and some limited quantities are locally available, it is still being used by a number of cement plants in Egypt as an alternative to natural gas.



Chapter 2: A Changing Energy Picture

2.1 Egypt's Energy Crisis

Historically, Egypt has been a net exporter of oil and gas, as domestic consumption was well below production. The Arab world's most populous nation enjoyed considerable energy security during the first decade of the 2000s, with widespread access to energy and reliable supply. In recent years, however, this situation has been dramatically reversed. Growing energy demand has put increasing pressure on available fuel supplies. The sector has been particularly sensitive to political turmoil and unrest, most notably in 2011 and 2013. The political unrest revealed large structural and financial problems, including the accumulation of arrears by the Egyptian General Petroleum Corporation (EGPC) with international oil companies, that in turn suspended new investments in the sector (Kouchouk and Alnashar, 2015). These developments led to continuous supply bottlenecks, complicated by deficiencies in power plants and the energy transportation infrastructure.

By 2013, Egypt's oil exports had drastically dwindled and the country become a net importer. Energy demand swallowed domestic production (Figure 4). According to estimates from the U.S. Energy Information Administration, exports dropped by an annual average of 30 percent between 2010 and 2013 (EIA, 2015).

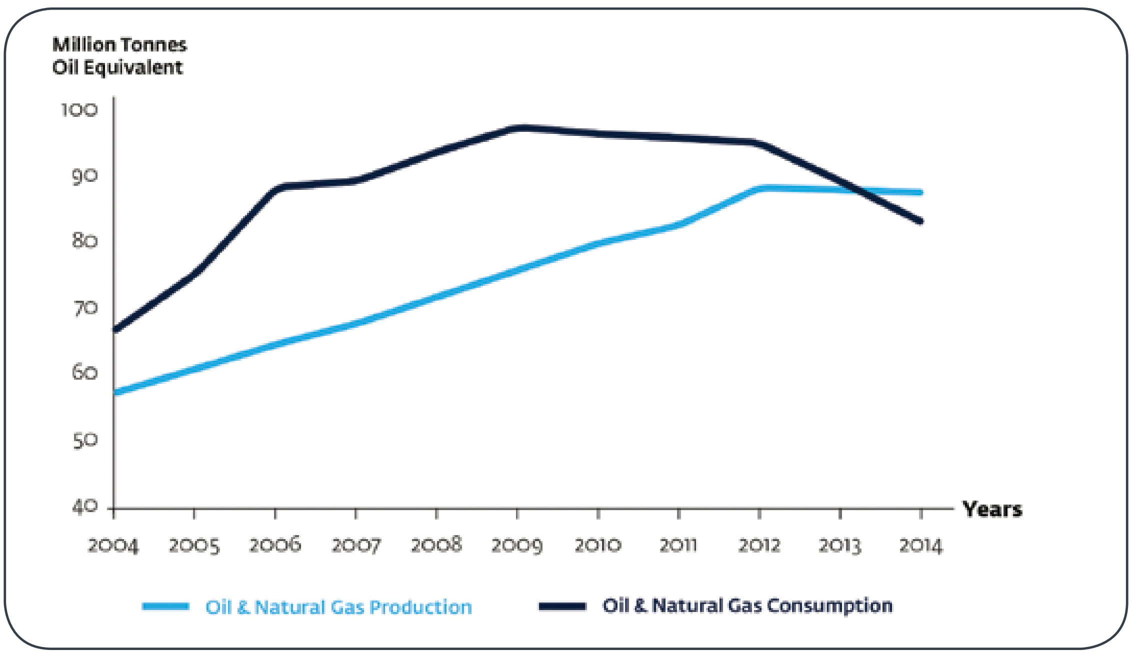


Figure 4: Oil and Natural Gas Production and Consumption

(Source: British Petroleum, 2015)

In 2014, Egypt's deficit of natural gas stood at 700 MMSCF/day, oil at 2.3 MM tons/day and petroleum products at 10 MM tons/day (GoE, 2015). By the summer of 2014, the situation had become critical, with the country experiencing continuous shortages of electricity, and a power generation deficit estimated at a maximum of 5,300 megawatts in the mid-summer of 2014, equivalent to one-eighth of the country's installed capacity.

2.2 The Cost of Energy Subsidies

Similar to other countries in the region, Egypt has long relied on generalized energy subsidies as a central instrument for social protection, economic development, and the sharing of hydrocarbon wealth.[4] Subsidies have often been seen as essential for attracting investment in the manufacturing sector. This has, however, led to a policy of buying or producing fuels at international prices and selling at subsidized prices in domestic markets. The low prices elicited a rising demand response from the economy, and the subsidy bill grew at a compound annual rate of 26 percent between 2002 and 2013.

As Egypt's energy demand soared, fuel subsidies produced several unintended consequences. Egypt's exposure to global market prices at a time when international oil prices were on the rise drove the government deeper into debt. By 2013-2014, fuel subsidies consumed around a third of government revenues, constituting a fifth of government expenditures and over seven percent of Gross Domestic Product (GDP).[5] Fuel imports also drained the government's foreign currency reserves, leading to a backlog of payments to international energy producers. Predictably, foreign oil and gas companies in Egypt reduced their gas production and investment levels, creating a vicious cycle of supply shortages and foreign currency scarcity (SPTEC Advisories, 2014).

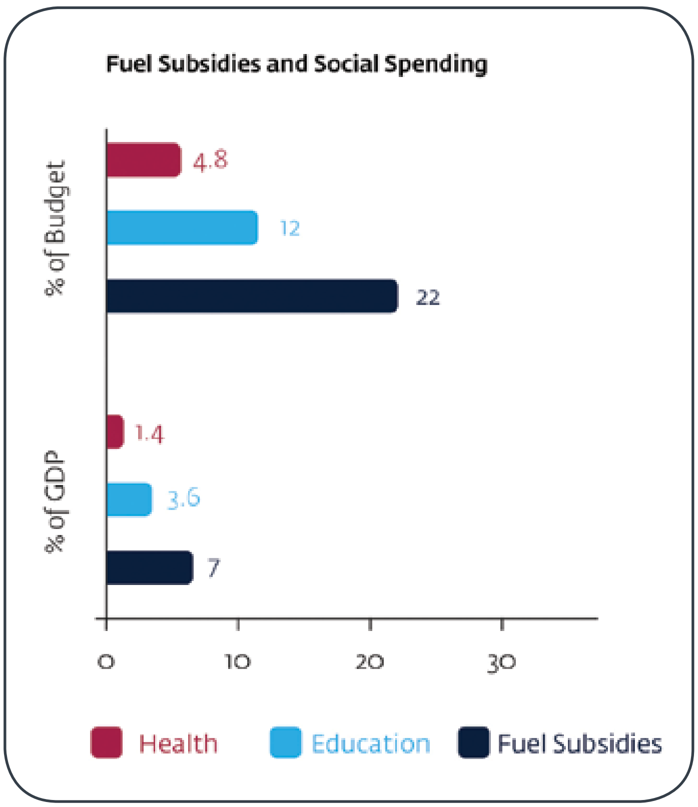


Figure 5: Comparison of Fuels in Subsidies with Social Sectors

(Source: Ministry of Petroleum, 2014)

As domestic production of oil and gas stagnated and energy imports slowed, Egypt began experiencing shortages of electricity, oil and natural gas (Citadel Capital, 2012). In response, the Egyptian government reallocated natural gas away from energy-intensive industrial sectors such as cement and steel, in order to prioritize power generation.

In July 2014, the Egyptian government reintroduced major reforms to phase out energy subsidies in a staggered increase of the officially mandated prices of petroleum, gas and electricity (Griffin et al., 2016). The reforms were intended to reduce energy subsidy spending by 44 billion Egyptian pounds ($6.2 billion) by 2015, according to the Minister of Finance. Griffin et al. (2016) estimate that the reforms will reduce subsidies by one-quarter to one-third.

2.3 Cement Producers and Rising Fuel Costs

As energy shortages forced the reallocation of natural gas and other primary energy towards domestic power production, Egypt's industrial sector suffered. This situation was particularly difficult for the country's cement sector, which accounted for about 3.7 percent of Egyptian GDP (Oxford Business Group, 2015), but almost 7.4 percent of total industrial natural gas consumption and 16.3 percent of the total industrial electricity consumption in 2011/2012 (FEI, 2014).

4 The IMF has estimated that for the MENA region as a whole, energy subsidies cost about $237 billion in 2011, approximately 8.6 percent of regional GDP, or 22 percent of aggregate government revenue. The figures are the equivalent to a sobering 48 percent of all global energy subsidies.

5 Refer to the *World Bank Macro-Economic Bulletin* for further details. Griffin et al. put the figure in 2013/14 for combined energy subsidies at about LE150 billion ($21 billion) or 8.5 percent of GDP.

The production of cement is extremely energy-intensive. Thermal energy, which is the energy generated in the plant's kiln by the combustion of fuels and needed to provide the required heat level to produce clinker, represents approximately 80 percent of the overall energy requirements of cement production. Worldwide, energy costs account for more than 40 percent of total cement production costs (UNIDO, 2009). Natural gas and HFO had been the primary source of thermal energy for cement producers from the inception of the industry in 1929. Until 2013/2014, the fossil fuel mix in the cement sector has been mainly 60% natural gas and 40% HFO.

The severe natural gas shortages between 2013 and 2014 caused a 20 percent drop in the cement industry's average production levels. Some cement companies halted a number of their production lines altogether. Even as shortages eased in 2014, the announcement that the government would phase out fuel subsidies for energy-intensive industries pushed up prices of natural gas and petroleum products. By 2016, natural gas prices were four times higher than in 2010 for many industries. For the cement industry, natural gas prices rose by roughly 33 percent in 2014 (World Bank, 2014). Clinker costs increased in tandem. According to the Egyptian Chamber of Building Materials, clinker imports reached six million tons per year at the peak of the energy crisis, as many plants turned to importing clinker instead of producing locally, due to the shortage of fuel.

2.4 Diversifying the Energy Mix

Even as the shortages eased in 2015, domestic energy prices continued to rise, a trend expected to remain in place through the foreseeable future until prices reach the cost recovery levels set as a strategic target by the government of Egypt. In addition, renewed availability of natural gas for the cement companies still remains uncertain. As a result, cement companies have been forced to explore alternative sources of energy, including imported coal and petcoke, to secure their energy needs.

Coal and petcoke have been perceived as the most cost effective option by the Egyptian cement industry. Coal remains the largest single source of fuel used by the cement industry internationally, with an annual average consumption of 330-350 million tons (Davidson, 2014). In Egypt, coal was positioned as a solution due its competitive cost, high calorific value (>6000 Kcal), more consistent quality, and its international availability from a variety of sources and markets.

The proposed use of coal has, however, sparked a highly polarized public debate over potential environmental and health impacts. The debate around coal use dominated energy policy discussions in Egypt during 2014. Criticisms revolved around the externalities of not only the combustion of coal, but also the import of a fossil fuel that is largely unavailable in the local market, as well as the lack of existing infrastructure to support the switch from natural gas to coal.

In response to this debate, the Egyptian government drafted the executive regulation Decree 964/2015, to address mitigation alternatives available to cement companies using coal as a fuel; this decree involved both emissions limits and controls over coal permits. The import and use of coal for cement production and other industries was approved in 2014 as part of a broader effort to diversify the country's energy mix and establish long-term fuel source diversification, giving priority to the use of natural gas in electricity production (Reuters, 2014). The Ministry of Environment has stipulated that coal licenses will be granted only to those firms presenting a mandatory greenhouse gases (GHGs) reduction plan. The decision on how such abatement targets can be met is left to the individual cement firms, based on their operational nature and the baseline of their emissions.

As of 2015, 19 cement companies had applied to the Ministry of Environment for licenses to use coal (MadaMasr, 2015). Twelve plants have been granted temporary permits to import. Permits issued by the Egyptian Environmental Affairs Agency (EEAA) are valid for two years. During the first year of the new regulations, total coal consumption in Egypt rose by more than 300 percent, from 0.2 million tons of oil equivalent (mtoe) in 2013 to 0.7 mtoe in 2014 (British Petroleum, 2015).

2.5 Alternative Fuels: A Key Substitute for Coal

The potential for alternative fuel usage in Egypt is supported by ongoing uncertainty about the availability of fuels as a result of foreign currency pressures, the heated political debate over GHGs emissions and health impacts, and the overall risks concerning the renewal of coal permits. Many cement plants have continued expanding their use of alternative fuels as a key solution.

Many of Egypt's key cement players have also committed to alternative fuels in their coal license applications, relying on AFR substitution to meet the mandatory GHGs target reductions. It is important to note that several cement operators in Egypt belong to international conglomerates. As such, many already have corporate-wide AFR substitution targets, as well as GHGs emission reduction plans. These standards are mostly based upon their participation in the World Business Council on Sustainable Development (WBCSD)'s Cement Sustainability Initiative (CSI).

Interest in the potential for AFR has been heightened by the successful use of AFRs in cement production around the world, most notably in the EU, where substitution rates of AFR for fossil fuels, or "thermal substitution rate" (TSR), have reached about 39 percent (WBCSD, 2013). Some plants have successfully reached TSR as high as 100 percent under a highly enabling regulatory environment. AFR has not been widely used in Egypt to date, but potential economic, social and technological benefits have increased awareness and interest on the part of the cement industry, waste management operators, government representatives and other stakeholders.

Besides being less vulnerable to global price and supply volatility, AFR has the potential to provide a cheap, locally available energy source for Egyptian industrial actors. Quite simply, Egypt's large and constantly growing population ensures a continuous abundance of waste material.

2.6 Other Market Drivers: Regulating Waste

As a significant alternative to fossil fuels in the cement sector, AFR is increasingly competitive based on market based dynamics alone. However, a fully thriving AFR market requires an enabling regulatory and professional environment. A key to success for waste-management systems in emerging economies is the ability to aggregate waste into meaningful volumes and to develop an organized supply chain (Engel et al., 2016). This requires a clear distribution of responsibilities and an institution that directs overall waste management efforts.

Egypt's waste management system faces a number of complex challenges, to be explored in depth in the coming chapters. Yet there are changing institutional dynamics that may positively impact the development of alternative fuel businesses.

In November 2015, a national Waste Management Regulatory Authority (WMRA) was established. Charged with setting institutional mandates and developing adequate legislation to improve waste management in Egypt, the agency will determine municipal and national responsibilities for collection and processing of waste. One central, self-proclaimed objective is to "transform waste from a burden to an economic and investment opportunity." (Mohsen, 2016).

WMRA, housed under Egypt's Ministry of Environment, will also produce guidelines and support capacity-building for waste management providers. The authority intends to become a singular coordination agency responsible for improving the collection efficiency of waste, setting codes for new landfills and composting facilities, encouraging investment opportunities in the sector and helping determine budgetary needs and funding mechanisms.

While it is too early to assess WMRA's impact, the development of a central agency to coordinate and supervise waste management may offer both cement firms and potential alternative fuel suppliers a clear partner and key stakeholder to collaborate with. At the very least, it is a step towards alleviating uncertainty in the market.

This institutional development is especially relevant to a 2015 Prime Ministerial Decree (964/2015) specifying environmental, technical and permit requirements that cement firms must comply with in order to obtain and maintain the permit to operate the cement kiln fired with coal, petcoke or waste-derived fuels (for further details on AFR regulations please refer to Annex E).

As previously noted, cement firms are now obliged to provide an environmental impact assessment to coincide with their application for coal use. Each firm is expected to submit an annual report, detailing environmental performance and demonstrating commitment to an individualized GHG reduction plan. The permit shall be renewed every two years, subject to EEAA approval.

Chapter 3: Co-processing: Making the Most of Resources

The use of AFR alongside traditional fuels in the cement industry, and other manufacturing industries, is known as "co-processing". Co-processing is defined as the use of waste as raw material, or as a source of energy, or both, to replace natural mineral resources (material recycling) and fossil fuels in industrial processes. This is primarily relevant for energy intensive industries (EII) such as cement. Co-processing reduces dependence on primary resource markets, which may be offshore; saves landfill space; cuts GHG emissions; reduces pollution caused by the disposal of waste and provides a sustainable solution to a local problem.

Alternative fuels are at the heart of the cement sustainability initiative (CSI), in which the largest worldwide cement firms have been actively involved under the World Business Council for Sustainable Development.

In addition to producing fewer polluting gases, especially carbon dioxide, utilizing alternative fuels can also indirectly lead to emissions reductions by improving refractory usage rates (Benhelal et al., 2013; Grosse-Daldrup and Scheubel, 1996).

3.1 International Trends

As already alluded to, large percentage of cement manufacturers in Egypt are owned or managed by international manufacturers, whose parent companies have TSR targets and wide-ranging experience in the use of alternative fuels. Globally, Cemex has the highest corporate average TSR rate, nearly 28 percent, followed by Heidelberg with around 21 percent, as summarized in Table 3.

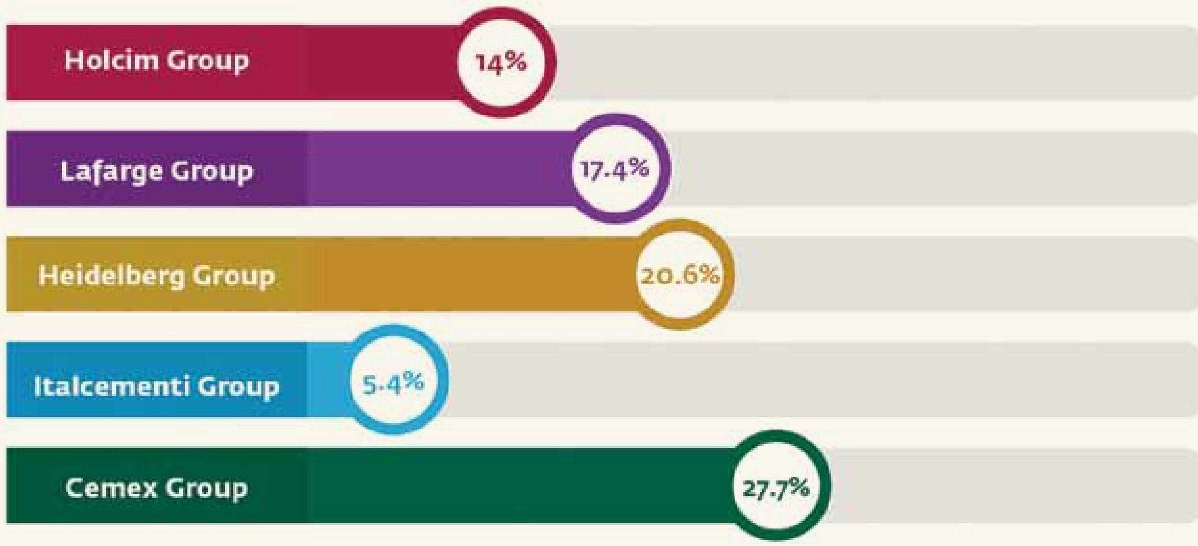
In 2009, the European Cement Research Academy (ECRA) and WBCSD proposed estimates in terms of AFR substitution rates for high-income countries and emerging markets (IEA-WBCSD, 2009). By 2030, emerging markets should have reached 10 to 20 percent, while developed countries should have achieved targets of 40 to 60 percent. By 2050, estimates predict a substitution rate of 25 to 35 percent for the emerging markets and a static rate for the other regions (Figure 6).

According to the latest statistics from the WBCSD's *Getting the Numbers Right* (GNR)[6] data for 2013, AFR use by cement plants worldwide reached 16 percent (WBCSD-CSI, 2013a). In the EU, co-processing represented nearly 39 percent of the thermal energy needs of the cement industry (Figure 7). In fact, the European cement industry was responsible for nine percent of all energy recovery inside the European Union in 2012 (EUROSTAT, 2015). Examples from cement plants in Germany, Poland and other EU countries show that it is technologically and economically feasible to further increase these substitution rates, possibly as high as 95 percent (de Beers and Hensing, 2016).

There have been some concerns about the impact of AFR use on clinker output, but many of those concerns can be answered when AFR quality and characteristics conform to established guidelines, such as those in the GTZ-Holcim guidelines (Holcim-GTZ, 2006). The following section will also discuss co-processing technical considerations.

6 The "Getting the Numbers Right" (GNR) is a voluntary, independently-managed database of CO_2 and energy performance information on the global cement industry.

Table 3: AFR Use by International Cement Manufacturers (Source: Corporate Sustainability Reports, 2014)



a) Average Corporate AFR Thermal Substitution Rates Globally

Alternative Fuels by Type (In %)	Holcim Group	Lafarge Group	Heidelberg Group	Italcementi Group	Cemex Group
Waste Oils	3		1.7	5.8	
Tires	9	14	9.3	20.5	9
Plastics	13		29	2.6	
Liquid Waste	9	15	4	12	
Solid Waste	34	32		16	49.7
Biomass	32	39	36.7	35.8	41.3
Other			19.2	7.3	

b) Corporate AFR Percentage by Type of Waste

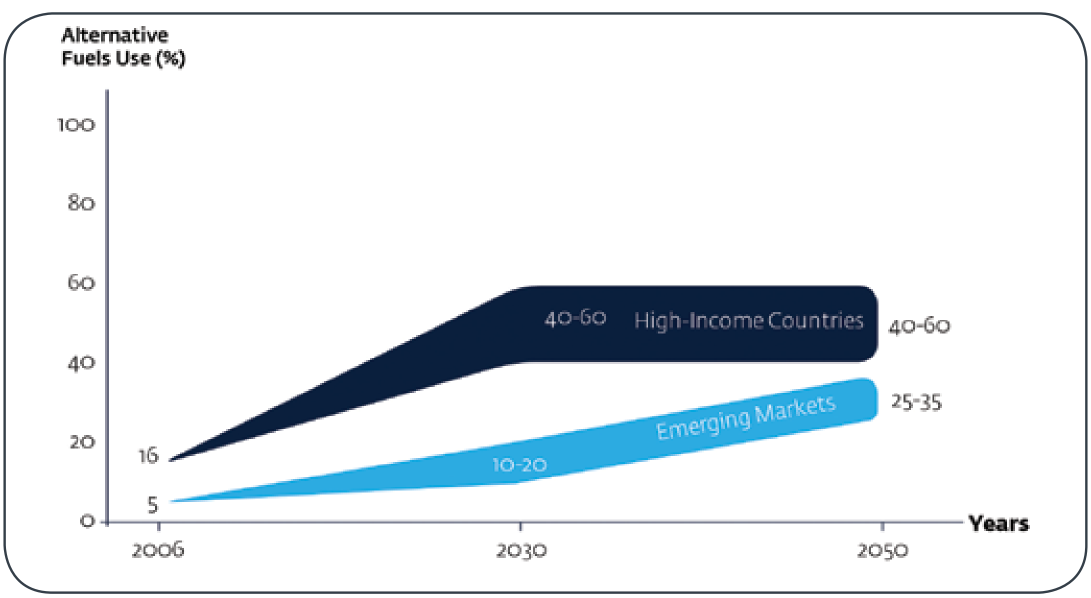


Figure 6: Estimated AFR Use Between 2006-2050

(Source: IEA-WBCSD, 2009)

Box 1: SUCCESS STORIES

Worldwide, the cement industry is driven to reduce thermal energy costs, in parallel with cutting its carbon dioxide and nitrogen oxide emissions. Alternative Fuels offer a tested method to help achieve both objectives. With energy normally accounting for 30-40 percent of the operating costs of cement manufacturing, any cost-saving opportunity can provide a competitive edge over cement plants using only conventional fuels (Mokrzycki and Uliasz-Bochenczyk, 2003). Substitution rates vary from one country to another, and from one plant to another.

Some cement plants have replaced up to 100 percent of their main fuel stream (petcoke and fossil fuels) with alternative fuels. Across the majority of cement conglomerates, an average rate of 10 to 30 percent substitution can be found. The wide variation in alternative fuel usage rates often rests on the type of cement technologies employed, the kiln system used, and the availability of alternative fuels with compatible chemical and physical characteristics.

There are many success stories. Since 1990, the Holcim Group has increased its energy consumption by only 45 percent since 1990, while boosting its cement production by 120 percent. Since the group uses AFR, their expansion rests on a mere 25 percent from traditional fuel sources.

The Cemex-operated Clinchfield Cement Plant in Georgia, U.S.A, has achieved a fuel substitution rate of 78 percent by burning nearly 90,000 tons of biomass, including peanut shells and wood sawdust, in addition to tire fibres and whole tires. As of September 2013, the factory averaged a monthly substitution rate of a little over 93 percent, with 100 percent reliance on alternative fuels for periods of 24 hours.

Although EU average AFR use is nearly 39 percent, some cement plants have reached much higher rates. Examples are two cement plants in Germany owned by Holcim: Rüdersdorf and Beckum. Both use AFR, and in 2011 had TSR rates of 73.8 and 77.5 percent respectively, which meant that around **three-quarters** of their natural resources (coal and lignite) could be saved. For both plants, this represented 260,000 million tons of coal or 194 railway trains.

Another cement plant ENCI, owned by Heidelberg in The Netherlands, reached a TSR of 85 percent in 2013. Such success was an outcome of landfilling fees and strict enforcement of laws on uncontrolled landfilling (Cemex Germany, 2013; Heidelberg SD report, 2014).

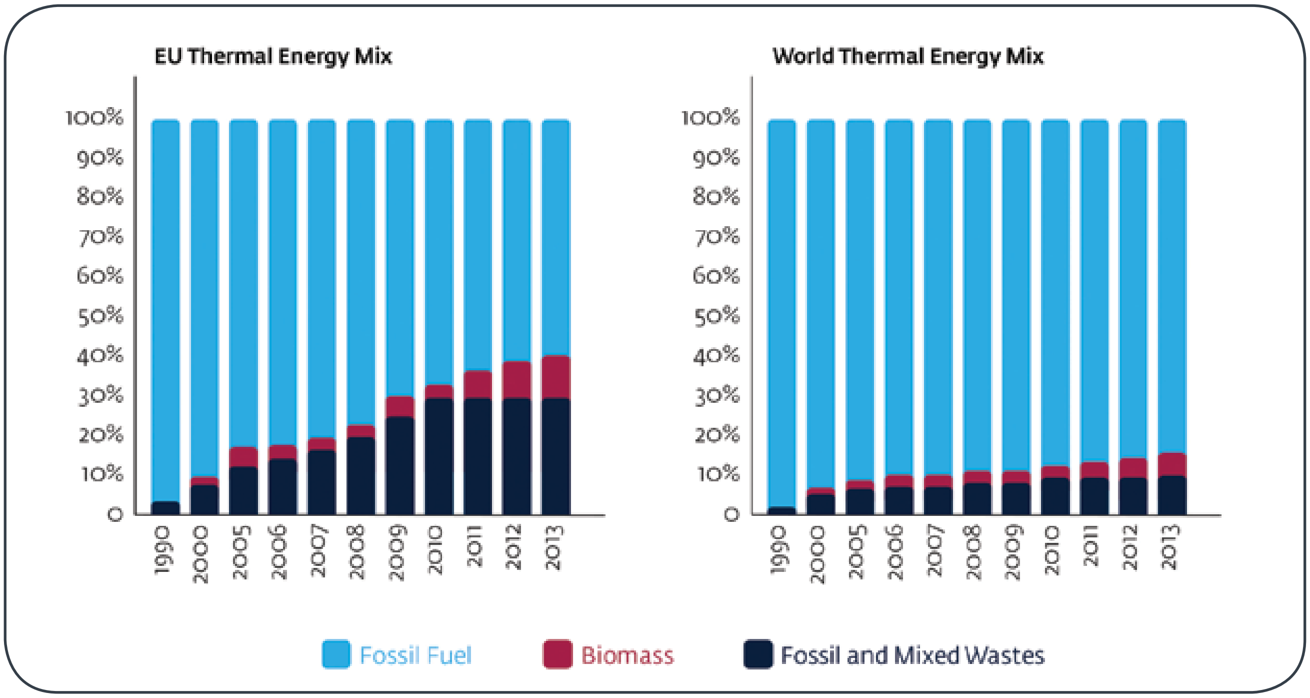


Figure 7: Average Thermal Fuel Mix in Cement Plants at the European Union and Worldwide[7]

(Source: WBCSD-CSI, 2013a)

3.2 Co-Processing Technical Considerations

It will be imperative to consider the criteria for physical and chemical properties which the cement industry applies in the selection of the various fuel types used in thermal processes and the technical impacts of co-processing. Any adjustment in fuel type used by a cement plant has an ultimate impact on the efficiency of the process and the characteristics and quality of the end product.

When co-processing using AFRs, which can fluctuate in terms of quality, volume, chemical and physical characteristics, plant operators must carefully select types of AFR and their respective suppliers. Cement plant operators would want to ensure that suppliers are able to provide a consistent product in terms of quality and physical characteristics. When a variation in the ash content occurs during the clinker production process, the plant operator must adjust the composition of the raw materials, since variations in ash content affect the clinker quality and the ultimate integrity of the cement product.

Generally, when large amounts of alternative fuels are used, the production process and the materials have to be monitored carefully (Wirthwein and Emberger, 2010). Physical parameters that affect the substitution levels of conventional fuels for AFR include the calorific value, the volatility and the burnability of the fuel, and its relative moisture content. Furthermore, any impact on the flame shape, as well as on the calciner, are crucial considerations in the decision.

The best replacement rates are achieved through the use of waste oils with higher ash content compared to HFO, waste solvent fuels and petcoke, all of which have a low ash content and very good calorific value. The EU Integrated Pollution Prevention and Control (IPPC) Directive [8] suggests limits to the thermal replacement of conventional fuels by waste solvent fuels of 40 percent of the total fuel used, whereas used oils and petcoke can replace any

7 Data cover about 96 percent of the cement plants in the EU28 and 21 percent worldwide.

8 The European IPPC Bureau was founded to organize the necessary exchange of information, and produces Best Available Techniques (BAT) and reference documents (BREF) which member states are required to take into account when determining best available techniques generally or in specific cases. The aim of the IPPC Directive is to prevent and control emissions to air, water and soil from industrial installations across the European Union.

amount of conventional fuels, provided that sufficient quantities are available. Other AFRs commonly in the cement sector globally, and their impact on the clinker properties, are further described in the following sections.

3.2.1 Municipal Solid Waste (MSW)

Municipal solid waste (MSW) is pre-processed and converted to refuse derived fuel (RDF). In addition to the quantity and quality of waste, the physical and chemical properties of RDF determine whether the raw waste will be recycled, converted to energy, or disposed of in a landfill. Relative density, humidity and heat content differ in accordance with the source of waste. RDF is a mixture of fuel materials with low volatility and with some of the constituents of low burnability, which results in lower replacement rates. However, if RDF is used at high temperatures with a sufficient flow of oxygen, or at the bottom of the calciner, then substitution rates of up to 30 percent are achievable. It is essential in such cases to have a fuel with two dimensions and high surface area (pellets are not recommended). Typical sample ranges are given in Table 4.

Fuel	Energy Content (GJ/dry ton)	Water Content (%)	Ash Content (%)	ΔCO_2 [a,b] (ton/ton coal replaced)	Data Sources
MSW	12-16	10-35	N/A	-0.4	European Commission, 2003; IPCC, 2006; NREA, 2014
RDF (density 350 kg/m3)	12.8 – 16	5 - 7.5	N/A		

a Change in CO_2 is calculated assuming average LHV when no range is given.
b Negative values for change in CO2 represent a net reduction in emissions; positive values represent a net addition of CO2 emissions.

Table 4: Sample Ranges for the Physical and Chemical Properties of MSW and RDF

3.2.2 Agricultural Waste

The same replacement rates as for the above RDF case can be achieved through the feeding of biomass such as straw and other agricultural by-products if used under the same conditions as for RDF. The main physical and chemical properties of agricultural wastes include ash content, humidity and heat content, where typical sample ranges are provided, as shown in Table 5.

Fuel	Energy Content (GJ/dry ton)[a]	Water Content (%)	Ash Content (%)	ΔCO_2 [b] (ton/ton coal replaced)	Data Sources
Tree Trimmings	16.4	< 16	3.8	-2.5	US DoE, 2014
Cotton Stalks	18.1	< 16	3.1	-2.5	
Corn Stalks	9.2 - 15.4	< 16	7.5	-2.5	
Rice Straw	13.2 – 16.2	< 16	15.9	-2.5	
Sugar Cane Leaves	15.8[a]	<15	7.7	-2.5	Jorapur and Rajvanshi, 1997
Bagasse	14.4; 19.4	10-15	4.2	-2.5	Li et al., 2001; Asian Development Bank, 2006

a Lower heating value (LHV) calculated based on reported higher heating value (HHV)
b A change in CO2 emissions assumes that biomass is carbon-neutral; negative values for changes in CO2 represent a net reduction in emissions

Table 5: Sample Ranges for the Physical and Chemical Properties of Agricultural Waste

3.2.3 Dried Sewage Sludge (DSS)

Despite a low calorific value, DSS has high volatility and burnability and can contribute to the replacement of conventional fuels at rates of up to 30 - 40 percent.

The range in calorific values of sewage sludge varies considerably and depends on the characteristics of the wastewater it is derived from, as well as the treatment method used . The calorific value range, water content, and moisture content are provided in Table 6.

Fuel	Energy Content (GJ/dry ton)[a]	Water Content (%)	Ash Content (%)	ΔCO_2[b] (ton/ton coal replaced)	Data Sources
Dewatered Sewage Sludge	10.5-29	75	21.8	-2.5	Fytili and Zabaniotou, 2006; IPCC, 2006; Murray et al., 2008
Dried Sewage Sludge	10.5-29	20	N/A	-2.5	

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

Table 6: Sample Ranges for the Physical and Chemical Properties of Sewage Sludge

3.2.4 Tire Derived Fuel (TDF)

TDF can only be fired at the kiln system entry point, and can lead to replacement levels of up to 30 percent through a valorization processing. The following tables provide general properties of car and truck tires, average weight, and energy content.

Material	Cars (%)	Trucks (%)
Rubber/Elastomers	45	42
Carbon Black/Silica	23	24
Metal	16	25
Sulphur	1	1
Zinc Oxide	1	2
Textile	6	

Table 7: General Material Composition of Tires *(Source: ETRMA, 2001)*

Type of Tire	Average Weight (kg)	Unit per Ton
Passenger car	6.5-10	154
Utility (including 4x4)	11	91
Truck	52.5	19

Table 8: Average Tire Weight *(Source: Basel Convention, 2011)*

Fuel	Energy (GJ/t)	Emissions (kg CO2/t)	Emissions (kg CO2/ GJ)
Tires*	25-35**	2,720	85
Diesel oil	46	3,220	70
Natural gas	39	1,989	51
Petcoke	32.4	3,240	100

* The ton CO_2 reduced by 1 ton of coal replaced by waste tires is -0.8 (tCO2/ton coal replaced)
** The calorific value of tires depends on several factors, including the origin of the tire (car or truck) and if the metal component is withdrawn.

Table 9: Tires Energy Content and CO_2 Emission Factor in Comparison to Selected Fossil Fuels *(Source: WBCSD, 2005)*

3.2.5 Other Technical Considerations

In order to achieve positive results with AFR substitution, the cement industry must be aware of possible variations in the moisture content of the AFR, any flame shape change, and any calciner rise in carbon monoxide, which would result in a loss of kiln production efficiency. When co-processing, operators should use an analyzing system at the kiln entry point which can continuously monitor the oxygen and carbon monoxide levels, in order to prevent any loss in kiln efficiency.

Aside from technical considerations and the impact on the cement product and production process, the cement industry should satisfy all legislative environmental requirements as set forth in the permit granted by government authorities. The main parameters that typically need to be monitored are the particulate emissions (dust) as total dust emissions and the content of micro silica and heavy metals in the flue gases. This can be done with special analyzing equipment two or three times a year, both with and without AFR use, to make sure that the emissions fall within the allowable limits. Gases which should be monitored are HCl, HF, NH3, VOCs, PAHs, dioxins/furans, as well as mercury (Hg) and thallium (Tl). The gases can be monitored using special analyzers; Hg and Tl need to be measured with separate analyzing methods.

3.3 AFR Pre-Processing

As described above, the impact of co-processing with AFR, if not managed correctly, can be detrimental to plant equipment, process efficiency, and end-product quality and integrity. Therefore, most AFR cannot be used without some degree of preparation or processing to ensure fuel quality and homogeneity. This preparation process is known as “pre-processing.” Pre-processing encompasses all activities needed to transform waste into an acceptable AFR for cement kiln co-processing. While wastes occur in different forms and qualities, their transformation into AFR produces a homogenous waste product with defined characteristics that complies with the technical specifications of cement production and guarantees that environmental standards are met.

The four targeted waste streams reviewed for the purposes of this study require the following pre-processing activities:

- **Refuse Derived Fuel from Municipal Solid Waste**
  MSW must be sorted in order to separate the recyclables (metals and some unpolluted plastics, glass bottles, dry unpolluted cardboard or paper), the inert materials (sand, stones, earth, glass) and the putrescible materials such as food, typically called “organics.” The light and combustible fraction, typically 20-30 percent, such as wet and polluted paper and cardboard and plastic films, is then shredded to reach the optimal size. The end product becomes RDF. There are technological solutions that allow for easier shredding and sorting of waste. Mechanical sorting and dedicated machinery has been developed to sort by material. Different drying technologies, thermal or biological, are also available.

- **Agricultural Waste**
  Agricultural waste covers a broad range of potential sources. Pre-processing is not always required (seeds, for example, can be directly co-processed), but size reduction by shredding is common. Pelletizing or drying is also often considered, but can be cost prohibitive.

- **Dried Sewage Sludge from Wastewater Treatment Plant (WWTP)**
  Typically, sludge from wastewater treatment plants has a moisture content of between 50-80 percent. Before sludge can be co-processed, it must be dried to below 20 percent water content and homogenized. The end product is called Dried Sewage Sludge (DSS).

- **Tire Derived Fuel from Scrap Tires**
  If no specific co-processing line for whole tires is installed, scrap tires must be shredded into chips (between 50mm and 90mm). The end product is called TDF.

Chapter 4: Unlocking Supply

Egypt generated nearly 90 million tons of solid waste in 2012. Municipal solid waste and agricultural wastes are among the principal types of solid waste generated by volume (Table 10), and when combined constitute 59 percent of total annual waste generated. Sewage sludge and scrap tires are generated at significantly lower quantities. This chapter calculates the potential quantities to be utilized for AFR, after deducting other possible uses. Details for each waste stream are presented in the subsequent sub-sections.

