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Developing of Alternative SRFs in Kerman's Cement Industry by Energy Optimization and Economical Feasibility Approaches

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Abstract
Optimizing and decreasing the fuel consumption and as a result preserving the national financial resources are so important purposes in the resistive economic which has been becoming so vital during previous years due to the implementation of sanctions against Iran. Using the alternative fuels stemming from municipal waste and using them in the energy industry of cement can be some suitable solutions in attaining these purposes. In this study, first, all kinds of operational alternative SRFs (Standard Refinery Fuels) in Iran have been surveyed and compared with known RDFs (Refuse Derived Fuels); then, in the county of Kerman, Bardsir, and Mahan in the province of Kerman which are located in the 50-kilometer buffer of Kerman Cement Company and Momtazan Cement Company has the potentiality of SRF production from the municipal waste been assessed. According to the results, 330 tonnes of SRF by common quality are producible which this amount of alternative fuel can decrease the consumption of fossil fuels such as mazut about 30,000 tonnes in Rotary furnaces in Kerman province's cement industry. This amount of substitution will have the great potentiality of foreign exchange savings in this region which will be very economical due to the required initial investment and noticeable due to the amount of Rials savings. The development of a conventional unit of SRF production and injection has also been surveyed economically.

Keywords: Alternative Fuel, Municipal Waste, Cement Industry, Kerman, Resistive Economy.

Introduction

Cement is one of the key construction materials needed for infrastructures and housing. The cement industry has widely faced with the growing challenges of preserving materials and energy resources and reduction of CO_2 emissions. Cement producers are endeavouring to increase the efficiency and use the raw materials and alternative fuels. Therefore, using the alternative AFs (after-burn fuels) has been increased dramatically in recent years; however, there is a huge potentiality for using alternative fuels (Madlool et al. 2013).

In recent years Iran has faced the economic crises stemmed from international sanctions which overcoming solution of this challenge is to develop the resistive economy in diverse economic and industrial levels of country according to the supreme leader guidance. One of the most important raised areas in the Iran's resistive economy is the fossil fuels and resources' area which the consumption reduction and optimization solutions and as a result preserving

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from the waste of national financial resources are from the most important purposes of resistive economy (Bosoaga et al. 2009; Madlool et al. 2011). Therefore, using the subsidiary and alternative fuels in the cement industry as one of the most energy consuming industries of country can be a suitable and noticeable solution in order to attain the resistive economy.

The cement role in resources preservation and environmental protection has been enhanced in recent years due to the rapid economic growth in vast regions such as China, India and the Southern Asia (Singhi and Bhargava, 2010). Cement industry is an intensely energy-consuming industry which conventionally 30-40 per cent of production expanses go for consuming energy. Table 1 shows the world's required amount of cement in future (Mokrzycki and Uliasz-Bocheńczyk, 2003; Mokrzycki et al. 2003).

Table 1. The World's Required amount of Cement in Future

Need to Cement (million ton)	2010	2020	Growth Percentage
World's Need	2836	3000	4.7
Western Europe	236	350	2.2
The South of USA	200	300	2.9
Other Regions	500	600	4.7
Asia	1900	2200	5.2

The consumption of energy in the cement industry is approximately 2% of the total energy consumption of the world and 5% of the total energy consumption in industry. The fuel mixing and Calcination process cause CO_2 production. Therefore, the cement industry causes the 5% of CO_2 emission (Madlool et al., 2011; Madlool et al., 2013). The cement production in EU in 2008 was 200mt which is almost 7% of world's total production. In 2008, in Europe, 158mt CO_2 emitted from cement companies which equals to 38.5% of industrial emission in Europe or 3.2% of total CO_2 emission in Europe.

In a modern cement company, 60% of the emitted CO_2 is from the Calcination of limestone, 30% is from the fuel-burning in the furnaces, and 10% results from the other company's downstream actions (Bosoaga et al., 2009). Improving the energy efficiency (usage of energy-optimization equipment, modification processes, etc.), changing the contemporary fuel to the alternative fuel, and producing mixture of cement by the usage of sidelong products are related to the reduction of CO_2 emission and reduction of energy-consumption (Bosoaga et al., 2009).

