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Uses of Alternative Fuels in Cement Industrial Sectors as Sustainable Development Option: Case Study Cement Company in Egypt

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Abstract

After the energy transition in 2014, companies switched to different fuels like coal as a primary fuel and used alternative fuels like refuse-derived fuels (RDF), tire-derived fuels (TDF), dried sewage sludge (DSS), agricultural waste (AW), and waste oil as a secondary fuel to meet energy demand. As a result, alternative fuels have become an important source of energy for cement companies in Egypt. This research demonstrated the potential use of alternative fuels by substituting fossil fuels, which helped to conserve natural resources and less damping waste. Waste-to-energy principal and material recycling applications are essentially made possible by the characteristics of the clinker burning process. The research was based on an evaluation of the various types of alternative fuels used, such as used tires, sewage sludge, waste oil, and agricultural waste. It demonstrated a positive impact on lowering NO_x emissions and energy consumptions for clinker production to approximately 3666 MJ/ton. In addition, 218.839 tons of refuse-derived fuels, specifically agricultural waste (AW) and refuse-derived fuels (RDF), were used in the company's cement production instead of being dumped on a landfill, which is a crucial option for attaining sustainable development in Egypt's cement production market.

Keywords: Cement industry, Alternative fuel, Sustainable development.

Introduction

Cement is considered one of the most important building materials around the world. The process of cement production is an energy-intensive one, requiring about 3.3 GJ of heat energy for every tone of clinker produced. About 90 to 120 kWh of electrical energy is used for every tone of cement **(Giddings et al., 2000)**. Typically, the thermal energy needed for the cement industry is provided by fossil fuels like coal, petroleum coke (pet coke), and natural gas. Because of rising fossil fuel costs, finite fossil fuel supplies, and

environmental concerns, the use of alternative fuels (AF) is becoming more and more common among cement manufacturers. All non-fossil fuels and waste from other industries, such as tires, biomass residues, sewage sludge, and various commercial wastes, are covered by alternative fuels. Because of the rotary kiln's continuous exposure to high temperatures, the clinker's inherent ability to absorb and lock impurities into it. The alkalinity of the kiln environment, a wide variety of materials can be burned in this kind of furnace. These days, bone meal and meat are also regarded as alternative fuels. **(Azad Rahman et al., 2013).** Since most alternative fuels (AFs) are produced from wastes and only require a small amount of processing, they are typically less expensive than fossil fuels. The ideal ratio of AF and fossil fuels is utilized to generate the thermal energy needed by the cement industry. The preservation of nonrenewable energy sources and the elimination of waste disposal sites are two major benefits of substituting alternative fuels **(Willitsch et al., 2002).** The practice of substituting waste products and other alternatives for fossil fuels in the production of cement is being adopted by different countries worldwide. Industrialized countries have achieved success for more than 20 years. **(Holcim, 2006).** The Netherlands and Switzerland, with respective national substitution rates of 83% and 48%; respectively are world leaders in this practice **(Cement Sustainability Initiative, 2005).** Refer to the perspective of industry and society, waste fuels represent an important way to prevent further pollution emissions as well as to recover energy from waste in the context of a sustainable economy (**Fyffe et al., 2016).** The **a**lternative fuels combustion allows for reducing NO_x emission and may reduce the SO_2 emission **(Fyffe et al., 2016).** When alternative fuels with the right qualities are co-burned, the effect on pollution emissions is negligible as long as the process is done properly and emissions meet legal limits **(Hasanbeigi et al., 2010)**. The use of RDF in the cement production can be environmentally and economically has positive impact or sustainable development **(Reza et al., 2013).** Alternative fuels are still being used in cement kilns. While 100% substitution rates have been achieved in some kilns, local waste markets, permitting requirements, and other factors prevent higher rates of AFR from being possible in other kilns. The flame shape can be adjusted to optimize the burning behavior of the fuels and the conditions under which the clinker burns using thermograph systems and modern multi-channel burners designed for using alternative fuels. Table 1 lists the waste used as alternative fuels in the cement industry **(Schneider et al., 2011).**

Table 1. Waste used as alternative fuels in the cement industry.