In addition to assessing the quantities of the various waste streams described in this chapter, the study has also provided a visualization of the locations of each waste source, as well as locations of all cement plants throughout Egypt on a GIS platform. It allows the user to compare the distribution of all waste sources discussed in this study, and measure the distances among attributes. The GIS platform can be accessed at: http://arcg.is/1ToAspz

Type of Waste	Generation (million tons/year)	Percentage of Total Waste Generated (%)
Municipal Solid Waste	21 (2012)	23.3
Construction and Demolition Waste	4 (2012)	4.5
Agricultural Waste	30 -35 (2012)	36.1
Industrial Waste	6 (2012)	6.7
Medical Waste	0.3 (2012)	0.3
Sewage Sludge	0.98 (year 2013)*	1.1
Waterways Cleansing Waste	25 (year 2012)	28
Total	**87.3 - 92.4 (89.8 average)**	**100**

Table 10: Volume and Percentage by Type of Waste Generated in Egypt (Source: NSWP, 2013; HCWW, 2014; HCWW, 2016)

4.1 Municipal Solid Waste (MSW)

Egypt generated approximately 21 million tons of MSW in 2012; with an annual increase estimated at 3.4 percent, it is forecast to reach 35 million tons in 2025 (Sweepnet, 2010; Sweepnet, 2014; NSWMP, 2013). Collection, treatment and waste disposal varies among different Egyptian governorates.

4.1.1 MSW Supply in Egypt

It is estimated that only 60 percent of the waste produced in Egypt is actually collected, of which less than 20 percent is recycled or disposed of properly. While public spaces in some municipalities are kept clean, less affluent districts are often neglected. A significant portion of the waste is disposed of in canals, rivers, streets or open areas without any treatment or preventive measures. This open dumping poses harmful threats to public health and negatively impacts the economy, posing down-stream costs higher than proper waste management would have cost from the outset.

In some areas, solid waste management can be the single largest budgetary item for local municipalities (World Bank, 2012). The cost of economic losses from inadequate waste management is between 0.4 and 0.7 percent of GDP (World Bank, 2005). WMRA even estimates that 2.2 billion Egyptian Pounds (around $248 million) are spent annually on waste management. Across the country, there is no primary sorting at household levels, and waste management facilities in Egypt are underdeveloped, inefficient, and require significant rehabilitation.

Within this context, there are three principal systems for MSW collection:

a) municipality or 'cleaning and beautification' authorities for Cairo and Giza hold the main responsibility for collecting, treating, and disposing of MSW in Egypt. Different management systems are, however, employed throughout the country;

b) local contractors and informal waste collectors, who manage MSW collection in metropolitan cities, such as Cairo, Giza and Alexandria. In Cairo, for instance, the *Zabaleen* collect up to an estimated 60 percent of the city's waste, and by their account, recycle nearly 80 percent of this figure. Over time, the *Zabaleen* have created one of the world's most efficient and sustainable resource-recovery and waste recycling systems (Fahmi and Sutton, 2010);

c) private multinational companies collect the waste, clean the streets and transport the waste to composting facilities and sanitary landfills under the supervision of municipalities.[9]

The average collection rate is estimated to be 30-95 percent in urban areas and 0-25 percent in rural areas (World Bank, 2005). WMRA calculates an aggregate of 80.4 percent for urban centers and around 50 percent for rural areas (Mohsen, 2016). The national average MSW collection rate is 59 percent, equivalent to approximately 12.4 million tons annually (NSWMP, 2013).

Figure 8 and Table 11 below illustrate the distribution of waste generated and collected throughout Egypt. Furthermore, the GIS platform displays the geographic distribution of MSW along with other waste sources in Egypt as illustrated at: http://arcg.is/1ToAspz

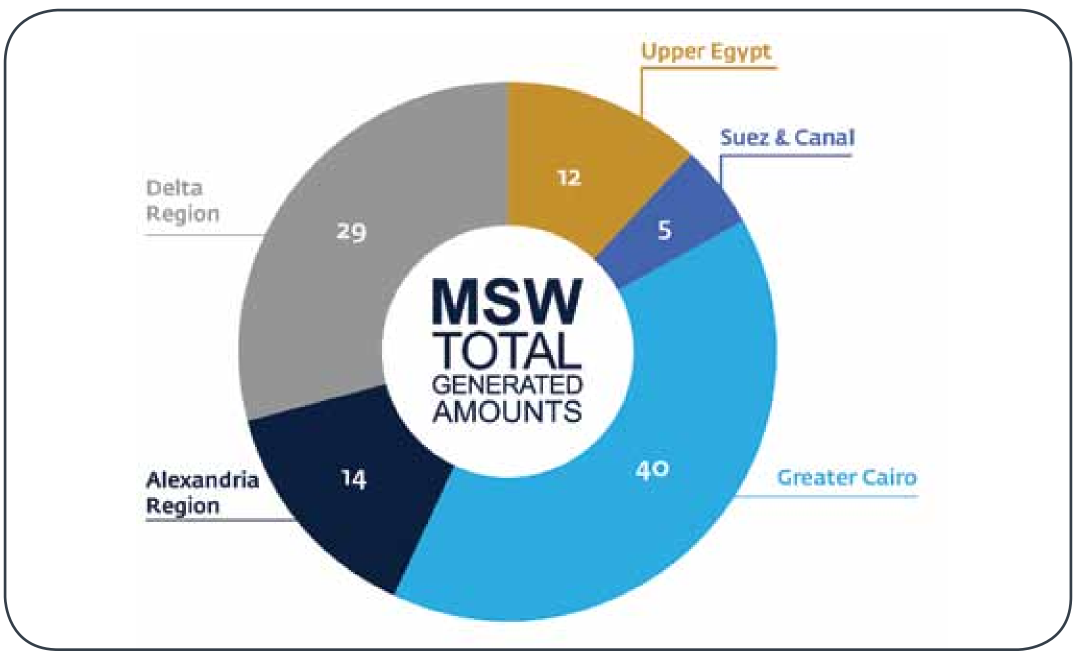


Figure 8: Total Generated MSW Amounts per Region by Percentage

(Source: Sweepnet, 2014)

9 See Zayani and Riad, 2010 for more information.

Governorate	Generated Waste		Collection Efficiency	Actual Collected Waste		Estimated Population
	(tons/day)	(tons/year)	%	(tons/day)	(tons/year)	2012
• Alexandria	4,000	1,460,000	65	2,600	949,000	4,564,979
• Gharbia	3,500	1,277,500	47	1,645	600,425	4,491,977
• Beheira	3,500	1,277,500	50	1,750	638,750	5,415,375
• Kafr El-Sheikh	2,500	912,500	50	1,250	456,250	2,979,258
• Matrouh	300	109,500	60	180	65,700	399,107
• Cairo	15,000	5,475,000	70	10,500	3,832,500	8,825,725
• Giza	4,500	1,642,500	60	2,700	985,500	7,104,805
• Qalyubia	3,500	1,277,500	60	2,100	766,500	4,811,673
• Dakahlia	4,500	1,642,500	50	2,250	821,250	5,623,639
• Monufia	2,500	912,500	40	1,000	365,000	3,706,194
• Sharqia	2,200	803,000	45	990	361,350	6,091,249
• Damietta	1,100	401,500	55	605	220,825	1,254,971
• Ismailia	600	219,000	60	360	131,400	1,096,956
• Port Said	650	237,250	70	455	166,075	633,905
• Suez	400	146,000	70	280	102,200	584,145
• Red Sea	450	164,250	60	270	98,550	324,553
• North Sinai	250	91,250	60	150	54,750	402,705
• South Sinai	500	182,500	80	400	146,000	160,645
• Fayoum	720	262,800	65	468	170,820	2,930,084
• Beni Suef	800	292,000	62	496	181,040	2,646,876
• Minya	1,300	474,500	55	715	260,975	4,792,638
• Assiut	700	255,500	65	455	166,075	3,953,263
• Sohag	1,100	401,500	60	660	240,900	4,283,902
• Qena	1,050	383,250	62	648	236,520	2,840,318
• Luxor	470	171,550	75	353	128,845	1,079,337
• Aswan	800	292,000	70	560	204,400	1,340,279
• New Valley	100	36,500	60	60	21,900	211,419
Total Egypt	**56,990**	**20,801,350**	**59**	**33,900**	**12,373,500**	**82,549,977**

• Greater Cairo Governorates • Alexandria Region Governorates • Delta Region Governorates
• Suez & Canal Governorates • Upper Egypt Governorates

Table 11: Total Annual MSW Generation and Collection Rates in 2012

(Source: NSWMP, 2013)

For the purposes of this analysis, RDF[10] is calculated as the processed solid, high calorific value fraction remaining after the recovery of recyclable elements of MSW. Therefore, RDF would typically constitute between 10 to 25 percent of the MSW. The processing of MSW usually takes place in sorting and composting plants located near the source of generation or central collection stations or disposal/landfill

10 There is no legal definition of the term 'Refuse Derived Fuel (RDF)' and it is interpreted differently across countries. Several countries have introduced quality standards and/or certification labels for RDF to specify product quality requirements (it is sometimes referred to as Solid Recovered Fuel (SRF) to distinguish it from RDF). European Commission, Directorate General Environment (2004, July), Refuse Derived Fuel, Current Practice And Perspectives, Report No.: CO 5087-4. Retrieved from http://ec.europa.eu/environment/waste/studies/pdf/rdf.pdf

sites. The final product, RDF, is traded and burnt in installations for power generation or in a manufacturing process where heat is required, as it is with cement production. Excluding recyclables prevents any disruption in the activities of informal sector recyclers, the Zabaleen, and reinforces respect for the principles and rankings of the waste management hierarchy.

Since the organic content of MSW is about 56 percent and the recyclables are about 29 percent, a conservative estimate for available RDF would be around 15 percent (Figure 9 and Table 12). This 15 percent may contain inert materials that are not suitable for RDF and therefore the usable component could be as low as 10 percent. On the other hand, since MSW in Egypt is not yet separated at the source, the contamination level of recyclables is high and could be rejected as feedstock for recycled product manufacturing. This could increase the “other” waste component to 25 percent. Therefore, the lower and upper limits of “other” waste could range between 10 and 25 percent.

It is also worth noting that these calculations presume that the organic component of MSW will be used for composting, yet it is theoretically possible that a percentage of such organic waste can be biologically dried and later used for co-processing purposes by a cement kiln. In the latter scenario, RDF volumes may be significantly higher.

The potential RDF quantities will be calculated based upon two approaches, (i) the design capacities of existing sorting and composting plants, and (ii) total MSW generated in Egypt.

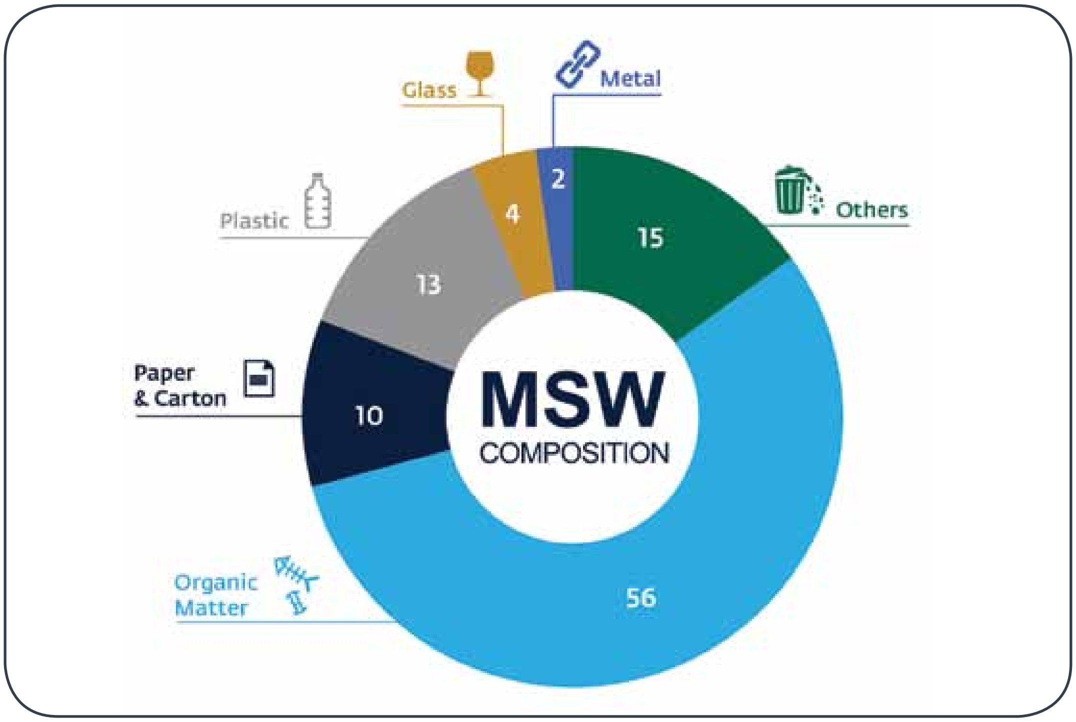


Figure 9: MSW Composition in Egypt by Percentage

(Source: Sweepnet, 2014)

i) <u>Existing Design Capacities of Sorting and Composting Plants</u>

The sorting and composting plants were selected as a good location for MSW access since they are mostly concentrated in the major urban centers in proximity as well to landfills/disposal sites. These plants have already sorting equipment installed and are mainly operated by the municipalities. RDF pre-processing could take place in these plants, along with composting of organic matter to produce soil fertilizer and screening of recyclables for sale.

Figure 10 below illustrates the location of these composting plants in relation to the cement plant locations, which can also be accessed through the GIS platform at: http://arcg.is/1ToAspz

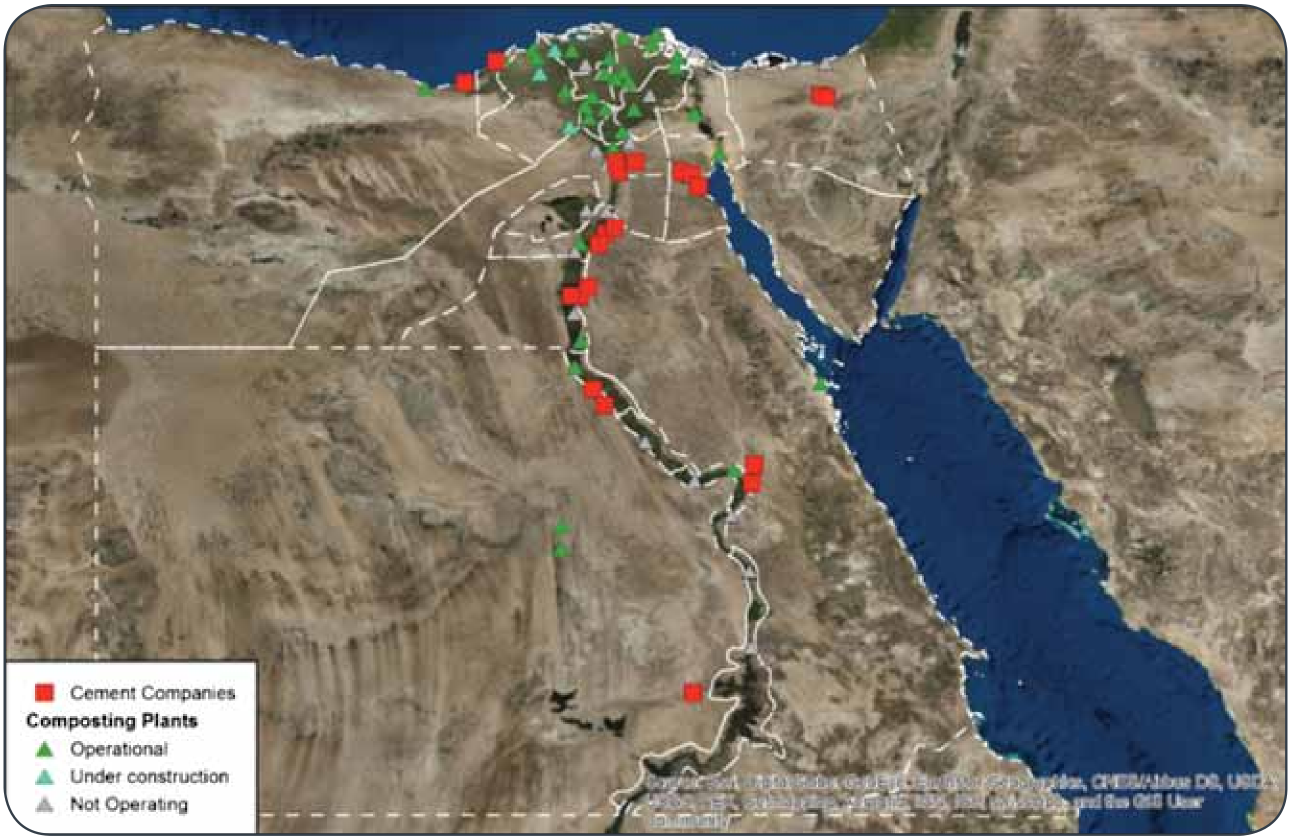


Figure 10: Locations of Sorting and Composting Plants and Cement Factories in Egypt

Currently, there are 64 sorting and composting plants throughout Egypt, of which 46 are operational, with a total design capacity for treating approximately 3.2 million tons annually, equivalent to 24 percent of total collected MSW. The average efficiency of these existing MSW treatment facilities is nearly 70 percent, sorting and treating about 2.2 million tons, or 18 percent of the total amounts of MSW collected (MoURIS, 2015). Such a discrepancy in figures clearly indicates that much more can be done to improve the efficiency of these facilities. Table 12 presents the amounts of MSW treated in the sorting and composting facilities, taking into account the three potential scenarios for RDF production of 10 percent, 15 percent, and 25 percent of generated MSW. As previously stated, typical RDF content of MSW in other countries is usually in the range of 20-30 percent, while in Egypt the most likely scenario is that RDF represents about 15 percent of MSW content.

At the current 59 percent average collection rate, only 1.2 to 3 million tons of MSW per year could actually be processed. However, due to the low MSW treatment facility efficiency, only 18 percent of the collected MSW is actually processed at the 46 sorting and composting facilities nationwide; this means that there is a potential RDF supply of between 220,000 and 560,000 tons/year. This potential could reach a maximum value of approximately 800,000 tons/year if the operational efficiency of sorting and composting facilities were increased to full capacity (Table 13).

Governorate	Operational Sorting and Composting Facilities	Total Capacity (tons/hour)	Design Capacity (tons/year)	Actual Waste Treated (tons/year)	RDF Production (as a proportion of MSW)		
					10% tons/year	15% tons/year	25% tons/year
Alexandria	3	30	153,300	107,310	10,731	16,097	26,828
Gharbia	1	10	51,100	35,770	3,577	5,366	8,943
Beheira	4	45	229,950	160,965	16,097	24,145	40,241
Kafr El-Sheikh	3	35	178,850	125,195	12,520	18,779	31,299
Matrouh	1	10	51,100	35,770	3,577	5,366	8,943
Cairo	6	151	771,610	540,127	54,013	81,019	135,032
Giza	3	40	204,400	143,080	14,308	21,462	35,770
Qalyubia	1	15	76,650	53,655	5,366	8,048	13,414
Dakahlia	4	55	281,050	196,735	19,674	29,510	49,184
Monufia	3	40	204,400	143,080	14,308	21,462	35,770
Sharqia	2	40	204,400	143,080	14,308	21,462	35,770
Damietta	3	35	178,850	125,195	12,520	18,779	31,299
Ismailia	0	-	0	0	0	0	0
Port Said	0	-	0	0	0	0	0
Suez	1	10	51,100	35,770	3,577	5,366	8,943
Red Sea	0	-	0	0	0	0	0
North Sinai	0	-	0	0	0	0	0
South Sinai	0	-	0	0	0	0	0
Fayoum	0	-	0	0	0	0	0
Beni Suef	2	20	102,200	71,540	7,154	10,731	17,885
Minya	3	30	153,300	107,310	10,731	16,097	26,828
Assiut	0	-	0	0	0	0	0
Sohag	1	10	511,000	35,770	3,577	5,366	8,943
Qena	2	20	102,200	71,540	7,154	10,731	17,885
Luxor	1	10	51,100	35,770	3,577	5,366	8,943
Aswan	1	10	51,100	35,770	3,577	5,366	8,943
New Valley	1	10	51,100	35,770	3,577	5,366	8,943
Total Egypt	**46**	**626**	**3,198,860**	**2,239,202**	**223,920**	**335,880**	**559,801**

● Greater Cairo Governorates ● Alexandria Region Governorates ● Delta Region Governorates
● Suez & Canal Governorates ● Upper Egypt Governorates

Table 12: Quantities of RDF Generated at Sorting and Composting Plants Based on 70% Average Efficiency

(Source: MoURIS, 2015)

Governorate	Operational Sorting & Composting Facilities	Total Capacity (tons/year)	RDF Production (as a proportion of MSW)		
			10% tons/year	15% tons/year	25% tons/year
● Alexandria	3	153,300	15,330	22,995	38,325
● Gharbia	1	51,100	5,110	7,665	12,775
● Beheira	4	229,950	22,995	34,493	57,488
● Kafr El-Sheikh	3	178,850	17,885	26,828	44,713
● Matrouh	1	51,100	5,110	7,665	12,775
● Cairo	6	771,610	77,161	115,742	192,903
● Giza	3	204,400	20,440	30,660	51,100
● Qalyubia	1	76,650	7,665	11,498	19,163
● Dakahlia	4	281,050	28,105	42,158	70,263
● Monufia	3	204,400	20,440	30,660	51,100
● Sharqia	2	204,400	20,440	30,660	51,100
● Damietta	3	178,850	17,885	26,828	44,713
● Ismailia	0	0	0	0	0
● Port Said	0	0	0	0	0
● Suez	1	51,100	5,110	7,665	12,775
● Red Sea	0	0	0	0	0
● North Sinai	0	0	0	0	0
● South Sinai	0	0	0	0	0
● Fayoum	0	0	0	0	0
● Beni Suef	2	102,200	10,220	15,330	25,550
● Minya	3	153,300	15,330	22,995	38,325
● Assiut	0	0	0	0	0
● Sohag	1	51,100	5,110	7,665	12,775
● Qena	2	102,200	10,220	15,330	25,550
● Luxor	1	51,100	5,110	7,665	12,775
● Aswan	1	51,100	5,110	7,665	12,775
● New Valley	1	51,100	5,110	7,665	12,775
Total Egypt	**46**	**3,198,860**	**319,886**	**479,829**	**799,715**

● Greater Cairo Governorates ● Alexandria Region Governorates ● Delta Region Governorates
● Suez & Canal Governorates ● Upper Egypt Governorates

Table 13: Quantities of RDF Generated at Design Capacities of Sorting and Composting Plants

(Source: MoURIS, 2015)

ii) Total MSW Generated in Egypt

If the full technical potential is unlocked through 100 percent MSW collection rate and improved treatment efficiency, then the total potential of RDF supply in Egypt would range from 2 to 5 million tons annually. This estimate is based on an assumption that 10 percent and 25 percent of total MSW would be convertible to RDF respectively.

Potential RDF yields, with optimized collection and processing efficiency, are summarized below:

	Current Case	Optimized Case	Best Case
Collection Rates	59%	59%	100%
Composting Facility Efficiency	70%	100%	100%
Tons per Year	224-560 thousand	320-800 thousand	2-5 million

Based on the distribution of waste collected from the various governorates throughout Egypt, the Delta, Greater Cairo and Alexandria present the greatest opportunity for MSW recovery and conversion to RDF in an efficient and least logistically challenging manner. Combined, they represent 83 percent of total generated MSW. The amounts generated in other regions are limited, and pose logistical challenges in collection. Figure 11 and Table 14 below illustrate the distribution of waste generated in these three regions. The potential RDF from Greater Cairo, Alexandria and the Delta, at 15 percent MSW to RDF conversion rate, is estimated at approximately 7,065 tons per day (Figure 12), which is equivalent to 2.5 million tons annually. The average range for RDF production for the three regions is between 1.7 to 4.2 million tons annually.

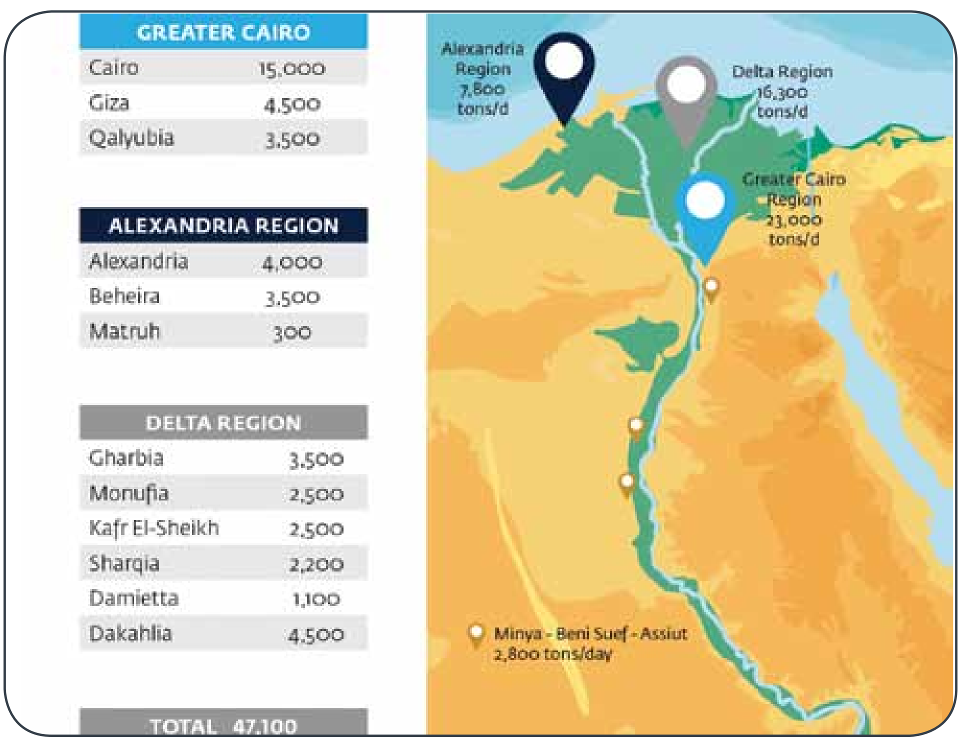


Figure 11: Municipal Solid Waste Generation by Region in 2012 (tons per day)

	Organic Waste	Paper & Cardboard	Metal	Plastic	Glass	Other Kinds of Waste [Potential RDF]	TOTAL TONS/DAY
	56%	10%	2%	13%	4%	15%	
Greater Cairo	12,880	2,300	460	2,990	920	3,450	23,000
Alexandria Region	4,368	780	156	1,014	312	1,170	7,800
Delta Region	9,128	1,630	326	2,119	652	2,445	16,300
Total in Tons	26,376	4,710	942	6,123	1,884	7,065	

Table 14: Amounts of Potential RDF Based on Waste Composition by Region in 2012 (tons per day)

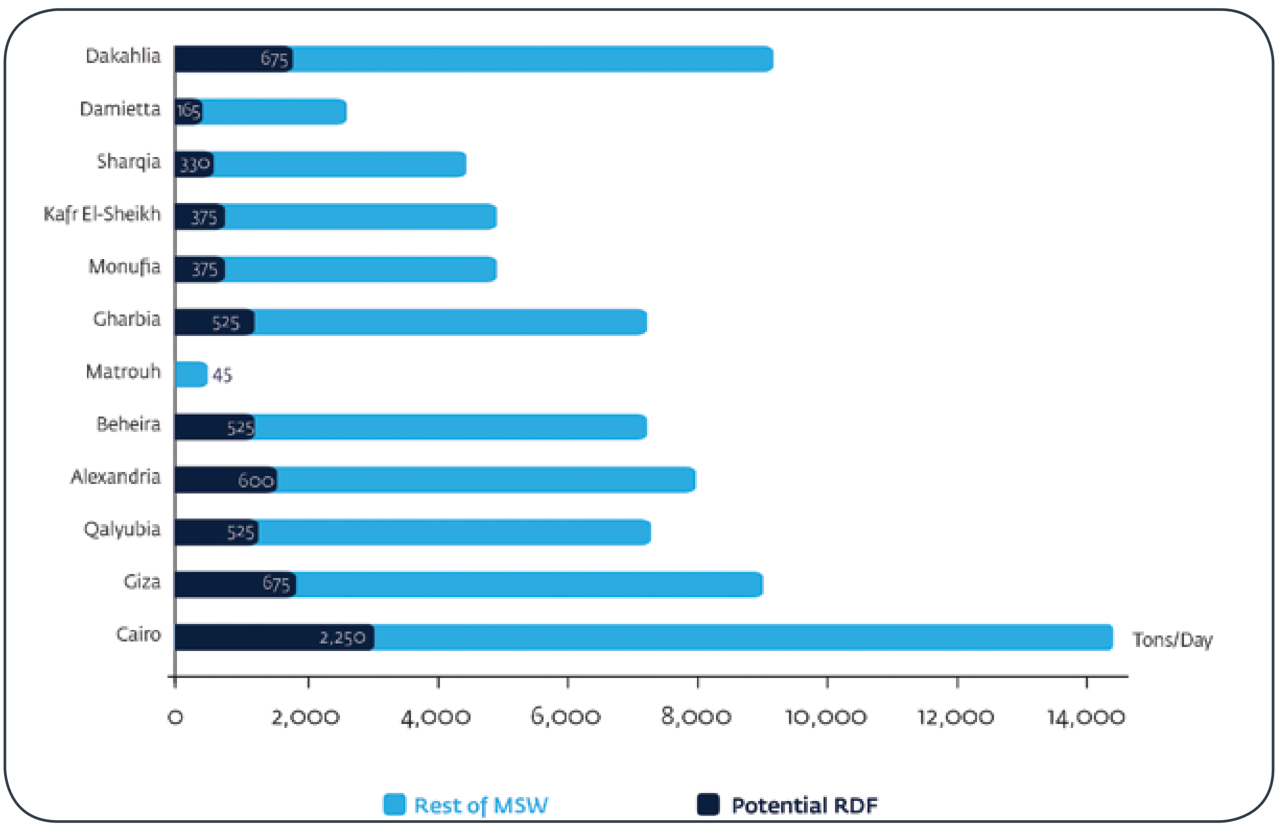


Figure 12: Amounts of Potential RDF in Greater Cairo, Alexandria and Delta Regions from Total MSW Generated (tons per day)

4.1.2 Challenges in Using MSW for AFR

The greatest challenges to the potential RDF supply in Egypt are presented below. Recommendations for addressing most of these challenges are discussed in Chapter 7.

- **Illegal dumping:** The ban on unauthorized landfills must be implemented and hefty fines imposed on the offenders, enforcing the "Polluter Pays" principal.
- **Underdeveloped and inefficient waste management facilities**: Existing facilities are currently treating about 10 percent of the generated MSW. A number of composting plants were shut down before ever beginning operations as a consequence of mismanagement, inappropriate technology selection, frequent mechanical breakdowns and poor maintenance (Elnaas et al., 2014). Most are in need of rehabilitation, and improved operation and maintenance systems.
- **Lack of a national consensus on a MSW strategy:** This includes overlapping and inefficient roles and responsibilities at the central government, governorate, and municipality levels. It is critical to address the lack of enforcement of the existing MSW framework. Primary waste sorting at the household level and promotion of MSW efficiency are also vital. The establishment of WMRA may help in changing this picture.

4.2 Agricultural Waste

Approximately 30-35 million tons in 2012 of different types of agricultural residues were generated throughout Egypt (NSWMP, 2013). Approximately seven to nine million tons, mainly residues from wheat, were used as animal feed. Another four to seven million tons were used as organic fertilizers and around two to four million tons were used by farmers for other purposes (MWRI, 2005; El Essawy, 2014). Approximately 12 to 15 million tons/year of agricultural waste is unused, disposed of, or burned (El Essawy, 2014). This presents enormous untapped potential.

4.2.1 Agricultural Waste Supply in Egypt

Burning unused agricultural waste in open fields, especially rice straw, is a common practice among Egyptian farmers, contributing to the seasonal "Black Cloud" phenomenon. Despite the efforts of the Ministry of Environment to discourage this practice, it remains the most convenient way to dispose of waste, given the high cost of collection, storage and transportation. However, there have been some important efforts to collect and process rice straw residues in order to reduce its negative impacts. The EEAA and the Ministry of Agriculture collected and handled 365,274 tons in 2011 (EEAA, 2012).

In Egypt, wheat and barley residues as well as rice husk are fully used for animal feeding. For the most part, rice straw, cotton waste, sugarcane residues, corn stalks, and tree pruning wastes are not currently of interest to any other consumers. Approximately 10-15 percent of rice straw is used in the production of compost and in other agriculture-related applications, leading to the yearly open burning of 70-80 percent of the remaining waste. The high silica content of new rice varieties (12-15 percent) renders rice straw inedible.

This study selected the following types of crop residues to be considered for AFR: sugar cane, sugar beet, cotton waste, rice straw, corn husk, and tree trimmings from orchards (refer to Annex D for details). According to the primary data collected from the Ministry of Agriculture (Table 15), a total of 21.4 million tons of waste was generated from these crops in 2012. Only about half, or around 10.7 million tons/year, would be available for AFR, because of inefficient collection on the one hand, and alternative uses such as animal fodder on the other. An additional 1.3–4.5 million tons annually are potentially available from other agricultural waste streams (i.e. Casurina, medical and aromatic plants), which were not included in this study.

Geographical Region/ Type of Waste		Sugarcane	Sugar Beet	Cotton	Corn	Rice Straw	Tree Trimmings	Total Agricultural Waste
		tons/year						
Total Northern	Alexandria, Beheira, Gharbia, Kafr el Sheikh, Matrouh, and Nubaria	19,503	704,820	458,993	1,748,470	2,301,775	1,327,160	6,560,721
Total Central	Monufia, Cairo, Dakahlia, Giza, and Qalyubia	28,539	272,790	99,916	1,473,800	1,697,209	472,375	4,044,629
Total Eastern	Damietta, Ismailia, South Sinai, North Sinai, Suez, Port Said, Sharqia, and Red Sea	648	287,369	112,275	1,097,431	1,281,150	767,730	3,546,603
Northern Upper	Fayoum, Beni Suef, and Minya	363,132	273,119	64,467	2,051,809	5,152	249,308	3,006,987
Southern Upper	Assiut, Sohag, Qena, Luxor, New Valley, and Aswan	2,519,856	25,560	14,409	1,393,963	14,414	341,680	4,309,882
Total Waste Generated		2,931,678	1,563,659	750,060	7,765,473	5,299,700	3,158,253	21,468,823
Total Waste Available For AFR		1,465,839	781,830	375,030	3,882,737	2,649,850	1,579,127	10,734,413

Table 15: Estimated Agricultural Residues Generated and Quantities Available as AFR for Selected Crops in year 2012

(Source: MoA, 2014)

There are three growing seasons in Egypt (Figure 13): winter from October/November to May/June, summer from April/May to October, and Nili from July/August to October (FAO, 2016). The summer growing season, which yields maize stover, cotton stalk, sugarcane residues and rice straw, contributes 65-75 percent of total agricultural residues.

The Nili (or autumn) growing season involves maize stover and tree pruning, and contributes 7-8 percent of total agricultural residues. The winter growing season contributes only 18-20 percent of total agricultural waste residue, including wheat straw, vegetable straw and tree trimmings. Trees trimmings contribute 6-10 percent of total agricultural residues and are available all year round.