Cement furnaces use different sources of energy in order to produce required high-temperature heat for making clinker. The most well-known fuel resources for the cement industry include: coal, fuel oil, coke, and natural gas (Singhi and Bhargava, 2010). Alternative fuels are one of the other used energy resources by cement-producers all around the world. These fuels are usually obtained from perilous waste and municipal or industrial waste (Mokrzycki and Uliasz-Bocheńczyk, 2003; Mokrzycki et al., 2003).

The alternative SRFs in the Austrian cement industry are commonly being used in that in 2011 more than 63.5% and in 2013 about 73.36% of the primary energy in the cement furnaces have been supplied from this alternative fuel (Mauschitz, 2013). According to the surveys done in Austria in 2013, from the environmental perspective, using the alternative SRFs has been suggested due to waste biomass content in order to decrease the cement industry pollutants; and environmental permissions have been issued for it (Ellerman and Buchner, 2007). According to the statistics published in 2012, the federal's plan for managing the waste in Austria, more than 1.5mt solid waste are annually being used in the cement furnaces as SRF (Allesch and Brunner, 2016). National standards have also been issued in order to prepare the waste to be used as alternative SRF in research centres named CEN/TS 15422; and now alternative SRFs are in operation practically (Pomberger and Sarc, 2014).

The used alternative fuels in the cemetery industry can be solid or liquid; indeed, according to their organic content and components, a suitable chemical content is required. Five groups of solid alternative fuels will be introduced in continuance. Generally, these fuels include: the agricultural remaining biomass waste, the non-agricultural remaining biomass, waste by the petroleum stems, other waste, and perilous and chemical waste (Madlool et al., 2011).

The major CO_2 producing parts are from fuel consumption, Clinker furnace's structure, and Calcination. Using the fuel content of low-carbon by high relevancy of hydrogen to carbon instead of conventional fossil fuels drastically decreases the CO_2 emission relativity in the production process; and it has also been shown that using the alternative fuels decreases resistant life and also the drops pressure in the pre-heat tower (Grosse-Daldrup and Scheubel, 1996).

Different kinds of alternative fuels are used in Cement Company which proper machinery is installed for exploitations. The usage of alternative fuels in cement companies also causes the reduction of emission on the burial locations. Therefore, it is estimated that exploitation of this kind of fuel will be increased 1% annually all around the world (Schneider et al. 2011).

Exploitation of alternative fuel in cement industry commenced form 1980s. Alternative fuel is used in clinker lines and approximately to 100% has been used in pre-clinker stages. AF is basically extracted from the animal waste, sewage sludge, and waste oil which can be seen in Table 2. Recently, solid recyclable fuels have been produced from the flows of industrial waste and are growing towards the usage of municipal waste. These produced waste fuels are purified by light beams and are processes by aerial separation unit or mechanical separation unit.

The waste produced fuels include: frayed papers, plastics, foils, fabrics, rubbers, and mineral and mental impurities. Usage of alternative fuels in cement furnaces is in progression yet. While in some furnaces substitution amount has reached 100%, the other local market's waste and legal circumstances do not allow for more usage of alternative fuels and raw materials.

Exploitation and usage of AFR are related to the adjustable ignition processes. Modern multi-channel heater and burner have been designed for AF usage; and thermometer systems allow the control of shape of flame for clinker for fuel exploitation of fuel manners and burning conditions.

Table 2 shows the derived fuels form different waste according to their phases (solid, liquid, gas).

Table 2. Alternative fuels derived from different wastes according to their phases

Gaseous Waste	Solid Waste Fuel	Liquid Waste Fuel
Burial location's Gas	Industrial Plastics	Sewage Sludge
Pyrolysis Gas	Plastic Waste	Powdered Asphalt
Flaring	Food Waste	Dyeing Waste
	Rubber Waste	Oil Coke
	RDF Plastics	Oil Waste
	Frayed Papers and Cardboards	Petrochemicals Waste
	SRFs	Drilling Mud

Table 3 shows the heat value of different fuels used in the cement industry (Schneider et al., 2011; Wirthwein and Emberger, 2010).

