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Abstract:
Rwanda is a landlocked country in the East Africa. It is surrounded by Uganda, Tanzania, Congo and Burundi. Rwanda is a fast developing country and it spends most of its revenues to import fossil fuels from either through Mombasa Port in Kenya or Dar es Salaam port in Tanzania because the energy production in Rwanda is not sufficient for its development. Transporting the fuels from these ports, add on to the cost of all materials, cement industry being no exception. There are three cement companies in Rwanda. The cement industries could not run in full production due to the shortage of fuel. Moreover, Rwanda is importing all the construction materials such as steel, roofing materials, etc from its neighbouring countries. This increases the cost of construction and the common man find difficult to own a house. In order to sustain the energy needs of Rwanda, different sources of energies should be focused. They are Peat, Geothermal, Methane gas, solar, wind, waste materials and Municipal wastes. Without affecting the environment, there is an urgent need to find a solution on sustainable energy in Rwanda. This paper discusses about the possible sources of energy in Rwanda which will improve the energy sustainability and turn the economy of Rwanda.

Keywords: Energy sustainability-Biomass-Cement production-peat

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Introduction

Hydraulic binders such as cement have played a key role as a construction material throughout the history of civilization. In Rwanda the use of cement and concrete in large civic works can be traced from 1984 through nowadays times. The annual production of cement is 100,000 tons in Rwanda; and it is being produced by one plant, called CIMERWA. The needed oil for the annual production is 12,000 to 13,000 tons. The cement industry is a highly capital intensive industry with yearly capital investments of 1,127 billion FRWs (1,349 million EUR/1,786 million USD). The other two cement plants produce cement by importing clinkers from neighbouring countries or from the continent. Cement production is an energy intensive process in Rwanda by using conventional fuels, but if alternate fuels would be used the cost can be reduced. This paper provides information on the usage of selected waste materials for cement production. For example, the cement production industry from CIMERWA can use 40% of heavy fuels, 20% of peat and 40% of waste materials. From CIMERWA it was noted that they have started using 20% of the peat and 80% of the heavy oil [1]. In addition to peat, the usage of organic and non-organic materials will reduce the cost of production and carbon emission. The principal purpose of this paper is highlighting the availability of different waste materials as an alternative fuel in cement industries in Rwanda. This paper also provides an overview of technical and qualitative characteristics of organic and non-organic wastes, chemical and hazardous wastes, petroleum based wastes, methane gas and miscellaneous waste fuels and their potential environmental impacts.

Alternative Fuels and Environmental Impact Control

Biomass can be considered as relatively 'carbon-neutral' because plants absorb carbon dioxide as they grow. Biomass waste such as forest products, fuel wood, foliage, shavings, agricultural crops, cotton stokes, rice straw, sugarcane, flower farm waste and wheat straw are widely used as renewable and carbon-neutral fuels. Industrial-scale animal wastes, such as bones, fats, meats and other animal wastes, also fall under the biomass category.

Opportunities to power Rwanda: Waste-to-Energy Process

Kigali produces around 450 tons per day solid wastes of which between 300 and 350 t/d is centrally collected. The fraction of organic wastes comes from households, restaurants, hotels and markets. Other types of solid wastes available in the country include: agriculture waste, livestock waste, etc. It is estimated that 100 t/d of raw municipal solid waste can produce 1 MW, using traditional thermal technologies.

Agricultural Residues: Large quantities of crop residues are produced annually in Rwanda. The most common agricultural residue is the rice husk, which makes up 25% of rice by mass. Other residues include sugar cane fibre (known as bagasse), coffee coats, groundnut shells, cereal straw etc. Current farming practice is usually to plough these residues back into the soil, or they are burnt, left to decompose. A number of agricultural and biomass studies, however, have concluded that it may be appropriate to remove and utilise a portion of crop residue for energy production, providing large volumes of low cost material. These residues could be processed into liquid fuels or combusted/gasified to produce electricity and heat.

