RDF AS AN ALTERNATIVE FUEL FOR THE CEMENT PLANTS IN BULGARIA

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ABSTRACT

With the growth of the world economy, the daily waste, generated by the industry and the way of life also increases. Since recycling does not solve comprehensively the problem about handling with the solid waste, significant resources are invested in the integration of combined systems and their management aimed at their complete utilization. As a member of the European Union (EU), Bulgaria is also committed to the entire concept for waste reduction, carbon dioxide emissions and other gases, causing the greenhouse effect on the earth surface.

The cement industry appears to be among the most suitable places for solving the mentioned tasks. The substitution of its traditional fuels with alternative energy sources has turned into a widespread method not only in Europe, but in all economically developed countries worldwide.

In the current work we discuss the possibilities for utilization of the highly calorific refused derived fuel (RDF) in Bulgaria, with the purpose to reduce the use of fossil energy resources in the cement production and to reach environment protection, according to the current Directives 2010/75/EC and 2000/76/EC of the European Parliament and of the Council.

The main findings from this research are that the input of RDF in the rotary kilns in the cement plants on the territory of Bulgaria would affect positively the industry, both in technical and in environmental terms, and thence – in its economic aspects. The more specific results of the established trends are: reduction of greenhouse emission and other atmospheric pollutants, in particular - of ammonium oxides; cost reduction for fossil fuels; increase of the efficiency of the observed kiln, as well as; complete drop of the landfilled waste quantities on the territory of the state.

Keywords: RDF, alternative fuel, rotary kilns, energy efficiency.

INTRODUCTION

Despite of the applied and constantly updated policies of EU in the field of waste management, within the last decades the household solid waste (HSW) has increased, so it is an increasing ecological problem. From the energy perspectives' point of view, waste has become a real alternative fuel that is used in the sphere of production of heat and electricity, as well as of cement clinker. The utilization of the potential of residues is one efficient measure for decreasing landfilling, avoiding disposal emissions and decreasing the demand for primary fuels' supply. In this way the energy and ecological efficiencies of the companies, related with those activities are improved.

For the leading industries (metallurgy, cement, etc.) the use of refuse derived fuel in the rotary kilns, decreases significantly the costs for fossil sources of heat energy. Within the years these sectors are facing growing challenges towards saving materials and energy carriers, as well as minimizing the CO_2 emissions in order to ensure a sustainable future both for the societies, and for the branch [1]. In this regard the producers are aiming at energy efficiency, increased production and utilization of alternative resources and fuels. The need for development in the direction of circular economy pushes the waste generators, and the industry itself, into optimization of the entire value chain from the residual to the resource. Therefore, the use of alternative fuels (AF) is in heading towards further increases [2].

A key factor for reaching a synergy effect for utilization of the energy from HSW and implementation of the circular economy policy, is the presence of a suitably localized plant for pre-treatment and stabilization of the residual fuel (such as a mechanical-biological treatment plant for HSW) near the generators, as well as of adjusted facilities and infrastructure for the incineration of this AF, like district heating plants and cement plants, for example.

The aim of the current paper is to examine the possibilities for use of the high-calorific fuel, produced from waste in Bulgaria, in order the use of fossil fuels in particular industrial branches to be reduced and to reach an improvement of the energy, ecological and technical-economical efficiency of the used aggregates.

REFUSED DERIVED FUEL

The Refused Derived Fuel (RDF) is a kind of utilized energy that after various technological processes as the final product becomes a residual fuel from waste. After dissociation and collection of suitable residuals for the RDF production, they are dried, i.e. stabilized. Two technologies are applied in order to produce the highly calorific fraction of the RDF, namely:

- a mechanical-biological treatment (MBT) [3], which in fact is applied in the modern facilities for HSW treatment both in the EU countries, incl. Bulgaria since 2012, and worldwide (USA, China, India, Canada, etc.), or
- drying with hot air.

As a next step, screening and magnetic separation are carried out to divide the obtained product into different fractions, as shown on Fig. 1.