In this research, it is tried to review and study the primary kinds of SRFs; in continue it is tried to survey the potential consumption rate of these alternative fuels in two cement companies of Kerman province by economical approaches; and it is tried to survey the differences between SRF and RDF.

Table 3. Heat values of different alternative fuels

Waste	Energy(MJ/kg)
Torn Tire	23.03
Leaf and Husk	19.93
Industrial Plastics	18.21
Oil Waste	14.56
Frayed Papers and Cardboards	14.23
Polluted Waste to the Industrial and Chemical Materials	14.23
RDF Plastics	11.72
Sewage Sludge	8.37

Materials and Methods

This study is done in two stages. The first stage is a review on the popular alternative fuels in different countries and the second stage is the prediction of SRFs production rated from re-collectable municipal waste in the buffer of 50 kilometres around the Kerman Cement Company and Momtazan Cement Company.

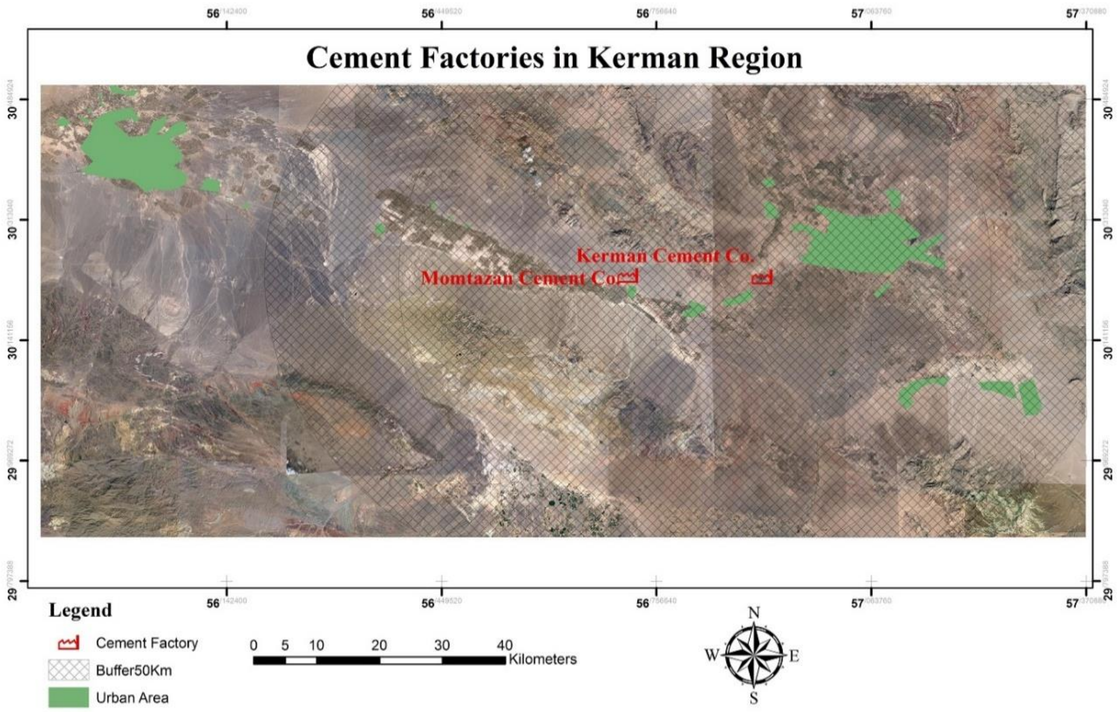

Figure 1. The Studied Location by 50 Kilometres Buffer

As it is shown in the figure 1, two intended companies with all of the surrounding municipal regions with the buffer of 50 kilometres around the cement companies are specified. In 50-kilometer-buffer of companies are three city of Kerman, Mahan, and Bardsir which can be considered as the closest and most economical options of waste transitions and SRF.

In this study, the intended municipal waste for producing SRF has been considered by 25% humidity. The analysis of the studied waste after unofficial re-collection in the city doing regularly and commonly has been considered. The statistics and used data in calculations of converting the municipal waste to SRF have been attained by field trips and interviewing by unlawful municipal waste re-collecting and recycling works which the information of this kind is presented for the first time in Iran.