Animal Waste; There are a wide range of animal wastes that can be used as sources of biomass energy. The most common sources are animal and poultry manures. In the past this waste was recovered and sold as a fertilizer or simply spread onto agricultural land, but the introduction of tighter environmental controls on odour and water pollution means that some form of waste management is now required, which provides further incentives for waste-to-energy conversion. The most attractive method of converting these waste materials to useful form is anaerobic digestion which gives biogas that can be used as a fuel for internal combustion engines, to generate electricity from small gas turbines, burnt directly for cooking, or for space and water heating. Food processing and abattoir wastes are also a potential anaerobic digestion feedstock.

Sugar Industry Wastes: The sugar cane industry produces large volumes of bagasse each year. Bagasse is potentially a major source of biomass energy as it can be used as boiler feedstock to generate steam for process heat and electricity production. Most sugar cane mills utilise bagasse to produce electricity for their own needs but some sugar mills are able to export substantial amount of electricity to the grid.

Forestry Residues: Forestry residues are generated by operations such as thinning of plantations, clearing for logging roads, extracting stem-wood for pulp and timber, and natural attrition. Wood processing also generates significant volumes of residues usually in the form of sawdust, off-cuts, bark and woodchip rejects. However it can be collected and used in a biomass gasifier to produce hot gases for generating steam.

Industrial Wastes: The food industry produces a large number of residues and by-products that can be used as biomass energy sources. These waste materials are generated from all sectors of the food industry with everything from meat production to confectionery producing waste that can be utilised as an energy source. Solid wastes include peelings and scraps from fruit and vegetables, food that does not meet quality control standards, pulp and fibre from sugar and starch extraction, filter sludges and coffee grounds. These wastes are usually disposed of in landfill dumps. Liquid wastes are generated by washing meat, fruit and vegetables, blanching fruit and vegetables, pre-cooking meats, poultry and fish, cleaning and processing operations as well as wine making. These waste waters contain sugars, starches and other dissolved and solid organic matter. The potential exists for these industrial wastes to be anaerobically digested to produce biogas, or fermented to produce ethanol.

Municipal Solid Waste (MSW): Millions of tonnes of household waste are collected each year with the vast majority disposed of in landfill dumps in Rwanda. The biomass resource in MSW comprises paper and plastic and averages 80% of the total MSW collected. Municipal solid waste can be converted into energy by direct combustion, or by natural anaerobic digestion in the landfill. At the landfill sites the gas produced by the natural decomposition of MSW (approximately 50% methane and 50% carbon dioxide) is collected from the stored material and scrubbed and cleaned before feeding into internal combustion engines or gas turbines to generate heat and power. The organic fraction of MSW can be anaerobically stabilized in a high-rate digester to obtain biogas for electricity or steam generation.

Sewage: Sewage is a source of biomass energy that is very similar to the other animal wastes. Energy can be extracted from sewage using anaerobic digestion to produce biogas. The sewage sludge that remains can be incinerated or undergo pyrolysis to produce more biogas.

Peat: Peat is a partially carbonized decayed vegetable matter that forms in wetlands and is saturated with water. It is a slowly renewable biomass fuel created under specific conditions of water logging, lack of oxygen or nutrients, high acidity and/or low temperatures. Peat is a sedentarily accumulated material consisting of dead organic material and has been used as a fuel in many countries for a long time. Peat is the earliest stage in the formation of coal. Peat is mostly used as heating energy source.

Rwanda has estimated national reserves of approximately 2.6 billion tons of wet peat, which if fully exploited can provide sufficient energy for many of the country's needs for several years to come. The peat reserve in Rwanda is estimated to 155 million of m^3. There are large quantities

of naturally occurring peat in Western and Southern province. Large reserves have been confirmed in Gishoma, Busoro, Akanyaru, Akagera-Nyabarongo, to mention but a few.
The peat quality varies by location. Good peat bogs like Gishoma & Busoro have:
• High carbon content (hence good heat properties)
• High calorific content (avg. 16 -18 MJ/kg); similar to fuel wood
• Low sulphur (less environmental pollution) [2]

Environmental impact Control
The use of wastes will increase particulate emissions but can be capably controlled by the existing air pollution control devices to meet the Rwanda Environmental Management Authority (REMA) emission standards. For other wastes, screening and control of waste materials delivered to the plant shall be implemented to ensure that it will not cause undesirable emissions at the plant stacks.
Collection, handling and transport of wastes from the source shall be monitored and controlled with the accreditation of waste transporters by the REMA and the Plant. The plants prepared the Protocol for the Use of Alternative Fuels that describe the procedures on delivery, handling and storage of wastes, analysis and testing of wastes delivered and testing of stack emissions.
The use of agricultural, domestic and industrial wastes in cement kilns will provide other means of managing waste. Use of waste in cement kilns will reduce disposal costs and potential contamination of land and water resources.