Agricultural waste in Egypt is, as one would expect, highly concentrated around the Nile and Nile Delta areas, as seen in Figure 14. Table 16 summarizes the most prevalent sources of agricultural waste for use as AFR in Egypt. Further information on the geographic distribution of agricultural activities and potential waste sources can be accessed at: http://arcg.is/1ToAspz

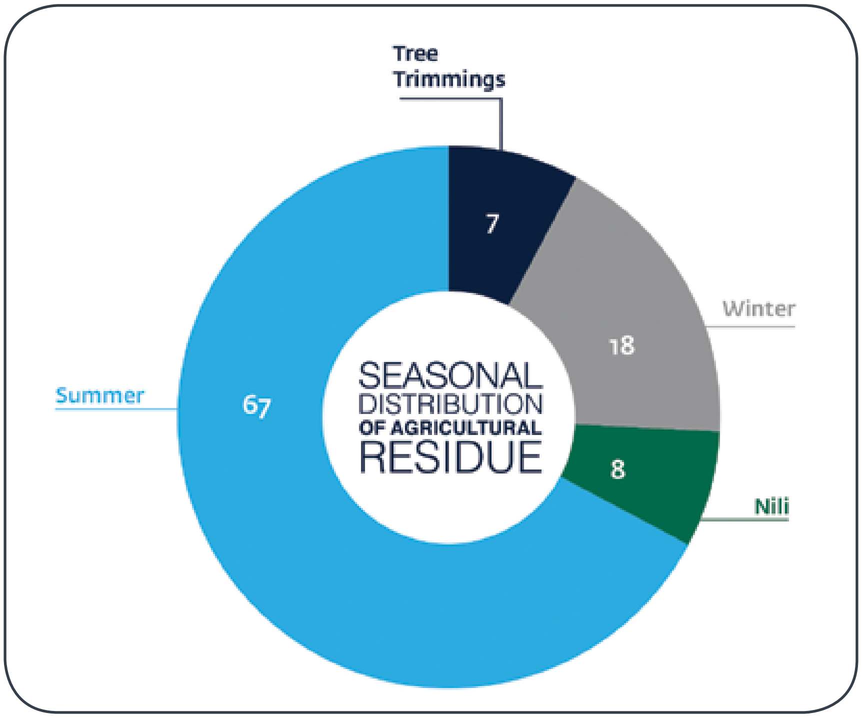


Figure 13: Distribution of Agricultural Residue by Growing Season by Percentage

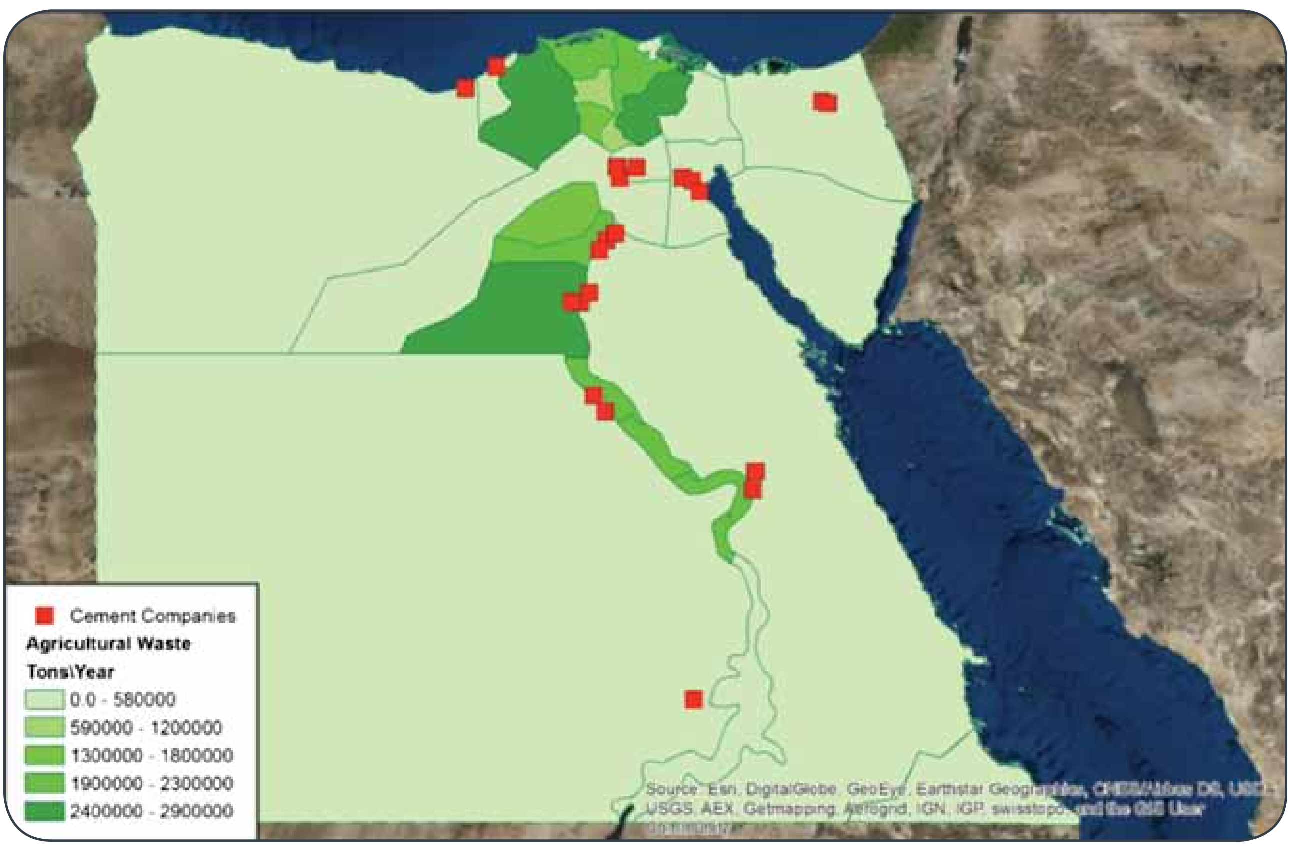


Figure 14: Distribution of Agricultural Areas and Residues Generation in Egypt in Proximity to Cement Plants

Crop	Geographic Concentration	Potential as AFR
Sugar cane leaves	Mainly in Upper Egypt (Hawamdeya)	• High protein component • Seasonal and regional • Collection is difficult • Farmers usually burn leaves • High calorific value **Limited Potential**
Bagasse	Mainly in Upper Egypt (Hawamdeya) and the Delta Region	• Used as fuel in sugar factories, most of which are currently operating on natural gas. Bagasse could be available if cement factories offer to buy it directly from sugar factories or plants. • High calorific value • Expensive prices (firms often ask for price ranges similar to those of HFO) • Generation sources are well-defined. It is easy to collect from sugar companies in a direct manner • Seasonal (needs storage areas) **Potential AFR product**
Cotton	Mainly in Northern and Eastern Regions	• Used by farmers for other purposes • Sporadically cultivated across several governorates **Limited Potential**
Corn	Predominantly found in Upper Egypt (Beni Suef, Minya, Sohag and Assiut)	• Seasonal: collection typically occurs between October and December • Farmers usually burn crop residues • Has a high solid content • Geographically concentrated • Collection and pre-processing systems can be easily installed **Potential AFR product**
Rice Straw	Mainly in Northern, Central, and Eastern Regions	• Some of the generated amounts are used as compost or animal fodder • To encourage rice straw collection, government subsidy schemes exist • Rice Straw has a high silica component. In this case, some training will be needed for the cement plants to use that waste.[1] However, It is essential to maintain the rice husk feeding at stable and accurate rates. Sustainable and continuous delivery is critical. **Potential AFR product**
Tree Trimmings	Available in Northern and Eastern Regions	• Available all year • Has no geographic concentration (available in all governorates) • Easily shredded and prepared for cement factories • Easy to handle, store and transport after shredding • High calorific value • Has no other competitive uses **Potential AFR Product (It represents the currently most used agricultural waste stream)**

1 Unless limestone quality is very poor, all plants can use this AFR with an LSF (Lime Saturation Factor) correction for the raw meal.

Table 16: AFR Potential By Crop Waste Type

4.2.2 Challenges in Using Agricultural Waste as AFR

Despite its availability in significant quantities, the supply of agricultural waste as AFR is challenging due to the following constraints:

- Agricultural residues are usually burned in open fields.
  - Farmers tend to burn crop waste quickly to remove residues, prepare their limited land area for the next crop, prevent pests and reduce the risk of fire.
  - There are often no feasible alternatives to burning, as paved roads rarely exist for the heavy transportation of raw waste or for balling equipment to reach the fields. Industry demand already exists to process biomass commercially, except for local composting, which represents between 10-15 percent of the waste materials.
  - Regulations and enforcement procedures related to the burning of crop residue are often contradictory, due to the involvement of several government agencies.

- Collection, storage and transportation are expensive.
  - Agricultural land ownership is fragmented, and land tenure is primarily made up of small-hold farmers.
  - The seasonal changes in crop export policies, especially for rice, creates an uncertain situation on the total outputs and the total cultivated land devoted to rice every season, with a minimum of 462,000 - 500,000 hectares per year, in addition to an instability in the cropping areas of corn and sugarcane. Cotton areas are also decreasing.
  - Rice straw has low bulk densities; the bulk density of chopped straw is 50 - 120 kg/m^3, which is very low compared with the bulk densities of coal, which is in the range of 560 - 600 kg/m^3 for brown coal and between 800 and 900 kg/m^3 for bituminous coal. The low densities of the rice straw complicate their processing, transportation, storage and firing. Special attention should be paid to shredding and balling equipment in order to produce high density balls to reduce storage area and transportation cost.

- Interventions by authorities are limited.
  - There is a signed protocol between the Ministry of Environment and the Ministry of Agriculture to combat the Black Cloud phenomenon and convert rice straw to fertilizers and animal fodder. This "Small Farms Project" aims to recycle 100,000 tons of rice straw produced by farmers who own properties of five feddans or less. Of the total, 90,000 tons is converted into fertilizer and 10,000 into animal fodder. Two options are proposed to the farmers in order to stop their burning of rice straw: either pile up the excess straw to be converted into fertilizers or sell it to companies. The government provides a subsidy of EGP 90 for each ton of rice straw the companies collect and press.
  - With this intervention, it has been possible to bail up to one million tons per season for rice straw and transfer the baled straw to the side of the field to reduce the storage area. The companies contracted for the work use a maximum of 25 percent of baled straw for composting, but they do not have the capacity for further processing. Consequently, the leftover rice straw that should have been collected and recycled exceeded government capacities, and authorities announced at the end of August 2014 that they were unable to collect all of it.
  - Many farmers still choose to burn their rice straw, as they need to clear their land of agricultural waste after the rice harvest. Furthermore, fertilizer projects are not economically viable. Roughly two tons of rice straw are used to produce one ton of fertilizer, at a cost of EGP 300 per ton. Yet every ton of fertilizer is sold for only about EGP 150.

4.3 Sewage Sludge

There are 357 municipal wastewater treatment plants under the supervision of the Egyptian National Holding Company of Water and Wastewater (HCWW) throughout Egypt's 25 governorates. The waste water treatment plants (WWTPs) had a total installed capacity of 13,266,159 m^3/day as of 2013. The estimated total annual national sewage sludge generation in Egypt was approximately 1 million tons in 2014. Table 17 describes in detail the quantities of sewage sludge per region.

4.3.1 Sewage Sludge Supply in Egypt

Cairo, Giza and Alexandria governorates produce the largest quantities of sludge, as compared to all other governorates. Together, they generate over 50 percent of the total amount of sludge (Figure 15). Upper Egypt produces the least sludge, mainly due to lower availability of wastewater services, and thus low treatment capacities.

Sludge generation is expected to continuously grow along with Egypt's growing population and anticipated investments in new wastewater treatment facilities. But there are shortcomings in the data available. While there are WWTPs located within new urban cities and huge industrial factories, limited information about sludge generation is available.

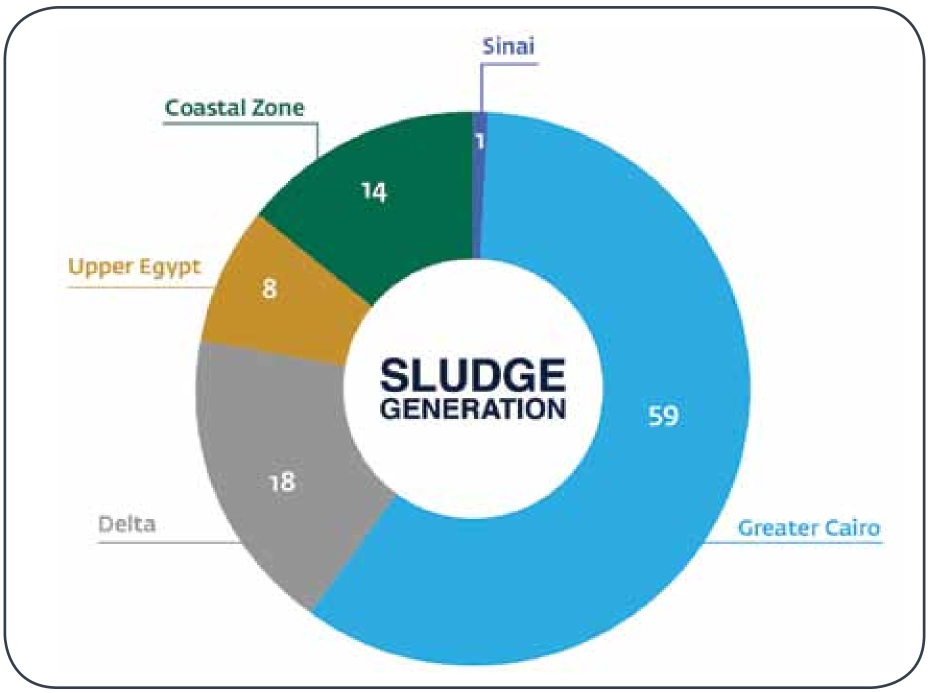


Figure 15: Sewage Sludge Generation by Region in 2013 in Egypt by Percentage

(Source: HCWW, 2014)

Governorate	Design Capacity (m^3/day)	Actual Capacity (m^3/day)	Produced Sludge (tons/day)	Produced Sludge (tons/year)
● Alexandria	1,436,880	1,240,680	497	181,306
● Gharbia	504,200	384,100	100	36,533
● Kafr El-Sheikh	277,700	173,300	46	16,827
● Beheira	440,500	290,400	73	26,536
● Matrouh	25,000	22,000	0	-
Total Northern	**2,684,280**	**2,110,480**	**716**	**261,201**
● Dakahlia	540,000	454,800	117	42,577
● Monufia	351,500	274,500	56	20,477
● Giza	1,740,000	1,485,000	543	198,341
● Cairo	4,758,000	4,097,000	867	316,382
● Qalyubia	246,500	197,500	49	17,976
Total Central	**7,636,000**	**6,508,800**	**1,632**	**595,753**
● Damietta	309,300	233,900	54	19,863
● Ismailia	247,000	175,000	13	4,563
● Suez	190,000	190,000	0	-
● Port Said	235,000	166,000	8	2,818
● Sinai	144,500	84,100	2	621
● Sharqia	395,100	289,250	76	27,594
● Red Sea	18,000	13,000	0	-
Total Eastern	**1,538,900**	**1,151,250**	**152**	**55,458**
● Fayoum	258,879	193,800	47	16,973
● Beni Suef	228,250	152,100	37	13,604
● Minya	189,500	132,000	31	11,388
Total North Upper	**676,629**	**477,900**	**115**	**41,964**
● Assiut	181,000	112,000	21	7,665
● Sohag	275,000	139,500	18	6,424
● Qena	72,000	76,800	12	4,234
● Luxor	56,000	55,500	7	2,409
Aswan	146,350	146,950	22	7,884
Total South Upper	**730,350**	**530,750**	**78**	**28,616**
Total Egypt	**13,266,159**	**10,779,180**	**2,693**	**982,992**

● Greater Cairo Governorates ● Alexandria Region Governorates ● Delta Region Governorates
● Suez & Canal Governorates ● Upper Egypt Governorates

Table 17: Sewage Sludge Production By Governorate in 2013 in Egypt

(Source: HCWW, 2014)

4.3.2 Challenges in Using Sewage Sludge

In terms of sourcing, the quantities of sewage sludge are constant and sizeable. But the biggest challenge to using sewage sludge as AFR is the drying process. Typically, the sewage sludge treatment process in Egypt includes pumping the primary and secondary sewage sludge to thickening facilities, where the material will be concentrated to 4-6 percent dry solids (DS) (Ghazy et. Al, 2009). Then the thickened sludge is pumped to natural dewatering units (drying bed facilities) where it is dried to concentrations of 40-60 percent DS. On the drying beds, sludge is placed on a bed layer and then allowed to dry either by water draining through the mass and the supporting sand bed, or by evaporation from the surface. The dewatering time is usually 25 days in summer periods and 40 days during the winter. The sludge is stored for 1.5 to 6 months before use. The dried sludge is mainly used for land application; it is rarely dumped into landfills.

The processed sludge still has high humidity (40-60 percent), and inert contaminants such as sand and gravel, characteristics that are unsuitable for the cement kiln. In order to produce AFR from sludge, it is necessary to identify cost-effective ways of drying the sludge to achieve 15-22 percent humidity. Most WWTPs can achieve this percentage. However, in order to do so, they need to invest in upgrading drying beds. Drying beds can reduce humidity to 30-40 percent, acceptable for agriculture uses.

However, in order to be used for cement kilns, the sludge humidity should be reduced to 10-20 percent. Therefore, additional thermal drying or dewatering processes are needed. These additional drying processes are outside the ordinary scope and budget of the WTTPs' operators, as their mandate is to treat the wastewater. A considerable opportunity for private sector actors would be to set up partnerships charged with drying. Yet, such agreements would also be subject to the availability of land, especially attractive if in close proximity to a cement producing facility.

In addition to moisture concerns, current sewage sludge treatment processes are unable to provide uniform sludge stabilization, which normally would remove key contaminants. Thus, the quality of the sludge produced in most of the WWTPs is below Egyptian and international standards, especially concerning limits on pathogens and other metals and minerals. As such, it is unsafe for agricultural use.[11] By comparison, the use of sewage sludge as AFR in clinker production is one of the most sustainable options for sludge waste management. The high temperature in the kiln will completely destroy the organic content of the sewage sludge and the sludge minerals will be bound in the clinker after the cement calcination process.

The regulatory framework is in place to support dried sewage sludge (DSS) as a thermal fuel in Egypt; therefore, additional regulation is not required. But, as discussed above, implementation of the existing legal framework must be enforced to overcome current illegal disposal and agricultural application practices, which pose an environmental and health challenge.

4.4 Tire Derived Fuel (TDF)

Tire Derived Fuels represent the most valuable AFR source in Egypt and abroad due to their high calorific value. However, in Egypt this is the most challenging source of AFR for reasons of commercial and regulatory barriers. In Egypt, waste tires are classified as hazardous waste under Law 4/1994. As such, their use is subject to strict disposal and/or recycling laws set by the Ministry of State for Environment and the Ministry of Industry and Trade.

Currently, most waste tires recirculate through informal markets. When not retreaded and resold for vehicular use, residual waste tires are partially burned to extract steel wires, and the remaining material is used in the production of intermediate and final products such as briefcase handles, animal-drawn cart wheels and pieces of conveyer belts. This process involves the uncontrolled burning of collected tires in open areas, resulting in negative environmental impacts. At present, only governmental and industrial entities and companies are subject to the hazardous waste law, whereas individuals managing illegal tire recycling activities in the informal sector do not face any legal consequences for openly burning tires to extract steel at the lowest possible cost.

4.4.1 TDF Supply in Egypt

There are three main supply streams for waste tires in Egypt:

- *Used tires disposed of at tire shops and collected by garbage collectors, to be sold to individuals*: According to tire suppliers interviewed for this study, this stream is the most significant and represents approximately 22 percent of the total annual

11 Despite these safety concerns, it is at present commonly used in agriculture due to the absence of monitoring and tracking by the WWTP operators of sludge sold to third-party contractors.

quantities. The source of this stream is discarded tires from privately owned vehicles and trucks, disposed of by tire workshops in open dumps, and subsequently collected by tire-scavengers. The selling price of these tires is very low in comparison to the cost of collection, transfer and delivery of used tires to end users. The tire-scavengers' capabilities and collection efficiencies are limited.

- *Expired and used tires sold by major tire companies.*
- *Used tires sold by the government or private companies*: The Egyptian Ministries of Interior, Transportation, Industry, and Defense sell considerable quantities of waste tires at annual auctions. In addition, private companies that have huge vehicle fleets sell waste tires.

Waste tires are sold through auctions or direct spot sales to companies that produce industrial floor mats, tire bags, shoe heels, and to firms that extract wires from tires, and recycle them. Currently, importing waste tires is prohibited by the government; hence, the supply of waste tires available to the cement industry is strictly local.

There are no official statistics on quantities of scrap tires generated in Egypt, but the number of tires can be roughly estimated. According to the Central Agency for Public Mobilization and Statistics (CAPMAS), the total number of licensed vehicles in Egypt in December 2013 was approximately 6.5 million. The following table illustrates the different assumptions used for calculating the total volume of waste tires. The analysis is based on the numbers for each type of vehicle and the expected generation of scrap tires projected for 2015, based on the average lifetime of the tire.

Type of Vehicle	Number of Vehicles in 2014	Number of Tires		Average Lifetime (years)	Expected Generation in 2015 (tons)
Passenger Cars	3,743,120	4		3	32,440
Buses	120,941	6	10	2	26,317
Trucks	965,149	6	10	2	210,016
Truck Attachments	68,700	12	16	2	21,723
Government	73,532	4		3	637
	49,022	6	10	1	16,001
Motorcycles	1,772,333	2		2	7,089
Tractors	16,984	2		3	1,132
Tricycles (Toctocs)	51,213	3		2	192
Total	6,860,994				315,548

Table 18: Number and Types of Vehicles in Egypt and Estimated Numbers of Scrap Tires Produced

(Source: CAPMAS, 2013)

Extrapolating CAPMAS data in 2014, the estimated total quantity of scrap tires in Egypt was approximately 315,000 tons in 2015 and expected to grow by 10 percent every year. But, there are other estimates. The Egypt National Cleaner Production Center (ENCPC) is conducting a detailed study about retreading scrap tires to be used in different sectors in Egypt, such as transport, construction, waste collection. According to the draft study, the amount of scrap tires in 2014 is estimated to be 209,000 tons. The methodology used for providing this estimation is based on manufactured, imported and exported data obtained from the Ministry of Industry and the Egyptian Customs Authority.

In terms of potential use for AFR, however, scrap tires have many different competing markets and uses in Egypt (Figure 16), including:

- **Direct use, re-treading and re-molding of tires:** According to tire dealers, at least 10-20 percent of truck scrap tires collected from auctions are directly sold as second-hand tires, or re-treaded[12] and sold as a lower quality new tire.

12 Generic term for reconditioning used tires by replacing the worn tread with new material. it may also include renovation of the outermost sidewall surface and replacement of the crown piles or protective breaker.

- **Recycling and processing:** Rubber manufacturers use scrap tires for producing fine grind mesh crumb rubber that is used in manufacturing a wide variety of products, in addition to exporting shredded and powdered tires, crumb and ground rubber, recycled powder from inner tubes and nylon cord of tires. A large tire recycling facility in Egypt indicated in interviews conducted for the purposes of this study that they are processing approximately two million scrap tires per year, which they usually purchase from special contractors who in turn buy the material at auction. Assuming the majority of these tires are from passenger cars, this is equivalent to approximately 3,000 tons per year or about five percent of the total scrap tire market at a single recycling facility.

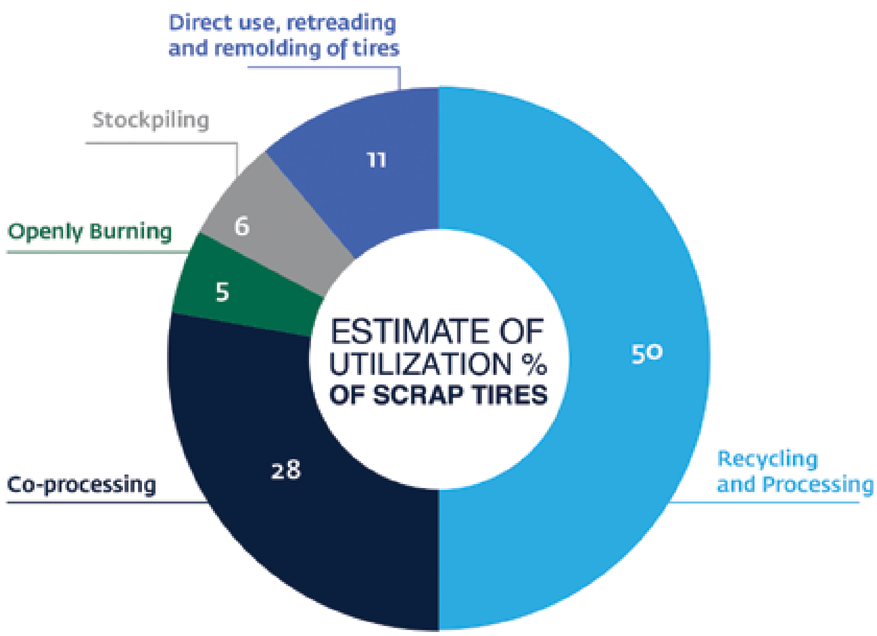


Figure 16: Estimation of Utilization Percentage of Scrap Tires in Egypt by Percentage

In addition to informal or unregistered tire recyclers throughout the country, a small village called Kafr Mit El Haroun is the main recycling hub for scrap tires collected from Lower Egypt. Scrap tires are pre-processed for various uses at the village, which is referred to as *Balad El Kawetsh*, meaning "*Tire Village.*" These uses include re-treaded tires, material recycling, splitting of scrap tires to produce free metal products and shredding, to produce 5x5 cm chips that are sold to cement factories as a fuel.

Recyclers at Kafr Mit El Haroun extract metal wire from the tires and strip it for further processing. Among the products made from scrap tires are gaskets, small swivel wheels, briefcase handles, and lining for the wheels of carts. Final residual waste generated from this pre-processing of tires is then sold per ton as fuel for brick factory kilns.

4.4.2 Challenges in Using TDF as AFR

As noted above, EEAA regards used tires as hazardous waste, and as such the regulations are more restrictive than those of the Basel Convention, which does categorize used tires as hazardous. As such, the intent to provide environmental protection through the regulated treatment of waste tires has prevented potentially more economic uses of this waste stream, and at this time, waste tires may not legally be burned in cement (or other) kilns.

The main challenges to increasing the use of TDF as an AFR for the cement sector include the following:

- Lack of legal and institutional arrangements for waste tire management, collection, transportation and disposal, as they are considered hazardous waste;
- Competitive uses in recycling and rubber manufacturing industries, which have contributed to a substantial increase in scrap tire prices;
- Illegal re-treading of scrap tires throughout the country;
- Fluctuations in used tire prices due to fluctuations in demand;
- Open burning of waste tires, because of a pervasive lack of law enforcement.

4.5 Summary

All of the waste sources which have been reviewed here are available in sufficient volumes to meet the AFR requirements of cement manufacturers, with the exception of TDF, as summarized in Table 19. This will be further discussed in the next chapter.

MSW and agricultural waste are available in the largest volumes, but each comes with unique challenges. The current low levels of collection, sorting, recycling and disposal for MSW underscore the low level of organization, oversight and law enforcement in the MSW sector. Attractive investment opportunities for waste operators exist at the 64 government collection sites, although many remain unused or are in need of rehabilitation.

For agricultural waste, the residues are voluminous and require little preparation. But the challenge for a supplier would be to organize an efficient collection method and convince farmers to save waste for collection, rather than burning it as they have always done.

DSS is available in large quantities with limited or no competing uses. The high calorific value DSS offers makes it an ideal fuel, but investors face technological challenges to ensure the water content of the waste is low enough to be suitable for AFR.

Tires are an excellent source of fuel and the most organized of the four potential AFR. Thus, waste suppliers face stiffer demand from competitive uses which puts pressure on pricing and availability.

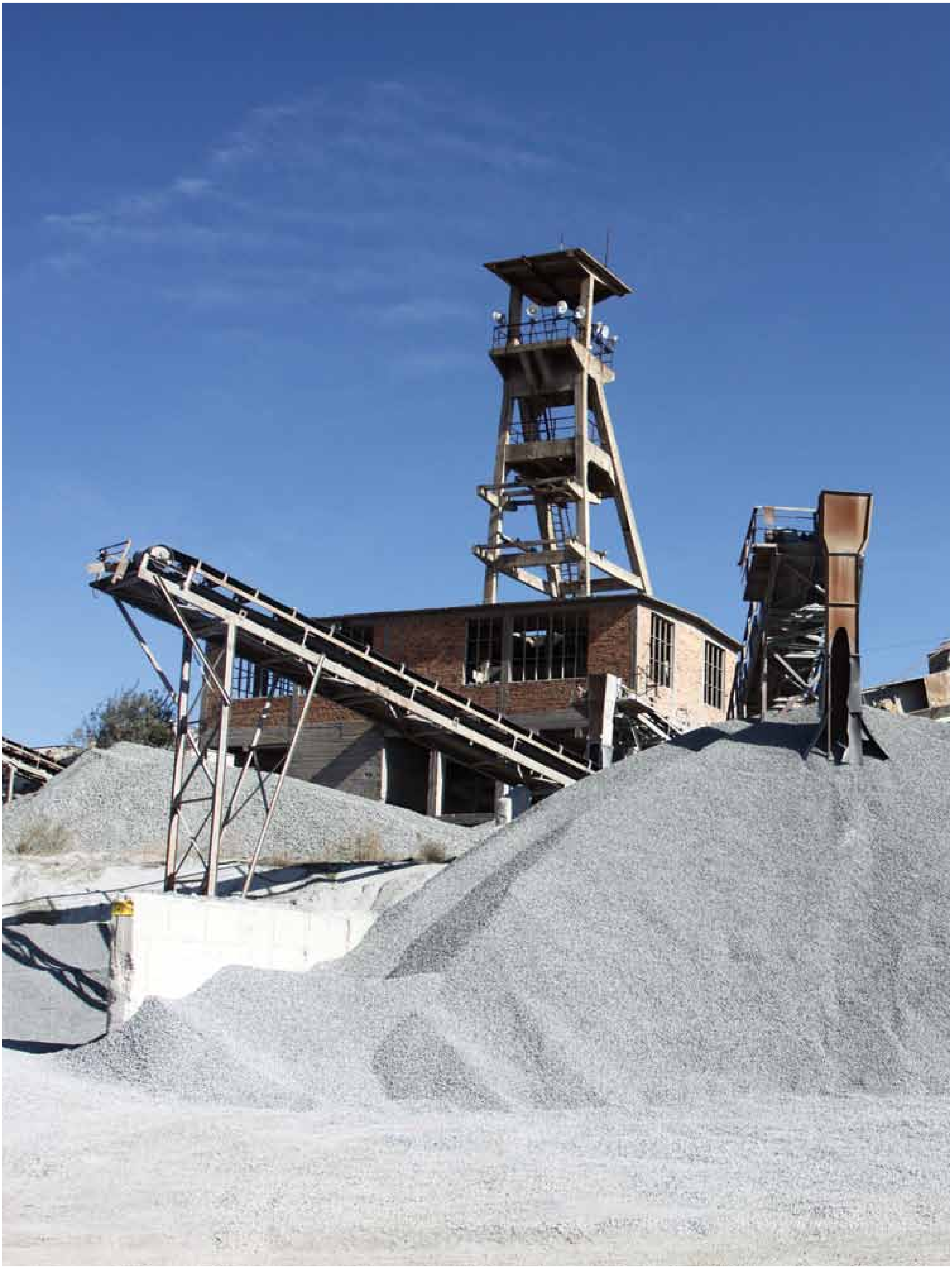
This overview of the AFR supply picture makes it clear that the Egyptian market can meet the needs of the cement sector. However, the cost of these potential fuel options, and the demand by the cement sector for AFR products, must be evaluated. For example, while these various waste streams in Egypt may be plentiful, the costs of pre-processing the waste material to a suitable standard must be considered. Costs of pre-processing vary significantly for each waste stream. Both the demand considerations and the pricing and economic considerations of the AFR solution in Egypt will be explored in the next two chapters.

Waste Stream	Quantities Available for AFR[1] (Million tons/year)	Calorific Value (GCal/Ton)	Equivalent Energy (Million GCal/ year)	Advantages	Disadvantages
RDF	2 - 5 (10-25 percent recovery rate)	3.1 - 3.8	6.1 – 19.1	• Plentiful supply • Costs tend to be low if MSW is secured unprocessed	• Low collection efficiency • Illegal dumping practices • Underdeveloped and in some cases, non-existent MSW treatment facilities
Agricultural waste	10.7	3.6 - 4.3	38 - 46	• Plentiful supply • Good calorific value	• Geographic dispersion • Many small farmers to deal with • Seasonal supply
DSS	0.98	2.5 - 6.9	2.4 – 6.8	• Good calorific value • Consistent chemical characteristics	• Handling and transport of hazardous waste • Investment for drying required
TDF	Limited amounts[2] (about 32,000 already utilized for co-processing)	6.0 - 8.4	NA	• High calorific value	• Current legal environment offers permitting challenges • Other industries use tires • Competing over a small supply
TOTAL	46 - 72 million Gcal per year				

[1] Includes remaining volumes after competing uses are assumed, except for DSS, where 100 percent utilization of generated sewage sludge is used, due to unavailability of data on current safe disposal practices.

[2] about 32,000 tons/year of scrap tires were substituted by cement companies in Egypt in 2014.

Table 19: Summary of the Availability of the Four Waste Streams as AFR



Chapter 5: Mapping Cement Industry Demand

5.1 Egypt's Cement Industry

Egypt is the 12th largest cement producer worldwide (Figure 17). It has 25 operating cement plants, 13 of which are subsidiaries of international conglomerates. Together the firms produce the equivalent of 64 percent of installed capacity. The remaining 12 firms are locally owned. For the purposes of this study, three plants have been excluded, as their primary product is white cement, for which AFR is unsuitable. The remaining 22 cement companies have a total annual clinker capacity of approximately 62 million tons and a total annual cement capacity of 68 million tons.

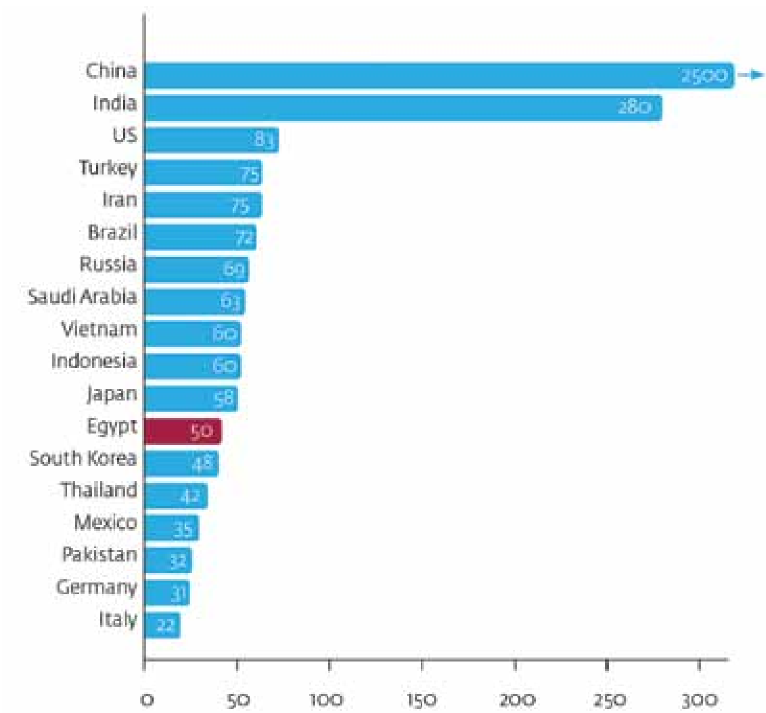


Figure 17: World Cement Production Country Rankings in 2014 in Million Tons

(Source: U.S. Geological Survey, 2015)

The Suez Cement Group[13] has the largest capacity, with five plants and around 11 million tons of clinker capacity. The second largest producer is Lafarge, with 8.4 million tons of clinker capacity.

13 Managed previously by Italcementi before consolidation with HeidelbergCement in July 2015. Following the agreement regarding the sale to HeidelbergCement of Italmobiliareia 45 percent stake held in Italcementi, Italmobiliare and HeidelbergCement decided to play an active role in the ongoing consolidation of the construction materials industry by creating the second largest global player in the cement sector, a leader in the aggregates business and the third in ready-mixed concrete. Retrieved from http://www.suezcement.com.eg/ENG/Media+Center/Press+Releases/20150729.htm

The cement plants are geographically distributed among the governorates, as shown in Figure 19. A few of these plants are also located inside populated residential areas.

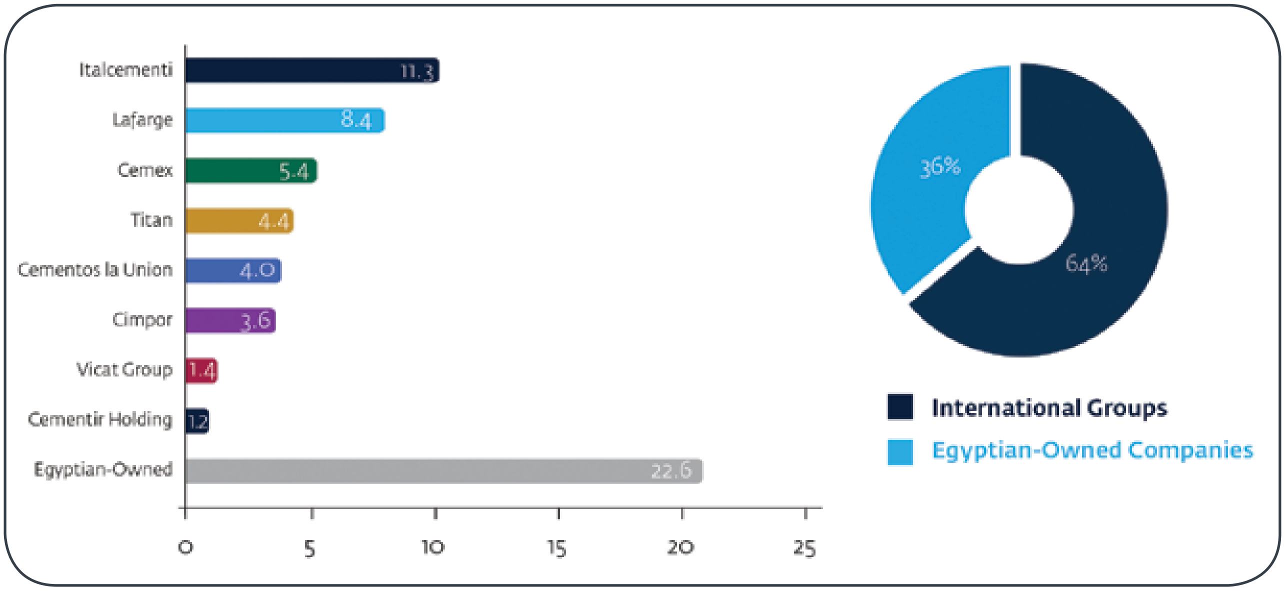


Figure 18: Installed Clinker Capacity in 2014 in Million Tons

(Source: Cement Egypt Interviews, 2015; Corporate Annual Reports, 2015)

Figure 19: Location of the Cement Plants in Egypt

5.2 Cement Production Forecast by 2025

In order to assess the potential use of AFR, it is necessary to understand the current and future energy needs of the Egyptian cement industry based on existing and forecast cement production (Figure 20). In 2014, total cement consumption was estimated to be 51.5 million tons per year, representing a 2.7 percent increase over total consumption in 2013 (Carré, 2014). In 2013, the Egyptian cement industry showed a negative growth of -1 percent. As previously noted, the main reasons were severe fuel supply shortages, rising costs (50 percent increases in natural gas and HFO prices) and the volatile political situation, which resulted in a sharp economic downturn from which Egypt hadn't yet begun to recover (Naeem Holding, 2013). In 2014, the fuel shortage remained severe, strongly affecting clinker and cement production. Capacity utilization rates dropped below 50 percent in some plants; others had to shut down temporarily. Consequently, many cement plants had to import clinker as they could not produce their own, and this led to higher costs (Global Cement, 2015).