Discussion and Results

Studying the Alternative Fuels Derived from the Municipal Waste on order to Be Used in Cement Industry (MSW)

MSW (Municipal Solid Waste) production in all of the countries is increasing noticeably. MSW as a common alternative fuel can be used in the cement industry. Although most of the cement factories do not use heterogeneous MSW directly (which are the results of inherent heterogeneity of municipal solid waste and some characteristics which cause the environmental waste and qualitative worries), RDFs or SRFs are used instead of it (Wirthwein and Emberger, 2010).

Alternative SRFs are commonly more economical for cement industry because there is the possibility of production according to consumption's need of cement furnace. However, in RDFs fuel batteries with defined standards are designed and produced for public usage and, generally, unnecessary and extra processes are implemented on the production of alternative fuels which cause the increase of final expanses of RDF products.

Studying the Production Potentiality of SRFs for Using in the Kerman's Cement Factories

According to the intended buffer with 50 kilometres around the two cement factories of Kerman and Momtazan, municipal regions which can have the ability of waste transition and converting to the alternative SRFs economically include Kerman, Bardsir, and Mahan. According to the comprehensive study, the waste management of these cities and the average physical analysis of waste in this cities are presented in table 4. In this table, flammability or inflammability of their components are also presented. It should be noted that only flammable components can be converted to the alternative SRFs and used in the cement industry furnaces.

Table 4. The Average Analysis of Municipal Waste in the Studied Cities

Order	Material	Percentage	Flammable	Inflammable
1	Bread	1.17	*	
2	Kinds of Plastic	2.79	*	
3	PET	1.05	*	
4	Plaster	1.59	*	
5	Plexiglas	0.7	*	
6	Foam	0.49		*
7	Paper	3.73	*	
8	Cardboards	3.4	*	
9	Iron Metals	1.62		*
10	Non-Iron Metals	0.83		*
11	Fabric	2.47	*	
12	Glass	2.89		*
13	Wood	0.93	*	
14	Rubber	0.54	*	
15	Leather	0.49	*	
16	Soil and Trash	2.75		*
17	Tetra Pak	1.05	*	
18	Special Waste	2.33	*	
19	Organic Waste	69.18	*	
Total Materials			100	
Total Flammables			91.42	
Total Waste Density (kg/m^2)				308.77
Capitation (Kg for each Person on a Day)				0.64

According to the aforementioned table about 99% of municipal waste in Kerman is flammable and as a result they have got the capability of being converted to the alternative SRFs. It should be noticed that high percentages of analysis of recollected waste are achieved and since the processing sites are manipulated and undergone the waste-robbing, it is necessary to revise the percentage of flammable materials presented in Table 4.

By the usage of field studies and interviewing the unlawful waste re-collecting works and wanderers recollecting the recyclable materials, the revised percentages have been achieved. Usable amounts of net weight after being dried and reaching to the desired humidity of 25% is presented in the Table 5.

Table 5. Calculating the dried waste usable for producing SRF

Inflammable materials of Waste	Percentage	Daily Weight (Ton/Day)	The Required Reducing Humidity	Daily Dried Weight (25% humidity) (ton/day)	Stolen Waste Percentage	Daily Dried Weight (Final) (Ton/Day)
Bread	1.17	6.1	3%	5.9	40%	3.5
Kinds of Plastic	2.79	14.5	3%	14.1	50%	7.0
PET	1.05	5.5	8%	5.0	80%	1.0
Plaster	1.59	8.3	5%	7.9	15%	6.7
Plexiglas	0.7	3.6	3%	3.5	10%	3.2
Paper	3.73	19.4	5%	18.4	25%	13.8
Cardboard	3.4	17.7	5%	16.8	70%	0.5
Fabric	2.47	12.9	5%	12.2	5%	11.6
Wood	0.93	4.8	5%	4.6	5%	4.4
Rubber	0.54	2.8	3%	2.7	5%	2.6
Leather	0.49	2.5	3%	2.5	5%	2.3
Tetra Pak	1.05	5.5	10%	4.9	0%	4.9
Special Waste	2.33	12.1	5%	11.5	0%	11.5
Organic Waste	69.18	360.0	30%	252.0	0%	252.0
Total	91.42	475.7	-	362.1	-	330

According to the aforementioned tables, it can be seen that there are almost 520 tonnes re-collectable municipal waste daily in the studied cities of Kerman, Bardsir, and Mahan which almost 330 tons of those are convertible to the alternative SRFs after processing; as a result, the factor conversion ratio of 63.4% is suggested for the conversion of municipal waste to the alternative SRFs in the studied locations.

