Int. J. Environ. Sci. Tech., 7 (1), 127-134, Winter 2010
ISSN: 1735-1472

Reduction of environmental pollution through optimization of energy use in cement industries

[1]*A. R. Karbassi; [1]H. R. Jafari; [1]A. R. Yavari; [1]H. Hoveidi; [2]H. Sid Kalal

[1]Graduate Faculty of the Environment, University of Tehran, P. O. Box 14155-6135, Tehran, Iran

[2]Nuclear Science and Technology Research Institute, J.I.H. Research Laboratories, P. O. Box 11365-8486, Tehran, Iran

Received 17 October 2009; revised 2 November 2009; accepted 18 November 2009; available online 1 December 2009

ABSTRACT: Industrial development has lead to higher energy consumption, emission of greenhouse gases, as well as air pollutants. Cement factories play an important role in over all greenhouse emissions. This study aims to investigate the role of Iranian cement industries and their contribution of greenhouse gases contribution. The measured emission factors for oil and fuel gas shows that carbon dioxide contribution from fuel oil based cement industries is almost 2.7 times higher than gas based cement factories. The strength, weakness, opportunity and threat technique analysis showed that the best strategy to combat greenhouse gases from Iranian cement factory is to implement energy efficiency measures. Further, strategic position and action evaluation matrix analysis indicates that Iranian cement industries fall within invasive category. Therefore, exploitation of opportunities must carefully be used. One of these opportunities is the utilization of financial assistance provided by clean development mechanism. The results show that replacement of ball mills with vertical roller mill can reduce the electricity consumption from 44.6 to 28 kWh/ton. As a result of such substitution about 720 million kWh/y of electricity would be saved (almost a power plant of 125 MW capacities). Though implementation of new mills may not be economic for the cement industries' owner, but the overall gain for the government of Iran will be about US$ 304 million. If the duration of such efficiency measure is considered as about 12 y, then the overall CO_2 reduction/phase-out would be around 4.3 million tons.

Keywords: *Cement industry; Efficiency; Energy; Global warming*

INTRODUCTION

Energy, efficiency and environment are of high importance and interest to many researches from various dimensions (Panjeshahi and Ataei, 2008; Barros and Assaf, 2009; Zare and Chen, 2009). Energy security in demand and supply sides and the geopolitical issues arising from global actors such as Iran are subjected to detailed studies (Coskun, 2009). Cement manufacture use high amount of energy which consequently causes environmental impacts at all stages of the process (Chiou *et al.*, 2009). These include emissions of airborne pollution in the form of dust, gases, noise and vibration when operating machinery and during blasting in quarries (Zerrouqi *et al.*, 2008 and Nasr *et al.*, 2009). The cement industry has recognized that the cost of energy can be significant, varying between 25 % and 35 % of total direct costs. Consequently, the industry is continuously investigating and adopting more energy-efficient technologies to improve its profitability and competitiveness (Tehrani *et al.*, 2005; 2009). In particular, plants have moved steadily away from less energy - efficient wet process kilns toward the more fuel-efficient dry process kilns (Choate, 2003; Mohsenzadeh *et al.*, 2006). Gielen and Taylor (2009) concluded that certain energy consuming sectors such as cement are relatively efficient in India. Avami and Sattari (2007) have reported that energy saving potential equivalent to US$ 50 million is feasible in 30 cement factory of Iran. Emission of greenhouse gases can be reduced from 752,156 to 560,791 Gg CO_2 equivalents in 2010 by implementing the policies proposed for the energy sub-sectors (Karbassi *et al.*, 2007). In the recent years, some attention has been paid to the energy efficiency measures in Iran. For example, energy efficiency as well as application of renewable energy has been investigated in

*Corresponding Author Email: *akarbassi@ut.ac.ir*
Tel./Fax: +9821 6111 2188

commercial buildings (Abbaspour *et al.*, 2006; Karbassi *et al.*, 2008a, b). However, it should be pointed out that due to high subsidized energy supply in Iran, residential, commercial and industrial sectors do not have enough incentive to reduce their energy uses (Karbassi *et al.*, 2007; Shafipour *et al.*, 2007). Therefore, it is very important to know the exact amount of energy consumption in cement factory of the country and subsequently provide proper measures to reduce pollutants as well as greenhouse gases (GHGs). One of the few ways of reducing CO_2 from cement production is CO_2 capture and storage (Barker *et al.*, 2009). Improvement of energy efficiency and regulation of emission of pollutants from passenger vehicles could provide effective means of easing the negative economic and environmental impact of urban transport systems (Farzaneh and Saboohi, 2007). Energy and exergy efficiencies of raw mill were investigated for plant performance analysis and improvement in Turkey (Utlu *et al.*, 2006). Production optimization and quality assessment of biodiesel from waste vegetable oil is improved (Refaat *et al.*, 2008).