Category	**Fuels**
Gaseous fuels	Refinery waste gas, landfill gas, pyrolysis gases.
Liquid fuels	Chemical waste, waste solvent, used oil, petrochemical waste, paint waste, oil sludge.
Solid fuels	Petroleum coke, paper waste, rubber residues, sewage sludge, used tires, wood waste, domestic refuse, rice husks, refused derived fuels.

After the Egyptian government diverted natural gas from heavy industrial Cement companies in Egypt are evaluating the possibility of substituting alternative fuels, such as

Tire-Derived Fuel (TDF), Dried Sewage Sludge (DSS), agricultural waste, and Refuse Derived Fuels (RDF), for conventional fuels due to energy costs and environmental concerns. Recent research studies have been developed to introduce sustainable raw materials or alternative fuels into the cement industry in an effort to lower greenhouse gas emissions and potential energy consumption during the cement manufacturing process **(Aranda Uson et al., 2012)**.

Materials and methods

The research methodology depends on assessment of using different types of alternative fuel as a secondary source of energy in cement sector through assess the energy consumption and emissions reduction principals during cement production between 2015 to 2020 in Titan Alexandria Portland Cement Company (APCC), as the company has changed the type of fuels in these periods.

Study question

How can the using of alternative fuel as a secondary source of energy achieving the sustainable development in cement sector?

Study area

The research was done in Titan Alexandria Portland Cement Company (APCC) which located in Wadi Al-Qamar region, west of Alexandria Governorate, on the Mediterranean coast of Egypt at 7º 24' 42.45"N and 8º 58' 31.28"E as shown in Fig. 1.

APCC is chosen in this study because it represents one of the most important and largest cement plants in Egypt that is concerned with applying local legal limits and regulations for environmental protection as one of the sustainable development goals. It also implements an online data monitoring system using multi-component analyzer systems to measure and report air emissions. The APCC works 24 h a day, 7 days a week (24 h/7 day), with a continuous monitoring system for emissions from the main chimney. These measurements are transferred directly to the EEAA control room which enables to monitor the emissions closely in real time and take actions accordingly.

Data collection methods

Data was collected from various sources. The min source was the Environmental Annual reports for using coal and alternative fuel in the cement company. The reports prepared according to the technical guidelines of Egyptian Environmental Affairs Agency (EEAA) for the environmental performance of cement companies which used coal, pet coke or waste-derived fuels **(Performance Report Guidelines, 2016)**. The reports explain the environmental performance and situations during fuel mix use, then Submit to EEAA for reviewing and assessment every year. In addition to the site visit and interview with employees and environmental manager in (APCC) served as the backup source.

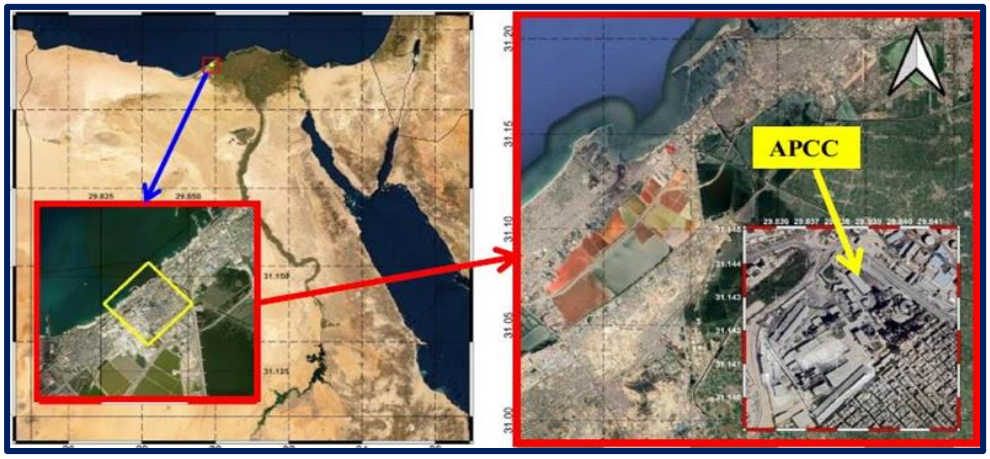

Fig. 1. Location of Titan Alexandria Portland Cement Company (APCC).