In the MBT installations inert materials, ferrous and non-ferrous metals, paper, plastics, textile, etc., are separated with infrared and magnet separators, or manually, while the organics goes into further processing for stabilization, with or without an absorption phase.

Drying is an efficient high temperature removal of the moisture from the waste (without inert materials and metals) through composting, which continues until reaching a residual mass with high calorific value, suitable for incineration.

The end product that is coming out from the MBT of HSW is in the form of pellets, bales or fluffed, depending

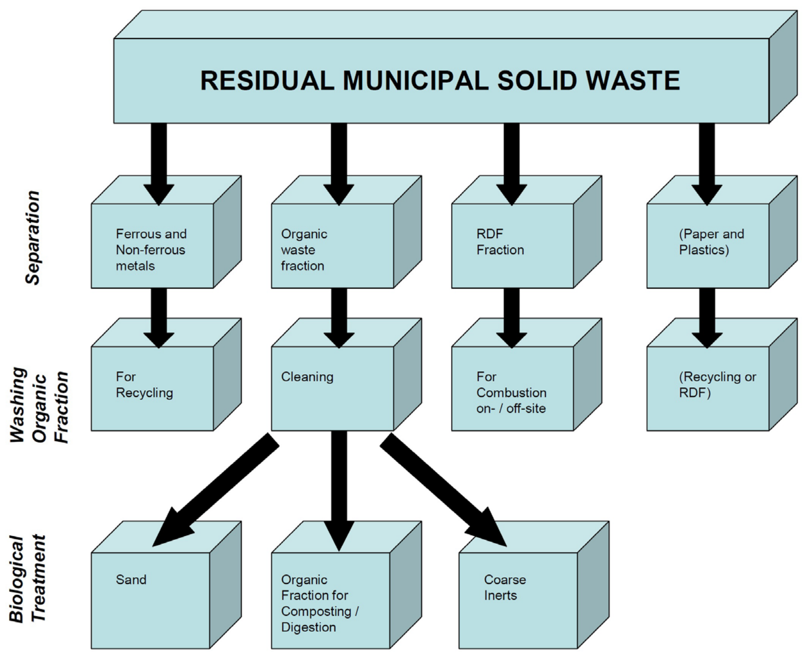

Fig. 1. A scheme of the production process in an MBT plant [3].