If 330 tons of converted waste to SRFs are used, according to their heat value, it is predicted that approximately 82 tons of mazut burning in the cement furnaces are saved daily. The calculations of these values are presented in Table 6.

Table 6. Saving Potentiality of Rial in Alternative SRFs Consumption in Kerman's Cement Industry

City	Produced Waste (Ton/Day)	SRF (Ton/Day)	Equivalent Mazut (Ton/Day)	Annual Percentage (Rials)
Kerman	462	293	73	3/72098E+11
Mahan	11	7	2	8,645,743,074
Bardsir	47	30	7	37,976,994,267
Total	520	330	82	418,720,851,283

Therefore, according to the predicted potentiality, more than 418 billion Rials† can be saved annually in consumed fuel of cement industry. This price in much more than the first predicted initial investment and is favourably economical.

The other advantages of using the alternative SRFs in the Kerman's cement industry are the reduction of environmental pollutions, the reduction of CO_2 emission, the reduction of municipality's expanses for waste disposal, the reduction of occupied lands by municipal waste burial locations, the improvement of municipal environmental quality, the omission of the waste management crisis in country, and the improvement of quality of produced cement (Boughton and Horvath, 2006; Massoud et al. 2015)

Priority to RDFs

RDFs and SRFs are very similar from different points. The most important similarity is that the basic component of their raw materials is the municipal waste. The main difference of these two alternative fuels goes to how to be produced, production expanses, consumption flexibility, and also their consumption market. RDFs are produced by the public distribution presupposes; therefore, their producing process is not designed for an especial industry and in most cases the final expanses of RDF are more than SRF and it questions the plan's justifiability.

Less heat value compared to alternative RDFs is one of the other important problems of RDFs. However, SRFs have the capability of increasing the heat value more than at least twice in comparison with RDFs. (Rotter, 2010)

Another important advantage of SRFs to RDFs is their high flexibility in production and providing raw materials for producing alternative fuels. Between 8 to 10 kinds of municipal, industrial, agricultural, oil, etc. waste can be used in SRFs in order to produce combined fuels. More than increasing the heat value, it follows by the capability of improving the cement quality and also the elimination of perilous and special waste and as a result the improvement of region's environmental circumstances.

During recent years in international communities SRF has been substituted by RDF. Major active cement industries in Europe and Asia have changed their producing systems and RDF injection systems according to their regional waste and have produced the optimized SRFs. According to the reported international experiences, one reason for increasing popularity of SRF to RDF is more stable quality and also more suitable standard (like international standard of CEN/TC 343) of SRF to RDF (Cuperus, 2015). From the producing perspective, SRFs to RDFs take less time and expense and finally have more suitable quality in order to be used in cement rotating furnaces.

The Financial Savings of Municipalities

According to the official statistics in 2015, municipalities in Iran spend about 410 Rials for re-collecting and burying each kilogram of municipal waste that 30% of these expanses is related to waste elimination (about 120 Rials for each kilogram solid waste). If alternative SRFs are used, more than 90% of waste which is sent in order to be buried is convertible to the alternative SRFs. If this system is developed, almost 2,310 billion Rials are saved in the country's municipalities which is so notable according to the consumed budget of these organizations. This phenomenon has bolded the role of municipalities' participations on development of this plan and has caused that most of municipalities look forward to participating and developing this plan.

† 3700 Rial $\approx$ 1 US Dollar

Here are other noticeable points like the reduction of environmental pollutions and the reduction of land's occupations and its elimination. According to the predictions, in development of alternative SRFs more than 428 hectares of lands are protected from the waste burial and being converted to landfills. Although the cost of these lands is not noticeable, in national scale (by the hypothesis that every square meter costs about 250,000 Rials) more than 1,000 billion Rials can be saved annually and national capital can be preserved.

