ECONOMIC VIABILITY OF SRF CO-COMBUSTION IN CEMENT FACTORY

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The modern society must face with different problems but one of the most important regards the waste management and greenhouse effects. One solution could be the production of solid recovered fuel from the waste remaining after the selective collection and its use in cement factory as a substitute to pet-coke. The present paper analyses some economical aspects of this solution, taking into account the improvement of the cement factory off-gas treatment line.

Results demonstrate that this proposal in viable form the environmental, economic and energetic point of view.

Keywords: cement factory, treatment line, SCR, SRF, costs.

1. Introduction

The modern society in industrialized countries is characterized by a high level of wellbeing, accompanied by a high consumerism against goods and products. In this context, the municipal solid waste (MSW) production is growing every day. The EU legislation has imposed targets for the waste reuse, recycling and recovery. The mechanical-biological treatment (MBT) is a viable option for many countries, in order to comply with the EU request regarding the decrease of biodegradable materials landfilling and energy recovery through Solid Recovered Fuels (SRF) [1-5].

In the last years the sector of combustible materials from waste has undergone under significant changes [6-8]. By the implementation of the UNI CEN/TS 15357 – 15747 norms, the SRF can be used in various thermal plants if its characteristics regarding its lower heating value (LHV) and its content of chlorine and mercury are suitable [1,6,9]. The current market for SRF in Italy has recently received some help with the introduction of the Decree of July 6, 2012,

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aimed at overhauling the system of incentives and mechanisms in support of the Italian electricity market [10]. Through this Decree, it is recognized the share of electricity production attributable to renewable energy sources at a flat rate of 51%, in the case of urban waste use.

Table 1

SRF and Pet-Coke characteristics [11,12,13]

Properties	Statistical measure	Unit	SRF classes					Pet-coke	
			1	2	3	4	5	-	
LHV	Mean	MJ/kg (a.r.**)	≥ 25	≤ 3	≥ 15	≥ 10	≥ 3	30 - 35	
Cl	Mean	% (d.m.*)	≤ 0.2	≤ 0.50	≤ 1.0	≤ 1.5	≤ 3	≤ 0.01-0.09	
Hg	Median	mg/MJ (a.r.**)	≤ 0.02	≤ 1.00	≤ 0.08	≤ 0.15	≤ 0.50	0.1	
	80th percentile	mg/MJ (ar**)	≤ 0.04	≤ 0.06	≤ 0.16	≤ 0.30	≤ 1.00		
Properties	Unit		SRF					Pet-coke	
			min			max		min	max
N	ppm		0.52			0.52		2	2
S			0.1			0.2		5	5
Sb			9			14,7		0.2	0.2
As			0.9			8.8		0.46	0.46
Cd			0.18			2.6		0.1	0,3
Cr			11.3			140		2	104
Co			0.6			4		-	-
Mn			28			210		-	-
Ni			0.1			0.4		0.02	0.1
Pb			0.85			21		200	300
Cu			25			157		2.4	100
Sn			45			266		-	-
Tl			4			500		-	-
V			0.02			0.5		0.04	3
Zn			0.3			7		400	2342

*d.m.= dry matter, **a.r.=as received

In many countries, the SRF is generally used in incineration plants for thermal and electrical energy production and presently only a little part is used in cement factory. The percentage of SRF in cement factory used in 2011 is reported in Fig. 1.

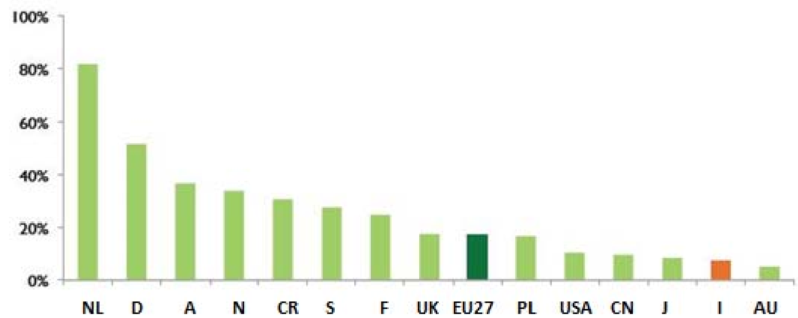

Fig. 1. SRF use in cement factory [14]