A New Proposed Cement Plant Using Peat as Fuel

A new Rwandan cement project is proposed to be located in Muganza Sector, Rusizi District of the Western Province. The location is about 350 km from Kigali and 60 km from Kamembe town. The new clay mining area is located in Muganza Sector; about 2 km from the plant and the limestone and sandstone mining areas are located in Nyakabuye Sector at about 3 km from the plant site. Pozzolana is available from Nyamyumba Sector of Rubavu District. The peat, which is proposed to be used as a fuel at the new cement plant in the future, is available from Gishoma bog, which is located close to the Rusizi-Bugarama road, 18 km south of Rusizi. Peat extraction shall be carried out by a separate company called Peat Energy Company, a subsidiary of Rwanda Investment Group. Other peat bogs over which concessions have been obtained include Mashya and Gihitasi, located close to Gishoma bog.
The existing CIMERWA plant has a production capacity of 100,000 tons of cement per annum and is constructing a 600,000 tons per annum plant that will be commissioned during 2014. The current demand for cement in Rwanda is estimated at 350,000 tons per annum. Based on Rwandan and the Great lakes region's positive economic outlook, regional cement demand is projected to increase to 1 million tons during the next decade.

Case study: CIMERWA energy needs & usage of alternative energy

In this study, it is observed, how much energy is used by CIMERWA in the process of burning the clinker and the respective prices are compared. This data is represented as classification of wastes (organic and inorganic), quantity of wastes collected and disposal methods. Table 1 shows the average amount of Heavy Fuel Oil (HFO) and peat used in CIMERWA and Table 2 shows the amount of wastes produced in the Kigali City in a month. The data in Table 2 was collected from COPED ltd, kabuye decotilage rice company, kabuye sugar company, MINAGRI, where different information where gathered and recorded [5].

The research carried out in CIMERWA indicated that; the main source of energy that CIMERWA used are heavy fuel oil, peat and electricity for running machines. To this end; among 739 tons of heavy fuels, 755 tons of peat is the maximum quantities used when machines have not been stopped. As far the proposal concerned, 40% of heavy fuel oils can be replaced in CIMERWA by energy from biomass as follows:

AE = (B *C_vb)*ε

Where: AE: alternative energy; B: Biomass quantity in tons; C_vb: calorific value of biomass as 17.5 MJ/Kg; Є: Efficiency of biomass =25%

➔ **AE = (2,631.03*17.5)*25%= 11,510.75 GJ per month**

CIMERWA is using 739,353 kg of heavy fuels and this can be converted into energy as follows:

FE = F*C_VF

Where: FE: fuel energy; C_VF: calorific value of fuels from table 2.1 = 38.9 MJ/Kg

➔ **FE = 739,353*38.9 MJ = 28,760,831.17 MJ = 28,760.831 GJ per month**

This means that in one month CIMERWA needs 28760.8 GJ energy from fuels and the waste provides 11,510.75 GJ. This is 40% of the heavy fuel oil used. So there is a brighter opportunity to transfer waste into a useful materials. Consequently, the research found that the quantity of energy yield from waste produced by Kigali city can replace 40% of heavy fuel oils transported from Kenya. Hence the cost of cement can be reduced and the field of waste management can be successful by transforming wastes into energy.