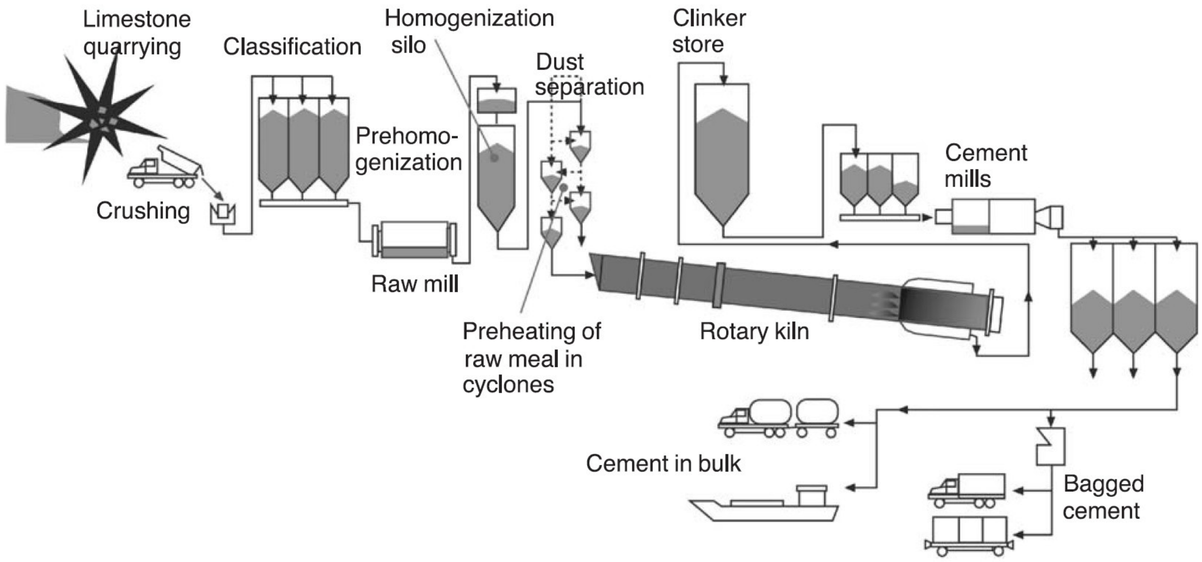

Fig. 2. The cement production process [4].

on the requirements of the users and the designation for which they will use the RDF.

Alternative fuels, used in rotary kilns in the industry

The technological process of the cement production is given on Fig. 2 [4].

Its main stages are:

● preparation of the raw materials and their mixture, including extraction, crushing and milling the components, homogenization and correction of the mixture;

● kilning the mixture to produce clinker, its cooling, and preparation to burn the energy carrier for kilning;

● production of cement – co-grinding of clinker, gypsum and additives.

The clinker is a main cement component (50 - 100 % content). Its technological characteristics determine the properties of cement. The composition of the raw material mix is calculated from the chemical composition of the raw materials and the type of fuel used.

The kilning of the raw mixture for obtaining clinker is the general technological process in cement production. For this purpose, the high quantity of heat, formed during the burning process of high-calorific energy sources is necessary. The type and the content of the fuels are factors determining the heating mode of the furnace – the kilning and its cooling are influencing on the clinker's microstructure. This determines its specific characteristics which are of significant value for the cement quality.

The raw mixture is fed into the rotary kiln, shown in Fig. 3 [5], with low temperature and 35 % water content. When raising the temperature in the kiln, the mixture undergoes chemical and physical-chemical changes. In consequence, the material is heated up and water is evaporated in the zone of dehydration (chain zone). Then the material goes into the calcination zone where the calcium carbonate ($CaCO_{3)}$ is decomposed to calcium oxide (CaO) and CO_2 at 850 - 950^{o}C. After that the material proceeds in the kilning zone where the reactions of CaO with the metal oxides are realized at 1200 - 1450^{o}C.

The zones in the kiln have been outlined in principle and do not possess strict borders. Their differentiation points out the main process which proceeds in the relevant temperature interval, as well as the sequence of the interactions in the kiln. After all reactions are completed, the product goes into the cooling zone. In it the final formation and crystallization of the mineral phases take place. The cooling of the clinker ends in drum or grid coolers. The final product is transported to storage.

The traditional fuels, used in the industrial kilns, are natural gas, oil and coal. Materials like residual oils, plastics, shredded elastomer wastes, used car tires, stabilized sludge from waste water treatment plants (WWTP), as well as residuals from slaughterhouses, are often an option as an alternative fuel in the cement