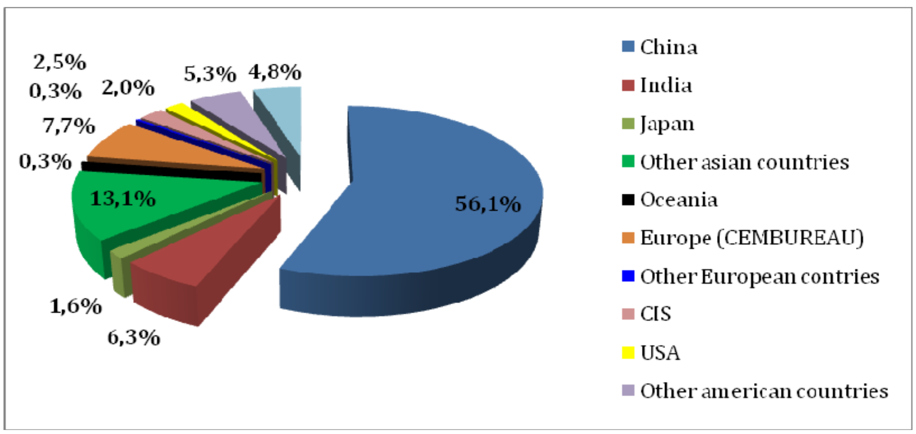

Fig. 2. Cement production in the world

In the present paper some consequences of the use of SRF in a cement plant are discussed and analyzed, together with the changes that can be requested to the plant regarding its process air treatment line, also from the economical point of view.

2. Material and methods

The cement factory is taken into account for the SRF use as the process of clinker in rotary kilns could create favorable conditions for SRF combustion (long residence times at high temperatures in an oxidant atmosphere and alkaline nature of raw materials). However, restrictions on the SRF composition and quantity are requested in order to avoid a negative impact on the quality of clinker produced and high emissions into the atmosphere.

Generally recent cement factories havea “low NOx burner” for decreasing the NOx emissions and two alternative systems for treating the process air:

- one containing a cooling and conditioning system and a bag filter for the particulate for the kiln process air;
- one containing an electrostatic precipitator for the clinker cooling process air.

In the sector the adoption of a selective catalytic reduction system(SCR) is considered the most enhanced approach to decrease the emissions of NOx.

Three scenarios regarding the improvement of the air process treatment line for a cement factory that uses SRF are analyzed and compared in this paper. For the development of the work, the starting point regarded the emission limits reported in Table 2, and imposed at legislative level for different plants: incineration with Best Available Techniques (BAT), co-combustion and cement factory [15,16].

Table 2

Emission limits for plants with BAT

		Incineration BAT [min-max]	Incineration [15] [daily average]	Cement Factory[16] [min-max]	Co-incineration [17] [daily average]
PM	$mg\ nm^{-3}$	1 – 5	10	50 – 150	30
NO_Xas NO_2	$mg\ nm^{-3}$	40 – 100	200	500	800
SO_2	$mg\ nm^{-3}$	1 – 40	50	500	50
CO	$mg\ nm^{-3}$	5 – 30	50	//	//
HCl	$mg\ nm^{-3}$	1 – 8	10	30	10
HF	$mg\ nm^{-3}$	< 1	< 1	5	< 1
TOC	$mg\ nm^{-3}$	1 – 10	10	//	10
Hg	$mg\ nm^{-3}$	0.001 – 0.02	0.05	0.2	//
PCDD/F	$ng\ nm^{-3}$	0.01 – 0.1 (as TEQ)	0.1 (as TEQ)	10,000 (0.01 $mg\ nm^{-3}$)	//

All the scenarios comprise the addition of adsorbents to the gas exhausted or directly in the oven for the removal of acid gases, the introduction of activated carbon for the control of dioxin and furans (PCDD/F) and adjustments for creation of SRF storage area:

- Scenario 1: update of the bag filter, followed by a new low-dust SCR for kiln emissions;
- Scenario 2: substitution of the present bag filter by an electro-filter (after a watering stage aimed to increase the electricity conductibility through humidification) followed by low-dust SCR system for kiln emissions. This solution is used in some Austrian cases;
- Scenario 3: high-dust SCR system put upstream of a bag filter for kiln emissions. This solution is used in some Italian cases.