In the present investigation, the internal and external aspects, as well as role of high efficient mills are studied in over all energy saving. The potential for carbon reduction is also discussed. This research is carried out in the 2009 and covers cement factories all over Iran.

MATERIALS AND METHODS

Three cement factories namely Tehran, Ardabil and Shahroud with different functional background were selected for field measurements. Therefore, their average results can be applied to the whole cement industries of the country. Moreover, continuous sampling method that is more accurate than random and moment measurement is applied. The measurement of pollutants was carried out for a continuous duration of 32 h. In each of the above mentioned industries, about 265 readings was done. The concentrations of pollutants were measured by varip plus analyzer (MRV). Table 1 shows the pollutants and their methods of measurements.

The dispersion coefficient was computed by the following formulae:

$$MER= {}^{Q}NMW.C^{10\text{-}6}/V.1000$$

$$Q_N= Q(P_a^{\ 273})/[760(T_s+273)]$$

Where,

MER: The amount of release flow (Kg/h)

QN: Emission volume flow in normal conditions (Nm^3/h)

C: Pollutant concentration (ppm)

MW: Pollutant molecular weight (gr/gr-mol)

V: Molar volume of ideal gas in normal conditions (0.0224 m^3/g-mol)

T_s: Flow gas output temperature from stack (K)

P_a: Atmospheric pressure (mmHg).

Furthermore, role and importance of management system to reduce greenhouse gases has been evaluated from the strategic point of view using SWOT and QSPM matrixes.

RESULTS AND DISCUSSION

The amount of CO_2 production is highly dependent on the cement processes. For instance, combustion of fuel (oil or gas) produces large amount of CO_2. In addition, considerable amounts of CO_2 are released by limestone calcinations. The obtained emission factors for greenhouse gases along with other pollutants are presented in Tables 2 and 3.

It should be noted that the amount of cement production has been variable from 175 to 180 tons/h in Tehran cement factory. Also in Tehran cement factory, the amount of heavy oil consumption ranged from 8200 to 9100 L/h during sampling. Therefore, the higher CO_2 production in Tehran cement factory can be attributed to the higher heavy oil use rather than two other factories. Since the emission is given for a ton of clinker, it automatically includes other variables such as technology and energy efficiency in the given industry. High SO_2 content in all the three cement factories is due to removal of sulfur by alkaline materials. In the case of Shahroud cement factory, the

Table 1: Methods of air pollutant measurement in selected cement factories

Pollutant	Method	Unit
CO	Non dispersive infrared sensor (NDIR)	ppm
CO_2	Non dispersive infrared sensor (NDIR)	Vol (%)
SO_2	Electrochemical	ppm
O_2	Electrochemical	Vol (%)
NO_x	Electrochemical	ppm
H_2S	Electrochemical	ppm
HC	Non dispersive infrared sensor (NDIR)	ppm (CH4)

amount of production ranged from 180 to 187 tons/h during sampling time. At the same time, the gas consumption was about 1076-10170 m^3/h. During sampling, the amount of production in Ardebil cement factory was about 235 tons/h and the gas and fuel oil consumptions were about 4700 m^3 and 5500 L/h, respectively. Tables 2 and 3 show that, in view of climate change context, fuel gas produces lower amounts of GHGs in comparison to the oil. Therefore, substitution of fuel oil with fuel gas can be considered as a suitable short and mid-term policy for the reduction of GHGs. However, analysis indicates that apart from fossil fuels, there are ample opportunities to reduce the overall electricity consumption in cement factories of the country. For instance, substitution of present ball mills with vertical roller ones can reduce the electricity consumption from 44.6 to 28 kWh/ton. In other words, through such substitution, 16 kWh/ton of electricity would be saved. At present, the overall production of cement in the country is almost 60 million tons in 2009. About 15 million tons of such production uses efficient vertical roller mills. Therefore, there is ample opportunity to save significant amount of electricity by modifying the remaining factories. The experiences of Energy Efficiency Organization of Iran (EEOI, Ministry of Energy) indicate that the overall expenditure for substitution of ball mill with vertical roller mills is about US$ 25000/ton/h. Therefore, if such substitution is made for 45 million tons of cement (5137 ton/h), an amount of US$ 128 million would be needed as the capital investment. As a result of such substitution, about 720 million kWh/y of electricity would be saved (almost a power plant of 125 MW capacities). The average CO_2 emission from Iranian power plants is about 0.5 Kg/kWh (Karbassi *et al*., 2007). In other words, about 360,000 tons of CO_2 emission would be prevented. If the duration of such efficiency is considered as about 12 y (personal communication with EEOI), then the overall CO_2 reduction/phase-out would be around 4.3 million tons. In fact, the cost of CO_2 reduction in cement factories of the country through modification of mills would be around US$ 29/ton of cement production. Though such computation may not provide enough incentive to adopt the above mentioned substitution, but taking into account that government of Iran is paying high subsidy on electricity, things would change. The average electricity subsidy is about US$ 0.05 /kWh in industrial sector. Therefore, during a 12 y period about 8640 million kWh will be saved; the overall benefit for the government of Iran would be around US$ 432 million. If the initial investment (US$ 128 million) is deducted from the profit (US$ 432), then the overall gain for the government of Iran will be about US$ 304 million. Though, carbon trade on the basis of clean mechanism development (CDM) offers different price almost from US$ 10 to 35 (Hustad, 2000; Timilsina and Shrestha,