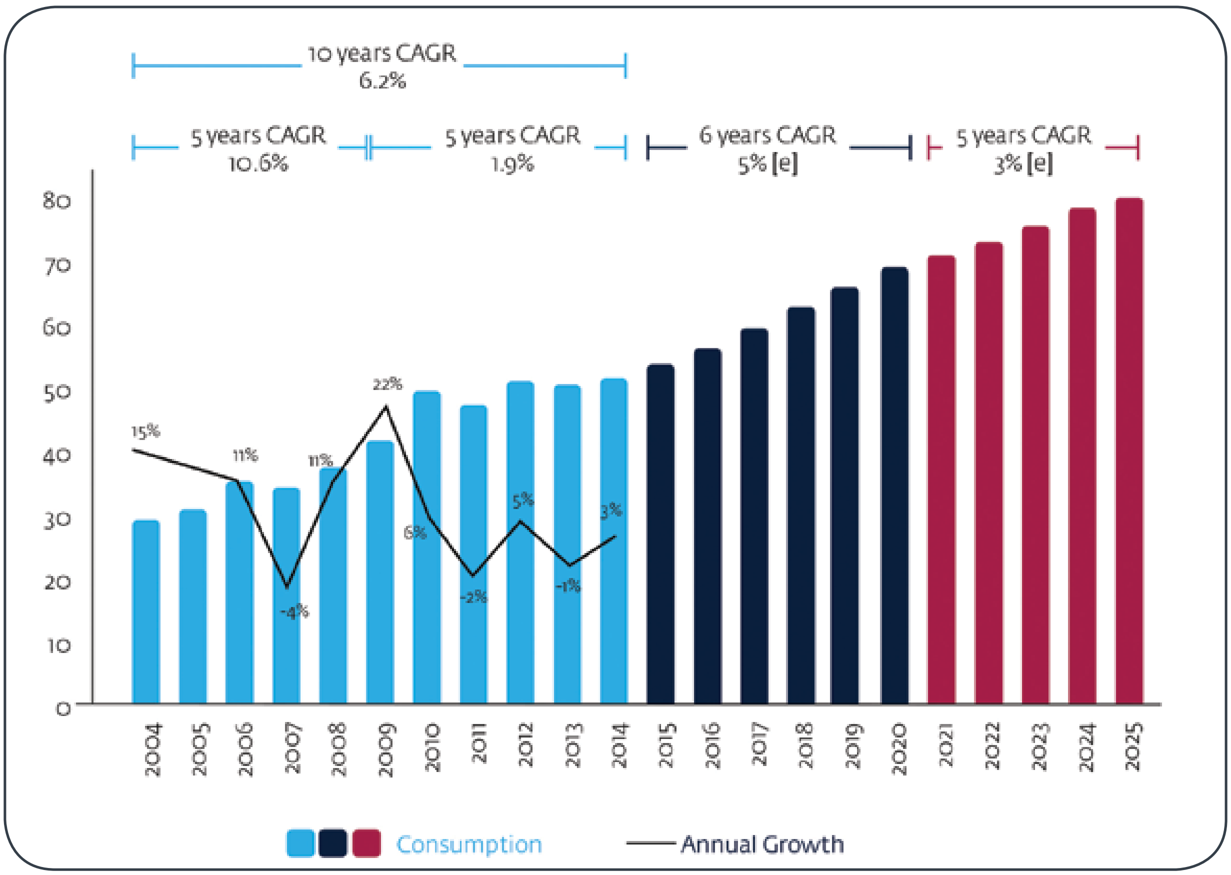


Figure 20: Historical and Future Estimated Cement Consumption in Million Tons (Bars) and Annual Growth Rate Percent (Lines)

(Source: Carré, 2014; Cement Egypt interviews, 2015)

Only limited estimates of future cement production are available for Egypt. Where forecasts are available or published, they rarely exceed five-year periods, and many do not disclose the methodology. Egypt's Industrial Development Authority, the body charged with licensing for new projects, has announced market demand of 80 million tons by 2020, which would represent an average growth rate of 7.5 percent for the next five years (IDA, 2015). Consumption growth stood at only 1.9 percent during the last five year period. This scenario is considered far too optimistic, according to interviews with representatives of the cement industry.[14]

14 The Egyptian Ministry of Industry and Foreign Trade foresees 90.4 million ton cement consumption by 2022, Daily Star (2016, January 3).

In the absence of reliable public sources for future cement projections, the methodology most commonly used to predict future cement demand is correlation with GDP growth. However, this is not a reliable method in Egypt because of the recent years of unrest, which have impacted economic growth more broadly and make projections even more challenging. As an alternative, for the purposes of this report, another common methodology has been applied in which future consumption is projected based on the Compound Annual Growth Rate (CAGR) of historical consumption, applying the same average yearly growth rate to future years as that observed in past years. In order to corroborate these projections, data collected through interviews with Egyptian cement industry representatives were then cross-checked with historical CAGR for consistency.

It is worthy to note that between 2015-2020, CAGR is estimated at five percent. Estimates for the 2020-2025 period are more conservative, with a CAGR of three percent. On average, between 2015 and 2025, a CAGR average of 4.1 percent is projected. By comparison, the cement consumption CAGR between 2004 and 2014 was 6.2 percent; that of 2009 - 2014 was 1.9 percent.

Extrapolating cement consumption based on CAGR leads to an estimate of 80 million tons by 2025. At the current 90 percent clinker factor, clinker production would be 72 million tons.

This estimated future cement consumption has been validated through sequential interviews with cement producers in Egypt and will serve as the basis for determining future thermal energy needs for the purposes of this report.

5.3 Thermal Energy Needs

Based on interviews with cement producers in Egypt, average thermal consumption is around 945 Kcal/kg (4 MJ/kg) of clinker (considering only dry kilns), which is 20 to 36 percent more than Best Available Technology (BAT) and 13 percent above the global average of 836 Kcal/kg (3.5 MJ/kg) of clinker produced. The reasons for this high thermal consumption are described in Annex A.

In 2015, clinker production (not capacity) was estimated by Egyptian cement producers at 48.7 million tons. At the above mentioned thermal consumption rate of 945 Kcal per kg of clinker, the total thermal energy need is for approximately 46 million Gcal per year. By 2025, based on the above estimates, the total thermal appetite of the cement sector would be approximately 68 million GCal per year or 284,512 MJ/year (at 945 kCal/ton of clinker).

It is important to note that cement consumption by the end of 2015 was estimated at 51.5 million tons, to be compared with a cement capacity of 68 million tons. In 2015, there was reportedly only one million tons of imported clinker, compared to several million tons per year during the peak of the energy crisis. Fuel supply constraints only slightly affected production in 2015. This signals that the Egyptian cement industry is currently facing about 16.5 million tons of over-capacity.[15] Assuming that a five percent consumption growth per year materializes, over-capacity is not expected to catch up with demand until approximately 2020.

Thus, in order to determine future thermal energy needs, it will be necessary to examine and estimate the future fuel mix. As previously discussed, the cement industry has lobbied to switch combustibles from natural gas to coal in response to gas shortages and price increases (Carré, 2014).

All cement plants interviewed are planning to use coal and petcoke as their main combustibles. AFR will be a secondary combustible, depending on cost and availability. AFR substitution rates were on average 6.4 percent across the industry in 2014 (Figure 21). The Cement Division of the Federation of Egyptian Industries estimates this future fuel mix is the most likely scenario. However, if large volumes of coal and petcoke are unavailable, at least in the short to medium term, the cement industry is willing to more aggressively engage in the co-processing of AFR.

Egyptian cement producers are unlikely to make significant use of other combustibles like HFO because of price considerations. Further, it is difficult to assess whether the recent discovery of large off-shore natural gas reserves may affect the fuel mix, once available. In an interview with the Associated Press, dated August 31st, 2015, Petroleum Ministry spokesman Hamdi Abdelaziz foresaw that Egypt will be energy "self-sufficient" by 2020. However, the future price of natural gas will most probably remain above coal prices, and Egypt urgently needs to restock its foreign currency reserves. It is unlikely that the cement industry will have access to or use natural gas in any significant quantities in the foreseeable future. This is particularly the case, as all cement plants have invested heavily in retrofitting to co-fire with coal and petcoke.

15 The recent announcements for new production license tenders may have the unintended consequence of discouraging investments in co-processing, if over-capacity reduces cement producers' margins. It is difficult to project such a correlation. However, several cement players have indicated that unrealistic capacity forecasts may in turn impact their financial decisions. According to initial media releases, the appetite for the new licenses has been very small. The IDA repeatedly extended deadlines for bids.

Assuming that the current 6.4 percent AFR substitution rates remain static, and that all remaining thermal needs for the production of clinker are to be met using coal and petcoke (average calorific value for the purpose of the calculation being 7,000 kcal/kg),[16] the theoretical volumes of coal indicated in Table 20 would be needed.

	2015	2020	2025
Clinker Production (million tons per year)	48.7	62.1	72
Thermal Consumption (million Gcal per year)	46	58.7	68
Coal Consumption (million tons per year)	6.2	7.8	9.1
AFR Percent in Fuel Mix (million Gcal per year)	6.4 (2.9)	6.4 (3.8)	6.4 (4.3)

Table 20: Theoretical Volumes of Clinker and Coal in 2015, 2020 and 2025

Whatever the fuel mix, which will likely include a combination of diversified sources, 68 million Gcal will be needed to satisfy the cement sector's thermal demand by 2025.

But such energy needs also come with a price. Switching to coal will nearly double the industry's CO_2 emissions. Comparing a CO_2 Emission Factor of 216 kg CO_2/GCal[17] for the combustion of natural gas with 402 kg CO_2/Gcal for coal, CO_2 emissions[18] from 100 percent coal-related consumption would be as follows:

	2015	2020	2025
Clinker production (million tons per year)	48.7	62.1	72
Thermal consumption (million Gcal per year)	46	58.7	68
CO_2 emission from 100 percent coal (million tons per year)	18.5	23.6	27.3

Table 21: Forecast of CO_2 Emissions in 2015, 2020 and 2025

The amended environmental regulations in Egypt require that any cement company applying for a license to import coal must provide its current specific thermal consumption (energy consumed per unit produced), which is capped at 4,000 MJ/kg (equivalent to 956 kCal/kg). This is slightly above the national average of 945 kCal/kg. Authorities then calculate the total energy required to produce at nominal cement capacity and issue allowances for the respective volume of coal required.

Companies are required to mitigate the difference between assumed GHG emissions from the theoretical consumption of 100 percent coal and a hypothetical baseline of 100 percent of heavy fuel oil (HFO) within two years of the date of issuance of the coal license. HFO was used for this baseline formula to avoid penalizing those who were totally or partially using natural gas before the new regulations. This formula is valid for all cement plants, regardless of their real fuel mix.

16 Standard average calorific values are: coal 6,000 kcal/kg and petcoke 8,000 kcal/kg.

17 Assuming 120,000 lb CO2/106 scf natural gas and 252 GCal/million scf. Retrieved from https://www3.epa.gov/ttnchie1/ap42/ch01/final/c01s04.pdf

18 The production of cement releases greenhouse gas emissions both directly and indirectly: the heating of limestone through a chemical process called calcination releases CO2 directly, while the burning of fossil fuels to heat the kiln and electricity consumption to operate machinery indirectly results in CO2 emissions. The calcination process accounts for ~50% of all CO2 emissions from cement production, while the combustion of fossil fuels to heat the kiln represents around 40% of cement emissions. Finally, the electricity used to power additional plant machinery, and the final transportation of cement, represents another source of indirect emissions and account for 5-10% of the industry's emissions. For the purpose of this report, only CO2 emissions and reductions resulting from the combustion of fossil fuels are reported.

This difference in emissions between 100 percent coal and 100 percent HFO by 2025 is equivalent to approximately 5.3 million tons of CO_2 per year sector-wide, based on 324 kg CO_2/kCal [19] for HFO, and assuming 72 mtpa installed clinker capacity, which requires a mitigation action plan (refer to Table 22).

Companies are free to use various GHGs mitigation measures, including clinker factor reduction, energy efficiency improvements, carbon credit purchase, or increased use of AFR. The option of using AFR may be attractive for this reason. Global estimates show that alternative fuels can reduce CO_2 emissions by 0.1-0.5 kg/kg of cement produced, compared to coal (Worrell et al., 2001). If, for example, agricultural waste only is considered (biomass = 0 kg CO_2/kcal, calorific value = 3.5 Gcal/ton) as AFR, then co-processing of 3.77 million tons per year (13.20 million Gcal per year) would fully mitigate the GHGs emissions difference. Most importantly, this amount, 3.77 million tons, would constitute only about 35 percent of the total agricultural waste available in Egypt annually.

No penalty exists yet for non-compliance. However, since the coal import authorization is valid for only two years, many cement firms expect that the EEAA may not renew licenses for companies that do not fulfill their commitments, or at the very least complicate renewal. This ambiguity must be addressed by regulatory parties, but in the meantime, the uncertainty currently motivates the sector to explore AFR opportunities as a business mitigation option.

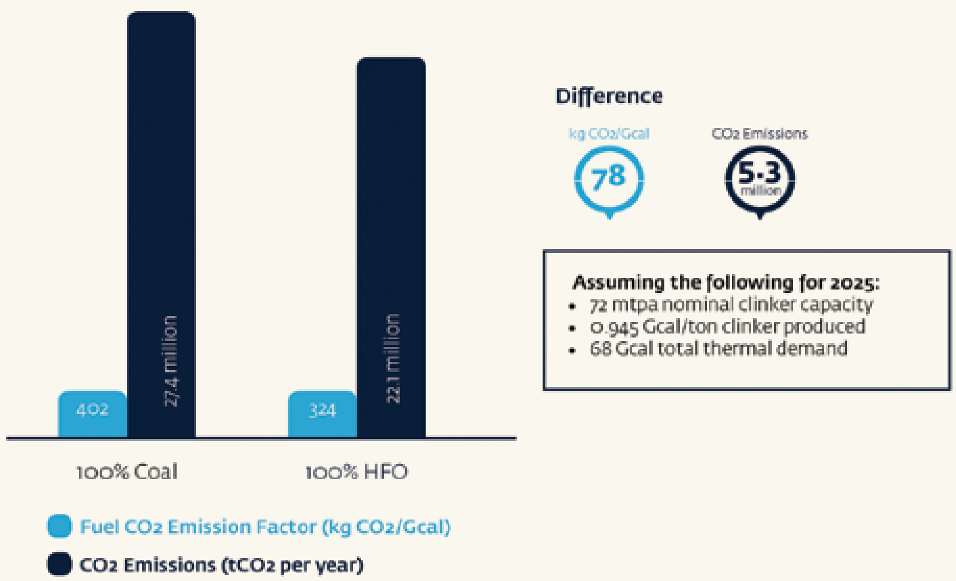


Table 22: CO_2 Emissions Gap Between the 100 Percent HFO Baseline Scenario and the 100 Percent Coal Scenario Forecasted for 2025

Waste Type	Emission Factor (kgCO2/kCal)	Minimum Calorific Value (Gcal/ton waste)	Required Amount to Mitigate GHGs Difference (million tons/ year)	Total Amount of Waste Available in Egypt (million tons/ year)	% to Cover Need from Total Waste Available
RDF	115	3	4.4	2 – 5	+100
Agricultural Waste*	0	3.5	3.8	10.7	+100
DSS	0	2.5	5.3	0.98	19
TDF	355	6	2.2	Limited Amounts	NA

* Agricultural waste and dried sewage sludge are considered to be carbon neutral since they have 100 percent biomass content.

Table 23: Mitigation of CO_2 Emissions Gap through AFR Amounts (13.2 million Gcal per Year) from Each of the Four Waste Streams[20]

19 Based on the default value of 77,400 kgCO2/TJ in IPCC, Guidelines for National Greenhouse Gas Inventories Report (2006).

20 RDF figure is based on the emission factor of 27,500 kgCO2/TJ from CEMEX Egypt, AFR CDM project. Retrieved from https://cdm.unfccc.int/Projects/DB/BVQI1273836212.26/view

In addition to compliance related drivers to adopt higher TSR rates, 64 percent of installed capacity in Egypt is managed by large multinational cement firms, most of which are also members of the World Business Council for Sustainable Development (WBCSD) Cement Sustainability Initiative (CSI). The majority of the 14 corporate members of the CSI have set emissions reduction targets as part of that initiative. In line with this initiative, most of the multinational cement firms have also set local AFR substitution targets.

Supported by corporate CO_2 emission reduction targets, the potential regulatory-driven demand for AFR for the cement industry is estimated to be at least 5.3 million tons of CO_2 by 2025, which equals 13.2 million GCal of AFR per year (i.e. 3.77 million tons of agricultural waste per year).

5.4 Alternative Fuels Status in Egypt

In 2014, the overall average thermal substitution rate (TSR) across the cement sector in Egypt was 6.4 percent or 2.9 million Gcal. For cement plants who said they were using AFR, the TSR was 9.6 percent on average per plant; two plants even reached a TSR of 13 percent, as shown in Figure 21. For purposes of confidentiality, the plant names have been represented by numbers.

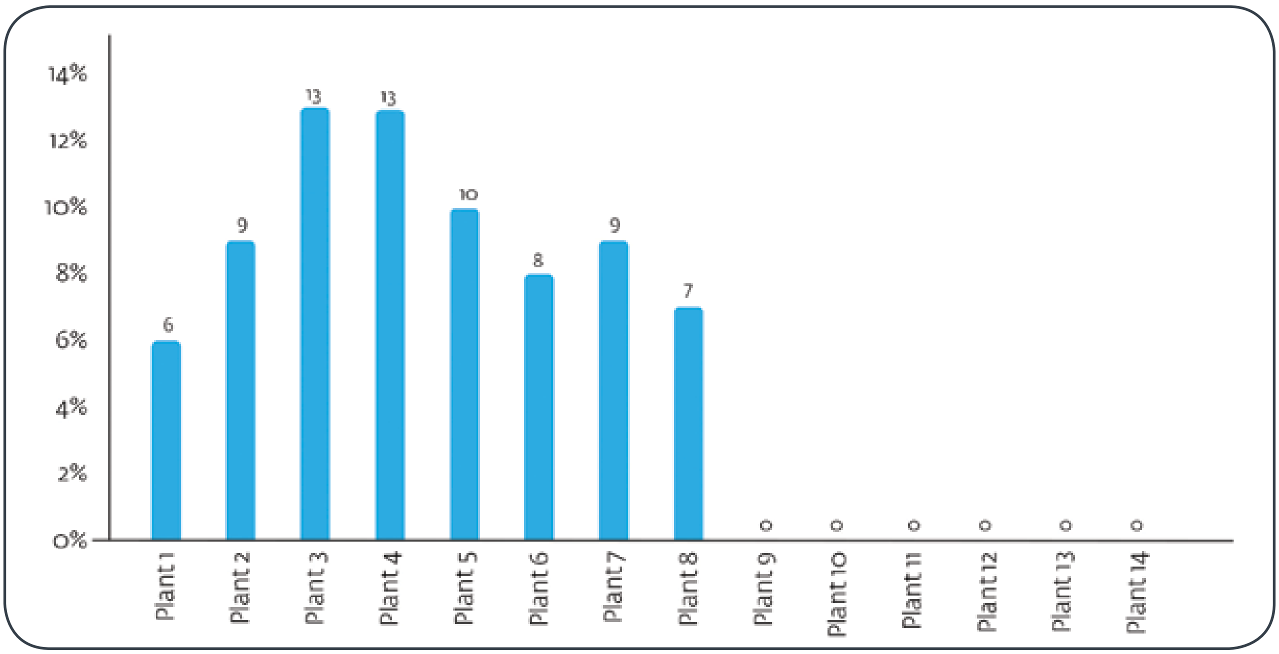


Figure 21: Thermal AFR Substitution Rates for the 14 Cement Plants Interviewed in April 2015 in Egypt

(Source: Cement Egypt Interviews, 2015)

Results from the cement industry show that in 2014, eight of the 14 cement producers interviewed co-processed approximately 388,000 tons of agriculture waste, 223,000 tons of RDF and 32,000 tons of shredded scrap tires. Table 24 presents the percentages of AFR mix currently applied by the cement plants interviewed.

	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8
% RDF	-	-	8	3	5	-	-	7
% Agricultural Waste	3	9	5	9	3	8	9	-
% Scrap Tires	3	-	-	1	2	-	-	-
% DSS	-	-	-	-	-	-	-	-

Table 24: AFR Mix Implemented by Interviewed Cement Companies

(Source: Cement Egypt Interviews, 2015)

The highest volume of AFR used in cement factories is agricultural waste, mainly tree trimming residues, because it is not affected by seasonality and is available in relatively large volumes. Its calorific value is around 3,500 Kcal/ton. Some volumes of bagasse from sugar cane are also used, although they are only available in limited quantities, have higher water content, and are seasonal. A limited quantity of agricultural waste such as olive residue, cotton stocks and rice straw are also used.

Some plants are currently using TDF as AFR, despite its prohibition by Egyptian authorities. Other companies surveyed expect to be able to use imported shredded tires in the near future; however, this is uncertain and will depend upon the regulatory framework, particularly given the current classification of TDF as "hazardous waste."

RDF from MSW comes mainly from areas near Cairo, and primarily through third party producers that conduct pre-processing. Only one cement producer has an agreement to pre-process and produce RDF in partnership with a waste management company. The calorific value of RDF reported in the interviews fluctuates from 2,800 kcal to 4,000 kcal per ton. Some plants reported quality issues such as high moisture content with the RDF received.

5.5 Future Scenarios for AFR Use in Egypt

Of the 14 cement plants interviewed, eight are already using AFR. Four companies are in preparation stages to co-process AFR, either in the commissioning phase of co/pre- processing equipment or have taken the management decision and allocated a budget for this purpose. This leaves only two plants that have not taken any action, indicating that a majority of cement companies are proceeding with the use of AFR. However, it should be noted that the principal motivation had been the absolute necessity of finding energy at any cost to avoid plant stoppages.

The cement plants have therefore been categorized into three different groups:

- ***Group 1***: Plants which have already reached around ten percent of TSR and could reach 20 - 40 percent goal by 2025. These include eight plants with a total installed clinker capacity of 32.4 million tons, all of which have been interviewed.
- ***Group 2***: Plants expected to begin using AFR within the next three years and which could reach 10 - 30 percent TSR goal by 2025. These include five plants with a total installed clinker capacity of 10.7 million tons; four of these have been interviewed.
- ***Group 3:*** Plants not yet considering the use of AFR, but which could reach a TSR rate of up to 10 percent by 2025. This group includes 13 plants with a total installed clinker capacity of 19.3 million tons. Two of them have been interviewed.

The producers interviewed are planning to expand the national average AFR use between 15 percent to 30 percent within five to ten years, a five-fold increase from current levels, equivalent to 10.2 – 20.4 million Gcal of AFR in 2025.

5.5.1 Group 1 – AFR Early Movers

5.5.1.1 Current Status

Eight of the 14 cement plants interviewed are currently using AFR. Four of these are using more than one of the four waste streams which are the subject of this study as indicated in Table 24 (Plants 1, 3, 4 and 5), demonstrating the cement sector's appetite for increasingly diverse sources of AFR. Only one plant within this group is commissioning a dry sewage sludge (DSS) line; but it faces technical problems which need to be solved in coordination with the local waste water treatment plant.

5.5.1.2 Expected Modifications of Existing AFR Feeding Equipment

Group 1 plants are more aggressive with their upgrades, in order to accommodate increasing levels of AFR. Storage capacity for AFR at these plants will typically be designed to guarantee feeding of the kiln, a strong signal of demand for continuous supply. Most of the transport and injection lines which are installed or which have been procured by the plants in this group can handle large volumes of waste, enough to achieve 30 percent TSR, with a mix of RDF, TDF, and agricultural waste.

Nevertheless, as these plants increase their TSR, the short-term fluctuations of the thermal value of energy supplied to the kiln will gradually impact the clinker process. Therefore, it is common that a cement plant can hit a limit of thermal substitution rates due to excessively high thermal fluctuations.

The following are two of the main sources of the fluctuations:

- Fluctuation of the fuel supply flow: this is often related to a weak regulation or automation of fuel supply to the kiln, and/or poorly designed equipment which can cause "bridging" or clogging. Sometimes this is also due to a lack of calibration of the dosing system, the rate at which the AFR is added to other fuels for feeding to the kiln.
    - o It can generally be solved with "light" modifications and fine tuning, eventually changing one or another part of equipment.
- Fluctuations of the calorific value of the AFR mix: this is primarily related to the heterogeneity of the waste material. This potential bottleneck is of major importance in Egypt, due to the variety of waste sources, some of which have specific seasonality.
    - o Manually mixing different AFR streams, using a front loader, can be an option. However, due to the different sizes and densities this is very difficult.
    - o The best options for a cement plant when striving to achieve TSR rates of > 10-20 percent include either
        - working by campaigns of a few days or weeks, co-processing one "pure" waste stream after another and adapting the mass flow and kiln parameters. This approach doesn't require investment, but it can be challenging in Egypt considering the type of AFR available (seasonality of agricultural waste, low density of RDF limiting the storage); or
        - adding a pre-dosing system for each type of waste, specifically waste with similar calorific values and densities, which feeds the common conveyer.

Feeding systems will thus require upgrades through the addition of separate pre-dosing systems when TSR increases.

5.5.2 Group 2 – Cement Plants Moving to Use AFR

5.5.2.1 Current Status

Four of the 14 plants interviewed have not yet started using AFR, but have made decisive steps in this direction, such as capex budgeting, commissioning and market prospects.

All plants interviewed in this group intend to use only RDF and/or DSS. None of them were considering agriculture waste or tires, for these reasons:

- Tires: high prices and limited volumes, and
- Agriculture waste: collection issues (large volumes but disseminated over too many locations) and seasonality issues (the plants can neither absorb all the volume in a short period of time nor store it during off-seasons, for safety reasons).

5.5.2.2 Expected Modifications in Existing Equipment

Though this group doesn't have co-processing lines in place, they have either already ordered the equipment or have at least allocated a budget for it.

During the interviews in 2015, two of the four plants indicated they will be equipped with a calciner feeding line for coarse solid waste before the end of 2015, and one will be equipped in 2016. The remaining plant should be equipped in 2017, but a commissioning date had not yet been given.

These lines are technically similar to the ones existing in the plants currently co-processing RDF and/or agricultural waste. Budgeted costs for the two lines currently under construction are 3.0 and 3.9 million $ respectively. The line to be built in 2016 is budgeted at $6.5 million for two kilns.

In two plants, which belonged to the same company, DSS injection lines were installed. Commissioning is ongoing for one line and will soon start for the other. Unlike RDF and most agricultural wastes, DSS is a fine solid (which can be conveyed pneumatically).

Typically such lines are comprised of:

- a silo with a planetary screw;
- a mechanical feeding of the silo based on a docking station and a drag chain conveyer;
- a lump breaker and a screw feeding an enclosed weigh-screw feeder; and
- a pneumatic transport to the main burner of the kiln.

Particular attention was paid to containing the explosion risk related to DSS, through explosion venting, and a 10 bars resistant dosing system. This risk is in reality rather low, considering the specific DDS received. The fuel mix line is designed to be extended for a complementary injection to the calciner, and eventually a second dosing unit for feeding a second kiln.

5.5.3 Group 3 – Cement Plants Taking No Action on AFR

Two of the 14 plants interviewed have not yet considered AFR, though no specific set of reasons were provided during the interviews.

5.6 Assessing Alternative Fuels Market Potential in Egypt

In order to better understand the market potential for AFR, three different scenarios are being assessed (Table 25). A "Best Case" scenario involves aggressive AFR market development, supported by improved waste management regulations and stricter enforcement. "Business-As-Usual" (BAU) would entail AFR market development continuing at the current pace. "Worst Case" scenarios reflect potential delays in meeting TSR targets due to market challenges and the lack of an enabling professional, waste management infrastructure.

Each scenario will present the fuel mix expected by 2025 in volume (tons) and in thermal energy (Gcal). The CO_2 emissions for each scenario will also be provided. These projections are based on the predicted clinker production levels of 72 million tons per year (see Section 5.3) and therefore total thermal needs of 68 million GCal per year.

	Fuel	TSR%	Thermal Energy (Gcal per Year)	Volumes (Ton per Year)
Scenario 1 Best Case	AFR	30	20,413,840	5,832,526
	Coal	70	47,632,295	6,804,614
Scenario 2 Business as Usual	AFR	20	13,609,227	3,888,351
	Coal	80	54,436,908	7,776,701
Scenario 3 Worst Case	AFR	13	8,845,998	2,527,428
	Coal	87	59,200,137	8,457,162

Table 25: Three Proposed Scenarios for AFR Thermal Substitution Rate by 2025

Scenario 1: BEST CASE – Aggressive AFR Market Development Supported by Waste Management Regulations and Implementation

Many different TSR targets were provided by cement companies during interviews. Some had an ambitious TSR target of 50 percent, while others remained at 0 percent, resulting in an overall average TSR target of 30 percent by 2025. It should be noted that many of these targets have been communicated to authorities in order to get approval for coal use. However, at the time this report was being prepared, such targets were indicative, not mandatory.

It took the EU more than 20 years to achieve an average TSR of 39 percent. Therefore, an average 30 percent TSR for Egypt by 2025 is quite ambitious and would require a significant level of effort from all stakeholders. This scenario considers a theoretical case, as has been seen in some European countries, in which the authorities take aggressive measures to mitigate their waste management issues through stringent policies and regulations. Such policies would need to be complemented by attractive economic incentives.

Poland's case study (Box 2) has been taken to illustrate this scenario. The percentage of TSR in Polish cement plants was 18 percent in 2007 and more than doubled to 39 percent in 2010 (Polish Cement Association). At the same time, landfill fees climbed from EUR 3 per ton in 2007 to EUR 24 per ton in 2009 and EUR 26 per ton in 2012.

The following TSR assumptions have been made under this scenario for each group of cement companies:

- Group 1 – TSR would reach 40 percent by 2025
- Group 2 – TSR would reach 30 percent by 2025
- Group 3 – TSR would reach 10 percent by 2025

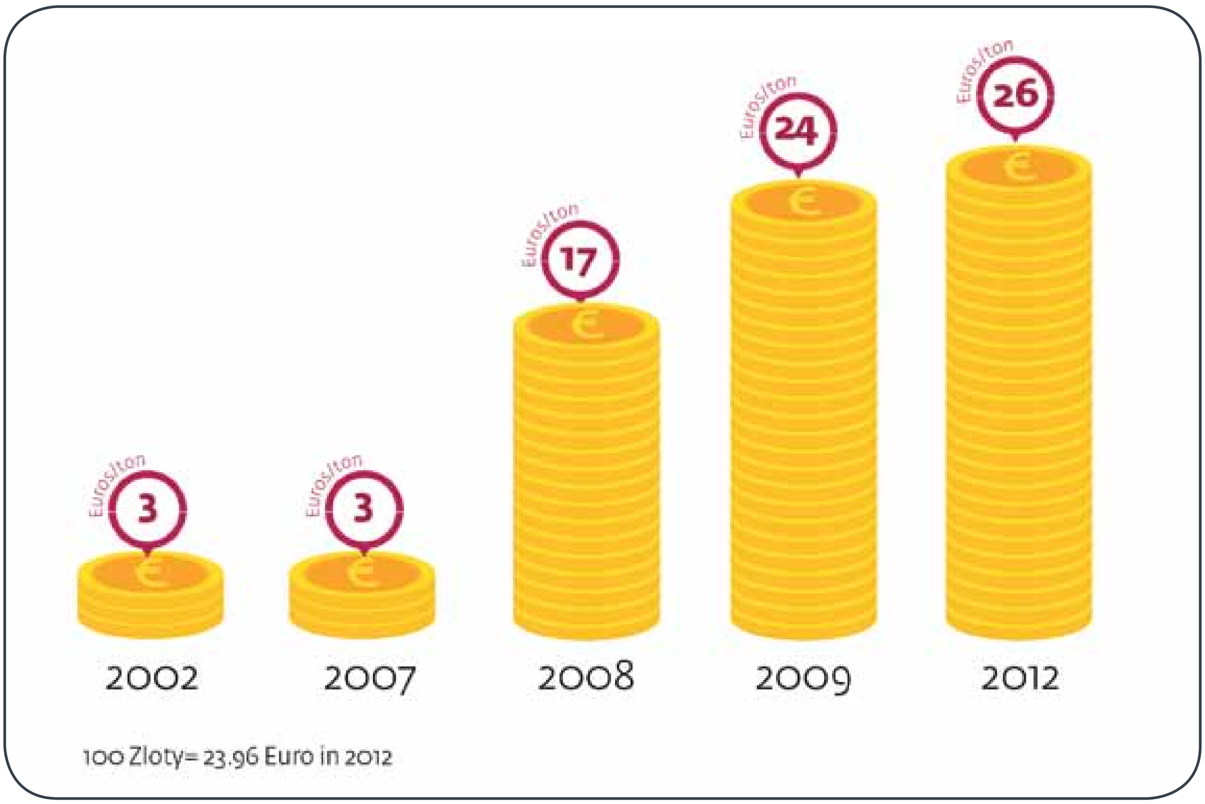


Figure 22: Evolution of Landfill Tax on Municipal Solid Waste in Poland between 2002 -2012

(Source: EEA, 2013)

In order to repeat this success story, and make this Best Case Scenario feasible in Egypt, some key lessons would indicate that

- Egyptian authorities should impose a landfill tipping fee, though not necessarily at Poland's level. In Mexico, according to interviews with cement plants, the tipping fee varies from $5 to $10 per ton, which can be translated into an incentive for those using AFR.

Box 2: IN BRIEF: POLAND'S ALTERNATIVE FUEL SECTOR

Cement sector commitment and quick responses to market opportunities have been the key to success in Poland. In 1998, the country adopted its first waste regulation protocol, which included a Marshall Tax on landfilling. Alternative fuel substitution rates grew slowly with that first step. By 2011, the Polish Ministry of Environment launched a target to divert 50 percent of all municipal solid waste from landfills. Their ambitious plan included reducing further landfilling to only 35 percent by 2020 (a 65 percent diversion rate). Moreover, since 2013, Poland has enforced a landfill ban on combustible waste. Close to 25 percent of the MSW is now being converted into RDF. As such, Poland's cement industry is the highest contributor to the country's waste reduction targets (Theulen, 2013; Theulen, 2015).

Another waste stream – used tires – also saw an important change. With the implementation of an Extended Producer Responsibility principle, tire manufacturers established a joint firm to manage used tires. Collection became more organized and was directly subsidized by the tire sector.

In parallel, as competition for used tires and other alternative fuel sources grew, cement plants invested in their own handling facilities for RDF. This move created a spiral impact and boosted demand beyond the local market. The cost-effectiveness of RDF preparation was improved. As time passed, the capacities of RDF production lines reached equilibrium with cement plants' alternative fuel capacities, allowing cement firms the ability to pressure RDF producers to further improve the quality of their product. RDF suppliers responded, and cement firms developed new tools to improve drying by, for instance, installing thermal dryers that use the waste heat of the cement kiln.

Poland had a substitution rate of 45 percent in 2011. Today, the figure has exceeded 60 percent, with some plants boasting thermal substitution rates higher than 85 percent.

The Polish example can provide key lessons. Business adaptation to changing market opportunities is essential. Long-term contractual agreements with the waste management sector has also proved to be of central relevance. Quality standards gradually improved under competitive pressure. Finally, the regulatory environment and a government commitment to enforce regulations provided the enabling infrastructure to allow the alternative fuel market the space to grow sustainably and commercially.

- Egyptian authorities should increase enforcement on the prohibition of uncontrolled landfilling and illegal dumping; stop the use of tires by red brick kilns and enforce fines and penalties on illegal retreading of tires; limit the burning of agriculture waste; and prohibit the use of untreated sewage sludge as fertilizer, a practice which causes human health problems and other environmental issues.

In order to achieve TSR rates as high as 30 percent across the entire cement industry in Egypt, a regulatory will for reform and market mobility are crucial prerequisites. In the absence of these measures, it is very unlikely this target will be reached.

A 30 percent TSR in 2025 would require 20.4 million Gcal of AFR (or 5.8 million tons at 3.5 Gcal/ton). The potential spending by the cement industry on procuring AFR in this scenario would be $326 million, while savings from replacing coal consumption would be $77 million annually. This in effect could reduce CO_2 emissions from the cement sector by 5.8 million tons of CO_2 per year, meeting fully the GHGs compliance target set by Egypt's government.

Scenario 2: BUSINESS AS USUAL (BAU) – AFR Market Development Continues at Current Pace

A more realistic TSR objective should be considered, given that regulatory changes, if any, will take time to implement and enforce. Such an objective accounts for the current situation in Egypt, particularly in terms of waste management and in terms of existing market-based drivers as well as the current state of the AFR supply chain in Egypt. This scenario considers that required normal policies and business models will be implemented at a realistic pace.

The following TSR assumptions have been made under this scenario for each group of cement companies:

- Group 1 – TSR would reach 30 percent by 2025
- Group 2 – TSR would reach 20 percent by 2025
- Group 3 – TSR would reach 5 percent by 2025

Based on these different assumptions per group, and assuming that these 14 cement plants are a representative sample of the entire sector, the total average TSR for the cement industry could reach 20 percent by 2025. This 20 percent would not only represent the four targeted waste streams, but could also integrate hazardous and non-hazardous industrial waste not included in this study .

Achieving a 20 percent TSR represents approximately four million tons of waste annually which could be diverted from landfills, illegal dumps and burning. As of 2014, the current average TSR across the cement industry in Egypt was approximately 6.4 percent, equivalent to 2.9 million GCal, or 388,000 tons of agriculture waste, 223,000 tons of RDF and 32,000 tons of shredded used tires. Chapter 4 has made it clear that AFR sources are available in Egypt which would allow a 13.6 percent TSR growth between now and 2025, a total 13.6 million GCal to reach a 20 percent TSR by 2025.

Based on this scenario, by 2025 cement plants could be spending around $217 million annually on procuring AFR (based on an average of $16 per Gcal). This would also represent annual savings for the cement industry of $51 million, in comparison with estimated coal prices. These savings would also obviate spending hard currency needed for coal imports. Emissions could be reduced from the baseline by 3.9 million tCO_2 in 2025, meeting 74 percent of the GHGs compliance target set by authorities.

Scenario 3: WORST CASE – Delays in Meeting Targets Due to Market Challenges

This scenario considers that no change takes place in the current situation in terms of waste management, and that implementation of AFR substitution is slow due to persistent market challenges. This implies that no new policy and regulations are established, and no incentives are provided to the waste supply chain. It would also mean that cement companies remain reluctant to incorporate AFR into the fuel mix. In such a case, AFR pricing is unlikely to compete with coal, given that economies of scale will be lacking.

The following TSR assumptions have been made under this scenario for each group:

- Group 1 – TSR would reach 20 percent by 2025
- Group 2 – TSR would reach 10 percent by 2025
- Group 3 – TSR would reach 0 percent by 2025

Again assuming that these 14 cement plants are representative of the whole industry in Egypt, the average TSR could reach approximately 13 percent.

A 13 percent TSR would require 8.8 million Gcal of AFR, or 2.5 million tons at 3.5 Gcal/ton in 2025. The potential spending by the cement industry on procuring AFR in this scenario would be $141 million, while savings from replacing coal consumption would be $33 million annually. This in effect could reduce GHGs emissions by 2.5 million tons of CO_2 in 2025, meeting 48 percent of the GHGs compliance target set by authorities.

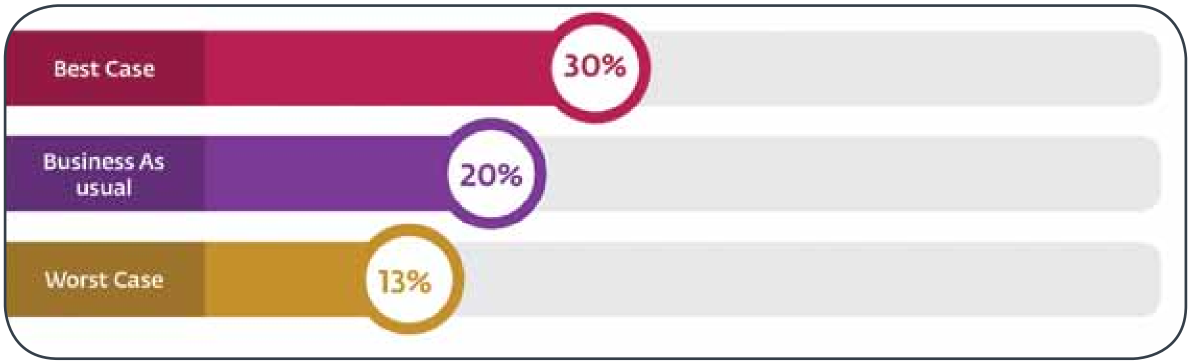


Figure 23: AFR Thermal Substitution Target in 2025 for Each Scenario

Waste Requirements by Scenario

Table 26 compares the various scenarios, as well as the costs and benefits to the cement sector for each of the scenarios. The table includes an assessment of how much the industry could potentially spend per year in procuring pre-processed AFR, as well as the potential savings in comparison to coal.