For the development of the proposed scenarios it was considered a substitution of 25% of the pet-coke with the SRF in the cement factory feed. It was also supposed that the cement factory receives the SRF for free. The pet-coke in Italy, generally is sold to the cement factory at the price of 120-130€ by ton [14].

The proposed SRF has a LHV of 20,000 MJ, and the following class according to the Italian regulation: 2,2,3 [6,7,9]. The proposed cement factory produces about $1*10^6$ ton of cement by year. The necessary energy for the plant operation being about $3*10^{12}$ kJ y^{-1} [17].

In order to calculate the economic effort that a cement factory must support to improve its process air treatment line, the following literature data were used:

- for the low-dust SCR, the price was considered about 200,000€ for a flow-rate of 16,000 $m^3 h^{-1}$ [18];
- for theelectro-filter, the price was considered about 10-12€ for every $Nm^3 h^{-1}$[19];

Also the following hypotheses were made:

- a new bag filter price was considered 70% of an electro-filter;
- the high-dust SCR price was considered 40-50% higher than the one for a low-dust SCR.

3. Results and discussions

In Table 3 the data regarding yearly cost taking into account the substitution of coal with SRF in the proposed cement factory are reported.

Table 3

Cement factory yearly costs

Energy from SRF [1,6]	$7.5 * 10^{11}$	kJ y^{-1}
SRF used	37,500	ty^{-1}
Revamping [14]	33.40	€ t^{-1}_{SRF}
Fixed yearly costs [14]	1.25	mln. € y^{-1}

In Table 4 the economical data for the proposed scenarios are reported, taking into account the creation / update of different solution for the improvement of the process air treatment line in a cement factory. The above mentioned costs have been recalculated taking into account the characteristics of the cement factory of the case-study.

Table 4

Overall investment costs

	Scenario I	Scenario II	Scenario III	
Fixed yearly costs (SRF related)	1.25	1.25	1.25	mln. € y^{-1}
SCR - low dust cost [18]	1,375,000	1,375,000	-	€
Electro-filtrer cost [19]	12	12	-	€ Nm^{-3} h
Electro-filtrer – bag filter ratio	70	-	-	%
Bag filter cost	924,000	-	-	€
Electro-filtrer cost	-	1,320,000	-	€
SCR extra costs	-	-	50	%
SCR - high dust cost	-	-	2,060,000	€
Total cost in the first year	3.55	3.94	3.31	mln. €

The overall investment cost for the three scenarios was calculated. The results showed that for a cement factory that produces about 1 million tons of cement, with a process air volume of 110,000 m^3 h^{-1} [21] the investment can be recovered from the second year thanks to the economic benefits from the price of pet-coke savings as reported in Table 5. Indeed the assessed savings are clearly favorable; a deeper economic analysis is not necessary to understand the advantage of this strategy.

Table 5

Potenziali risparmi di un cementificio che impiega CSS

LHV Pet-coke [21]	34,000	kJ kg^{-1}
Pet-coke yearly saved	22,058	t y^{-1}
Pet-coke cost for the cement factory	123	€ t^{-1}
Cement factory economic benefit	2,71	mln € y^{-1}

This result points out that the EU vision of a SRF market more related to the concept of industrial fuel and not to a waste originated product makes sense.

4. Conclusions

Some notable advantages could be considered for the SRF usage in cement kilns in comparison with conventional fuels (pet-coke) due high amount of biogenic carbon, with hourly CO_2 emissions reductions of about one ton comparing with pet-coke [18]. Other advantages regard the NOx and SOx reduction.

The use of SRF in cement factory improves also the MSW management and helps to the achievement of the EU targets regarding the recycling, reuse and energy proposes [1]. The SRF produced from the residual MSW and used in cement factory avoids landfill use reducing in this way fugitive emissions of methane from landfill that can be expressed in equivalent CO_2.

However the SRF use in cement factory has also disadvantages because some characteristics of SRF are worse than the one of pet-coke (for example the percentage of chlorine, mercury, lead, cadmium) [7,11,12,13], as reported in Table 1. For this reason the cement factory treatment line must be modified in order to avoid atmospheric pollution.

Summing up, a SRF based strategy coupled with cement factory adaptation can give some clear advantages, in agreement with the principle of EU of promoting the BAT for an efficient use of the resources: the pathway is energetically and economically sustainable; moreover, the production of SRF integrates the selective collection [23]; indeed the residual MSW is characterized by high energy content fractions that are not interesting for material recovery.

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