Table 2: Emission factors for GHGs and air pollutants in cement factories using fuel gas (Kg/ton Clinker)

Cement factory	CO_2	CO	NO	NO_2	NO_x	SO_2	CH_4	PM
Tehran	211.6	0.03	0.257	0.019	0.276	0	0.119	0.0229
Shahroud	ND**	ND	ND	ND	ND	ND	ND	ND
Ardebil*	296.3	1.808	0.604	0.048	0.653	0.0006	0.278	1.665
Maximum	296.3	1.808	0.604	0.048	0.653	0.0006	0.278	1.665
Minimum	211.6	0.03	0.257	0.019	0.276	0	0.119	0.0229
Mean	253.98	0.919	0.431	0.036	0.466	0.0003	0.258	0.855

*59.3 % fuel gas and 40.7 % fuel oil; ** ND: Not detected

Table 3: Emission factors for GHGs and air pollutants in cement factories using fuel oil (Kg/ton clinker)

Cement factory	CO_2	CO	NO	NO_2	NO_x	SO_2	CH_4	PM
Tehran	734.6	0.198	0.606	0.050	0.657	0.041	0.761	0.1009
Shahroud	340	5.889	0.341	0.042	0.384	0	2.731	0.073
Ardebil*	296.3	1.808	0.604	0.048	0.653	0.00006	0.278	1.665
Maximum	734.6	0.198	0.606	0.050	0.657	0.041	0.761	0.1009
Minimum	296.3	1.808	0.341	0.042	0.384	0	0.278	0.073
Mean	456.9	2.631	0.517	0.046	0.564	0.0136	1.256	0.612

*59.3 % fuel gas and 40.7 % fuel oil

2008). The above Figs clearly show that Iran can be benefited from partnership to implement the energy efficiency measure in the cement industries of the country.

The strength, weakness, opportunity and threat (SWOT) analysis was applied to assess and evaluate the strengths and weaknesses, opportunities and threats of cement factories in Iran in 2009 (Table 4). Subsequently, Quantitative strategic planning matrix (QSPM) analysis was carried out to evaluate the strategies (Table 5). It should be pointed out that SWOT and QSPM analysis were prepared by the help of managers from cement factories, policy makers from ministries of energy and oil, experts from energy efficiency organizations, cement dealers and so on. These techniques were already applied in environmental management of coastline regions by the first author (Nouri *et al.*, 2008). In short, about 37 people were interviewed and the results were checked with them.

It is evident from SWOT and QSPM analysis (Table 6) that the best strategies to reduce the amount of

Table 4: Ranking strengths and weaknesses of Iran's cement industry

	Title	Weight	Evaluating mark	Final Score
	Opportunities			
1	Reducing dependency on oil income through export of non-oil goods	0.12	4	0.48
2	Possibility to join the world trade organization	0.09	2	0.18
3	Rich resources and reserves of raw materials	0.12	4	0.48
4	High Potential to reduce energy carriers	0.1	4	0.4
5	Possibilities to use financial help from clean development mechanism	0.12	2	0.24
Threats				
6	Limitations and obstacles in the country's laws to export cement	0.09	3	0.27
7	Lack of attention to save energy carriers	0.09	3	0.27
8	Non availability of local technology to renovate and replace old machinery and equipment	0.09	4	0.36
9	Factories disability to invest on building private docks and ports to secure exports	0.1	3	0.3
10	Lack of local technologies to combat GHGs	0.08	2	0.16
Total				3.14