	Fuel	TSR%	Energy (Million Gcal per year)	Volumes[a] (mtpa)	CO_2 Emissions[b] (mtpa)	CO_2 Reductions (mtpa)	Annual Fuel Spending[c] (Million USD)	Savings per Year[d] (Million USD)
Scenario 1 Best Case	AFR	30	20.4	5.8	2.3	5.8	326	77
	coal	70	47.6	6.8	19.1		943	
Scenario 2 BAU	AFR	20	13.6	3.8	1.5	3.9	217	51
	coal	80	54.4	7.7	21.8		1,077	
Scenario 3 Best Case	AFR	13	8.8	2.5	1	2.5	141	33
	coal	87	59.2	8.4	23.7		1,172	

(a) Volumes of waste – in million tons per annum (mtpa) - are calculated based on the calorific value of 3.5 Gcal/ton.

(b) Calculated based on the CO2 emission factor of coal (402 kgCO2/Gcal) and RDF (115 kgCO2/Gcal). If agricultural wastes and/or DSS are utilized, the CO2 emission factor for AFR is zero.

(c) Assumption that average cost of AFR is 56 USD/ton (16 USD/Gcal) at the burner for calorific value of 3.5 Gcal/ton. Cost of coal of 118.8 USD/ton coal (19.8 USD/Gcal) at the burner for calorific value of coal at 7,000 kcal/kg.

(d) Savings from price difference between coal and AFR.

Table 26: Fuel Mix Forecast in 2025 According to Each Scenario

Should the BAU scenario be successful, about 1.9 million tons of coal could be reduced by 2025. In comparison to Scenario 3, where stakeholders do not take the required measures to improve the use of AFR, about 1.2 million tons of coal could be reduced by 2025. Such savings could even reach 2.9 million tons of coal in 2025, if Egyptian stakeholders decide to aggressively reform the current waste-to-energy infrastructure in the country.

However, in order to reach this BAU scenario of 20 percent TSR, a combination of the various waste streams would be needed. No single waste stream could meet the demand, as shown in Table 27. Together, the waste streams would offer approximately 13.6 million GCal. In addition, **a diversified AFR fuel base** would reduce concerns over supply reliability.

Achieving the BAU 20 percent TSR target in 2025 will require an additional 13.6 percent in AFR substitution. This would be an equivalent of a 10.7 million GCal increase from current levels. The total calorific thermal needs of the cement sector in Egypt in 2014 were approximately 46 million GCal per year (945 kcal/kg clinker produced). In 2025, it is expected that clinker production will have increased to 72 million tons per year, requiring a total of 68 million GCal per year.

Based on the projected thermal demand by 2025, and after assessing the available volumes for each AFR waste stream, can the cement sector realistically reach 20 percent TSR by 2025 in Egypt? Table 27 below indicates an initial answer of "yes." This is technically achievable based on available supply, but must be further evaluated according to the economics of AFR (see Chapter 6). The assumptions are based on various factors, including a) volumes available, b) accessibility of the waste stream, c) current contribution to the total AFR market and d) calorific values.

AFR Type	Gcal per ton	Current Case (2014) TSR = 6.4%			Business as Usual (2025) TSR = 20%			Total Volumes Available in 2014 (Thousand tons)	Volumes Expected to be Available in 2025 (Thousand tons)
		Volume (Thousand tons)	Energy (Thousand Gcal)	% in Energy Basis	Volume (Thousand Tons)	Energy (Thousand Gcal)	% in Energy Basis		
RDF	3.5	223	781	31	1,361	4,763	35	2,000 – 5,000	2,431 – 6,078
Agricultural Waste	4.5	338	1,521	60	1,512	6,805	50	10,700	NA
DSS	3.1	0	-	0	439	1,361	10	983	1,195
TDF	6.7	32	214	9	102	680	5	32 (limited amounts)	NA
TOTAL			2,516	100		13,609	100		

1 For TDF, the amounts available are assumed to be the volume co-processed by the cement sector in 2014.
2 The volumes expected to be available in 2025 are extrapolated based on an annual population growth rate of 1.8 percent (2015 estimate).

Table 27: Estimated Additional AFR Volumes Required to Reach 20% TSR by 2025

In conclusion, this chapter has shown that the amounts needed to reach the 20 percent TSR target in Egypt are indeed achievable with the current AFR supply. However, investments and related market building efforts will be necessary in order to tap into each waste stream. Reaching a 30 percent TSR may prove challenging, given the competing uses and (mis)uses of the various AFR waste streams, particularly in the absence of regulatory support.

The next chapters will turn to determining if the 20 percent TSR targets are economically viable, and to examining supply chain developments that may be required in order for alternative fuels to become a sustainable industry and fuel source for the cement sector.

Chapter 6: AFR Economic Perspectives

6.1 Introduction

The entry of coal into the Egyptian energy landscape can be expected to create fierce competition for other fuel sources, but there is still a market for waste-based alternative fuels in Egypt and a potential appetite for investing in co-processing solutions, if the commercial and business opportunities are captured quickly. AFR could theoretically compete with coal on a large scale as a secondary fuel, provided AFR prices are competitive. But for the two to compete, the price difference between traditional fuels, coal and petcoke, and alternative fuels must take into account the additional costs to be borne by the cement sector.

While it is true that coal will have similar cost elements, it will have greater economies of scale. AFR may in the end see greater specific costs and externalities per unit, due to lower quantities used – unless AFR use can be facilitated at a large scale. AFR prices on a like-for-like basis must be less than the main fossil fuel used by cement plants in order to compete. Capital costs (CAPEX) and operational costs (OPEX) for each of fossil fuels and AFR fuel streams are evaluated in the following section.

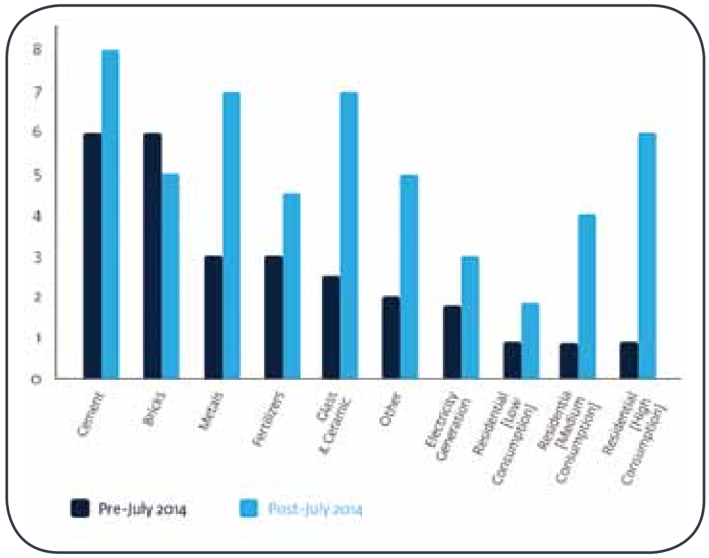


Figure 24: Natural Gas Price Increases Pre- and Post- July 2014 Government Announcement

(Source: Ministry of Petroleum, 2014)

6.2 Fossil Fuels

6.2.1 Fossil Fuel Prices and Externalities

As previously mentioned, natural gas prices were raised significantly on a complex usage-dependent scale after the Egyptian Government announcement in July 2014 on energy price increase for petroleum products and electricity. Figure 24 shows increases in natural gas fuel prices in Egypt before and after the price increase announcement. Although Figure 24 indicates that the cement sector experienced only modest increases in natural gas pricing in the pre- vs. post-2014 energy crisis, the overall net impact on the sector is significant because the sector alone consumed 46 percent of all natural gas allotted to energy-intensive industrial sectors in Egypt. In addition, this was the second significant price increase for the cement sector, since as late as 2011/2012 cement companies were paying about \$2.5 per MMBTU of natural gas.

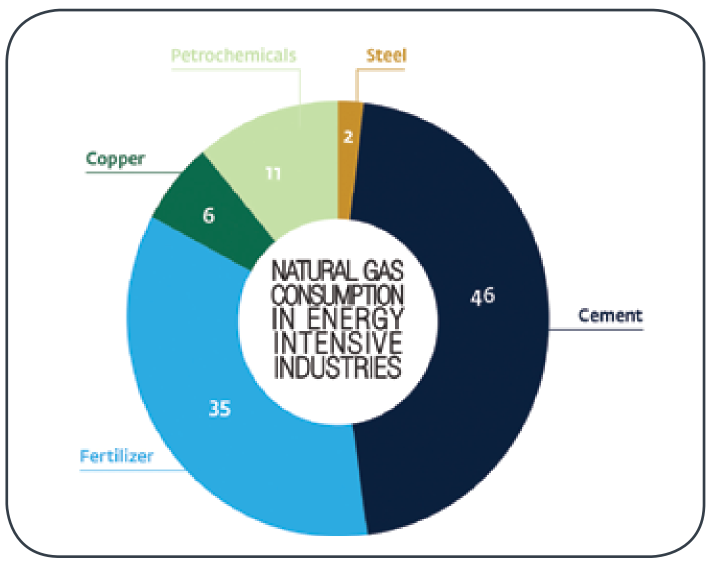


Figure 25: Natural Gas Consumption in Energy Intensive Industries By Percentage *(Source: Hussien, 2015)*

Similarly, prices of HFO in Egypt pre- and post-2014 have risen significantly (Figure 26), depending on the industry. Cement companies, the hardest hit of all energy-intensive sectors, suffered a 50 percent increase.

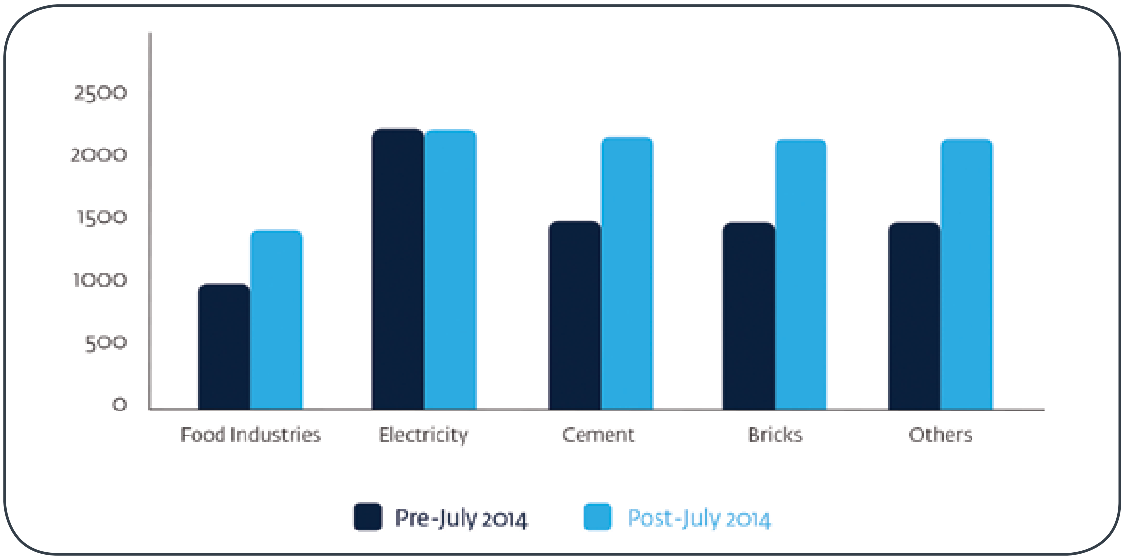


Figure 26: Heavy Fuel Oil Prices in EGP per ton

(Source: Ministry of Petroleum, 2014)

The interviews conducted in the summer of 2015 with EGAS management indicated that coal and petcoke are likely to become the primary fossil fuel for the cement industry. However, as described earlier, limited volumes of HFO and natural gas will be available to the cement sector for the coming several years, until all cement plants obtain coal and petcoke import authorizations and are equipped with coal and petcoke mills. At the time this report was being prepared, only Suez Cement (Tourah and Helwan) and National Cement had not yet received coal authorizations, due to their location and proximity to urban areas. All other plants in Egypt had already invested in the required coal grinding and co-firing equipment, even if not all had yet been commissioned. In terms of port capacity, it is still expected that some upgrades will be necessary in order to meet full demand.

Coal is very new to the market in Egypt; therefore, historical price trends are not available. Based on interviews with cement companies conducted as a part of this study, the cost of coal has been estimated at approximately $19.8 per Gcal ($119.4 per ton coal) at the burner tip for calorific value of coal at 6,000 kcal/kg. One interviewee provided details related to the cost of coal, applicable in September 2015:

- Cost and freight (CFR) coal price (6,000 kcal/kg) = $72 per ton [21]
- Discharge cost and handling cost at port = $13 per ton
- Taxes = $7.9 per ton
- Transport cost over an average of 200 km = $10 per ton
- Handling, grinding, and storage at plant = $7 per ton
- Total: $109.9 per ton coal with eight percent moisture or $119.4 per ton dry coal at the burner.

In this particular example, port costs are significantly higher than international standards, for two principal reasons:

(i) Egypt lacks hard currency availability at present. Traditional payment tools like letters of credit are more difficult to obtain, and coal traders increase their margins in order to account for payment delays or payment in local currency.

(ii) Egyptian ports lack experience with coal handling, and this affects efficiency and cost, though this is expected to change with time.

Cement producers, however, expect that port operations, including traders' margins, will decrease to approximately $5 per ton coal as soon as Egypt solves its hard currency issue and port operators gain experience.

21 Consolidated Bulk Inc. Lebanon.

Current prices at the burner tip for fossil based fuels for the cement industry in Egypt are summarized in Table 28.

	Price (USD per Volume)	**Price** (USD per GCal)
Natural Gas	8 per MMBTU	32
HFO	311 per ton	32
Coal	119 per ton	19.8

Table 28: Fossil Fuel Prices at the Cement Plant Burner Tip in Egypt in 2015

6.2.2 Coal: CAPEX and OPEX Considerations for Cement Plants

Switching to coal requires investment in a “coal line”, consisting of a preparation line (drying and grinding of raw coal), plus a feeding line (to feed coal to the injection point); it also requires adaptation to the process parameters of the kiln, such as oxygen content at kiln inlet and burner settings.

Generally, in a modern installation, indirect firing is considered. This means that grinding installation is completely separated from the kiln. The pulverized coal is stored in an intermediary storage bin and exhaust air from the mill is released through a filter into the atmosphere. In this way, kiln operation is totally independent from the combined drying and grinding operation.

Based on interviews, the expected investment for a complete coal line will be approximately EGP 135 million ($19.2 million), but can range from $15 to $25 million, excluding the price of land. This calculation assumes that a cement plant produces three million tons of clinker per year and uses approximately 400,000 tons of coal.

Typically, in a plant with several kilns, only one preparation line is installed and supplies one feeding line per kiln. According to best practices, coal should be kept in a closed storage space.

In order to be fired at the kiln burner, coal needs to be prepared by drying and grinding. To operate safely, avoiding fire or explosion, it should be done under an inert atmosphere (< 10 percent O_2). The preparation cost for coal depends mainly on the availability of waste heat (kiln exhaust gases), the cost of electricity and potential economies of scale on the fixed costs. The typical preparation cost varies between $2 and $3 per Gcal, according to interviewees.

6.3 Alternative Fuels

6.3.1 AFR CAPEX and OPEX Considerations for Cement Plants

A differentiation must be made between pre-processing and co-processing equipment. *Co-processing equipment* is always located at the cement plant and usually comprises AFR storage, handling, dosing and feeding equipment. *Pre-processing equipment* is usually built on an external platform, and is usually owned and/or operated by a third party.

The pre-processing equipment, or part of it, is then preferably installed near to the main source of the waste generation or deposit (collection center or landfill/disposal site, for instance), to avoid transporting the portion of waste not suitable for co-processing in the plant. Depending on the type of waste, pre-processing generally includes processes and equipment for sorting, size-reduction (grinding or shredding) and homogenization (mixing, blending).

The following section will explore CAPEX and OPEX considerations to co-process AFR.

Co-Processing Equipment

As AFR co-processing is in its early stages in Egypt, only a small number of plants are already equipped with AFR feeding lines.

The variability and limited availability of waste streams generally require installing polyvalent coarse solid AFR feeding lines, as described below, for mechanical feeding of coarse solids to the calciner. Of the cement plants interviewed in 2015, eight were co-processing AFR. Six plants are equipped with AFR feeding lines and two plants have lines in construction phases.

Coarse waste can only be fed to the calciner, or, in a limited way, to the kiln inlet. Coarse solid feeding lines usually consist of:

- a storage area – for best practice, it requires enclosed storage, typically a hall operated with a loader, and several pits operated with a bridge crane. Considering the variety and limited size of waste streams in Egypt, pre-blending is generally done manually in the storage space;
- a dosing system – generally a belt weigh-feeder;
- a mechanical transport to the calciner – generally a tube-belt conveyer or its equivalent. For best practice, it requires a closed system, not a simple belt conveyer to avoid dispersion caused by windy conditions;
- an injection system – typically a double or triple flap valve. For best practice, it requires an additional safety (emergency) sliding valve.

The typical cost for the coarse solid feeding line[22] for one kiln is between \$2 million and \$5 million,[23] depending on the storage capacity, the maximum throughput, and the conveyor length. Significant economies of scale can be realized when such lines feed several kilns, as storage areas could be shared. This system accepts a variety of coarse solid AFR, and a range of consistencies. The use of AFR may make equipment modification necessary to prevent inefficiencies in the feeding line. The other alternative would be to use only specific RDF of a high density and calorific value.

One of the cement plants where interviews were conducted is equipped with a HOTDISC that is integrated to the calciner. This system allows for the co-processing of coarser waste, including bigger 3D materials such as full tires, RDF 300-500mm. However, investment in this case was significantly higher: approximately \$10 to \$15 million.

Typical operational expenses for co-processing waste vary between \$2 to \$5 per Gcal, depending on the volume throughput and labor cost, to be compared with \$2.5 per Gcal for coal on average, which includes grinding, drying and storing.

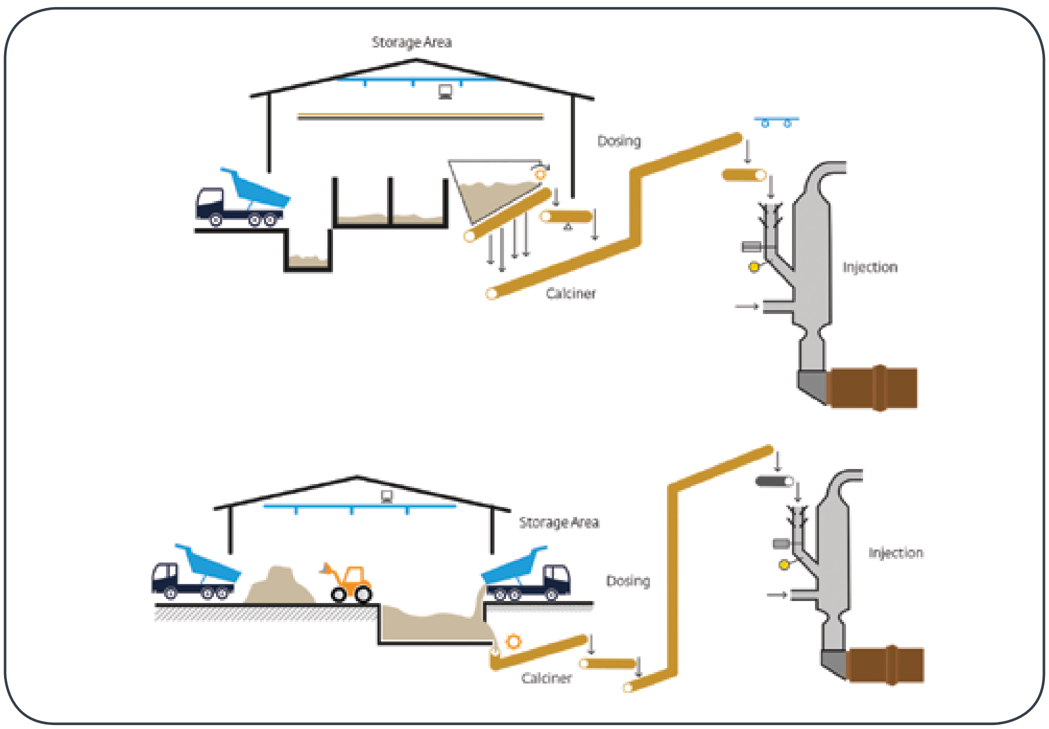


Figure 27: Schematic for Loader (top) and Bridge Crane (bottom) Operated Halls

22 Such a system allows for feeding at the calciner with various coarse solid AFR, typically 50-90 mm for 3D material and 100-200 mm for 2D material. The feeding of tire chips, agricultural waste or coarse RDF can be done using the same feeding line. Nevertheless, since the system is designed for a specific volumetric throughput, a very low density of RDF and certain agricultural waste (sometimes as low as 0.08 t/m3) can limit the maximum thermal substitution rate which can be achieved, if the system was not originally designed for very light material. Moreover, the blending of waste of different size and density is not very efficient. This explains the existence of bottlenecks in certain plants. The design volumetric throughput of the RDF feeding line can restrict increased AFR use. Without modifying the equipment of this line, the only way out is to use alternative fuels with a higher density or calorific value, such as TDF. Pelletizing RDF could be an option, but is rarely economically feasible. Designing a fully polyvalent feeding line using the full range of AFR in high volumes is technically impossible. Each technology has its own limits in terms of AFR physical characteristics (granulometry, density, elasticity, abrasiveness) and throughput (design capacity).

23 Interview with ATS Group, Mulhouse, France.

It is worth noting that co-processing electro-mechanical equipment already present in the plants, which were visited as part of this study, can generally be considered of "high quality." They are supplied by well-known and experienced suppliers.

Only two of the plants interviewed are using basic equipment. One is equipped for DSS, with a very basic injection system: hopper and injection screw feeding the coarse waste conveyer. This is adequate for limited volumes, but is not yet in use. The second plant is equipped with a basic pneumatic injection system for fine agricultural waste (ground rice straw). These two examples can be considered "pilot projects" rather than a true initiation of co-processing, due to the limited throughput and the insignificant impact on the plants' fuel costs. No real cost savings can be realized at these limited levels.

Most Egyptian plants are quite modern, and thus could theoretically accept TSR up to 30 percent without significant kiln modifications and related investments, such as calciner and cyclones upgrades. Only the investment related to the feeding of the AFR would be required. Furthermore, in specific regions, chlorine content in raw materials is high, but all plants are already equipped with a chloride (Cl) by-pass system. This could be an opportunity for profitable RDF use of this available by-pass capacity and related chlorine input capacity. Detailed chloride balances would be required for each plant in order to establish Cl acceptance criteria for AFR use.

Though achieving limited five to fifteen percent TSR is relatively easy, reaching high TSR (> 20 to 30 percent) requires technical knowledge that needs to be encouraged and developed in Egypt. TSR development will follow the learning curve, depending mainly on the efforts of the cement producers to acquire this knowledge and train their employees. International producers (which represent the majority of installed capacity) have this technical knowledge at the corporate level,[24] and are thus likely to lead the market to higher TSR levels.

6.3.2 Economics of Alternative Fuels

Evaluating the economic viability of AFR is a complex task, given the variety of sources and the requirements of pre-processing. However, the following sections will provide an overview of the economics for this waste stream as an alternative to coal and petcoke.

6.3.2.1 Purchasing the Source Material

The purchase price of raw and semi-processed AFR materials varies across regions within Egypt, as well as from one supplier to another. The variation is also dependent on the type of AFR. In addition to the purchase price of the raw materials, transportation costs and the calorific value of the AFR are also important cost and value determinates. The prices described in the table below are indicative, representing the average values collected through field interviews conducted in 2015.

Purchase Price – MSW and RDF

Waste Supplier	Current Price Range (without transportation)	
	USD/ton	USD/Gcal*
Municipalities – unsorted, unprocessed	1.15	0.4
Informal Sector (zabaleen groups) – sorted but unprocessed	Between 26.9 and 38.4	Between 8.9 and 12.8
RDF providers – sorted and pre-processed	64.1	18.3

* Calorific value is assumed to be 3 Gcal/ton for MSW and 3.5 Gcal/ton for RDF.

Table 29: Current Price of MSW and RDF

(Source: Cement Egypt Interviews, 2015; AFR Suppliers Interviews, 2015)

24 International cement producers usually have large technical research centers and technical departments at their worldwide head offices, and not in each of their subsidiaries.

Purchase Price – Agricultural Waste

Type of Agricultural Waste	Current Price Range (without transportation)		Remarks Calorific Value (Gcal/ton)
	USD/ ton	USD/Gcal	
Tree Trimmings	Between 19.2 (shredded) and 64.1 (pellets)	4.9 – 16.4	3.9 on dry basis
Cotton Stalks – wet	Between 25.6 and 32	6.8 - 8.5	3.8 (4.3 on dry basis)
Corn Stalks – wet	Between 25.6 and 32	6.8 - 8.5	3.8 (2.2 – 3.7 on dry basis)
Rice Straw – wet	19.2	5.4	3.6 (between 3.1 – 3.9 on dry basis)
Sugar Cane leaves – wet	Between 25.6 and 32	6.8 - 8.5	3.8 on dry basis
Bagasse – fully processed	Sugar companies request the equivalent of HFO price (US$311 per ton in 2015)	67.2	4.6 on dry basis

Table 30: Current Price of Selected Agricultural Crop Residues

(Source: Cement Egypt Interviews, 2015; AFR Suppliers Interviews, 2015)

Purchase Price – TDF/Scrap Tires

Truck tires consist of 25 percent steel wires. Hence, one ton of steel can be extracted from four tons of scrap tires. The price of steel scrap is around $105 to $155 per ton. Interviewees indicate that scrap tire prices have increased dramatically since December 2014.

Transportation costs for whole tires is a critical factor that contributes to the price of the tire. Collection and transportation of scrap tires generated from passenger cars are costly due to their volume. One ton of scrap passenger car tires is approximately 150 tires, and one ton of scrap truck tires is approximately 18 tires. As such, a five-ton capacity truck can only transport a maximum of 1.5 tons of scrap car tires. Transportation costs would also vary depending on the volume of tires and whether they have been previously shredded or not. Figure 28 summarizes this dynamic, and Table 31 provides some indicative prices for their transportation.

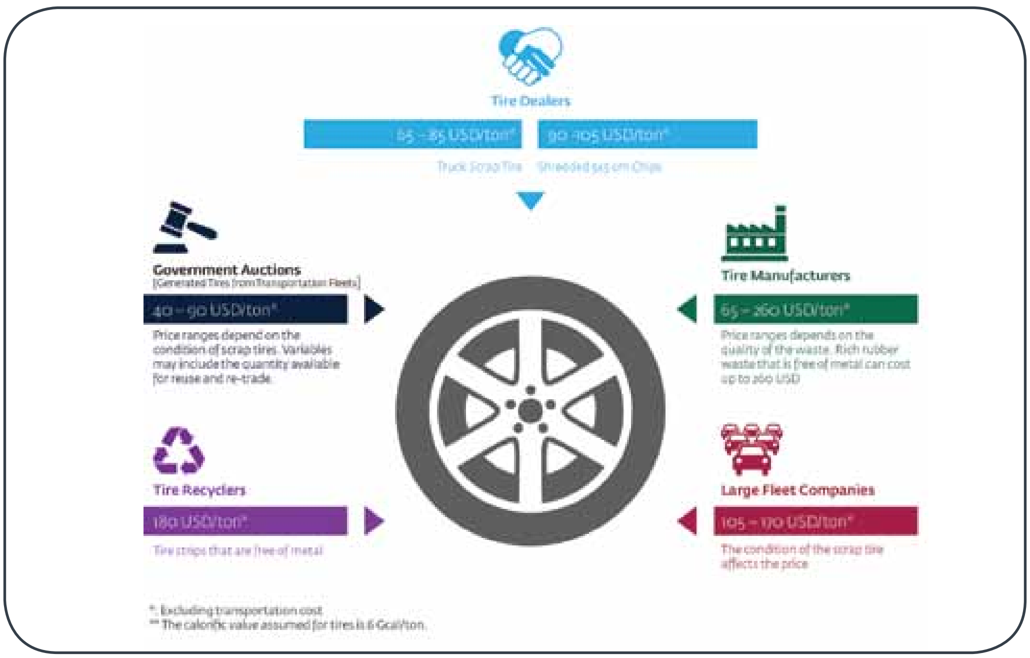


Figure 28: Current Price of Scrap Tires

(Source: Cement Egypt Interviews, 2015; AFR Suppliers Interviews, 2015)

Truck Design Capacity	Price (in USD per Km)	Minimum Charge (USD)	Remarks
5 ton	0.35	30 – 35	Price includes the return trip of the truck to its starting point, after delivery
20 ton	0.65	65 – 80	Price includes the return trip of the truck to its starting point, after delivery
It should be noted while calculating the transportation cost that the actual capacity of the truck depends on the origin of the tire, and its physical characteristics.			

Table 31: Transportation Cost of Tires

Purchase Price – Dried Sewage Sludge

The Holding Company for Water and Wastewater sells dried sludge as compost at an average cost of $8.3 per ton ($3.32 per Gcal or $0.79 per GJ). This price is offered at the treatment plant, and does not include transportation costs. HCWW is responsible only for loading the truck at the site.

6.3.2.2 Pre-Processing AFR and Related Costs

Most AFR cannot be used without some degree of pre-processing, the preparation or processing necessary to ensure fuel quality and homogeneity. Pre-processing produces fuel that complies with the technical specifications of cement production and guarantees that environmental standards are met. At the same time, however, pre-processing increases the operational (OPEX) and sometimes capital (CAPEX) costs of the cement plant. The four targeted waste streams in this study require a variety of pre-processing activities, as previously outlined in Chapter 3. As such, the expense of pre-processing will add to the initial purchase of the raw material.

- **Refuse Derived Fuel from Municipal Solid Waste**

  RDF is one of the most difficult wastes to prepare because the input (unsorted municipal waste) is often heterogeneous, and only part of the MSW is suitable for co-processing. The complexity of this pre-processing requires the waste to go through several preparation phases, thus raising the capital investment and operational costs required. MSW must be sorted in order to separate the recyclables (metals and some unpolluted plastics, glass bottles, dry unpolluted cardboard or paper), the inert materials (sand, stones, earth, glass) and the putrescible materials such as food, typically called “organics”, before it can become usable as fuel. The light and combustible fraction (typically 20-30 percent), such as wet and polluted paper and cardboard and plastic films, is then shredded to reach a usable size.

- **Agricultural Waste**

  Agricultural waste includes a broad family of different wastes. Its physico-chemical properties can be very different, particularly in terms of bulk density, granulometry, moisture content and calorific values. Moreover, the availability of most types is seasonal, which must be considered when designating storage volume. The design of installations dedicated to the pre-treatment, storage, handling and injection of agricultural waste is consequently specific to each project, depending on the local conditions, which may include

  - Type of biomass (granulometry, shape, density, water content)
  - Volume available and seasonality
  - Distances between the waste production site, the eventual collection/pre-treatment platform and the cement plant and transport mode
  - Local weather conditions (rain, wind)
  - Estimated consumption of the cement plant.

  Pre-processing is not always required. Seeds, for instance, can be directly co-processed. Size reduction by shredding is the most common practice. Pelletizing or drying, while also considered, can be cost prohibitive. Three processes are generally followed in agricultural waste pre-processing, depending on the waste properties and transport requirements:

  - *Shredding or grinding*: to decrease the size, as of wood, or increase the bulk density and the efficiency of baling, as with rice husk. The technology - shredder, chain mill, vortext mill - will be selected depending on the waste and any contamination with foreign bodies, such as stones.
  - *Drying* (natural air/solar drying, forced drying): to eliminate the water content and improve the calorific value, and to facilitate storage and handling. For economic reasons, natural or solar drying is generally preferred.

- *Compaction* (baling): to increase the density and to lower the transport and storage cost, as for straw or rice husk. Pelletizing is sometimes considered for specific streams, converting dusty materials such as into a material easy to handle. Its high cost, however, may be prohibitive for co-processing in a cement plant; pelletized fuel is mainly for domestic use and for co-processing in power plants or industrial boilers.

- **Dried Sewage Sludge from Wastewater Treatment Plants**

  Typically, sludge from wastewater treatment plants has a moisture content of between 50-80 percent. Before sludge can be co-processed, it should preferably be dried to below 20 percent water content, and homogenized. The different options for sludge preparation for co-processing are as follows:

  Sludge at 80 to 60 percent moisture content

  - If no significant fee is paid, no cement plant will consider co-processing sludge with a moisture content of 80 percent or above because of the difficulties in handling and injection, and the negative impact on kiln process (almost no heating value, loss of production capacity, risk regarding the flame temperature). Sewage sludge with very high moisture can be eliminated through the cement kiln, but since it has almost no calorific value, it cannot be considered as a viable option for energy recovery and thus the cement plant should be fully paid for the service.
  - Sludge can be directly injected into the riser duct using a concrete pump.

  Sludge at approximately 50 percent of moisture content

  - Pre-processing can occur by co-grinding the sludge together with coal or petcoke in the coal mill. It requires on one hand spare capacity in the coal mill (thermal power) and on the other a limit to the sludge volume so as not to exceed the volatile organic compounds (VOCs) emission limit at the stack of the coal mill. The dried sludge is then mixed with the ground coal, and they are fired together.
  - Pre-processing in a sludge dryer can reduce moisture content to below 30 percent. Various technologies are available, generally with significant investment or significant operational cost. Waste heat from the clinker cooler or from the flue gas of the kiln can be used, as well as biological degradation or solar energy. In Egypt, solar drying is an option. After drying, the sludge is screened, and then co-processed in a standard feeding line (generally using pneumatic transport).

  Sludge at between 15 and 30 percent moisture content

  - Direct feeding can take place, together with other solid alternative fuels, via a mechanical transport feeding the calciner. This solution would be not be appropriate for dusty dried sludge in typical calciner feeding lines.
  - Direct feeding to the calciner or the main burner can take place using a dedicated line with pneumatic transport.

  Since sewage sludge can sometimes contain large amounts of pollutants, such as heavy metals or phosphate, a strict quality control system must be in place.

- **Tire Derived Fuel from Scrap Tires**

  If no specific co-processing line for whole tires is installed, scrap tires must be shredded into chips of between 50mm and 90mm.

  These waste streams are clearly feasible as potential AFR for the cement industry. The costs of the necessary pre-processing, CAPEX and OPEX, are summarized in Table 32 and Table 33 based on interviews with cement companies and consultant experience.

	MSW/RDF	Agricultural waste	DSS	TDF
CAPEX (in million USD) per annual preprocessing capacity	Total = USD 5 Million • New sorting plant (300,000 tons per year MSW, trommel, magnetic iron separation and manual sorting): 1.4 million USD • Drying floor (open air, solar): USD 0.8 million • Shredding line (100,000 tons RDF per year) and basic baling: USD 2.8 million	USD 1.62 million (for 50,000 t tree trimmings)	USD 1.85 million or USD 3.3 million (for 30,000 t DSS)[3]	USD 0.6 Million (for 50,000 t TDF)
OPEX* in USD per ton (USD per Gcal)	Sorted: 45-58[1] (11.8-19.2) Unsorted: 36-38 (9.5-12.5)	8[2] (1.8-2.24)	9[4] (1.3-3.6)	19[5] (2.2-3.2)
Sourcing (USD per ton)	Sorted: 26.9 to 38.4 Unsorted: 1.15	19 to 47.4	8.3 (22% humidity)	40 to 260
Sorting and Drying (USD per ton dry)	17	2.5	3	NA
Shredding (USD per ton dry)	7.2	2.5	NA	15
Baling (USD per ton dry)	3	NA	NA	NA
Transportation (USD per ton dry)	8-10	3	6	4
Calorific Value (Gcal/ton)	3.05 – 3.82	3.56 – 4.32	2.5 – 6.93	5.97- 8.36

*OPEX includes sourcing, sorting, drying, shredding, baling, and transportation unless stated otherwise.

[1] Excludes amortization, transport, and any relevant tipping fee.

[2] Based on tree trimming waste, excludes amortization, transport, and purchase price of raw material from farmer.

[3] The estimate of USD 1.85 million is based on open-air solar drying and concrete floor, while the USD 3.3 million estimate is based on a closed solar drying greenhouse.

[4] Excludes amortization, transport, and purchase price of raw material from WWTP.

[5] Excludes amortization, transport, and without price paid for the waste tires.

Table 32: Estimate for CAPEX and OPEX of AFR Pre-Processing at Platform or Other Facility (Outside Cement Plant)

Waste Source	CAPEX per annual co-processing capacity (million USD)	OPEX in USD per ton (USD per Gcal)*
MSW/RDF	**USD 4 Million** (2 kilns co-processing lines, 100,000 tons of RDF per year)	8.8-10.8 (2.3-2.8)
Agricultural waste	**Fine Materials: USD 1 Million** Fine materials are alternative fuels which can be transported pneumatically, e.g. rice husk, sawdust or small size wood chips. They can often be stored in a silo, an enclosed storage being preferred for dusty products. For fine materials, a specific feeding line is generally selected, due to the relative low cost of pneumatic transport and the limited footprint of a silo. **Coarse Materials: USD 2.5 Million** Coarse materials, e.g. shredded wood, cannot be fed pneumatically and are generally fed to the calciner, using a common feeding belt with other alternative fuels such as RDF or TDF. Storage facilities are often halls operated with cranes or loaders.	17 (3.9-4.8)
DSS	**Dry Fine Material USD 1.8 Million** Storage and feeding line for 30,000 tons per year dry sewage sludge	19 (2.7-8.8)
TDF	**Whole tire feeding line** is approximately **USD 2.2 million** for a 20,000 tons per year capacity **Coarse solid mechanical feeding line** is approximately **USD 2.5 million** for a 50,000 tons per year capacity. **Tire shredding line** for 50,000 tons per year is approximately **USD 600,000.**	Whole tire feeding line: 15 (1.8-2.5) Coarse solid mechanical feeding line: 7 (0.8-1.2) Tire shredding line: 17 (2.0-2.8)

* Including transport and amortization.