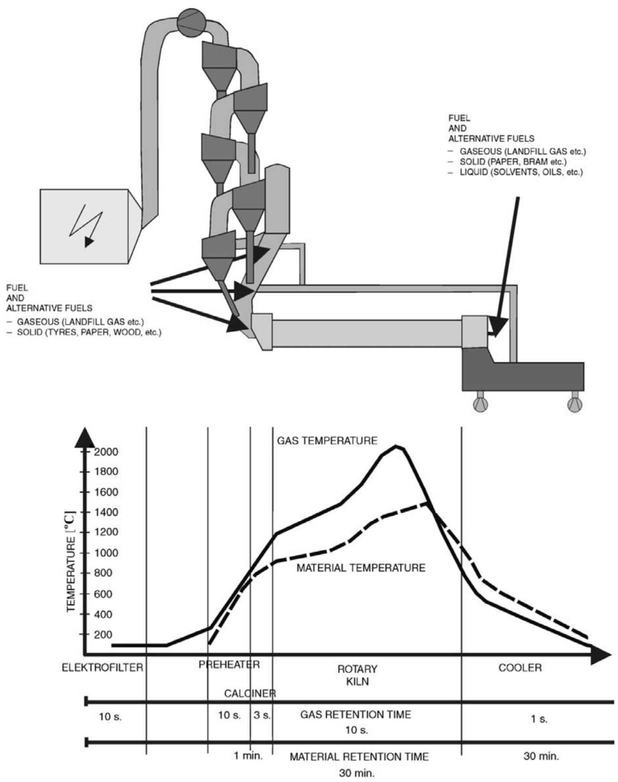

Fig. 3. Temperatures of gases and materials in the cement kiln [5].

industry nowadays. According to the classification of the European Cement Association (Cembureau) the AF are divided into the following five classes:

● class 1: gaseous AF (for example: refinery waste gas, landfill gas);

● class 2: liquid AF (for example: low chlorine spent solvents, used hydraulic oils);

● class 3: pulverized, granulated or finely-crushed solid AF (for example: sawdust, dried sewage sludge, granulated plastic, animal flours, finely crushed tyres);

● class 4: coarse-crushed solid AF (for example: crushed tyres, rubber/plastic waste, wood waste, reagglomerated organic matter);

● class 5: lump AF (for example: whole tyres, plastic bales) [5].

In order to use any of these AF in rotary kilns of in the cement clinker production processes, it is necessary to have available detailed information for the chemical content of the relevant energy carrier and its calorific value including ash, water and volatiles contents. In some countries the residual fuel is blended in various proportions until producing of mixed dried and biologically stabilized HSW (or RDF), in order to ensure prescribed chemical and energy contents. The choice of the type energy carrier is usually based on price and availability [4]. Table 1 presents the characteristics of different AF, considered most appropriate for the cement industry. In the last column are given the expected characteristics for quality and content of the RDF from the "Mechanical-biological Treatment Plant with production of RDF" around Sofia [6].

RESULTS AND DISCUSSION

It is necessary to review the alternative fuels, incl. RDF, used in the cement plants in Bulgaria.

According to the documents for reduction of the carbon emissions of the European cement sector within the period up to 2050, the further decrease of the emissions is to reach up to 32 % of the levels from 1990 and up to 80 %, if the projects for carbon capture are introduced successfully [7]. There are three cement plants in operation on the territory of Bulgaria currently, namely:

● "Devnya Cement" S.A., Devnya town, daughter company and of the international "Italcimenti Group";

● "Zlatna Panega Cement" S.A., Zlatna Panega village, "Titan Group"';

● "Holcim (Bulgaria)" S.A., Beli Izvor village, "Holcim Group".

The above mentioned companies modernize their production systems and periodically are making new investments, looking for opportunities to decrease costs by replacing traditional energy carriers with alternative ones. This trend is enforced from the already mentioned high consumption of such resources in the branch. One of the options for control of the used power is to apply a dry method for clinker production, which is a worldwide tendency (Fig. 4), together with the substitution and modernization of the kilns. As a result, on average, the energy consumption for the global cement production, between 1990 and 2013, has decreased from 115 to 103 kWh/t cement. Table 2 shows details for the used electricity and heat energy, according to the submitted annual reports about the activities of the cement plants in Bulgaria, for which they have obtained an integrated pollution prevention and control permit [9] in the period from 2007 to 2015.

From the given data it is obvious that, with certain exceptions, there is a tendency to decrease the specific

Table 1. Characteristics of the AF that are suitable for utilization of rotary kilns in the cement plants.