Table 5: Ranking opportunities and threats for Iran's cement industry

	Title	Weight	Evaluating mark	Final score
Opportunities				
1	Reducing dependency on oil income through export of non-oil goods	0.12	4	0.48
2	Possibility to join the world trade organization	0.09	2	0.18
3	Rich resources and reserves of raw materials	0.12	4	0.48
4	High potential to reduce energy carriers	0.1	4	0.4
5	Possibilities to use financial help from clean development mechanism	0.12	2	0.24
Threats				
6	Limitations and obstacles in the country's laws to export cement	0.09	3	0.27
7	Lack of attention to save energy carriers	0.09	3	0.27
8	Non availability of local technology to renovate and replace old machinery and equipment	0.09	4	0.36
9	Factories disability to invest on building private docks and ports to secure exports	0.1	3	0.3
10	Lack of local technologies to combat GHGs	0.08	2	0.16
Total				3.14

Table 6: Priority of strategies in the cement industries of Iran (QSPM)

	QSPM	Weight	S1 Mark	S1 Value	S2 Mark	S2 Value	S3 Mark	S3 Value	S4 Mark	S4 Value
	Strengths									
1	Promoting environmental knowledge amongst professional staffs	0.12	2	0.24	2	0.24	4	0.48	4	0.48
2	Improvement of quality	0.12	2	0.24	2	0.24	1	0.12	2	0.24
3	Growing demand in Iran and regional countries	0.1	1	0.1	1	0.1	1	0.1	2	0.2
4	Low energy and raw materials prices compared to world's average prices	0.1	0	0	1	0.1	3	0.3	3	0.3
5	Existence of R &D sectors in cement industries	0.12	2	0.24	4	0.48	3	0.36	4	0.48
	Weaknesses									
1	Inactive presence in international markets	0.09	1	0.09	1	0.09	1	0.09	1	0.09
2	Low efficiency in many cement industries	0.08	2	0.16	2	0.16	1	0.08	1	0.08
3	Lack of attention to cement products diversity	0.08	1	0.08	1	0.08	1	0.08	1	0.08
4	Lack of attention to the role of manpower in overall efficiency	0.09	2	0.18	3	0.27	2	0.18	2	0.18
5	Poor attention to environmental aspects	0.1	3	0.3	2	0.2	3	0.3	3	0.3
	Opportunities									
1	Reducing dependency on oil revenues through non-oil exports	0.12	1	0.12	1	0.12	1	0.12	1	0.12
2	Possibility to join the world trade organization	0.09	2	0.18	2	0.18	1	0.09	2	0.18
3	Rich resources of raw materials	0.12	1	0.12	2	0.24	1	0.12	2	0.12
4	High potential to reduce energy carriers consumption	0.1	2	0.2	2	0.2	2	0.2	3	0.3
5	Possibilities of utilizing of CDM financial resources	0.12	3	0.36	2	0.24	3	0.36	4	0.48
	Threats									
1	Limitation in country's laws to export cement	0.09	1	0.09	2	0.18	1	0.09	0	0
2	Lack of attention to save energy carriers	0.09	2	0.18	2	0.18	3	0.27	3	0.27
3	Unavailability of local technologies to renovate and replace old machinery & equipment	0.09	3	0.27	1	0.09	2	0.18	1	0.09
4	Factories disability to invest on building docks and ports for the purpose of export	0.1	2	0.2	2	0.2	1	0.1	1	0.1
5	Lack of capital investment to afford new technologies	0.08	2	0.16	2	0.16	2	0.16	2	0.16
	Marks			3.51		3.75		3.78		4.25
	Ranking			4		3		2		1

Table 6 (continue): Priority of strategies in the cement industries of Iran (QSPM)