Table 33: Estimate for CAPEX and OPEX of AFR Co-Processing in Cement Plant

Taking into consideration the level of CAPEX required to pre-process each waste stream, and the conclusions to be drawn from Table 32, a high level estimate of the total additional investment required by 2025 for BAU Scenario is provided in Table 34. This estimate is calculated by dividing the pre-processing capacity of each waste stream,[25] then the result is multiplied by the CAPEX of this specific capacity. For example, for 50,000 tons of tree trimmings pre-processing capacity (refer to Table 32) is divided by 1.5 million tons in volume required in 2025 under BAU Scenario, then multiplied by $1.62 million CAPEX to result in a total investment figure of $49 million (refer to Table 34).

AFR Type	Volume in 2025 (tons per year)	Thermal energy for TSR of 20% (million Gcal)	Investment (million USD)
RDF	1,361,000	4.8	22.6
Agricultural waste	1,512,000	6.8	49
DSS	439,000	1.4	27 - 48
TDF	102,000	0.7	1.2
Total		**13.6**	**100 - 121**

Table 34: Estimate of Investment Required for Pre-processing Facilities by Waste Type by 2025 under BAU Scenario

25 Indicated by the volume of waste available in 2025

Consequently, the total investment required to pre-process the required AFR amounts to reach a 20 percent TSR by 2025 will range between $100 - 121 million. This investment scale is directly correlated with the increase of the AFR thermal substitution rate. For example, it could reach up to $320 million if AFR pre-processing equipment is newly installed/re-habilitated in the 64 sorting and composting plants currently existing in Egypt (calculated on the assumption that on average $5 million investment would be allocated per plant).

While total CAPEX needs for co-processing across Egypt's entire cement sector have not been estimated,[26] this investment picture represents significant opportunity to attract investors and financial institutions to promote the AFR market. In general, the economic feasibility of AFR pre-processing projects, with the exception of TDF, results in an internal rate of return (IRR) of above 15 percent and a payback period of three to five years. However, this estimate should be confirmed through detailed feasibility studies on a project-by-project basis.

6.3.3 Comparison: Economics of Fossil Fuels versus AFR

Various fuel types have different calorific values, and so the cost of each combustible is expressed in $per Gcal to be comparable. For example, the average calorific value of heavy fuel oil (HFO) is 9,600 kcal/kg, whereas it is approximately 3,300 kcal/kg[27] for agricultural waste.

Since the start of the energy crisis, cement plants in Egypt have rarely used only a single fuel type, but rather have been co-processing with multiple fuels. Information gathered during interviews with the cement companies has allowed the 2014/2015 fuel mix cost to be estimated at an average of $30 per ton of clinker, based on a fuel mix including natural gas, other fuels such as HFO and including an overall average of six percent AFR. The price per Gcal of each fuel has been collected from the surveyed cement plants. In Figure 29, the bars represent individual value per plant and the encircled number is the average.

	Average Fuel Cost (USD/GCal)
MSW/RDF	15.7
Agricultural Waste	18
DSS	13
TDF	17
Natural Gas	32
HFO/Diesel	32
Coal	20

Table 35: Average Price of Fossil Fuels and Alternative Fuels at Cement Burner Tip

(Source: Cement Egypt Interviews, 2015)

26 Estimates vary for each plant and is subject to criteria such as existing production processes and equipment

27 Based on interviews with cement companies in April 2015.

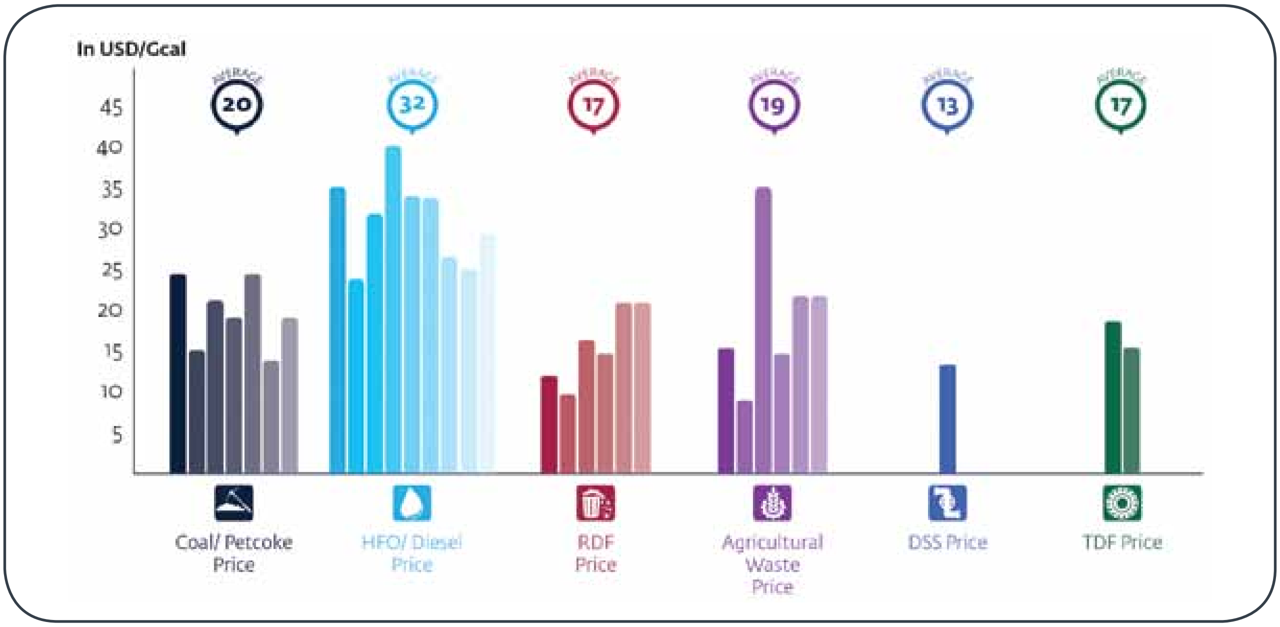


Figure 29: Average Fossil Fuels and AFR Prices at the Burner per Interviewed Cement Plant

(Source: Cement Egypt Interviews, 2015)

6.4 Summary

As long as coal is available, it will likely be the primary combustible used by Egypt's cement industry. This is not simply a product of price competitiveness, but also due to coal's physical and chemical properties when used in the clinker process.

However, it must also be noted that AFR could compete with coal prices and contribute to economic savings for the sector, if produced at scalable levels. To achieve this, the price difference between traditional fuels, such as coal, and AFR must cover the following additional costs borne by the cement plant in procuring and utilizing AFR:

- the amortization of the additional equipment that must be installed by the cement plant to co-process the AFR, such as the storage and handling equipment, and the dosing system.
- the additional operational cost related to co-processing, including the cost of the utilities (mainly electricity and compressed air), the wear part cost and the labor cost for operation and maintenance. This would also include any negative impact of the AFR on the kiln process and equipment, resulting in increased maintenance of the kiln system.
- the cost related to the sourcing of the waste, such as the labor cost of the AFR commercial team, and costs related to the AFR quality assurance lab.
- the cost related to the potential reduction of clinker production capacity because of the use of AFR.

To summarize, HFO is not widely available and will be unable to compete with coal in terms of price.[28] AFR, however, offers a potentially abundant, locally available and price competitive alternative to coal if produced at scale, and at required quality specifications.

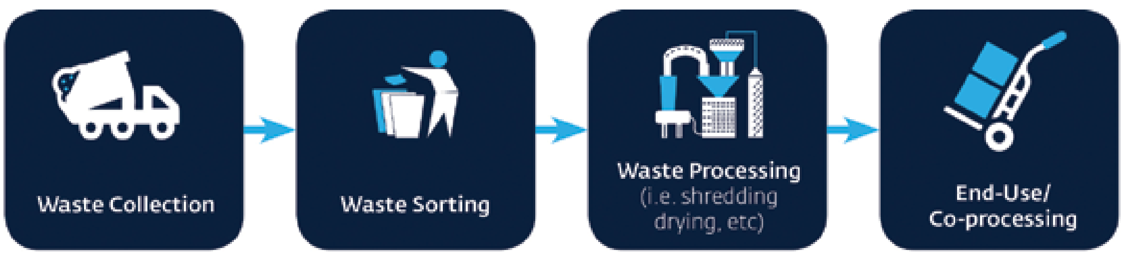
28 Future HFO and diesel in fuel mix is not expected to exceed five percent, according to interviews with the Egyptian Cement Producers Association.

Chapter 7: Establishing the Supply Chain

7.1 AFR Supply Chain

A structured waste supply and value chain is important to the success of increased AFR integration into the cement sector's fuel mix. The value chain involves procurement of waste and services, transformation of AFR into intermediate and final products, and delivery to the cement plant. These activities are realized through coordination and collaboration with channel partners, which can be municipalities and other public entities, intermediaries, third-party service providers and cement companies. In essence, effective supply chain management integrates supply and demand within and across multiple companies and entities.

In this chapter, various AFR business models will be presented, based on international experience. The perspectives of multiple actors in the supply chain in Egypt will be explored, and suitable integration models for each waste stream will be proposed that are suitable for country-specific circumstances.



7.2 International Experience on AFR Business Models

International experience shows that different business models are available for the waste supply chain. The integration models usually depend on the strategies of the cement companies. Vertical integration is one strategy used by a company to gain control over its suppliers or distributors in order to reduce transaction costs and secure supplies or distribution channels.[29] Backward and forward integration two approaches. A company that expands backward integrates into upstream activities in the supply chain, while forward integration means engaging in downstream activities towards the end-customer. The AFR supply chain is an upstream activity for a cement company, and therefore backward integration would be applicable in this case.

How can a cement plant integrate into the supply chain of alternative fuel suppliers and to what degree? Where can waste management firms be positioned to increase the use of AFR and take advantage of market-based opportunities? In general, options fall under three levels of integration: outsourcing (no integration), partial integration, full integration. This is illustrated in Figure 30.

29 Strategicmanagementinsight.com definition.

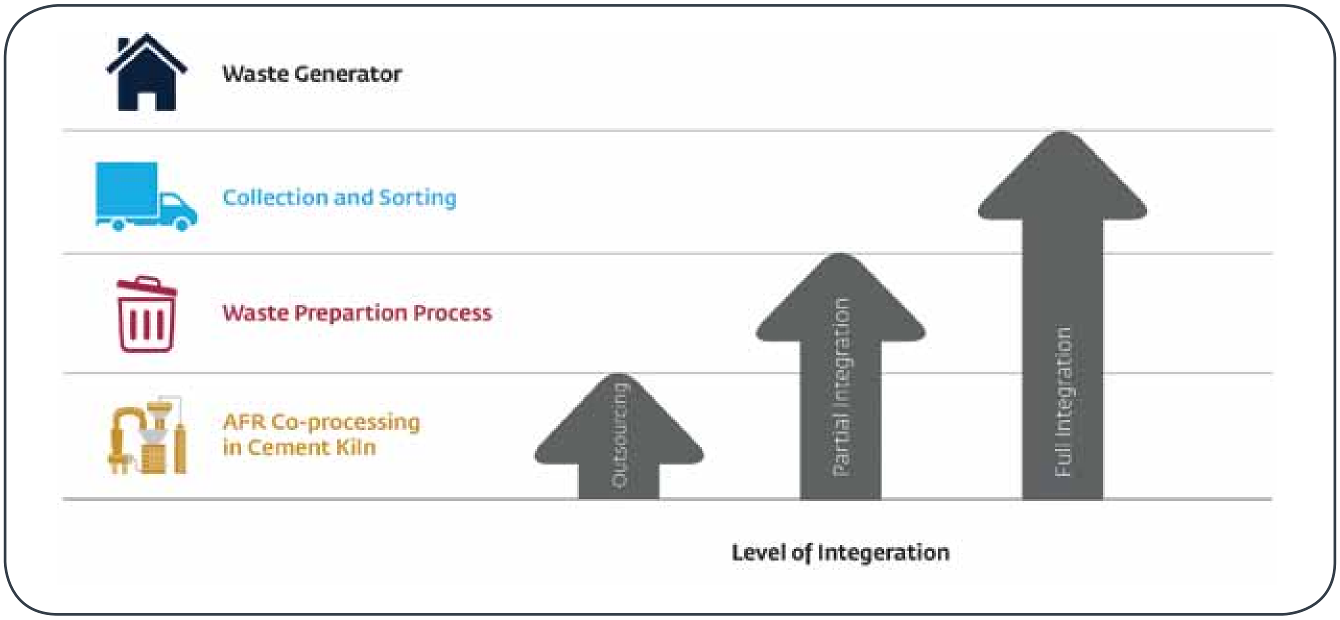


Figure 30: Backward Integration Levels into the Energy Supply Chain

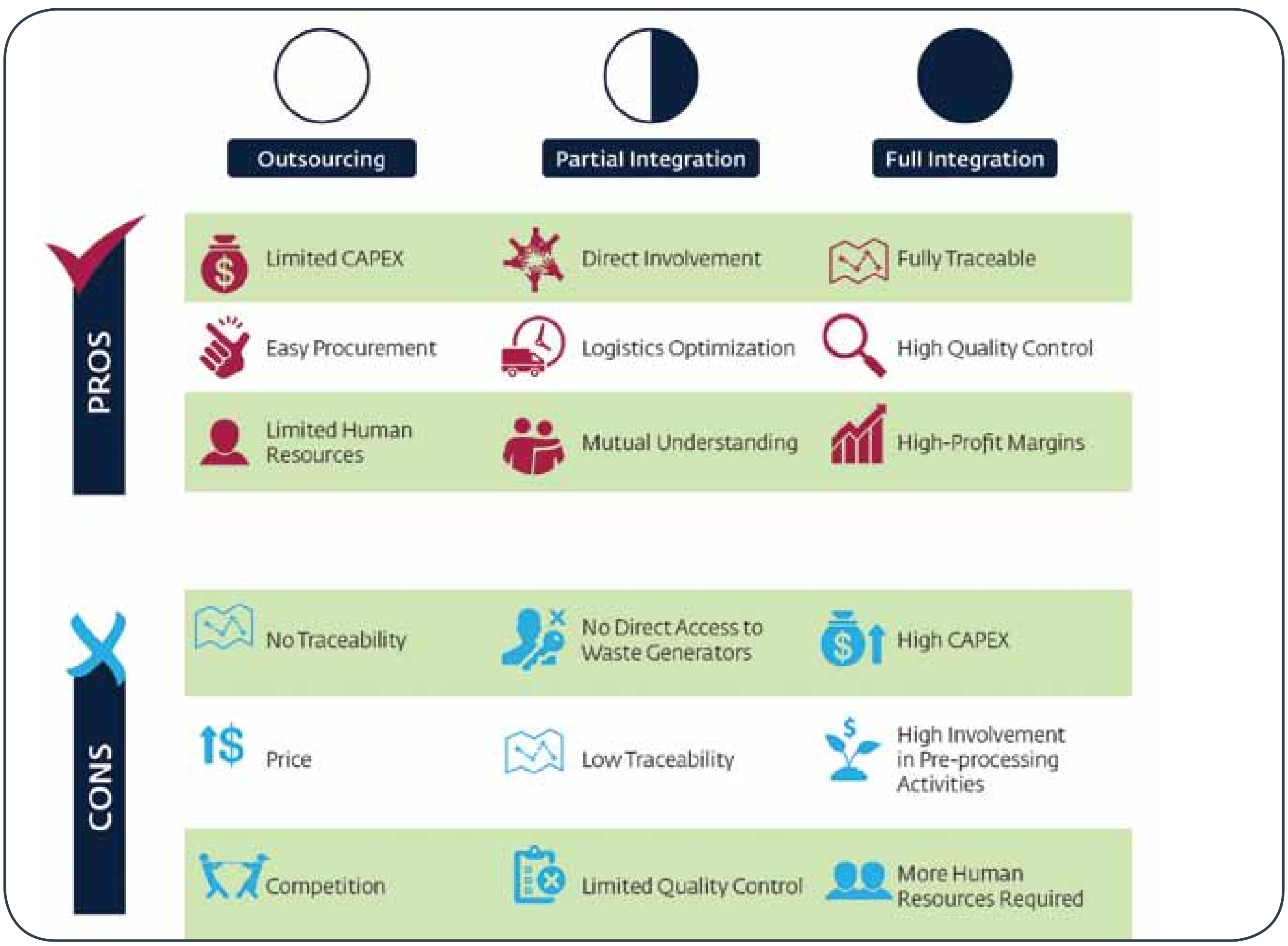


Figure 31: Viable Integration Levels for AFR

Integration Level 1: Full Outsourcing

In this model, the cement company directly sources "ready to use" pre-processed AFR from a third-party waste management company that is responsible for the entire process, from collection to pre-processing, and in some cases delivery. The cement company needs only to invest in equipment for the co-processing and storage of the AFR. It defines the AFR acceptance criteria that will be stipulated in the contract. If the AFR supplied to the cement plant gate does not meet the acceptance criteria, then the cement company has the right to refuse it according to the terms in the purchase contract. The cement plant may, however, be obligated to accept certain "take or pay" arrangements according to expected volumes, in exchange for offloading the quality risk to a third party.

From the perspective of the cement company, this model has advantages and disadvantages:

- Advantages:
  - o The cement plant does not need to invest in pre-processing activities; thus CAPEX is limited.
  - o Sourcing/procurement is easy when the waste is available.
  - o Fewer human resources are required in the cement plant to operate it.
- Disadvantages:
  - o There is no traceability and a lack of quality control. Thus, there are operational risks due to the uncertain heterogeneity of the incoming waste.
  - o As all intermediaries will take a certain percentage, the commercial terms of AFR may not be as attractive to the cement plant when compared with coal.
  - o There is a risk of competition for AFR with other thermal energy users, such as power plants, unless there are long-term contractual agreements on commercial terms.

In this model, all the activities between waste generation and delivery to the cement plant can be undertaken by waste management companies and other third parties. However, these companies should have solid knowledge of AFR preparation to meet cement plant requirements. This model will also require long-term upstream agreements between the waste generator and the management company on the one hand, and downstream agreements between the waste management companies and the cement plant on the other. Without which, waste management firms would be unable to secure a return on investment.

Integration Model 2: Partial Integration

In this model, the cement company invests in selected pre-processing activities such as sorting, shredding and drying. The cement plant does not collect the waste, but receives "raw waste" or an intermediary product from a waste supplier. The sustainability of this model requires a long-term commitment between the cement company and the waste supplier.

The cement company must consider the following:

- Advantages:
  - o There is direct involvement in waste sourcing, but with limited CAPEX and risks. Cement firms are in some ways protected from price volatility.
  - o Logistics are optimized between the pre-processing platform and co-processing location in the cement plant.
  - o There is better mutual understanding of each partner's business constraints.
- Disadvantages:
  - o The cement plant does not necessarily have direct access to the waste generators. This leads to a lack of waste traceability and lower profit margins.
  - o Quality control is limited because there is no direct link to the waste generator.
  - o Price and volume control may continue to be an exposure, with the cement plant having already made needed capital investments.

In this model, the cement plant makes the principal investment in the pre-processing platform, while the waste management company and other third parties are responsible for the waste collection, sorting and logistical arrangements. This offers the waste management company business opportunities, with lower risks when compared with the outsourcing model. In some cases, a joint venture for a pre-processing platform could be envisaged, but it is common practice for the cement company to retain management and control of the platform to maintain the desired AFR quality.

Integration Model 3: Full Integration

This model reflects the full integration of the cement company into the waste supply chain, in some cases even participating in the waste collection stage. There are only a very few cases worldwide, mainly in China and Japan, where a cement plant is fully integrated. In those examples, cement plants are located close to a landfill and the volume of MSW corresponds to the needs of the cement plant. Typically, a cement company will not undertake the collection of small volumes of wastes scattered geographically over vast expanses.

This business model requires that the cement firm significantly invest in the supply chain. The pre-processing activities would take place on dedicated land, owned or rented by the firm or inside its premises. Usually, this business model has its own profit/loss center, independent of the cement plant.

From the perspective of the cement company, the following should be considered:

- Advantages:
    - The cement company will be able to control and fully trace any type of AFR.
    - Higher margins are expected since there are no intermediaries.
- Disadvantages:
    - The cement plant will have to invest fully in the sourcing and pre-processing activities (and in rare cases in the collection stage).
    - The company will be directly exposed to price fluctuations in the procurement of raw waste materials.
    - The company will need to be involved in national or subnational waste management contracting.
    - Higher CAPEX and dedicated human resources are required.

Though the scope of activity for the waste management company is much more limited in this business model, it may still include waste collection and logistical arrangements.

Selecting a Model and Meeting Basic Commercial Requirements

Each cement plant can select a model by evaluating the following criteria: (1) price, volume and risk exposure; (2) degree of AFR quality control; (3) scale of investment required; and (4) complexity of operations. Some cement companies may be more comfortable with increasing their levels of AFR integration if they have been successful in other markets. Furthermore, the appropriate business model will vary depending on the type of waste stream, as summarized in Table 36.

Level of AFR Pre-Processing Integration	RDF	Agricaltural waste	DSS	TDF
Outsourcing	X	X	X	X
Partial Integration	X		X	X
Full Integration	X		X	

Table 36: Suitable AFR Integration Level by Waste Stream

Whatever the type of waste, there are basic commercial arrangements that should be in place in all integration models:

- **Security of Supply and Long-Term Pricing Options:** there needs to be a guaranteed AFR supply through both higher collection efficiency and long-term contracts of at least five years. In order for both the cement company and third parties to secure a return on their investments and ensure the sustainability of their operations, two major agreements are needed:
    - (i) a long-term supply agreement between the pre-processing firm and the collectors or suppliers (including municipalities), which need to agree on volumes and price; and

- o (ii) a long-term offtake agreement of the same duration between the pre-processing company and the cement company. The agreement would specify AFR off-take volumes and price, and any physical and chemical characteristics such as moisture content, calorific value and shredding size. For the pre-processing company, having both a supply and an off-take agreement could facilitate access to external financing.

- **Specifications and Quality Criteria:** it is critical for the cement firm and the waste management actor to agree on clear acceptance criteria for AFR. In order to ensure fairness in the execution of the contract, an independent expert should assess claims related to AFR characteristics.

Though not necessarily required, economic and regulatory **incentives/disincentives** such as tipping fees could increase waste collection, increase AFR supply, and improve project economic feasibility.

Global Trends

In the sustainability reports, global cement groups usually publish their level of TSR, fossil fuel savings and GHGs reductions, but do not disclose the economic savings related to the use of AFR. Further, little information is available on the specific AFR business models followed by each of the global cement groups. However, the following trends can be observed:

- Holcim operates several waste management platforms through its widely-known integrated subsidiary "Geocycle".
- Cemex tends to operate according to the outsourcing business model.
- Lafarge relies on both models.

These companies could follow different business models according to each country's waste portfolio. In Egypt, the most common AFR business model is outsourcing, where the cement companies simply source AFR from waste suppliers. ECARU and Cemex follow an intermediate model, where ECARU collects municipal waste and brings the sorted material to Cemex installations, located on ECARU land near a landfill. Cemex has not only invested in the equipment, but also produces, manages and transports the RDF. Another business case model defined as "integrated" is the one of ECOCEM (Lafarge). In 2010, Lafarge established a waste management subsidiary called ECOCEM Industrial Ecology Egypt, dedicated to the management of both municipal and industrial waste.

One of the cement producers interviewed is already equipped with a secondary shredder (the last step for RDF production), and receives baled pre-shredded RDF from a third party. Another cement plant interviewed has its own RDF production, but on a remote location and under another brand.

The majority of cement companies interviewed as part of this study plan to increase AFR thermal substitution rates. Many increasingly envisage entering into pre-processing as a consequence of the high prices of AFR on offer from the existing waste management companies in Egypt, unless competitive options can be offered.

None of the cement plants interviewed for this study have considered the "full integration" model, as it would require the cement plant to be located near a large landfill providing enough waste for its needs. Another major deterrent is that such an approach would force a cement firm to enter into MSW management, which is beyond the sector's business scope, interest and expertise.

7.3 Egyptian Specificities

The following section discusses the divergent opinions of cement industry actors and waste management companies, as vetted in multiple rounds of stakeholder dialogue conducted in conjunction with this report. The main constraints and solutions for AFR upscale include:

Cement Industry

During the energy crisis in Egypt, several of the cement companies purchased AFR at unreasonably high prices in order to be able to continue operations. Internationally, the main driver for co-processing of AFR is the reduction of thermal energy costs and the achievement of corporate GHGs commitments. But in Egypt, the principle motivation was at the beginning one of economic survival. To take advantage of the situation, several AFR providers had been selling AFR to cement companies on the same pricing scale as that for imported coal and petcoke (in Gcal). Clearly, this is an uncompetitive offer.

Several cement producers have stated that AFR use will continue only if the thermal cost at injection point will not exceed two-thirds (2/3) of the price of imported coal and petcoke. This difference is due to the fact that the use of AFR involves CAPEX, operational constraints, additional quality control, emissions monitoring and increased process complexity, as previously discussed.

For wider AFR utilization, the cement industry requires:

- sustainable, uninterrupted access to energy to produce cement;
- reliable, sustainable and predictable AFR supply inflow;
- stable product characteristics (granulometry, chlorine content, ash content, pollutant content, calorific value, water content); and
- AFR costs which are significantly cheaper than traditional fossil fuels.

The cement industry has proposed the following solutions:

- Clear acceptance criteria as part of contractual purchase agreements;
- Binding long-term arrangements between AFR suppliers and cement factories;
- Cement plant participation in financing equipment upgrades or technological introductions;
- Guidelines that include potential pricing and specifications in comparison with fossil fuels;
- Adoption of the Best Available Technologies (BAT) for AFR utilization and partnering with qualified experts in knowledge-sharing workshops and training programs.

Waste Management Companies

Waste management service providers include, but are not be limited to, SMEs working in informal recycling areas, more organized firms which may operate locally, and private companies that have not yet been involved in the supply of RDF and/or agricultural waste, but who foresee a possible opportunity. Waste management companies aim to produce stable AFR that will be accepted by clients in terms of quality and price, and that will generate profits.

The perspective of these service providers can be summarized as follows:

- Waste management service providers perceive waste as any standard combustible and want to align its price per energy content (in Gcal) to coal and petcoke.
- Waste management providers would be willing to invest if the price is attractive enough to make their operation economically feasible. Some of those currently involved in the supply of AFR do not believe that the prices deemed acceptable by the cement industry are attractive enough, especially given the required specifications and the current price of coal.
- Waste management providers would like to understand the technical specifications and constraints of cement plants.
- Small and medium sized enterprises lack adequate financial resources.
- The waste sector's expertise on AFR pre-processing needs to be improved.
- Some firms perceive insufficient AFR demand and expect non-cement sector clients.

Waste management companies have proposed the following solutions:

- Issue guidelines on AFR specification and pricing.
- Provide financial incentives. Specifically, create corporate social responsibility funds and clean energy funds.
- Facilitate the issuance of permits for AF producers.
- Enable knowledge-sharing in AFR production, including establishing a reliable data base for available waste quantities and specifications.
- Improve the efficiency of the waste supply chain for better business.
- Guarantee minimum contract terms and duration.
- Establish and support efficient and reliable waste collection chains.

This section has thus demonstrated the divergence in view points on what is needed to ensure commercial viability for the sector. Alternative fuel providers often have a different perspective from that shared by players in the cement industry. In the next section, business models will be proposed to bridge this gap and address the challenges which have been identified.

7.4 Proposed Business Models for Egypt and Recommendations per AFR Stream

7.4.1 RDF

Unlike the other waste sources, MSW has a much more complex value chain. In order to be used as a combustible, RDF needs a specific preparation process, as described in Chapter 6. It is one of the most difficult wastes to prepare because the input (unsorted municipal waste) is often heterogeneous, and only part of the MSW is suitable for co-processing. The complexity of this pre-processing requires the waste to go through several preparation phases, and thus requires substantial investments. The numerous processing phases which occur from waste collection through to the point of feeding into burn point at the cement plant suggest three main kinds of integration models, depending upon how a cement plant ventures into the waste preparation and supply process:

- *The full integration model:* This model is not often encountered for RDF and none of the cement plants interviewed are planning to consider it. Therefore this model will be omitted.
- *The partial integration model*: the cement plant injects the majority of investment into the RDF pre-processing platform, and the waste management company is responsible for the MSW sourcing and sorting. The pre-processing platform is preferably located on or close to the sorting and composting plant or landfill/dump site, thus avoiding re-transporting any waste that is unsuitable for co-processing. This model is often seen as optimal by cement companies because the cement plant controls the quality of the RDF it produces.
- *The outsourcing model:* The role is reversed and the waste management company invests in the RDF pre-processing facility and undertakes the risk of sourcing raw material, while the cement plant purchases the ready-for-combustion product.

Regardless of whether the partial integration or the outsourcing model is followed, the economic feasibility of the RDF pre-processing facility for the investor will be examined in comparison to coal at the burner tip in the cement plant. For example, the RDF pre-processing facility could have the following characteristics:

- A minimum annual volume of 200,000 tons per site (ideally 300,000 tons) is assumed. Below this volume, operating costs and amortization will be too high to compete with coal.
- The MSW is received at zero cost to the investor. Should there be a tipping fee, about $8 per ton is paid to the investor.
- The RDF pre-processing facility is located at an existing sorting and composting plant or landfill/dumpsite. The investor is the concession holder at the site and the investment is depreciated within ten years.

Five potential scenarios for the RDF pre-processing facility project arrangements are put forward in Table 37 under the assumption that the CAPEX is fixed and MSW is provided to the investor at zero cost (except in Scenario 3 where the investor is provided with a tipping fee). The scenarios interplay between three main OPEX variables by which revenue streams can be increased for the investor, which are: i) improving MSW input through separation from source, ii) payment of a gate fee, and iii) sale of recyclables. These improvements will optimize the RDF fuel source as a commercial opportunity. Source segregation in homes into compostable (organic) and non-compostable materials will reduce the sorting costs to the investor at the pre-processing facility. The tipping fee is paid to the investor by the authorities/municipality or by any private sector waste hauler seeking to dispose of waste (charged per ton of MSW delivered). The investor would pay the same tipping fee on any remaining residual waste material after sorting and processing, which would be sent to landfill for final disposal. The recyclables are mainly plastics, paper and cardboard, glass, and metals.

In brief, the main features of each scenario are (refer to Table 37):

- **Scenario 1:** there is neither separation of MSW taking place at homes, nor gate fee is received from the municipality; however the investor is fully entitled to the revenues from the recyclables sale.
- **Scenario 2:** there is no additional revenue stream to the investor, whether from gate fee, recyclables sale, or reduced sorting costs.
- **Scenario 3:** the investor will receive a gate fee from the municipality and a portion of the recyclables sale.
- **Scenario 4:** the investor will have two additional revenue streams: reduced sorting costs and recyclables sale.
- **Scenario 5:** the investor benefits from reduced costs after separation of MSW at homes.

	Scenario 01	Scenario 02	Scenario 03	Scenario 04	Scenario 05
Separation at Source	No separation at the source	No separation at the source	No separation at the source	Separation at the source	Separation at the source
Gate Fee	No gate fee	No gate fee	Gate fee (8 USD/ ton)	No gate fee	No gate fee
Recycables	recyclable fraction (sold at USD 120/ ton for dry waste)	no recyclables	very limited recyclable fraction (sold at USD 100/ ton for dry waste)	recyclable fraction (sold at USD 120/ ton for dry waste)	No recyclables

Table 37: Five Scenarios for RDF Pre-Processing Facilities

The economic feasibility of each scenario is assessed based on comparing the final RDF cost to the cost of coal at the burner tip. In Table 38, the RDF cost breakdown is detailed for each scenario along the entire operation chain at the pre-processing facility: from receipt of MSW, to drying, baling, and transport to the cement plant. After this, the costs of RDF storage, co-processing CAPEX, and production losses from water content in RDF are accounted for. In Table 39, the final RDF cost by energy content is compared to the average cost of coal of $19.8 per Gcal. It can be concluded that RDF pre-processing projects, under the five scenarios are in fact economically feasible. Scenario 3 and Scenario 4 are the most economically feasible, while Scenario 2 is the least feasible, at price ranges 51 percent and 76 percent lower to coal respectively.

Waste Stream	Cost in USD/ton	Scenario 01	Scenario 02	Scenario 03	Scenario 04	Scenario 05
Municipal solid waste	sorting plant gate	0	0	-8	0	0
RDF fraction sorted - before drying	sorting plant without drying (30 to 40% moisture)	3	15	1	1	7
RDF fraction sorted - after drying	sorting plant with drying (10 to 20% moisture)	5	20	2.6	2	9
RDF loose after shredding	sorting plant	14	29	12.1	11	18
RDF baled	sorting plant	18	33	16	15	22
Transport cost		10	10	10	10	10
RDF after transport to cement plant gate	cement plant gate	28	43	26	25	32
RDF including cost of storage and co-processing capex	burner tip	36	51	34	32	39
RDF (including cost of increased thermal specific consumption of kiln due to water content of the RDF)	Co-processed	38	53	36	35	42

Table 38: RD Cost Breakdown under Each Scenario Along the Value Chain

	Scenario 01	Scenario 02	Scenario 03	Scenario 04	Scenario 05
Cost of Dry RDF (in USD/ton at burning point)	38	53	36	35	42
Cost of Dry RDF (in USD/Gcal) *	11	15	10	10	12
% Cost of Dry RDF (Compared to coal at burning point)**	55%	76%	51%	51%	61%

* 1 ton dry RDF = 3.5 Gcal
** Coal = USD 19.8 per Gcal

Table 39: Final RDF Cost Comparison with Coal for Each Scenario

Therefore, there are significant opportunities for RDF in **the short-term** which can be pursued by private sector investors, as well as public stakeholders through establishing and securing commercial arrangements. These arrangements include improved investor access to disposal sites, such as landfills and composting sites, and prevailing MSW to investors at zero cost.

Scenarios 3 and 4 are the most economically attractive in comparison with coal, since they include additional revenue streams from gate fees and proceeds from recyclables. Even when there is no separation at source under scenario 3, the gate fee and the selling of the small recyclables portion should cover the cost to the investor of sorting at the RDF pre-processing facility. This RDF price under these two scenarios should be the **medium- to long-term** objective, given the institutional changes required. Two government interventions will be necessary to 1) establish source separation, 2) sustain it through transport to an RDF pre-processing facility, and finally to 3) enforce the payment of the gate fee or tipping fee. The economics could be further improved if a portion of the taxes levied on coal imports could be credited to the cement companies per ton of RDF.

The above factors will be further elaborated upon as recommendations for RDF upscale in Egypt.

<u>Investor Access to Disposal Sites</u>

As described in Chapter 4, a portion of the 60 percent of MSW collected annually in Egypt (equivalent to 12.6 million tons per year) is delivered to the 64 compost plants. The pre-processing of MSW to produce RDF consists of two main steps, excluding the composting processes, as shown in Figure 32:

- (i) Sorting of the MSW (sorting plant).
- (ii) Shredding of the light combustible fraction of the MSW (shredding plant).

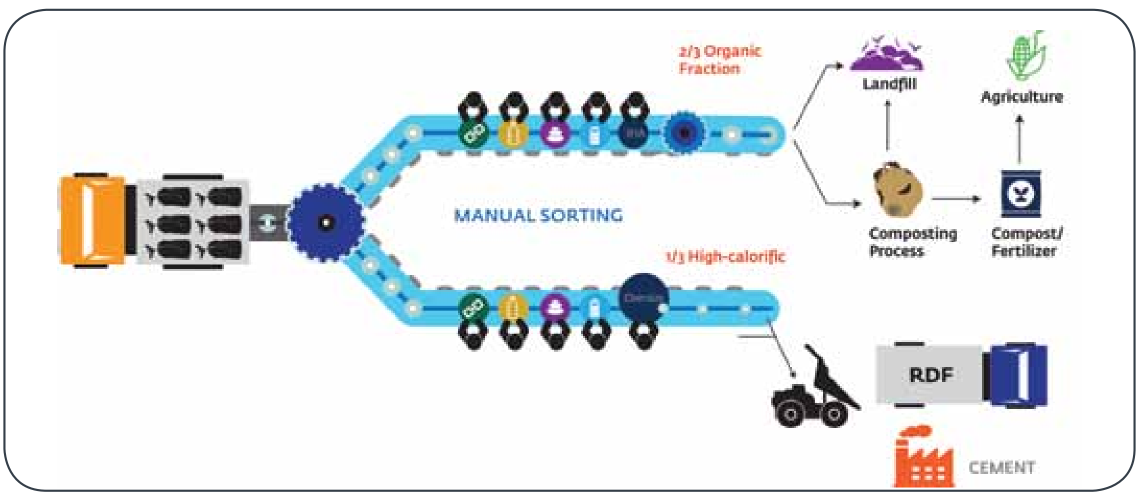


Figure 32: RDF Pre-Processing Platform

Currently, there are 64 composting plants distributed throughout the various governorates in Egypt (see GIS platform for exact locations of the composting plants: http://arcg.is/1ToAspz The exact condition of the equipment on each site is not known, but seems outdated based on interviews with stakeholders.

Public stakeholders who wish to offer concessions to the private sector for the sorting and composting plants or gain access to landfill sites will need to meet certain requirements:

- They must provide a selection criteria when tendering the management of landfills or sorting and composting plants which includes and evaluates the qualification of the bidder.
- Their concessions should be guaranteed for a minimum of 10 years.
- Waste collectors within the oversight of, or under contract with, the relevant authority, will be required to deliver all collected waste to the sorting and composting plants or landfill sites.
- Data on volumes of waste must be delivered to sorting and composting plants or landfill sites.
- Concessions and access to the sites are to be provided for free or at low cost.

One of the most important recommendations is that all revenues from any recovered recyclables, or other recoverable materials such as compost, should belong to the concession holder.

The existing sorting and composting plants under auction are without RDF production facilities, and will need to be equipped with new pre-processing equipment. Further, new pre-processing facilities could be installed at or near existing landfills. Therefore, landfill sites can also be considered as potential facilities, in addition to the existing 64 composting sites.

Tipping Fees:

It is common practice worldwide for waste disposal tipping fees to be levied in order to recover the costs of waste management. Such costs include landfill or processing site capital investment, site operational management, waste separation and safe disposal for final residues and recycling activities, and various other site management costs. Such tipping fees allow RDF to be economically more attractive, which creates a market for alternative uses for waste products.

According to the Confederation of Waste to Energy Plants, the average gate fee in 2015 for the EU27 is EUR 87 per ton MSW (CEWEP Landfill Taxes, 2015). Mexico, on the other hand, levies gate fees of approximately $10 per ton MSW in some landfills where pre-processing of RDF occurs. The main difference between European and Mexican prices is the difference in the level of sophistication of the equipment required in order to comply with local regulations.

As previously discussed, Egypt does not at the moment have a policy on tipping fees, but it is important to consider that even modest tipping fees, as in the case of Mexico, will have a positive impact on the use of MSW for other uses, offering a market-based incentive for this fuel and its alternative applications. It may be some time before tipping fees come into effect in Egypt, primarily because only a small fraction of all waste is landfilled in the first place. However, the existence of a tipping fee could encourage more efficient waste collection.