Applicable local laws and regulations for emission levels

The Egyptian Environmental Affairs Agency (EEAA) established the local laws, rules, guidelines, and requirements for environmental preservation. It also kept an eye on industrial facilities' compliance and prosecuted offenders. The present study is concerned with the law No. 4 of 1994, which was amended by Law 9/2009 and its Executive Regulations in 1995, as well as the amendments No. 1095 in 2011, 710 in 2012, and 964 in 2015 for using coal and fuels in cement industries.

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Results and Discussion

Alternative fuels options in cement production

Between 2015 and 2020, Titan Alexandria Portland Cement Company (APCC) began producing cement using various alternative fuels. The findings indicated that the company began using waste oil as an alternative fuel in 2015, accounting for 23% of the total fuel mix. However, the company discontinued this practice in 2015 due to waste oil impurities, which had a negative impact on air emissions, particularly NO_x emissions, and the quality of cement production. Use of alternative fuels, such as agricultural waste (AW) and refuse-driven fuel (RDF), began in 2016 and 2017 at 4.28 % and 14% of the total fuel mix, respectively, these fuels were good choices due to their natural components and the conditions under which the combustion process controlled for the production of clinker. The company also began using Dried Sewage Sludge (DSS) at the same time, but it was not a good option at the time due to its high moisture content, which affected cement production and energy consumption.

As a result, the company stopped using DSS. In 2018 the company used only agriculture waste (AW) and refuse drive fuel (RDF) with high substitution rat 17.16 % of total fuel mix, which improve the environmental performance by reducing NO_x emissions

from stack kiln, as well as improve the energy consumption rate for clinker productions. In 2019 and 2020 APCC has started using Tire-Derived Fuel (TDF) with 2.7 %and 4.8 % in addition to agriculture waste AW and refuse drive fuel RDF with 16.8 %, 12.2%, respectively (Fig. 2).

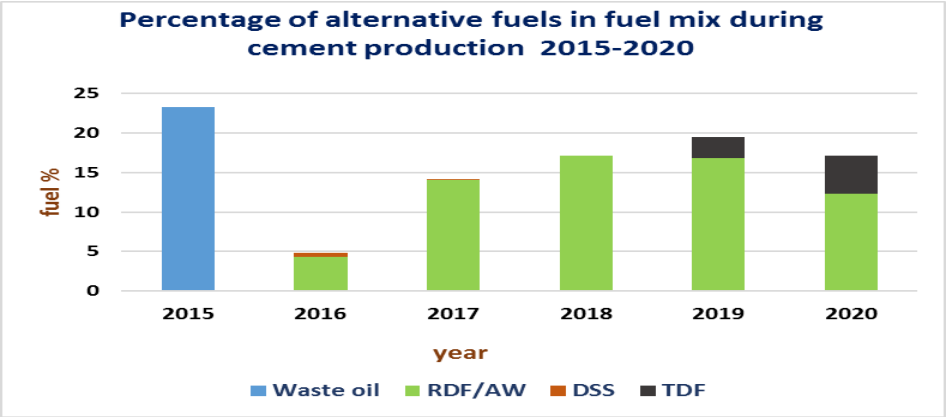

Fig. 2. The percentage of alternative fuels options in cement production.