Primary Economic Estimation for Development of SRF Production and Injection Unit by Capacity of 300 Tons a Day

Furnaces by the common capacity of 36 tons mazut per hour or similar capacity of 1 million m^3 per hour natural gas conventionally work in the cement industry. In the following, by the presupposes of building and managing 300 tons SRFs per day and its injection to the indented cement furnaces, the primary economic analyses in order to survey the justifiability of plan are presented:

Table 7. The Primary Economic Estimation

Consumed Natural Gas in the Conventional Cement Furnace	1,013,472	M^3/day
Injectable Consuming SRF	300	Ton/Day
Savings of Natural Gas	85,165	M^3/day
Savings Percentage	8.4%	%
Savings of Foreign Exchange	11,071	$/Day
Total Annual Currency Savings	4,041,067	$/Year
Expenses of Setup Process	4,000,000	$
Expenses of Producing each Year	1,000,000	$/Year
Useful Age of Project	10	Year
Increasing Rate of Operational Expanses Annually	0	%
Increasing Rate of Prices of Products Annually	0	%
Major Maintenance Times	2	Number
Discount Rate	20	%
Tax (Tax-Exempt)	0	%
ROI	1,003%	%
PBP	14	Month
Break-Even (Operational Expenses and Working Capital to Sale)	25%	%
IRR	80%	%
NPV (i=20%)	9,780,739	$

As it is shown in the aforementioned calculations, the development of SRF plan in the cement industry is justifiably suitable and attracting for the investors. 80% invest return rate (IRR) by considering the plan's useful age will create very low investment risk and certainty for investors.

Conclusion

Optimizing and decreasing the fuel consumption and as a result preserving the national financial resources are so important purposes in the resistive economic. Using the alternative fuels stemming from municipal waste and using them in the energy industry of cement can be some suitable solutions in attaining these purposes. According to the surveys done in the county of Kerman, Bardsir, and Mahan in the province of Kerman which are located in the 50-kilometer buffer of Kerman Cement Company and Momtazan Cement Company, 330 tons SRF by conventional quality is producible daily that this amount of alternative fuel can decrease the consumption of 30,000 tonnes fossil fuels like mazut in the Rotary furnaces of Kerman's cement industry annually. This amount of saving can create the potentiality of currency savings of more than 418 billion Rials in this region.

Table 8. The Financial Process of SRF utilization in Kerman's cement industries

Cash Flow	Annual Sale ($)	Operational Expenses and Working Capital ($)	Major Maintenance Expenses ($)	Residual Value	Net Income ($)
Initial Investment	-	1,000,000	-	-	-5,000,000
Year 1	4,041,067	0	0	-	4,041,067
Year 2	4,041,067	0	0	-	4,041,067
Year 3	4,041,067	0	0	-	4,041,067
Year 4	4,041,067	0	400,000	-	4,041,067
Year 5	4,041,067	0	0	-	3,641,067
Year 6	4,041,067	0	0	-	4,041,067
Year 7	4,041,067	0	0	-	4,041,067
Year 8	4,041,067	0	400,000	-	3,641,067
Year 9	4,041,067	0	0	-	4,041,067
Year 10	4,041,067	0	0	500,000	4,041,067
Total	40,410,670	1,000,000	800,000	500,000	40,110,674
IRR					79.9%
NPV (i=20%)					$9,780,739

According to the predictions, by the development of SRFs producing units in country by presupposition of thorough coverage of major cities in country, there is the potentiality of producing more than 38,105 tons alternative SRFs daily. Using this amount of alternative SRFs can decrease the consumption of more than 4.63 million tons mazut or the equivalent amount of that which is about 3.95 billion m^3 natural gas; this amount of savings by considering the budget and operational expanses of the developing plan is very noticeable and desirable (by the heat value: every cube meter of Iran natural gas: 8,600 kcal- every litre of mazut 9,790 kcal). According to the export price of natural gas in 2015 which was 13 cents per cube meters, there is the saving potentiality of 413.3 million dollars annually. According to the results, the development of producing system and using the alternative fuels such as SRF can be considered as a national master plan and so noticeable results in the country's market of energy and fuel and noticeable improvement in the quality management of municipal waste in Iran can be viewed.

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