There is an abundant supply of MSW throughout Egypt, as indicated earlier. However, the lack of consistent collection, sorting, and disposal of waste poses a challenge to the efficient use of this resource. This waste stream is still usable, nevertheless. Potential investors can approach local governments with cost effective solutions to dispose of MSW, reducing the burden on infrastructure and hazards to public health. They can take advantage of the presence of waste processing sites to reduce investment costs and project development efforts. They can also work with waste haulers to agree upon supply arrangements with more logistically convenient drop-off locations, and help them understand the potential fuel savings of using these drop-off/pre-processing locations as opposed to traveling long distances to dump illegally in off-road areas.

Cement companies can define quality standards for RDF based on existing environmental conditions and communicate these standards to RDF pre-processing suppliers.

Government stakeholders should in the short term insist upon more rigorous enforcement of dumping penalties, while offering waste haulers cheaper solutions. For the longer term, public stakeholders should continue shaping a comprehensive MSW strategy which clarifies roles and responsibilities, as well as detailing authorization routes to supply agreements. Egypt's waste management vision must adopt a holistic approach that considers the system from household to disposal.

7.4.2 Agricultural Waste

Agricultural waste is a viable source of AFR, and given its large quantities, the reward of overcoming collection and transport hurdles is immensely promising. Due to seasonality, the diversification of agricultural waste streams is a risk mitigation step needed to secure the supply of the waste. However, the selection of the agricultural waste types used for co-processing should not compete with other high-value uses, such as animal fodder.

Cement companies do not usually involve themselves in the collection and preparation of agriculture wastes. In some cases, the cement plant does the final shredding, due to its in-situ acceptance criteria. Therefore, the outsourcing model is preferred by cement companies for agricultural waste. The waste management company should be in charge of the collection, storage, shredding, baling and final transport to the cement plant. Shredding, if needed, can also be done at the cement plant in order to avoid accidental fires during storage, and to facilitate transport. Bales are easier to transport than shredded agricultural waste.

Collection and storage locations are paramount to the success of the business, since most of the cost is related to logistics. Locations shall be carefully assessed, taking into consideration the location of the targeted cement plants as well as the collection points (farms). Intermediary collection points, to which the farmers bring their waste, could be sited in areas where crop volumes are very fragmented.

Though conversion of agricultural waste to AFR offers perhaps the highest potential to local entrepreneurs in comparison with other waste streams, it needs government incentives and regulations. The scope of this business for waste management companies would not be limited only to the cement sector, but also to other future users, such as power plants.

<u>**Further Action:**</u>

Investors in waste pre-processing activities can invest in the development of a collection and supply chain. Ideally, the chain must reach geographically distributed small-holder farmers, and do so in a logistically efficient manner. Awareness can be raised in the farming community about the potential value of selling rather than burning agricultural waste products.

Government stakeholders can review regulations governing the storage of agriculture waste and amend them in order to accommodate the need for large waste volumes. Such regulations should define, among others, the safety criteria for a storage facility. Government authorities should also more strictly enforce bans on open air burning.

As it has with RDF, the government could encourage agricultural waste usage by directing taxes collected from the cement industry for coal into the market development of AFR. This incentive can be allocated per ton of waste co-processed, and its amount can depend on the waste's calorific value. Authorities should maintain the subsidies, facilitate access to storage space (generally a piece of land) for waste management companies, and allow storage under strict safety conditions.

7.4.3 Dried Sewage Sludge (DSS)

Sewage sludge has an important advantage in Egypt, compared with other AFR sources: it is under a single holding company for water and wastewater treatment, without multiple intermediaries to deal with. But as previously described, the main obstacles for co-processing of sewage sludge in Egypt are high moisture content and contamination with inert materials such as pebbles and sand.

The scale of investment and operating costs are directly linked with final moisture content and environmental constraints such as odor control. There are, however, several drying technologies available. Sun drying is preferable to the costly investment required for mechanical dewatering through filter presses. Sun drying depends mainly on the volume of sludge, on the civil engineering cost, and on the need to produce DSS during winter months. Winter operations, and odor issues, require construction of a greenhouse, a costly investment, and perhaps also bio-filters to treat the odors. The inert material could be removed simply by setting up a concrete floor when drying sludge. The sludge can be turned using agricultural equipment, and screened to eliminate pebbles and other inert material.

The three potential integration models that are applicable for sewage sludge include:

- *The 'full integration' model:* the cement plant or its subsidiary AFR company collects the sewage sludge from the waste water treatment plants, transports it for drying in another location, and then finally co-processes DSS in the cement plant. This model requires significant investment in drying technologies, land purchase, and transport infrastructure (truck fleet, pipeline). This could be a viable option if the WWTP is close to the cement plant and land is available for drying.
- *The 'partial integration' model:* the cement plant fully or partially invests in drying technologies at the WWTP facility.

Cement plants seldom invest in the WWTP itself, but a JV and/ or direct involvement can be considered on a case-by-case basis for the final dewatering system and the logistic optimization, provided that long term contracts are secured. The drying process could be operated either by personnel hired by a cement plant or its subsidiary AFR company. Alternatively, this role may be extended to WWTP personnel, under the supervision of cement plant experts, to ensure that the DSS achieves the required quality criteria.

- *The 'sourcing' model*: the most common practice is for the cement plant to receive the sewage sludge directly from the WWTP after an auction. However, at present sewage sludge from WWTP is available at 80 percent of moisture content. The moisture content should be decreased to 20 percent to attract cement plants to source from WWTP. A third-party waste management company could be invited by the WWTP to submit proposals to invest and operate the sewage sludge drying process, whether at the WWTP facility or at another location, in order to supply cement companies with DSS at acceptable quality.

For future wastewater treatment plant projects, HCWW could initiate discussions with neighboring cement plants during the design phase. Such partnerships can develop mutually acceptable solutions that aim to maximize sewage sludge recovery by minimizing the moisture content. This will also help to define the optimum investment required for DSS recovery as a fuel and raw material.

<u>**Further Action:**</u>

Investors in AFR pre-processing activities can

- consider co-investing in drying facilities at the WTTP plant as a joint venture with the WWTP operator, in exchange for attractive terms in the supply contract;
- agree with the WWTP operator on the quality and humidity of the final product.

WWTP operators can

- investigate and invest in innovative technologies for sludge treatment to reduce the water content of sludge, including specially-designed greenhouses or indirect thermal dryers which use less heating (DAAD, 2011). Reducing moisture can also make transportation more cost effective, which may warrant a premium price and increased sales quantities of the DSS product by off-takers.

Government stakeholders can

- offer incentives to WTTP operators to invest in drying facilities in order to reduce other environmental hazards and improve disposal options;
- allocate land for natural drying, in accordance with environmental and social standards. Land allocations should be reviewed for economic viability, with factors such as transportation costs from the WWTP to the cement plant taken into consideration;
- increase enforcement banning the use of non-stabilized sewage sludge.

7.4.4 Used Tires (TDF)

TDF is potentially very attractive for co-processing in cement plants due to its high calorific value and simple pre-processing (mainly shredding). Further, scrap tires offer the highest yield for recycling. Since recycling is above co-processing in the Waste Management Hierarchy Pyramid (refer to Annex B), it should be given priority. As with agriculture waste, however, collection of waste tires is a major obstacle that impacts the final cost.

It is difficult to apply the *full integration* business model, since the sources of scrap tires are usually too scattered for a cement company to enter into collection. The only possible exception would be direct collection from tire dealers, or government and private company auctions. The cement plant could adopt the *partial integration* business model by investing in a shredder near a tire collection center, while obtaining whole tires from the market through tire dealers or auctions.

Under the *outsourcing* business model, the cement plant would only source pre-shredded tires size 50 mm to 80 mm that are ready to co-process, should a whole tire feeding line not be installed. The shredding of tires would then be performed by a third-party waste management company at a collection site. This could be the preferred model since it has a number of advantages for cement companies. The first is the reduction of logistic costs, as shredded tires are on bulk density of 0.6 ton per m^3, while whole tires are 0.2 ton per m^3. Further, it allows the use of existing co-processing facilities in the cement plant (calciner mechanical feeding systems) and eliminates the need for specific investment due to relatively inexpensive storage (open air storage, limited fire protection).

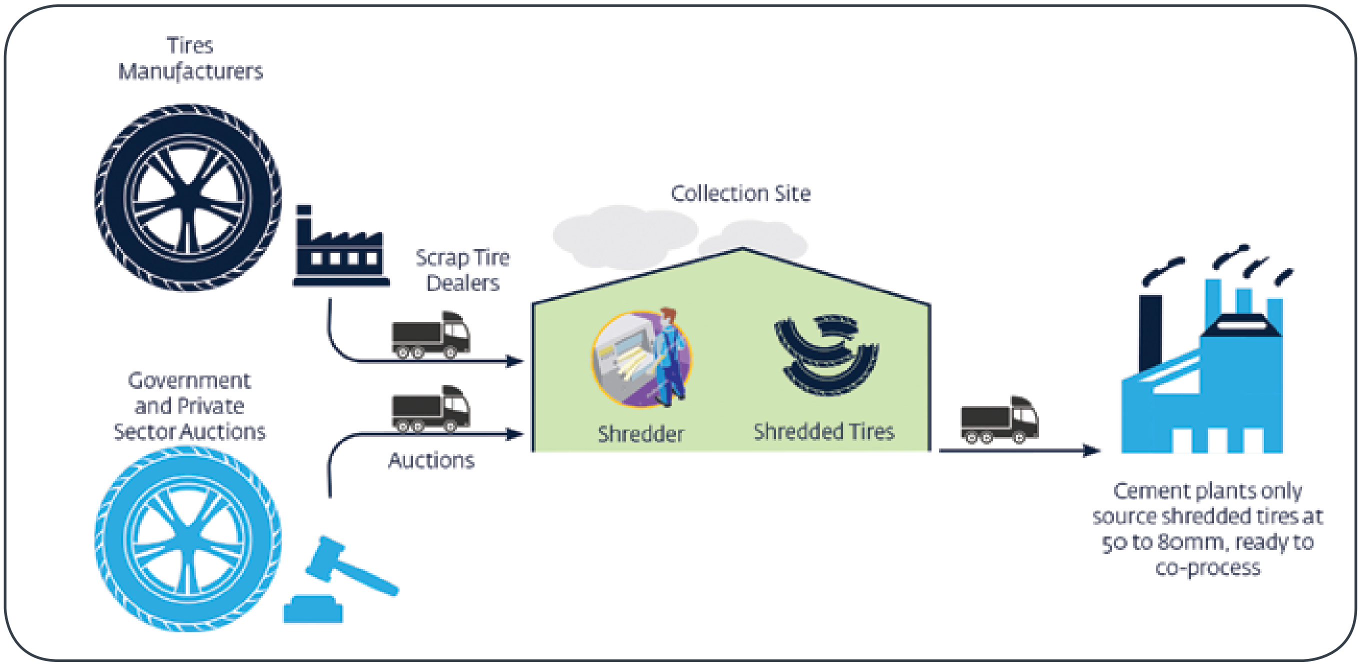


Figure 33: Proposed Scrap Tires Supply Chain Under Partial Integration or Outsourcing Models

Box 3
AGGREGATION SCENARIOS

The supply chain of used tires for cement plants is often based on direct agreements with manufacturers. In cases where there are multiple buyers and suppliers, aggregation emerges as a key route to support material recovery efforts.

One case study involved South Africa's Recycling and Economic Development Initiative (REDISA). Established in 2012 to reduce the environmental and health impacts of poor tire-management practices, the initiative put together a collection network to discourage the opening burning of discarded tires. This aggregation effort helped increase collected volumes from 4 to 70 percent of end-of-life volumes from 2013 to 2015 (Engel et al., 2016).

REDISA is working on developing commercial and environmentally sustainable infrastructure for tire treatment. At larger streams, it becomes easier to distribute to processors across South Africa.

The success of the TDF business model will be mainly price driven if scrap tires can be collected in greater quantities. If waste management companies enter this market, there are opportunities for them to supply and provide pre-shredding services at acceptable quality and at lower prices than the whole tires provided by the tire dealers. To improve the collection rate, it will be essential to divert local scrap tires from burning to co-processing. This would be more environmentally friendly, and could be achieved by imposing a traceability mechanism for end-use on scrap tire dealers, regulating and aggregating the collection and disposal of waste tires from tire workshops and other sources, and formally registering buyers in tire auctions. The budget could be raised by the government under the *polluter pays principle*, where vehicle owners pay an extra fee for every new tire purchased, to ensure the safe disposal of old tires. Similarly, an ecotax imposed on new imported tires would also be an option.

In Europe, the introduction of the principle of *extended producer responsibility* facilitated the development of this market. In France, for example, Aliapur, owned by major manufactures, managed the bulk of tire deposits. In general, supply chains of used tires for cement plants are based on direct agreement with manufacturers.

Further Action:

Investors in pre-processing can raise awareness on the use of TDF as a fuel in other countries.

Cement companies can raise awareness with government stakeholders on the use of TDF as a fuel in other countries, as well as on environmental mitigation measures.

Government stakeholders can consider aligning with the Basel Convention's categorization of tires, which does not classify tires as hazardous waste. They ought to also consider adopting environmental mitigation requirements similar to those of cement companies in using TDF as a thermal fuel.

Strict governmental auditing and monitoring of the whole process will be crucial to the proper implementation of the system. A legal framework regulating the collection and disposal of waste tires must not only be adopted, but rigorously enforced, for the good of the environment as well as for commercial advantage. Only at the government level can the uniform monitoring take place which will equitable application of fee policies, providing financial incentive to waste collectors to improve their efficiency. In addition, the government will be responsible for increasing the monitoring of workshops, which can be done by monitoring tire imports.

The authorities can increase enforcement of the ban on open air burning or dumping through regular controls and fines, in particular with regards to the informal sector of brick manufacturers that combust scrap tires as fuel. They can formalize the second hand market for waste tires: for example, auctions held by the government on waste tire streams must no longer be open to informal players, but only to registered buyers, who should represent end users like recyclers or production facilities able to co-process used tires in an environmentally safe method. Dealers who have been reselling used tires for open-air burning should be banned from participating in such auctions to force compliance.

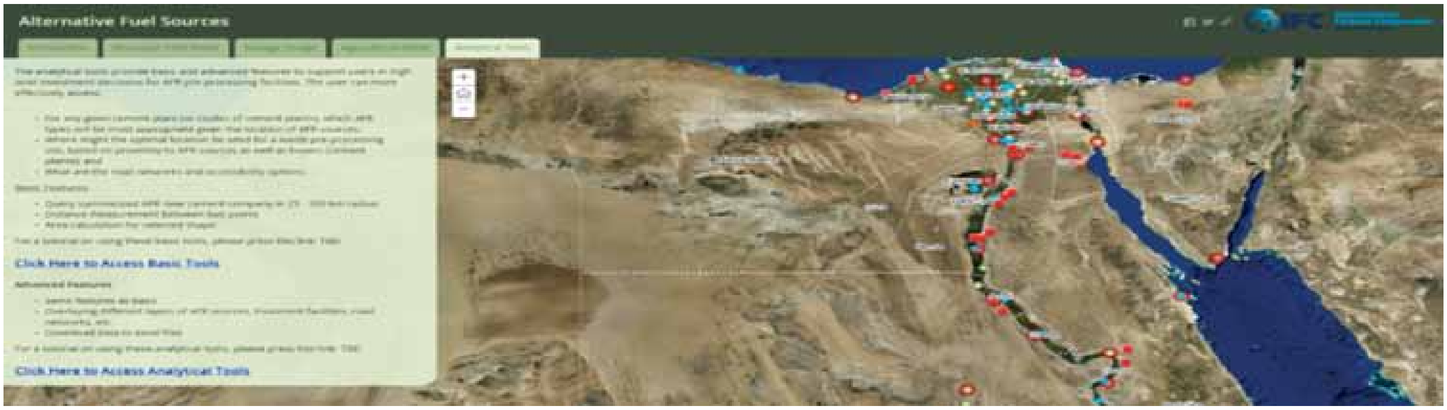
7.5 Geographic Distribution

Logistics challenges constitute one of the most important factors in assessing the economic viability of AFR use in Egypt. Transporting waste materials, processed and unprocessed, to cement plants involves costly transportation charges. As an example, cement plants are commonly located on the outskirts of the main cities, while MSW sources are concentrated in the inner cities. Agricultural waste sources are concentrated along the Nile and Delta region, while disposal sites are more convenient to urban needs.

In order to address these challenges, this study has produced a Geographic Information Systems (GIS) tool to allow evaluation of the concentration levels of the AFR sources, and to assess distances between the supply and demand points. In doing so, the user can more effectively assess:

- For any given cement plant (or cluster of cement plants), which AFR types will be most appropriate, given the location of AFR sources;
- Where the optimal location might be sited for a waste pre-processing site, based on proximity to AFR sources as well as buyers (cement plants);
- What the road networks and accessibility options are.

The Egypt AFR GIS tool can be found here: http://arcg.is/1ToAspz



7.6 Summary

This chapter has aimed to show that structured waste supply chains are an important success factor for AFR projects. While Egypt has yet to develop a fully integrated system, international experience has shown that there are different commercial models available within the waste supply chain. Economic and regulatory incentives and disincentives, while not mandatory, could increase waste collection, increase AFR supply, and improve overall economic feasibility for any given project.

The models reflect three levels of integration into the upstream activities of the supply chain: outsourcing (no integration), partial integration and full integration. Each has its advantages and disadvantages. These vary by waste type in the following ways:

- **RDF:** the *partial integration* and *outsourcing* business models are preferable with this stream. Commercial arrangements to guarantee improved investor access to disposal sites are necessary. Municipalities should provide MSW to the investor at zero cost. Cement companies and waste management companies can then arrive at agreements on RDF price and quality. Additional revenue streams from gate fees, proceeds from recyclables, and separation at source would also improve the economies of RDF projects.

- **Agricultural waste:** the *outsourcing* model is preferred by cement companies as they seldom involve themselves with the collection and preparation of agriculture waste. Since most of the cost is related to logistics, the location of the pre-processing facility should be carefully assessed, taking into consideration the location of the plant as well as collection points.

- **DSS:** all three business models are applicable for sewage sludge. The main bottlenecks for co-processing of sewage sludge in Egypt is quality-related, due to its high moisture content and contamination with inert materials. The major advantage over other AFR sources is that it is under the control of one government entity.

- **TDF:** the *partial integration* and *outsourcing* business models would be mainly price driven, if scrap tires become more accessible through higher collection efficiency. This could be achieved by regulating and aggregating the collection and end-use of scrap tires.

There is a need for all stakeholders to react quickly to grasp the alternative fuel market opportunity. Waste pre-processing companies have an advantage in shaping and consolidating their positions, but they must understand that all cement plants are not equal regarding their ability to co-process alternative fuels. The success of alternative fuel projects will depend greatly on the establishment of transparent dialogue and trust relationships among stakeholders that would allow them to openly assess the type of processes needed, the quality of raw materials, and the nature of the business approach required. For whatever the type of waste, there are basic commercial arrangements that should be in place. Secure supply, a fair pricing mechanism and acceptable quality will guarantee a return on investment for each party in the supply chain.

Chapter 8: Conclusions and Recommendations

8.1 Summary

Egypt's energy crisis forced cement players into the AFR market. In the search for a combustible to compensate for natural gas shortages, the industry was compelled by economic necessity. Today, that picture is changing. By removing the subsidies on natural gas, and allowing the use of coal and petcoke for the cement industry, Egyptian authorities have definitively changed the fuel mix for the cement industry in the medium- to long-term. As all cement plants complete the equipment investment necessary to use coal and petcoke, the shift is expected to become permanent. It is within this context that any attempt to further the uptake of alternative fuels must be understood. To be competitive, price, volumes and quality considerations of alternative fuels must be put at the forefront.

Alternative fuels form one of the main levers for carbon dioxide reduction in the cement industry. Co-processing AFR in cement kilns could offset the additional GHGs emissions generated by the fuel switch to coal. It can also reduce the volume of waste that is currently available, but generally (mis)managed, and make efficient use of its energy content. This promises to create sizeable new business opportunities for local or international waste management companies that will enter into waste management services dedicated to the production of AFR. Further, co-processing reduces the use of raw materials by the cement industry and reduces dependence on hard currency, at a time when it is critically needed to keep the country's economy afloat.

Egypt's cement industry has had an advantageous start. A large majority of cement producers are either already equipped to co-process AFR, or soon will be. As the country's energy mix is diversified, the sector is in an increasingly valuable position in consolidating and shaping the waste-to-energy market more broadly. The TSR goals of up to 30 percent may be ambitious, as compared with European experiences, but the business-as-usual scenario could lead to 20 percent TSR by 2025, up from six percent on average in 2015. This move would save up to 1.9 million tons of coal per year[30].

In addition to those recommendations presented in the previous chapter, a brief summary of overall key recommendations to unlock the market potential for AFR is presented below.

8.2 Addressing the Supply & Demand Gap

Egypt's nascent alternative fuel market started off on difficult grounds. While there is a significant business opportunity for AFR waste processing companies in Egypt, waste processing firms and the cement industry do not necessarily understand each other's viewpoints. At the peak of the energy crisis, there were too few waste processing players and not enough supply. Alternative fuel products were arriving at plants without matching the quality preferences of cement manufactures or meeting their expected prices.

This experience, however, also offered valuable lessons. Alternative fuels are demonstrably available in sufficient quantities, enough to reach very high levels of TSR rates across the cement sector in Egypt. AFR can potentially compete with coal and other fossil fuels if managed throughout the value chain in a prudent and commercially-oriented manner. But this also means that all stakeholders in the supply chain must understand that each AFR stream has specific pre-processing requirements. AFR pre-processing activities range between the waste generators (supply) and the cement producers (demand), and involve very different business models and mindsets. The gap engendered and exposed by early mistakes in transactions between cement plants and waste processing firms can be bridged. In fact, arriving at a common understanding will be necessary to develop the AFR market. This requires transparency, open dialogue, and a systematic effort at building trust with and among stakeholders.

30 Savings in coal volume, based on 2025 cement production generated by a 20% TSR.

Table 40 and Table 41 show some of the most significant differences in mindsets and business approaches among the cement industry actors and those in the waste processing business.

The Supply Side: The Waste Sector

Business Differences	Mindset Differences
Waste is usually generated seven days a week – 365 days a year	Entrepreneur mindset
It is a very dynamic and moving business model where priorities can change daily	Generally managed as small organizations and often under sole ownership
Waste is highly variable in volumes and physical and chemical characteristics	Short decision-making process
Waste can be generated from any human-related processes. Waste materials could also be "out-of-spec"	Quick adaptation to strategy shifts
Waste can be considered hazardous or not; the corresponding legal framework can often vary or be subject to different interpretations	Tolerance for risk
Waste usually requires low CAPEX and has a short-term return on investment	Quick reactions
Heavy dependence on logistics arrangements	Offers full services to client
	Waste owner expects to be paid for raw waste and considers the business a service

Table 40: Operational Characteristics of Waste Suppliers

The Demand Side: The Cement Industry

Business Differences	Mindset Differences
Steady and stable business	Static mindset
Production of the same intermediate product (clinker) for decades – standard chemical process worldwide	Generally big organization with multiple internal and external stakeholders and complex management lines
Capital intensive industry – high CAPEX – with long-term return on investment	Long reaction time
Specific and fixed legal framework	Long decision-making process
Long-term permitting system	Slow adaptation

Table 41: Operational Characteristics of the Cement Industry

It is thus clear that both waste suppliers and cement plants need clear acceptance criteria when sourcing AFR. Precise acceptance criteria will prevent conflicts between the cement plant and the waste provider by defining the conditions under which the cement plant can refuse the waste. Pollutant content, moisture, minimum thermal energy content, particle size and shape will need to be defined. The cement plant will have to be cautious when accepting waste and/or AFR because of the possible impact on emissions, on its kiln and on its final product. Trust will have to be developed during years of collaboration, on a basis of clear and transparent contractual arrangements among all stakeholders. Clear boundaries of responsibility must also be established in order to avoid misunderstandings.

8.3 Recommendations

Each of the four waste streams has different characteristics. RDF, DSS, and agricultural waste seem financially attractive, even when compared with coal. Current prices of scrap tires appear to be higher. In order to organize the features of these four streams for more efficient decision-making, they are prioritized below in Table 42.

	Priority 01		Priority 02	Priority 03
	Agriculture waste	Dried Sewage Sludge	RDF	Scrap Tires
Reason for Ranking	• Waste ready for use (no major pre-processing CAPEX needed) • Easy & quickly adaptable for AFR usage	• Waste is ready for use after drying and removal of inert material • Low investments	• Waste volume is huge • High CAPEX • Requires strong collaboration between all parties: cement companies, waste sector, and municipalities	• Limited amounts available due to competing uses • High prices

Table 42: Prioritization of the Four Waste Streams as AFR for the Cement Sector in Egypt

The first priority should be agricultural waste, as it requires mainly logistical interventions, but limited CAPEX and OPEX. The second priority should be dried sewage sludge, as it doesn't depend on policy action and also requires limited CAPEX and OPEX. RDF is in third place, as it requires high CAPEX and OPEX. Further, municipal waste availability depends heavily on the improvement of collection rates and the overall management of waste across the country. The lowest priority is scrap tires, as the numerous alternative options to their co-processing in cement kilns make their price unattractive.

DSS has the highest potential in the long term. If the largest part of the MSW and agricultural waste could be recycled or used as combustibles in power plants, cement plants would be the most efficient way to eliminate DSS and avoid landfilling. Co-processing of this waste can begin immediately if the WWTP agree to arranging to dry the sludge, according to cement plant specifications or other commercial arrangements, as discussed earlier in Chapter 7.

RDF from MSW is usually the most complicated and costly non-industrial waste stream to co-process, because of the heterogeneity of its content. This waste is widely available in Egypt, but will require a combination of financial incentives to become economically feasible. At present, globally AFR from RDF is largely dependent on tipping fees. Therefore, in developing economies where tipping fees are limited, it is recommended to start with waste streams requiring less investment and lower operating costs. The technical complexity of RDF preparation requires close collaboration between the waste management companies and the cement plants. Over the long term, there is a supply risk that RDF could be used in power plants, reducing the volume available for co-processing by cement plants.

Agricultural waste can also turn into a major AFR source, once its seasonality is mitigated through adequate baling and storage. Like RDF, agricultural waste could also be used in power plants.

All three waste streams represent major opportunities for local waste management companies, but the sustainability of their investment will need to be guaranteed through long-term supply and offtake agreements. Each waste stream requires its own approach.

This study has shown that the success of an alternative fuel project depends upon a combination of multiple factors:

(i) The waste sector needs improved operational efficiency, reliable waste collection chains, and more inclusive business models.

It is imperative to set realistic prices through open dialogue with cement companies and with municipalities. Controlling waste treatment is critical to the quality and regularity of alternative fuels. As such, knowledge of safe waste handling techniques, compatibility, and traceability processes are all crucial and need specific focus. Waste processing firms must understand that in order for a cement firm to substitute fossil fuels, large CAPEX investments may be required. Thus, the economics of waste-derived alternative fuels have to bring value. But developing the alternative fuel market opens a clear opportunity to include new SMEs and involve the informal waste collection and recycling sector in the value chain. These new actors are likely to be eager to compete. Finally, a holistic approach to waste management will also translate into shaping and supporting an integrated waste processing industry.

(ii) The cement industry needs criteria, longer-term partnerships and benchmarks.

The cement sector clearly understands that the use of waste is not comparable to the traditional procurement process of fossil fuels, but that alone should not prevent action. It is imperative to adopt new business ideas that may entail more creative partnerships with waste firms. Egypt's cement industry is well-positioned to share best practices, to help showcase regional and global benchmarks and to raise broader market awareness on co-processing (both its benefits and risks). The success of an alternative fuel project requires a good knowledge of available waste sources at a competitive price. It is thus vital to analyze and understand the market in depth. Cement plant managers cannot base their judgments or selection of waste ranges solely on their experience or technical know-how elsewhere. Further, the industry should encourage and lead other stakeholders in issuing AFR quality guidelines and standards to ensure there is a common understanding of the sector's needs.

(iii) Incentives are more effective than penalties.

Egypt's alternative fuel market can only grow if ambiguities are removed, uncertainties addressed and market distortions regulated. But this cannot be done solely by imposing penalties and increasing landfilling costs. While the *polluter pays principle* must be enforced to help discourage the illegal dumping and open burning of waste, it is also advisable for all stakeholders – specifically regulatory actors – to develop innovative financial mechanisms that would give companies interested in establishing AFR projects a helping hand. The issuance of permits for AFR producers should be facilitated and eased through a single authority that coordinates with other relevant entities. Egypt must create adequate incentives and methodologies for reliable monitoring, reporting and verification of energy permits.

(vi) Data is crucial, market trust must be developed and technical knowledge across the market needs to be improved.

It is essential that the cement and alternative fuel treatment industries work closely together to secure the quality and consistency of the end product. Gaps in data are an obstacle that must be addressed. The provision of accurate national data and statistics is crucial to enable investors to make informed decisions. There is a great deal to be done to raise awareness on global best practices in the use of alternative fuels. Capacities must be built across the board, and especially among authorities to ensure the appropriate selection of civil servants with adequate technical background equipping them to control, supervise and regulate co-processing. Officials across various branches of government need to be able to articulate, monitor, and implement fair, long-term and workable contracts between cement firms and alternative fuel providers. It is advisable to establish continuous dialogue among stakeholders. This may include regular meetings and workshops, bringing together the cement industry, the waste management companies and the authorities, in order to jointly remove the barriers impeding alternative fuel usage.

Egypt's cement industry is a crucial economic sector that can lead the way today in demonstrating that overcoming challenges such as climate change, waste management and pressure on fossil fuels, will in fact be powerful drivers of economic and commercial profitability. Through better management, new sources of value can be created to shape a healthy, sustainable and lucrative alternative fuel market.

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Annexes

Annex A: The Cement Manufacturing Process

Cement is the most widely used building material in the world. Raw materials are limestone and clay. Cement is manufactured in two stages, the manufacture of clinker and clinker grinding. These differ in terms of process complexity, production and investment cost.

The cement industry is energy-intensive, with thermal and electric energy accounting for about 40 percent of total cement production cost. While electrical energy is needed throughout the production of cement, only clinker manufacturing requires thermal energy. Thermal energy needs may be most efficiently managed by reducing the clinker content in cement. The percentage of clinker in cement can vary depending on the type of cement produced.

Four basic oxides form cement clinker: calcium oxide (65 percent), silicon oxide (20 percent), alumina oxide (10 percent) and iron oxide (5 percent)[31]. In the manufacturing of clinker, raw material is fed into a rotary kiln heated to 2000°C. Two processes take place in the kiln:

- Calcination, which occurs at between 850°C and 950°C. Limestone (calcium carbonate-$CaCO_3$) is heated to disassociate into lime (calcium oxide-CaO) and carbon dioxide (CO_2), which chemically react with other oxides;
- Sintering, which binds the calcium oxide with the oxides of silica, aluminum and iron as they are heated to 1,450°C, forming the clinker.

In the second phase, clinker is ground together with additives in order to produce cement. Cement is a fine powder used to bind fine sand and coarse aggregates together into concrete. Cement is a hydraulic binder, which means that it hardens when added to water. Cement production is either "wet" or "dry" depending on the water content of the raw material; these two processes involve different kiln types. Dry processes are most commonly used as they require less thermal energy.

31 *Cembureau: About Cement - Cement manufacturing process*

Annex A.1: Current Characteristics of the Egyptian Cement Market

According to the Cement Sustainability Initiative's (CSI) "Getting the Numbers Right" (GNR), the worldwide average thermal energy consumption is 836 kcal per kg of clinker produced;[32] Egypt uses 945 kcal per kg of clinker produced. The average thermal consumption and the CO_2 production per ton of cement are significantly[33] higher than the value provided by the Best Available Technologies (BAT), based on interviews with Egyptian producers. The two main causes are the following:

The Systematic Use of High Rate Bypass Systems

In most of the country, the raw materials (limestone and clay) are extremely rich in chlorine. During the kiln process, the chlorine forms salts which coat the cyclone stage walls and hinder or even prevent clinker production. Inside the kiln, the chlorine is volatilized before being condensed, mainly on the fine dust present in the flue gas and on the cyclone walls. This phenomena is called the "chlorine cycle".

Bypass systems are applied to improve the operation of pre-heater kilns by extracting hot gas (approximately 1000°C), enriched in chlorine, at the kiln inlet. The hot gas is then reduced to a lower temperature, typically by addition of cold air, to condense the gaseous chlorine (HCl) on the dust present in the flue gas. The bypass process allows clinker production to proceed with relatively high chlorine inputs, but has a negative impact on the thermal consumption of the kiln. It is technically impossible to recover the heat of the bypass gas. In Egypt, bypass rates from 10 to 55 percent are required, causing significant heat loss. Moreover, the bypass dust (volume roughly estimated at over two million tons per year) is landfilled or dumped and consequently lost and wasted.

32 *GNR WBCSD, 2012*

33 *Typically 15 to 20 percent.*

The bypass dust is a clinker dust enriched with chlorine, alkalis, sulfur and sometimes heavy metals, depending mainly on the composition of the raw materials and to a smaller extent on the composition of the fuels. Bypass dust can be added in the cement mill without impairing the cement quality; it is a common practice in the EU and other countries. The maximum amount of bypass dust fed to the mill in substitution for clinker depends mainly on local standards[34] and on its chlorine and alkali content. In Egypt, only part of the total volume and chlorine content of the bypass dust could be recycled in current cement production. However, bypass dust can be useful in higher quantities in hydraulic binders, and can serve for soil stabilization and other low grade uses.

Encouraging the use of bypass dust in cement production, and for hydraulic binders production, would lead to:

- An increased capacity for cement production;
- A reduction in the specific thermal consumption[35];
- A reduction in specific greenhouse gas (CO_2) emissions; and
- A reduction in the potential impacts of the dumping of bypass dust on underground water.

The situation described here can impact AFR use both positively and negatively, as numerous alternative fuels contain chlorine[36]. On the one hand, the pre-existence of broadly designed bypass systems reduces significantly the investment required for co-processing alternative fuels such as RDF, making it much more affordable. On the other hand, some of the bypass systems are already operating close to their maximum rate, limiting the maximum chlorine input related to the fuels[37]. This issue has to be taken into account when defining acceptance criteria[38], as does the potential impact on the bypass dust quality, especially if dumped.

The Cement Market, Mainly CEM I (Ordinary Portland Cement or OPC)

All Egyptian cement producers have around 90 percent of clinker content in cement, while the EU average is about 70 percent, according to the WBCSD initiative "Getting the Numbers Right" (GNR).[39]

34 Local cement standards may mention the amount of clinker dust which can substitute clinker (5 percent weight according to EN 197-1) and the maximum chlorine (0.1 percent and alkalis (0.9 percent for CEM III) contents of the different cement types.

35 The specific thermal consumption is the amount of thermal energy (amount of fuel) required per ton of clinker or cement produced.

36 Solid Recovered Fuel (RDF) from municipal waste contains typically 0.5 to 2.5 percent chlorine (wet), coming from both chlorinated plastic (PVC) and cooking salt [sources: information from cement plants; Refuse Derived Fuel, current practice and perspectives (B4-3040/2000/306517/MAR/E3) Final Report].

37 The bypass (extraction) of 1% of the total flue gas flow allows an increase in the total chlorine input of approximatively 100 g per ton of clinker.

38 RDF can be classified into five categories depending on their quality, according to the standard EN 15357:2011.

39 Source: World Business Council for Sustainable Development – Cement Sustainability Initiative. The WBCSD initiative "Getting the Numbers Right" (GNR) is a voluntary, independently-managed database of CO2 and energy performance information on the global cement industry.

Annex B: Co-Processing Within International Regulations

The World Business Council for Sustainable Development (WBCSD), in its "Waste Management Hierarchy" (refer to Figure B-1), classified different ways of handling waste, from the most efficient (preferred) to the less efficient (to be avoided). Avoiding waste generation and limiting waste volume are clearly the most efficient ways to deal with waste problems worldwide, but co-processing can lead to both energy and material recovery: The Basel Convention, under the aegis of the United Nations Environment Program (UNEP), stipulates that "co-processing in cement kilns provides an environmentally sound resource recovery option, preferable to landfilling and incineration". Landfilling is the least preferred solution in accordance with the waste management hierarchy. This objection applies most urgently in Egypt, where illegal and uncontrolled dumping prevails.

Co-Processing Definition

Co-processing has been defined by the Basel Convention as the "use of suitable waste materials in manufacturing processes for the purpose of energy and/or resource recovery and resultant reduction in the use of conventional fuels and/or raw materials through substitution."[40]

Co-Processing Recognition within the Global Legal Framework

The first country having specifically developed a legal framework on co-processing was Brazil in 1993, followed by Mexico in 1995. In 2003, GTZ and Holcim published a document, "Guidelines on Co-Processing Waste Materials in Cement Production." In 2005, the Cement Sustainability Initiative (CSI) of the World Business Council for Sustainable Development (WBCSD) released its Guidelines for Co-Processing Fuels and Raw Materials in Cement Manufacturing (updated in 2014 by WBCSD).

Application of these guidelines is part of the commitment in the CSI Charter. In 2009, all major cement associations, including CEMBUREAU (EU), VDZ (Germany), and Ficem (Latam countries), officially endorsed the wording "co-processing" for AFR use in cement kilns. In 2010, guidelines for co-processing in the cement, power and steel industries were developed by the Central Pollution Control Board (CPCB) in India, showing that this concept can be applied for different types of energy intensive industries (EII's).

In October 2011, the UN/SBC COP 10, in the presence of representatives from more than 190 countries, endorsed the proposal by Chile regarding "Technical guidelines on the environmentally sound co-processing of hazardous wastes in cement kilns". These guidelines are the legal basis that each country shall refer to when developing its specific legal framework on co-processing (Basel Convention). In March 2014, China, which represents about 60 percent of world cement production, implemented its national standard for pollution control on co-processing solid wastes in cement kilns, based on the UN/SBC guidelines (Ministry of Environment, China).