Table 1: Fuels used by CIMERWA to generate energy

Month	HFO in kg	Peat in tons
January	712,978	653
February	700,123	701
March	654,678	698
April	627,978	668
May	711,112	710
June	698,987	611
July	739,353	755
August	606,043	727
September	700,008	539
October	675,021	740
November	641,003	645
December	612,567	705

Table 2: Monthly distribution of wastes in Rwanda and their quantities

	Organic in Tons (ow)	Water content %	Overall organic wastes in tons	Non organic in tons
Nyanza landfill	4,104	80	820.8	2,736
Supermarkets	522.6	60	209.04	257.4
Ministries	390	40	234	210
COOPED	450	78	99	150
From rice hush	105.8	45	58.19	0
From coffee	500	43	285	0
Sugar Cane hush	2,500	63	925	0
Total	**10,906.2**		**2,631.03**	**5,913.6**

Overall organic wastes=ow-(wc*ow)

Benefits of Using Biomass and Alternative Waste Fuels

Economic: Between 30-40 percent of the total cost of cement production is accounted for by energy needs. This means a significant reduction in cost can be achieved by using renewable and waste fuels. Hence, burning biomass and waste as a source of energy could save significant costs [3]. This provides energy security for land-locked countries and hedges against volatile global energy markets. The use of waste as alternative fuels in the cement industry has numerous environmental benefits, such as: Alternative fuels reduce the use of fossil fuels, contributes towards lowering emissions of greenhouse gases from materials that would otherwise have to be incinerated (with corresponding emissions), maximizes the recovery of energy from waste. All the energy is used directly in the kiln for clinker production, which maximizes the recovery of the non-combustible part of the waste and eliminates the need for disposal of slag or ash, as the inorganic part is incorporated into the cement and environment shall be protected from unnecessary landfills by wastes [4]

Environmental: Biomass is a renewable energy resource that can be replaced by growing trees, crops or other vegetation to maintain the level of sequestered carbon in the environment. In addition to capturing carbon dioxide, planting vegetation protects land fertility, prevents solid erosion, reduces sedimentation at dams and water reservoirs, provides ecosystems for wildlife and insects, and, of course, produces wood for high-value timber use as well as biomass.

Potential Barriers

Burning alternative fuels is beneficial to cement companies as well as the environment. But there are barriers to successful utilisation of biomass in the cement industry, which are constant and sufficient supply of biomass product, consistency of biomass fuel to keep the constant calorific value, infrastructure barriers such as highways, machineries and power, capacity building and awareness among the local people to make the biomass sustainable material and harmful materials may be removed safely without affecting the people. However, agricultural wastes have also shown to be important fertilizers and suppliers of minerals for next generation crops. Therefore, the benefits need to be used carefully and to the benefit of all involved parties. Furthermore residues from wastes incorporated into the clinker burning process can have strong impact on the cement chemistry. E.g. phosphates from meat and bone meal combustion are known to have strong impact on the setting of cement [6].

Conclusions and Recommendations

The financial and other benefits of switching on wastes as source of energy in cement plants are evident from the above. Cement plants in Rwanda have to consider the option of utilizing wastes as alternative energy source and thereby replacing some portion of the fossil fuels they are currently using. Cement factories need to study what types of wastes are available in their locality and what can effectively be utilized in the short term to replace 50% of the conventional fuels they are using. In the longer term, they need to study all options for switching to higher-percentage wastes as source of energy utilization.

The use of alternative fuels by the cement industry offer two important benefits of environmentally safe waste management and disposal, as well as the generation of energy. The growing use of alternative fuels by the cement industry as a method to dispose solid wastes and generate energy has greatly reduced environmental impacts of municipal solid waste management, including emissions of greenhouse gases. Waste-to-energy conversion reduces greenhouse gas emissions in two ways. Electricity is generated which reduces the dependence on electrical production from power plants based on fossil fuels. The greenhouse gas emissions are significantly reduced by preventing methane emissions from landfills. Moreover, waste-to-energy plants are highly efficient in harnessing the untapped sources of energy from a variety of wastes and those wastes are locally available here in Rwanda. An environmentally sound and techno-economically viable methodology to treat biodegradable waste is highly crucial for the sustainability of modern societies. A transition from conventional energy systems to one based on renewable resources is necessary to meet the ever-increasing demand for energy and to address environmental concerns.

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