Dry matter, in %	Bituminous coals (Poland)	Petcoke	Meat and bone meal	Sewage sludge	Car tyre rubber	Coal–petcoke mix	RDF (Bulgaria) in mg/kg dry matter [6]
C	70.6	89.5	42.1	40.5	79.6	75.1	
H	4.3	3.08	5.38	7.0	7.0	4.20	
N	1.2	1.71	7.52	0.84	033	1.70	
S	1.3	1.3	4.00	0.38	0.12	0.80	<1
O[a]	11.8	11.8	1.11	15.3	25.2	5.0	
Cl	0.07		0.20	1.0			<0.75
P (P_2O_5 in ash)	0.016		(41.2)			(0.046)	<0.3
Na (Na_2O in ash)	0.05		(1.47)		(0.9)	(2.4)	
K (K_2O in ash)	0.12		(0.28)		(1.1)	(2.8)	
Ca (CaO in ash)	0.18		(18.4)	1.83	(8.7)	(11.7)	
Fe (Fe_2O_3 in ash)	0.31		(0.14)		(1.7)	(5.4)	
Al (Al_2O_3 in ash)	1.07		(0.02)		(16.6)	(1.2)	
Si (SiO_2 in ash)	2.0		(0.45)		(27.8)	(55.8)	
MG (MgO in ash)	0.08			0.32	(1.2)	(2.6)	
Ni (NiO in ash)		0.0432			(0.0065)	(0.044)	<25
Hg (mg/kg)		0.05					<6
Pb (PbO in ash)		0.00053			(0.0373)	(0.0054)	<70
Zn (ZnO in ash)		0.00103			(56.6)	(0.0092)	<400
Mn (MnO in ash)					(0.021)	(0.027)	<50
V (V_2O_5 in ash)		0.0906			(0.0043)	(0.251)	<10
Sn (mg/kg)							<30
As (mg/kg)							<5
Cr (Cr_2O_3 in ash)		0.0013			(0.0008)	(0.0018)	<40
Cd (mg/kg)		0.46					<4.0
Co (CoO in ash)		0.0001			(0.495)	(0.00017)	<0.6
Cu (мг/кг СВ)							<100
Ash (%)	11.1	0.50	28.3	17.9	2.20	11.1	<20
Volatiles	35.9	10.0	64.5	85.0	66.6	20.0	
C-fixed	53.0	89.5	7.20	5.00	31.1	69.2	
H_2O (%)	3.0	1.50	8.09	5.20	0.73	1.30	<20
LHV (Mj/kg)	27.4	33.7	16.2	15.8	35.6	29.0	13.00
HHV (Mj/kg)	28.4		(0.28)		37.3	29.7	17.00

costs for the two resources.

The years of experience in the utilization of alternative fuels, mainly waste, in the cement industry in Bulgaria and around the world, show that their application is justified from all points of view.

Ecological benefits

The fact that the used amounts of traditional fossil fuels, like coal, and the ecological influence related with their excavation, is reduced, is a sufficient argument for the attractiveness of AF use, in itself. The contribution