The European Integrated Pollution Prevention and Control Bureau (EIPPCB) (2010) specifies the main criteria that shall be met in cement production in order to allow for the co-processing of waste materials (hazardous and non-hazardous) into the kiln via appropriate feed points. They can be summarized as follows:[41]

- Maximum temperatures of approximately 2,000°C (main firing system, flame temperature) in rotary kilns;
- Gas retention times of about eight seconds at temperatures above 1,200°C in rotary kilns;
- Material temperatures of about 1,450°C in the sintering zone of rotary kilns;
- Oxidizing gas atmosphere in rotary kilns;
- Gas retention time in the secondary firing system of more than two seconds at temperatures above 850°C; in the pre-calciner, the retention times are correspondingly longer and temperatures are higher;
- Solids temperatures of 850°C in the secondary firing system and/or the calciner;
- Uniform burnout conditions for load fluctuations due to the high temperatures at sufficiently long retention times;
- Destruction of organic pollutants because of high temperatures at sufficiently long retention times;
- Sorption of gaseous components such as HF, HCl, and SO_2 on alkaline reactants;
- High retention capacity for particle-bound heavy metals;

40 *UNEP, Basel Convention, Technical guidelines on the environmentally sound co-processing of hazardous wastes in cement kilns - October 2011.*

41 *Technical guidelines on the environmentally sound co-processing of hazardous wastes in cement kilns, 2011 , pp. 4-5.*

- Short retention times of exhaust gases in the temperature range known to lead to formation of PCDDs/PCDFs;

- Simultaneous material recycling and energy recovery through the complete use of fuel ashes as clinker components;

- Product-specific wastes not generated due to a complete material use into the clinker matrix (although some cement plants dispose of CKD or bypass dust); and

- Chemical-mineralogical incorporation of non-volatile heavy metals into the clinker matrix.

Egypt's specific regulatory frameworks and considerations related to co-processing by the cement industry of the four studied waste streams are described in Annex E .

Comparison of Clinker Quality

Some may be concerned that the use of waste as fuel or raw material could influence the concrete, and more specifically, that some constituents contained in some wastes could be released from the cement product or concrete. UNEP Basel guidelines endorse the GtZ guidelines by stating that cement quality must remain unchanged with co-processing and the end product must not have any negative impact on the environment. They suggest certain tests which are regulated by the European Committee for Standardization;[42] for example, a leaching test to determine the release of dangerous substances from construction products into soil, surface water and groundwater.

WBCSD has enumerated a list of different organizations that have published studies on clinker produced with AFR, prominent among them L'Association Technique de l'Industrie des Liants Hydrauliques, Construction Technology Laboratories, Forschungsinstitut der Zementindustrie, CEMBUREAU, the European Committee for Standardization. Aggressive testing carried out by NSF/ANSI Standard 61[43] has shown that "metals in the cement become bound in the concrete calcium silicate structure and in this form do not leach from the product."[44] It is therefore strongly recommended that the final product undergo regular control procedures required by the usual quality specifications according to national and international quality standards.

42 *European Committee for Standardization (2014) - CEN/TS 16637-1:2014.*

43 A third party certification process for drinking water pipes in the United States.

44 Colucci M., P. Epstein, B. Bartley (1993, March), *A Comparison of Metal and Organic concentrations in Cement and Clinker Made with Fossil Fuels to Cement and Clinker Made with Waste Derived Fuels. NSF International. Ann Arbor, MI.*

In co-processing, the energy content of the waste is used to substitute traditional fuel and its ashes replace non-renewable raw material. Ashes are composed of the same elements as the raw material for clinker: oxides of calcium, silica, iron and aluminum. They are fully integrated into the clinker.

As described in

- the GTZ-Holcim "Guidelines on Co-processing Waste Materials in Cement Production"

- Article 52 on "Technical Guidelines of UNEP- Basel Convention"; and

- BAT (Best Available Technology) guidelines and provisional guidance on BEP (Best Environmental Practices), published by the Secretariat of the Stockholm Convention.

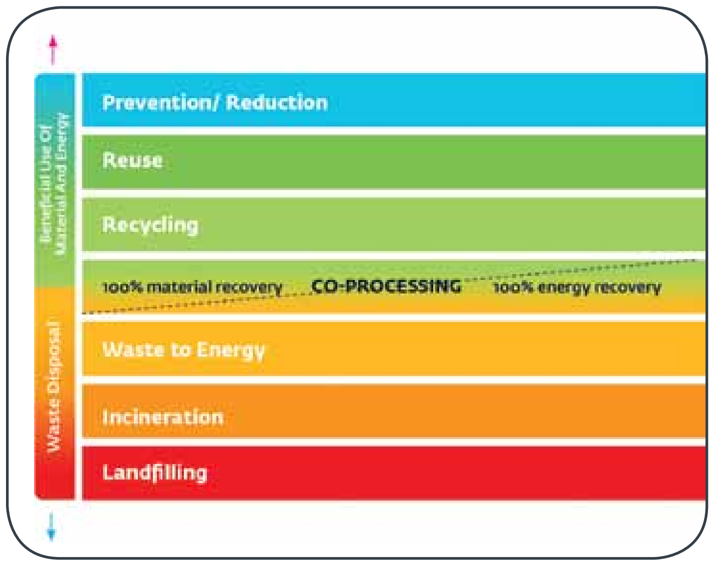

Figure B-1: Co-Processing within the Waste Management Hierarchy[45]

It is not recommended that the following wastes be used for co-processing in cement kilns:

- Radioactive waste from the nuclear industry
- Electrical and electronic waste (e-waste)
- Whole batteries
- Corrosive waste, including mineral acids
- Explosives and ammunition
- Waste containing asbestos

45 WBCSD co-processing guidelines.

- Pathogenic medical waste
- Chemical or biological weapons destined for destruction
- Waste of unknown or unpredictable composition, including unsorted municipal waste
- Waste raw materials with little or no mineral value for the clinker (heavy metal processing residues).

These wastes are banned for combustion, not only for health and safety concerns, but also because of potentially negative impacts on kiln operation, clinker quality or air emissions.

Co-Processing Benefits

Co-processing is based on the principles of industrial ecology, which considers the best features of the flow of information, materials, and energy of biological ecosystems, with the aim of improving the exchange of these essential resources in the industrial world.

UNEP, Basel Convention, acknowledges that "the numerous potential benefits possible through the use of hazardous and other wastes in cement manufacturing processes by the recovery of their material and energy content include the recovery of the energy content of waste, conservation of non-renewable fossil fuels and natural resources, reduction of CO_2 emissions, reduction in production costs, and use of an existing technology to treat hazardous wastes".[46] This means, in terms of benefits from co-processing, that it preserves natural (non-renewable) resources of energy and materials, and reduces CO_2 emissions.

According to the latest available data (2006),[47] cement production contributed eight percent of anthropogenic CO_2 emissions, or six percent of total global emissions of greenhouse gases. Carbon dioxide emissions arise mainly from the calcination of the raw materials (60 percent) and from the combustion of fossil fuels (40 percent). The CO_2 emissions due to calcination cannot be avoided in the production of clinker. Therefore, reducing the percentage of clinker in cement (producing blended cement) is the most efficient way to reduce CO_2 emission per ton of cement.

CO_2 emission from the combustion of fuel can be reduced by substituting part of the conventional fossil fuels with organic waste. Thus, direct CO_2 emissions from combustion are reduced, as CO_2 emissions from wastes ("waste-to-energy conversion") are less than in traditional fuels, and biomass waste is CO_2 neutral. In addition, and as pictured here, co-processing of AFR also results in indirect GHGs savings at landfills and incineration plants, where these wastes may otherwise be disposed of. Moreover, it prevents methane emission, a GHG 25 times more potent than CO_2.

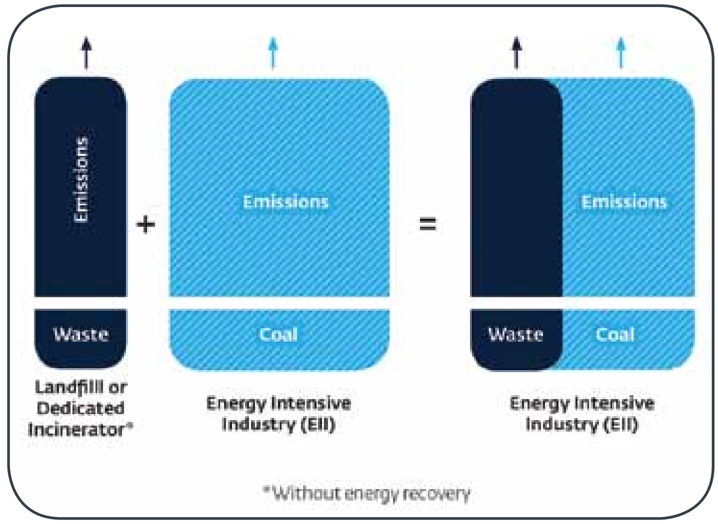

Figure B-2: *GHGs Reductions resulting from Co-Processing*
(Source: TNO–LCA of Thermal Treatment of Waste Streams in Cement Clinker Kilns in Belgium, October 2007)

Co-processing reduces environmental impacts resulting from the extraction (mining or quarrying), transporting, and processing of raw materials; reduces dependence on primary resource markets; saves landfill space and reduces pollution caused by the disposal of waste; provides a local and sustainable solution to a local problem and completely eliminates the waste.

Some EII's, such as the cement sector, offer co-processing as a sustainable waste management service. It is usually more cost effective to adapt existing facilities of EII's, rather than building new waste treatment installations such as incinerators, thereby reducing waste management costs to the public. Moreover, co-processing being a local waste management solution, there is no need for external transboundary shipment of wastes.

Potential Health and Safety Concerns for AFR

Health and safety for all employees, contractors, and the population living in the neighborhood are fundamental for the cement industry. The CSI[48] and GIZ/Holcim guidelines on safety procedures also address AFR usage. Clear protocols must be in place for the delivery and the reception of AFR. All materials must have an identification

46
47

48 *Health and safety in the cement industry: Examples of good practice- chap 4.3.7. - Cement Sustainability Initiative (CSI) - December 2004*

document. In case a waste doesn’t comply with the contract specifications and local regulations, appropriate protocols should exist to refuse or renegotiate.

Strict safety rules and procedures must also apply to the storing and handling of any fuel, including AFR. Employees must undergo regular training in health and safety. On-site emergency procedures complying with relevant local regulations must be enforced. Performance indicators, such as the Lost Time Injury Analysis, Lost Time Injury Frequency Rates and Lost Time Injury Severity Rate, should be reported on a regular basis.

When beginning AFR use, the following steps are recommended:

- A specific OH&S directive must be developed for the pre-processing and co-processing of AFR, based on the recommendations of CSI and GIZ/Holcim;
- Special Health and Safety reporting must be in place to monitor employee health;
- Regular training of all persons in contact with the AFR, and specially designed safety training for the project teams, shall take place; and
- External independent auditing systems shall take place at regular intervals.

Annex C: Emissions Control and Monitoring for the Cement Industry

Emissions from industries have always been a concern for stakeholders. Cement plants emit a variety of pollutants that are subject to regulations and controls. In general, emission limits for the large combustion units using traditional fuels (gas, HFO, coal and petcoke), as is the case with the cement industry, refer to the three main pollutants, NO_x, SO_2 and dust. Additional limits for metals, HCl, HF, CO, organic compounds and PCDD/Fs can be found in some countries. The limits fixed by the EU regulation 2010/75/EU on emissions apply to cement plants using traditional fuels such as coal. The same EU directives also define more stringent limits for co-processing of AFR.

In 2012, the Commission launched the process for transforming relevant parts of the original cement Best Available Techniques (BAT) reference document (BREF) into BAT Conclusions. In 2013, the Commission Implementing Decision 2013/163/EU[49] established the Best Available Techniques Associated Emission Levels (BAT AEL's), BAT conclusions on industrial emissions in the production of cement for the relevant date of compliance, 26 March, 2017. EU BAT conclusions are for

- New installations: that they comply with the BAT conclusions; and
- Existing installations: that, according to Article 15(4)50, the competent authority may, in specific cases, set less strict emissions limit values. These may apply when meeting the BAT AEL, but would lead to disproportionately higher costs compared to the environmental benefits, due to the geographical location of the installation, and the local environmental conditions of the installation or the technical characteristics of the installation.

Table C-1 compares Egyptian standards with those of the EU, comparing not only the emission limits but also the emission monitoring requirements. The following is recommended for the new Egyptian regulation:

- Within its permit, Egypt should extend the new regulation to the use of AFR in the cement kiln fuel-mix.
- As in the EU regulation, the current Egyptian regulation permitting system must consider more flexibility for SO2 and TOC, taking into consideration sulfur and organic compounds coming from the raw material itself.

Emissions must be monitored, some only once a year, others continuously. The WBCSD (CSI)[51] guidelines document (2012), has made recommendations to fill the gap created by the absence of EU requirements:

- continuous emissions monitoring of main kiln stack emissions for NOx, SOx, dust and VOCs;
- complete emissions monitoring at least twice a year by a recognized institution for the whole set of elements, including heavy metals and Dioxine / Furanes.

49 http://www.prtr-es.es/Data/images/ConclusionesBATcementoENabril13.pdf

50 The European Parliament, The Council of 24 November 2010, Directive 2010/75/Eu Art 15 (4), p 29.

51 The Cement Sustainability Initiative (CSI) is a global effort by 24 major cement producers with operations in more than 100 countries who believe there is a strong business case for the pursuit of sustainable development.

	Unit	Egypt's April 2015 Regulations Governing Coal Use	EU- IED- 2010- Annex VI Coprocessing	BAT-AEL's BAT Conclusions
Particulates	mg/Nm³	30 for new plants 50* for existing ones	30	10 - 20
NOX	mg/Nm³	450* for new plants 600* for existing ones	500 for preheater <800 for Lepol and long kiln	200 - 450 for preheater 400 - 800 for Lepol and long kiln
SO2	mg/Nm³	400*	50**	50 - 400
TOC	mg/Nm³	10*	10**	10
Hg	mg/Nm³	0.05	0.05	0.05
Cd+Tl	mg/Nm³	0.05	0.05	0.05
Sb + As + Pb + Cr + Co + Cu + Mn + Ni + V	mg/Nm³	0.5	0.5	0.5
HCl	mg/Nm³	10*	10	10
HF	mg/Nm³	1*	1	1
Dioxins and furans	ng/Nm³	0.1	0.1	0.1

* Continuous monitoring
** Applied only to emissions produced from co-processing

Table C-1: Cement Kiln Emissions Limits Values: Egypt versus EU[52]

Pollutant	Frequency of Measurement
Dust	Continuously
NO2	Continuously
SO2	Continuously
VOC/THC	Continuously or at least once a year
PCDD/F	Once every two years
Hg	Once every year
Other Heavy Metals	Once every two years

Table C-2: WBCSD Guidelines for Emissions Monitoring and Reporting in the Cement Industry

52 Based on Egypt coal regulation 2015, EU Directive 2010/75/EU and Chinese directive.

ANNEX D: Total Agricultural Waste in 2012 by Type

Governorate	Sugar beet	Sugar Cane	Cotton	Corn	Rice	Pepper	Eggplant	Okra	Orange	Tangerine	Lemon	Dates	Grapes	Mango	Guava	Banana	Apple	Pear	Fig	Olives	Apricot	Plum	Peach
Alexandria	20,398	54	13,019	128,207	7,366	13,635	12,874	753	1,694	47	-	4,559	1,104	44	9,531	117	1,240	1,467	1,452	1,128	9	-	26
Behiera	118,220	1,683	189,853	806,976	719,597	12,334	15,252	1,350	123,858	4,328	3,227	67,630	16,368	7,034	30,731	9,970	3,389	442	127	5,403	1,982	32	2,250
Gharbiya	38,328	12,951	37,892	230,918	528,351	802	2,238	529	26,701	892	75	2,554	23,157	370	103	2,450	1,461	2	3	1	3	-	13
Kafr el Shiekh	459,571	765	203,036	287,662	1,044,461	1,375	4,357	273	8,483	608	79	27,160	108	76	1,829	630	248	5	-	-	-	-	268
Matrouh	-	-	-	4,680	-	702	1,224	-	772	101	18	17,132	8,646	-	2,140	23	818	1,085	52,239	26,064	104	7	400
Nubaria	68,302	4,050	15,194	290,027	1,001	19,251	18,290	-	238,932	49,790	11,802	26,096	202,044	31,346	4,212	36,203	5,135	3,962	1,469	33,965	7,494	135	12,365
Total Northern	704,820	19,503	458,093	1,748,470	2,301,775	48,038	54,281	2,905	400,438	55,745	15,200	145,131	251,426	38,870	48,546	49,394	58,291	6,962	60,289	66,551	9,592	175	15,322
Menufiya	2,952	198	7,178	770,338	4,709	1,955	3,773	35	64,726	7,899	815	9,097	3,175	6,933	457	14,708	3,574	2,781	5	3,843	1,799	404	1,194
Cairo	-	126	-	425	11	122	176	24	531	189	38	2,025	521	2,111	122	22	85	23	56	8,897	50	4	69
Daqhliya	266,241	5,130	92,079	208,332	1,636,909	2,824	4,099	332	10,206	129	10	14,755	12,658	41	68	1,768	76	15	-	1	6	-	777
Giza	1,937	16,263	-	231,343	-	15,287	12,744	12,304	10,080	8,307	327	45,412	12,446	7,152	367	4,662	454	57	47	5,085	893	586	362
Kaliobeya	1,664	6,822	659	263,322	55,580	1,901	7,976	386	78,678	1,411	172	11,707	808	941	6,849	4,563	35	143	81	215	302	1,245	13
Total Central	272,791	28,539	99,916	1,473,800	1,697,209	22,089	28,717	13,082	164,221	17,935	1,362	82,995	58,147	17,177	7,864	25,722	4,223	2,980	188	18,061	3,009	2,238	2,365
Damietta	21,136	270	15,419	6,552	240,919	427	1,150	51	79	3	836	49,473	19	884	7,276	196	-	8	-	-	-	-	2
Ismailia	24,299	-	4,228	130,684	22,133	12,083	10,481	2,030	82,384	5,937	1,239	36,385	5,126	88,620	1,100	2,280	289	443	87	17,614	508	18	794
South Sinai	-	-	-	-	-	19	16	-	351	95	191	4,429	164	897	376	-	19	4	170	12,474	20	-	14
Suez	-	126	-	10,134	-	1,885	702	448	11,750	449	155	2,748	1,318	7,344	441	110	188	43	31	2,066	256	3	194
North Sinai	-	-	-	673	-	667	1,139	329	6,534	4,824	225	19,066	1,089	300	531	-	806	158	608	39,121	4	2	41,499
Port Said	72,826	-	3,087	40,597	71,946	-	-	-	18	2	-	421	19	9	77	-	-	-	5	30	-	-	-
Sharqiya	169,109	252	89,541	908,842	946,152	17,383	23,031	4,423	93,914	11,978	6,534	54,308	6,826	36,163	1,204	2,219	19	138	245	1,708	224	10	260
Red Sea	-	-	-	-	-	14	14	-	-	-	-	2,201	-	-	-	-	-	-	-	434	-	-	-
Total Eastern	287,370	648	112,275	1,097,431	1,281,150	32,476	36,534	7,281	195,039	23,278	9,160	178,980	14,561	134,277	10,957	4,736	1,320	793	1,146	73,447	1,011	37	42,763
Fayoum	100,468	4,851	45,785	354,200	2,686	2,778	2,690	3,144	1,454	155	3,837	35,349	2,791	6,989	173	-	34	142	69	13,402	595	-	55
Beni Suef	100,582	6,084	15,446	643,248	2,466	13,433	1,528	1,796	7,263	2,510	51	17,533	13,843	563	538	4,948	85	94	73	2,491	91	1	50
Minya	72,069	352,197	3,236	1,054,361	-	15,112	4,892	1,650	2,410	2,942	746	20,752	53,438	1,390	950	4,043	91	30	456	359	17	13	-
Total North Upper	273,119	363,132	64,467	2,051,809	5,152	31,323	9,113	5,589	11,626	5,607	4,634	73,634	70,073	8,941	1,661	8,991	210	266	599	16,252	673	14	105
Assiut	25,391	16,182	9,970	573,358	-	2,516	2,543	1,423	15,813	3,908	1,922	24,804	6,618	2,104	787	4,137	164	-	96	2,678	113	-	320
Sohag	-	146,322	4,367	504,490	-	1,693	1,307	1,733	2,696	1,155	662	22,493	976	356	580	4,223	5	-	86	499	-	-	9
Qena	-	1,059,651	-	186,070	-	3,402	1,175	810	583	188	1,113	19,267	864	614	209	10,062	11	1	128	317	-	-	11
Luxor	-	557,163	-	70,186	-	365	1,820	1,137	1,170	249	251	9,184	2,216	1,729	758	12,089	-	-	131	118	-	-	-
New Valley	369	-	72	26,445	14,414	157	162	591	7,902	475	815	62,606	1,048	3,645	1,746	23	115	43	67	4,543	320	4	21
Aswan	-	740,538	-	33,415	-	2,506	1,083	1,655	1,343	129	689	57,789	1,324	9,011	389	2,819	1	-	149	-	72	-	-
Total South Upper	25,591	2,519,856	14,409	1,393,963	14,414	10,638	8,089	7,349	29,507	6,104	5,453	196,142	13,046	17,539	4,468	33,343	296	44	657	8,155	505	4	360
total waste generated in egypt/ crop	1,563,660	2,931,678	750,060	7,765,424	5,299,700	144,563	136,733	36,207	800,831	108,669	35,809	676,884	407,253	216,724	73,496	122,186	64,340	11,045	62,879	182,469	14,790	2,452	60,915
Agricultural Waste Generated in Egypt												21,468,825											

Annex E: Regulatory Framework for Alternative Fuels in Egypt

Legal basis for using waste as AFR	• Law number 4/1994 and its amendments by law 9/2009 • Prime MinisterialDecree 338/1998 amended by decree 1095/2011, 710/2012 and 964/2015 • Law of Public Cleanliness 38/1967 and its amendments by Presidential decree 106/2012
Requirements for establishing waste treatment, disposal and landfilling facilities	• Law number 4/1994 and its amendments by law 9/2009 • Prime Ministerial Decree 964/2015
Requirements for operation of waste treatment, disposal and landfilling facilities	• Law number 4/1994 and its amendments by law 9/2009 • Prime Ministerial Decree No 964/2015
Environmental requirements for industrial and commercial facilities using AFR	• Law 453/1954 • Law 12/2003
Regulations that encourage the investment in waste management	• Law 141/2004 and its executive regulations, Prime Ministerial Decree 1241/2004 • Law 8/1997 and its amendments by law 17/2015
Waste collection and handling regulations	• Law 38/1967 amended by law 10/2005 • Law 31/1976 • Decrees number 1741/2005, 1095/2011 and 964/2015 • Presidential Decree 86/2010 • Prime Ministerial Decree 1095/2011 • Ministerial Decree 134/1968 • Presidential Decree 284/1983
Regulations related to hazardous waste	• Law number 4/1994 and its amendments by law 9/2009 • Executive regulations 1095/2011 amended by Prime Minister Decree number 964/2015 • Decree of Minister of Industry 7/1999
Requirements for using coal & AFR in cement factories	• Prime Ministerial Decree number 964/2015
Biomass	• Prime Ministerial Decree number 1740/2002 • Law number 4/1994 and its amendments by law 9/2009 • Directive 63/2002 of the Ministry of Agriculture and Land Reclamation • Annual Ministerial Decree from Ministry of Water Resources and Irrigation
Sludge	• Executive regulation issued by decree 44/2000 and law 93/1962 • Prime Ministerial Decree 254/2003

Legislation governing waste management in Egypt goes back 50 years, when Law 38/1967 was drafted, the first piece of legislation concerning SWM. It regulates the collection and disposal of solid wastes from residential areas, commercial and industrial establishments and public areas. Subsequent legislation has provided the legal basis for using waste as AFR. WMRA is tasked with reviewing current legislation and proposing necessary changes.

The legal basis for using waste as AFR can be found in Environment Law number 4/1994 and its amendments 9/2009, which encourage material recovery. Other laws that govern the solid waste management (SWM) sector can be found in Law 38/1967 and its subsequent amendments in Law 10/2005, Law 4/1994, Law 9/2009 and its Executive, which constitute the legal framework for the SWM sector in Egypt. Law 38/1967, the first piece of legislation concerning SWM, regulates the collection and disposal of solid wastes from residential areas, commercial and industrial establishments and public areas. It states that Local Administration Councils are responsible for waste collection and disposal, as well as issuing licenses for workers employed in waste collection. WMRA is tasked with reviewing all relevant SWM regulations and proposing necessary changes. Law 4/1994, amended by Law 9/2009, focuses on the protection of the environment and consequently on managing hazardous wastes. Under this law, Environmental Impact Assessments are mandatory for all commercial and residential developments or industrial projects. In addition, this law establishes the Environmental Protection Fund, a solid waste fund to finance a variety of relevant environmental activities. It also offers incentives to institutions and individuals involved in environmental protection projects, especially those dealing with land, water and air pollution.

A summary of waste and AFR related laws and regulations are provided below:

Table E-1: Summary of Waste and AFR Related Laws and Regulations in Egypt

Co-processing Relevance	Law/decree Number	Waste Stream	Key Relevant Issue	Comments
Legal basis for usage of waste as AFR	**Law number 4/1994 and its amendments by law number 9/2009 and its executive regulations** **Prime Ministerial Decree 338/1998 amended by decree 1095/2011, 710/2012 and decree 964/2015**	All waste streams	This law is concerned with regulating all issues related to protection of the environment. The laws encourage recycling and reuse activities for the different types of waste streams. Article 37 of law 4/1994 and Article 38 of its executive regulations considers the use of waste as AFR part of the legally approved recycling processes.	In general the law offers incentives to institutions and individuals involved in environmental protection projects through the environmental protection fund. EEAA is responsible for the enforcement of the law and its executive regulations. A gate fee needs to be imposed on landfilling in order to minimize amounts sent for final disposal and allow more recycle and reuse activities. Necessary definitions for the ownership of the waste are recommended, to prevent bargaining by local actors.
	General Public Cleanliness Law 38/1967 amended by presidential decree 106/2012	All waste streams	• This defines “garbage and solid waste” as including both domestic and industrial waste.	Deterrent fines must be imposed on random disposal of waste, to encourage proper disposal. Waste segregation must be encouraged at the household level.
Requirements for establishing waste treatment, disposal and landfilling facilities	**Law number 4/1994 and its amendments by law number 9/2009** **Prime Ministerial Decree No. 964/2015**	All waste streams	The law sets requirements for establishing waste management facilities: • Approval of the location for waste storage or treatment facilities by EEAA (Article 37 of law 4/1994 and Article 38 of the executive regulation detailed in annex II). • A requirement that all facilities involved in waste recycling and treatment **conduct an EIA study** to ensure compliance with all environmental legal requirements. • An environmental management plan, monitoring plan, contingency plan and time frame for removing any violations.	• Technical support is provided for facilities aiming to enter this business and meet the technical requirements of EEAA. • A specific guideline is to be developed for the EIA studies of waste treatment facilities. • Financial support is provided for innovative projects in AFR through available financing mechanisms such as the Environmental Protection Fund (EPF) or other CDM projects.

Co-processing Relevance	Law/decree Number	Waste Stream	Key Relevant Issue	Comments
Requirements for operation of waste treatment, disposal and landfilling facilities	**Law number 4/1994 and its amendments by law number 9/2009** **Prime Ministerial Decree No. 964/2015**	All waste streams	The law sets requirements for the operation of waste management facilities: • Operational permit from the governorate. • Waste transportation contracts. • An environmental register including all operations, follow up forms, delivery and receipts for transported waste amounts. • An approved system for waste collection, transportation, handling and disposal of waste (remains of pre-processing). • An environmental register for handling any hazardous waste generated. • An approved system for final disposal, collection and transportation of any hazardous waste generated. • Regular monitoring of stacks, incinerators and boilers. • EEAA approval of the location of final disposal, controlled landfills.	• Waste facilities contracts are monitored and enforced. .
Requirements for Monitoring of environmental requirements for industrial and commercial facilities using AFR	**Law 4/1994 and its Amendments**	All waste streams	All facilities using AFR need to have approval from EEAA. Facilities using AFR shall be compliant with EEAA requirements for stacks and emissions.	
	Law 453 /1954 related to commercial and industrial facilities regulations	All waste streams	The law is concerned with environmental requirements for industrial and commercial facilities that are harmful to public health. The law promotes the following: • Identifies technical specifications for selection of location. • Identifies requirements for issuing permits related to safety, civil defence, industrial safety requirements and other special requirements. • Oversees the implementation of these requirements by local administrative units.	
	Law 12/2003 concerning occupational health and safety (labor law)	All waste streams	This is the general labor law in Egypt, applicable to all activities and facilities. • Identifies occupational safety requirements. • Protects workers in the work environment.	

Co-processing Relevance	Law/decree Number	Waste Stream	Key Relevant Issue	Comments
Regulations that encourage investment in establishing waste management and waste treatment facilities	**Law 141/2004 and its executive regulations based on Prime Ministerial Decree number 1241/2004**	All waste streams	This law is related to establishing SMEs. It promulgates the environmental safety requirements.	• The law develops necessary funding mechanisms to finance cement companies interested in investing in AF. • It provides funding mechanisms for SMEs who are interested in becoming involved as part of AFR supply chain. • It governs the issuance of relevant regulations to formalize the participation of informal actors involved in waste collection.
	Law 8/1997 and its amendments by law 17/ 2015	All waste streams	This law relates to investment guarantees and incentives.	
	Law 38/1967 amended by law 10/2005	MSW	• This law regulates the collection and disposal of solid wastes from residential areas, commercial and industrial establishments and public areas. • It imposes a cleanliness tax on all housing units equivalent to two percent of the rental value. • Law 10/2005 Imposes a new solid waste collection fee added to the electricity bill, which citizens pay according to their residence area and income level, leading to partial cost recovery of money spent on MSW services. • Article 6 of law 38/1967 requires local councils to issue a license for all workers employed as waste collectors.	The consultant proposes engaging the SMEs at the level of waste collection, since the legal framework allows this type of opportunity. This will represent an opportunity to involve the private sector in AFR, the Zabaleen, for example, or other SMEs that offer employment opportunities for youth.
	Law 31/1976	MSW	• This law specifies the means of transportation, the types of garbage containers and the frequency of solid waste collection.	
	Decrees number 1741/2005, 5/2011, 1095 and 964/2015 (amendments for the executive regulations of Law 4/1994)	MSW	• These decrees set the requirements for the selection of locations for waste treatment facilities, as well as the selection of locations for landfilling. • They specify the necessary equipment for waste collection and transport.	
	Presidential Decree 86/2010	MSW	• This decree regulates the closure of all existing landfills and dumping sites in Cairo and their rehabilitation. • It allocates five new sorting, recycling and final disposal sites, to be located outside the commercial and residential belt of Cairo.	

Co-processing Relevance	Law/decree Number	Waste Stream	Key Relevant Issue	Comments
	Prime Ministerial Decree 1095/2011	MSW	• This decree requires waste collectors to maintain their garbage bins and vehicles in a clean state. • It determines the requirements for garbage bins and their capacity and standards as prepared by EEAA. • The garbage containers shall be collected and transported at suitable intervals according to the conditions of each area.	
	Ministerial Decree (134/1968) of Minister of Housing	MSW	• This decree promulgates regulations related to the collection and transportation of waste generated from domestic and industrial sources.	
	Presidential Decree 284/1983	MSW	This decree has established the Cairo and Giza Beautification and Cleansing Authorities, whose mandates include the collection of garbage and solid wastes and their disposal in special areas. As a result, many Zabbaleen have formed co-operatives to be able to buy pick-up trucks to continue their waste collection services.	This decree has established financial mechanisms to encourage young people to start local waste collection companies, providing the service to homes.
Regulations related to hazardous waste	**Law 4/94 amended by law 9/2009 and its executive regulations 1095/2011 amended by prime minister decree number 964/2015 issued in April 2015**	HW (tires)	The law stipulates the definition of hazardous waste and hazardous substances in Article 1. The Executive Regulations shall designate the competent authority, which, after consulting EEAA, will issue the list of hazardous wastes to which the provisions of this Law shall apply. • Article 29 forbids the handling of hazardous substances and wastes without a license from the competent administrative authority. • Article 30 requires management of hazardous wastes to be subject to the procedures and regulations stated in the Executive Regulations of this Law. • Article 31 forbids constructing any establishment for treating dangerous wastes without a permit from the competent administrative authority and before consulting EEAA. The Minister of Housing, Utilities and New Communities shall assign, after consulting with the Ministries of Health, Industry and EEAA, the disposal sites and the required conditions to authorize the disposal of dangerous wastes. • Article 32 forbids the import of dangerous waste or its entrance into or passage through Egyptian territories.	• Egyptian regulations forbid the import of scrap or shredded tires, although waste tires are not classified as hazardous waste by the Basel Convention, which entered into force in Egypt in the early 2000's. .

Co-processing Relevance	Law/decree Number	Waste Stream	Key Relevant Issue	Comments
			The law deals with the handling of hazardous waste: • Disposal of hazardous wastes shall be according to the regulations stated in the Executive Regulations. • The owner of an establishment whose activities may result in hazardous wastes should maintain a register of these wastes and the method of disposing thereof, as well as contracting concerned agencies for receipt of these wastes. • Article 40 requires that, when burning any type of fuel or otherwise, whether for industrial, energy production, construction or other commercial purpose, the harmful smoke, gases, and vapors resulting from the combustion process be within the permissible limits. The person responsible for such activity shall take all precautions necessary to minimize the pollutants in the combustion products. The executive regulations of this law shall define such precautions as well as the permissible limits and the specifications of chimneys and other means of controlling the emission of the smoke, gases and vapors resulting from the combustion process.	• Several companies have applied for permits to import waste tires (or any form of raisins according to Ministry of Industry classification of tires as either shredded tires or rubber pellets), but none has obtained an approval from EEAA to date, and it is not expected that EEAA will permit importing of TDF. The Tenders and Auctions Law 89/1998 does not indicate any environmental requirements for scrap dealers who buy scrap tires.
	Decree of the Minister of Industry 7/1999	HW (tires)	• Hazardous materials and hazardous waste cannot be handled or imported except with special permits.	
Regulations related to GHG – CO_2 **Requirements encouraging the use of AFR mix to reduce GHG emissions**		All waste streams	• Climate Change Central Department (CCCD), EEAA, is responsible for Egypt's climate change policies. • Suggested CO2 mitigation options for the cement industry include using either alternative fuel, sustainable sources of energy or other measures approved by EEAA. • In Egypt, there is no bottom-up GHG inventory as yet. Companies are not obliged to comply with the monitor report or verify (MRV) of their CO2 emissions. • The operation permit of cement companies does not limit the annual licensed quantity of coal to be used, which is purchased by the installations according to operational needs, a function of the specific thermal energy consumption, the fuel mix and the production quantity of the installation. • Entities using coal as fuel are committed to reducing GHG emissions resulting from combustion processes in accordance with clear procedures. These procedures shall be part of the EIA.	

Co-processing Relevance	Law/decree Number	Waste Stream	Key Relevant Issue	Comments
Requirements for using coal and AFR in cement factories	**Prime Ministerial Decree Number 964/2015**	All waste streams	This decree specifies a number of environmental, technical and permitting requirements that cement companies must comply with in order to obtain and maintain the permit to operate cement kilns fired with coal, petcoke or AFR. • Companies handling coal or using coal as a fuel must obtain a permit issued by the EEAA. • The delivery of the permit is conditional upon the elaboration of **an EIA study** and the assurance of the fulfilment of the requirements provided by the EIAs. • Companies must submit an annual report on environmental performance of the import, treatment or use of the coal or waste. • The permit shall be renewed every two years after approval by EEAA of the environmental performance reports submitted by the facility. • The Industrial Development Authority (IDA) remains responsible for granting operating permits and licenses for energy supply for industrial enterprises. • Cement companies using coal or waste as a fuel must comply with a number of stack emission limit values (ELV). To this end, the companies must monitor the emissions, either continuously or periodically, depending upon the nature of the pollutant.	This decreee provides for the enforcement and monitoring requirements of permits issued by cement companies.
			• The permit shall also define the maximum amount of licensed coal. The annual licensed coal quantities are defined on the basis that the consumption rate of thermal energy does not exceed 4,000 MJ per ton of black cement clinker and 6,200 MJ per ton of white cement clinker. • Facilities using coal as fuel shall control the increase of GHG emissions resulting from burning coal, and describe specific measures to reduce such emissions. This task shall constitute part of EIAs and the environmental performance reports. • Finally, the decree specifies a number of mechanical and technical requirements for the handling, storage, transport and feeding of coal and for the collection, handling, storage, transport and disposal of waste.	

Co-processing Rele vance	Law/decree Number	Waste Stream	Key Relevant Issue	Comments
Biomass	**Prime Ministerial Decree Number** 1740/2002	Biomass	• This decree is related to regulating the collection of agricultural waste and banning the burning of agriculture waste. • The law also bans disposal of agricultural waste in locations other than those designated by the competent authority.	Relevant regulations that can stimulate investment in biomass are related to reducing energy and fuel subsidies and also to a lesser extent fertilizer subsidies available for the market.
	Law of Environment 4/1994.	Biomass	• The law prohibits the open burning of waste. This applies to agricultural residue in general. • It prohibits agricultural residue which is used as animal fodder from being used for other purposes.	It is important to enforce the ban on the burning of agricultural waste, which would allow a greater proportion of agricultural waste to be available for pre-processing.
	Directive 63/2002 of the Ministry of Agriculture and Land Reclamation	Biomass	• The directive prohibits the growing of rice (except in certain amounts) and the burning of rice straw in Qalyubia Governorate, to minimize air pollution in Greater Cairo. • The annual land area officially devoted to rice plantation is mandated by a Ministerial Decree from The Ministry of Water Resources and Irrigation (MWRI). • For safety reasons, it is illegal to store agricultural waste on agricultural land. This issue poses a problem of allocating special plots for storage within agricultural lands.	The directive defines governmental or approved areas designated for primary storage of agricultural waste on cultivated areas.
	Environmental Law 9/2009	Biomass	• Article 37 prohibits disposing of any solid wastes, including agricultural solid wastes, outside designated areas, according to the agreement between EEAA and local authority.	
	Ministerial Decree from The Ministry of Water Resources and Irrigation (MWRI)	Biomass	• The area of land annually allocated for rice plantation is mandated by a Ministerial Decree from The Ministry of Water Resources and Irrigation (MWRI), depending on the irrigation water budget available.	
Sludge	**Executive Regulations issued by decree 44/2000** **Law 93 / 1962 amended by decree 44 /2000**	Sludge	There is no law or decree that prohibits or prevents the re-use of sludge as alternative fuel. • The regulations have approved re-use of sludge in energy production. • They are related to the protection of the public sewer system, and set the conditions for a commitment to the standards and the environmental dimension within the larger framework of sludge management and disposal.	Another regulatory issue concerning sludge is to reduce GHG emissions, and particularly CO_2 emissions. Sludge is a biogenic material that is "CO_2 neutral." Use of sludge in cement production to replace fossil fuels can therefore reduce the total CO_2 emissions per ton of clinker produced.
	Prime Ministerial Decree 254 /2003	Sludge	• This law approves using sludge as organic compost according to Egyptian CODE 501/ 2005, concerning the handling and use of treated sludge in Egypt.	

Notes

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