Energy consumption

According to environmental impact approval from Environmental Affairs Agency (EEAA) for the cement company (case study), the required energy should not exceed 3700 MJ to produce one-ton clinker. In 2014 during using natural gas the consumption rat per each ton clinker was 3434.26 MJ while in 2015 and 2016 when using small amount of alternative fuels in fuel mix the consumption rate was 3837.43 MJ and 3723.95 MJ; respectively, which was higher than allowing limit. From 2107 to 2020, while using a high amount of alternative fuels AF in fuel mix with 17% substation rate of fuel mix, the energy consumption rate for one-ton clinker has decreased to 3666 MJ/ton lower than the EEAA limits of clinker energy consumption (Table 2 and Fig. 3).

Table 2. Total energy consumption MJ / tone clinker production.

Years **Items**	**2020**	**2019**	**2018**	**2017**	**2016**	**2015**	**2014**
Total clinker production ton /year	927979	1200099	1175896	1401606	1395631	1118155	881561
Total energy consumption Tj/ year	3402.7	4371	4329	4371	5197	4290,69	3027,50
Energy consumption MJ/t clinker	3666	3642	3682	3832	3723.95	3837,43	3434,26

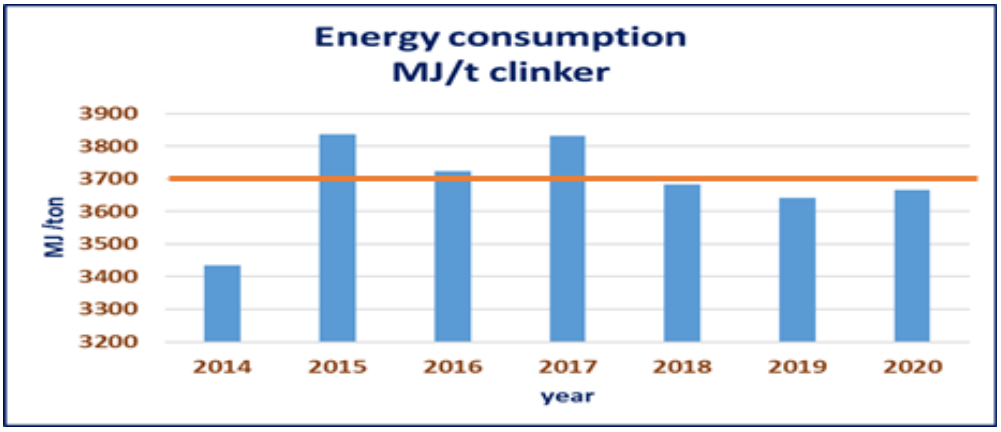

Fig. 3. Energy consumption per one-ton clinker.

NO_X emissions reduction

The results in Fig. 4 showed that using of alternative fuel in fuel mix as agriculture waste AW, refuse drive fuel RDF has reduced the NO_x concentrations to be lower than AQL of 600 mg/m^3, as in 2016 to 2020 due to the lower temperature combustion of pre-calciners process **(Cembureau, 1999)**. In addition, in pro-claimers, where kiln exhaust gases pass through, the NO_x emissions were reduced more due to re-burn reactions **(Cembureau, 1999)**. While using natural gas only during 2014, or using waste oil in fuel mix with high impurities in 2015, the concentration of emitted NO_x was higher than AQL of 600 mg/m^3 **(Cembureau, 1999a and EC, 2001)**.