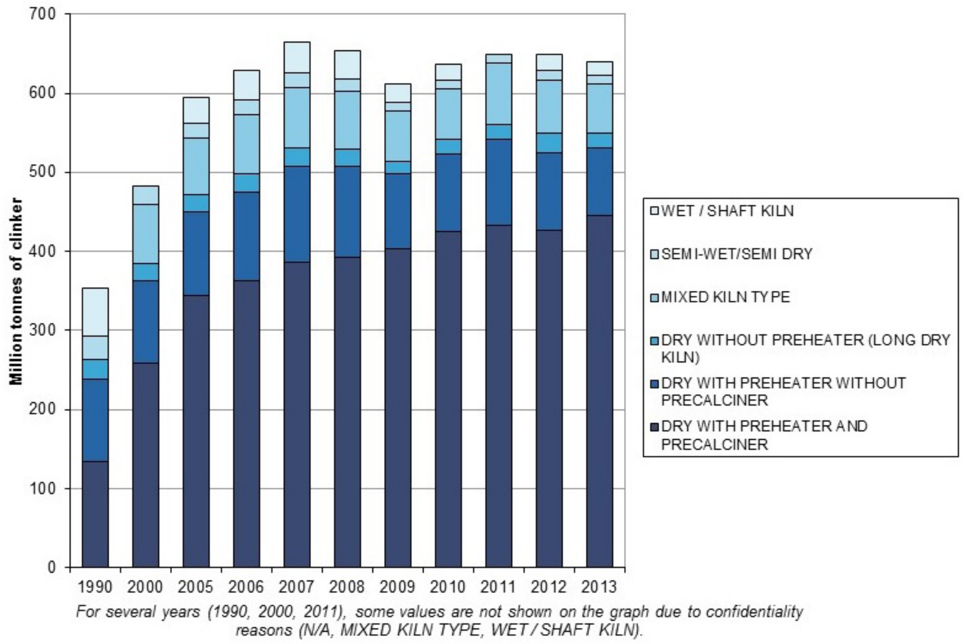

Fig. 4. Total production quantities of clinker (grey cement) with the wet and the dry method in the world, for the period 1990 - 2013 [8].

to reduction of greenhouse emissions and of the relevant final residues from burning must be taken also into account. In this regard, the use of RDF in the manufacturing kilns allows for reduction of around 1.61 kg of CO_2/kg RDF compared to conventional combustible materials (coal) [11]. Moreover, if we use as an example the recently constructed plant for production of RDF from Sofia's household waste, it can be stated that all priority tasks of the economy and ecology are combined not only for this important region of Bulgaria, but for the whole country as well. The cement plants operating here and solving the global dimensions of the waste quantities and the needed area for their disposal, present a sustainable and mutually beneficial solution which is in compliance with the requirements of the package of measures for circular economy, accepted by the European Commission at the end of 2015 [12].

Table 2. Quantities of consumed electrical and heath energy by the cement plants on the territory of Bulgaria for the period 2006 – 2015.

Period	**"Zlatna Panega"**		**"Devnya Cement"**		**"Holcim"**	
Years	Electricity/ kWh/ t	Heath energy/ MWh/t	Electricity/ kWh/ t	Heath energy/ MWh/t	Electricity/ kWh/ t	Heath energy/ MWh/t
2006	-	-	-	-	105.00	1.07
2007	100.71	-	57.17	0.0051	92.00	0.97
2008	92.23	-	69.90	-	94.00	0.996
2009	93.57	-	71.00	-	81.00	1.023
2010	97.00	-	71.00	-	74.00	-
2011	98.00	-	69.31	-	80.00	-
2012	93.00	-	62.44	-	73.00	-
2013	98.00	-	63.96	-	78.00	-
2014	99.00	-	56.00	-	81.00	-
2015	-	-	57.00	-	80.00	-

Technological benefits

At the flame temperature of 2000°C, provided by the RDF, the material has a temperature around 1400°C, and its the total residence time is only of 4 - 5 s. This allows for the reduction of quantities of the non-combustible residuals. These conditions, including also the neutralization of the acid gaseous phase formed during combustion, ensure extension of the aggregate's life cycle [2].

Economic benefits

The averaged value of the needed energy for production of 1 t cement is around 3.3 GJ, which is equivalent to 120 kg of typical coal [2]. The resources for its provision equal to nearly 40 % from the total costs for cement production, and the application of AF allows the costs to be reduced. Depending on the concrete indicators of RDF, such as heating value, market price, difference in the operational costs in using conventional fuels and RDF, as well as the imposed fees and taxes for AF, for every particular case a technical-economical analysis has to be conducted [13].

CONCLUSIONS

The analysis presented in the current paper shows that the using of AF and RDF in particular, in the cement kilns is an actual and complex solution with huge technological, energetical, ecological and economical advantages. In the recently constructed plant for production of RDF from Sofia's household waste, a clear synergy effect of their utilization is provided. It consists of combining the priority tasks of the economy and ecology, not only for this important region of Bulgaria, but also on the whole territory of the country, through improved operation of the cement plants and a contribution to the solving of the global problem with waste quantities and the necessary areas for their disposal. This leads to a sustainable and mutually beneficial solution, in compliance with the package of measures for the circular economy, adopted by the European Commission at the end of 2015.

The obtained results could be used also in other industrial branches with high energy consumption, like metallurgy.

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