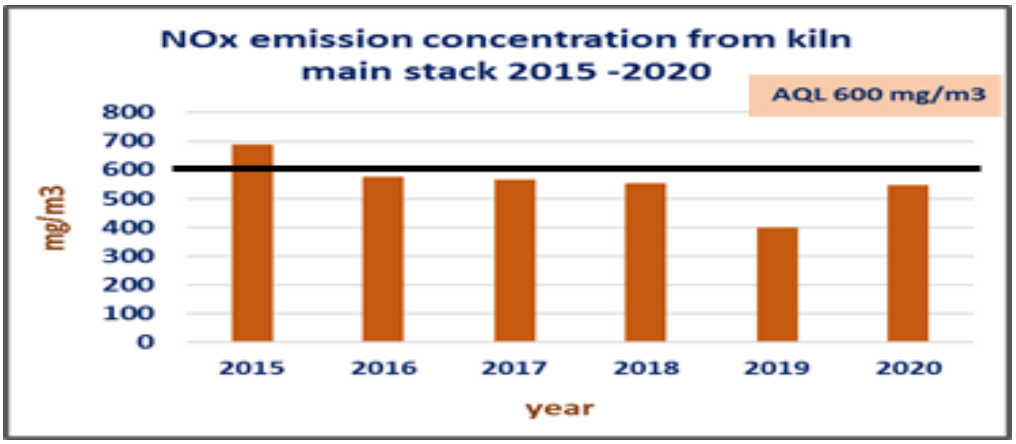

Fig. 4. NO_x emission concentrations.

Using alternative fuel in Cement Company achieving sustainability

Egypt produced about 21 million tons of MSW in 2012; at a projected 3.4 % annual growth rate, that amount is expected to increase to 35 million tons by 2025. It is estimated that Alexandria has a potential RDF of about 4000 tons per day, or 1460000 tons annually **(International Finance Corporation, 2016)**. Titan Alexandria Portland Cement Company (APCC) used about 218,839 tons of refuse-derived fuels from 2016 to 2020 to produce cement rather than a landfill damping. Using alternative fuels in cement production is saving non-renewable resources and reducing waste disposal requirements for achieving sustainability in the manufacture of cement (Fig. 5).

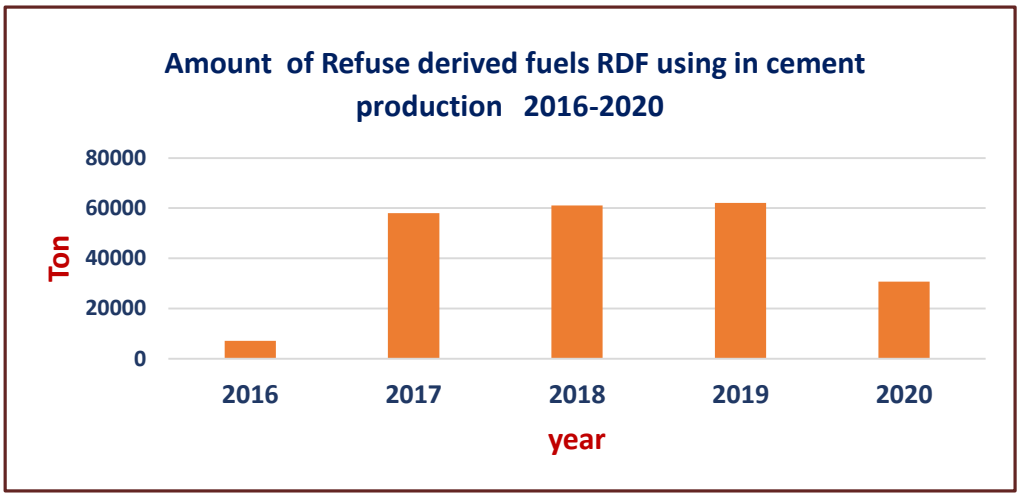

Fig. 5. Amount of refuse derived fuels in cement production.

Conclusion

Using alternative fuels as agriculture waste (AW), refuse drive fuel (RDF), Tire-Derived Fuel (TDF) in cement production process as secondary source of energy is an important option for achieving sustainable development through less damping waste and convert waste to energy which lead to reduce the number of disposal sites. In addition, the use of alternative fuels in cement manufacture is ecologically beneficial for the conservation of non-renewable resources as natural gas and other fossil fuel, as well as to decrease the environmental impacts of pollutants emissions such as NO_x. Also the use of waste as a fuel is related to energy-consuming process of clinker production and allowed to reduce the production costs.

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