	QSPM	Weight	S5 Mark	S5 Value	S6 Mark	S6 Value	S7 Mark	S7 Value	S8 Mark	S8 Value
Strengths										
1	Promoting environmental knowledge amongst professional staffs	0.12	0	0	0	0	1	0.12	1	0.12
2	Improvement of quality	0.12	4	0.48	4	0.48	2	0.24	2	0.24
3	Growing demand in Iran and regional countries	0.1	4	0.48	2	0.24	1	0.1	1	0.1
4	Low energy and raw materials prices compared to world's average prices	0.1	2	0.2	1	0.1	1	0.1	1	0.1
Weaknesses										
1	Inactive presence in international markets	0.09	4	0.36	1	0.09	0	0	1	0.09
2	Low efficiency in many cement industries	0.08	2	0.16	3	0.24	2	0.16	2	0.16
3	Lack of attention to cement products diversity	0.08	1	0.08	2	0.16	1	0.08	2	0.16
4	Lack of attention to the role of manpower in overall efficiency	0.09	2	0.18	2	0.18	2	0.18	2	0.18
5	Poor attention to environmental aspects	0.1	2	0.24	2	0.2	4	0.4	2	0.24
	Opportunities									
1	Reducing dependency on oil revenues through non-oil exports	0.12	1	0.12	2	0.24	1	0.12	1	0.12
2	Possibility to join the world trade organization	0.09	1	0.09	1	0.09	1	0.09	2	0.18
3	Rich resources of raw materials	0.12	1	0.12	1	0.12	1	0.12	2	0.24
4	High potential to reduce energy carriers consumption	0.1	1	0.1	1	0.1	1	0.1	2	0.24
5	Possibilities of utilizing CDM financial resources	0.12	1	0.12	2	0.24	3	0.36	2	0.24
	Threats									
1	Limitation in country's laws to export cement	0.09	2	0.18	2	0.18	1	0.09	1	0.09
2	Lack of attention to save energy carriers	0.09	1	0.09	2	0.18	2	0.18	1	0.09
3	Unavailability of local technologies to renovate and replace old machinery and equipment	0.09	1	0.09	1	0.09	2	0.18	2	0.18
4	Factories disability to invest on building docks and ports for the purpose of export	0.1	1	0.1	2	0.24	2	0.24	1	0.1
5	Lack of capital investment to afford new technologies	0.08	2	0.16	2	0.16	2	0.16	2	0.16
	Marks	2		3.47		3.49		3.22		3.31
	Ranking			6		5		8		7

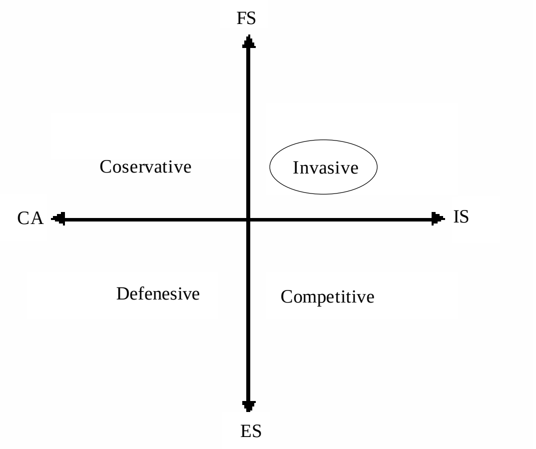

Fig. 1. Position of cement factories according to SPACE analysis

greenhouse gases in cement industries of Iran include:
- Promoting the environmental knowledge of professional staffs through educational courses;
- Focusing on the research and development (R and D) projects to improve efficiency of production for a better competition in the international market;
- Adaptation of new and modern technologies to achieve better specific energy consumption (SEC) per ton cement of production,
- To equip the cement industries with advanced pollution control facilities for the reduction of social and environmental costs associated with cement production;
- To assess the new usages and needs for varieties of cement for proper implementation of relevant technologies;
- To remain competitive in the international markets through production of more varieties of cement types and
- Implementation of integrated environmental management system in the cement industries of the country following the more strict environmental rules and regulations set by the government of Iran.

Finally, the position of cement industries in Iran was subject to strategic position and action evaluation matrix (SPACE) analysis (Fig. 1). When a vector is in an home – invasive matrix , the system is in its best situation and regarding the internal strengths can do the following acts:
- Exploiting external opportunities
- Eliminating internal weak points
- Avoiding external threats

CONCLUSION

The present investigation showed that through simple measures such as replacing ball mills with vertical roller mills about 125 MW of power plant can be saved. The price of carbon dioxide substituting mills would be around US$ 29/ton of CO_2. It would be worthy for the government of Iran that pays subsidy on electricity to financial help cement industries of country to implement energy efficiency measures. Due to the cheap energy and availability of raw materials, Iranian cement factories stand in an invasive position. If the challenges of exports are somehow solved, a better position for cement industries will take place. It can be concluded that in view of climate change context, fuel gas produces lower amounts of GHGs in comparison to the oil fuel. Therefore, substitution of fuel oil with fuel gas can be considered as a suitable short and mid-term policy for the reduction of GHGs. Substitution of present ball mills with vertical roller ones can reduce the electricity consumption from 44.6 to 28 kWh/ton. It should also be concluded that subsidized energy supply have lead to wasteful consumption of energy in industrial sector. Though the removal of energy subsidy may to some extent reduce the opportunity of the cement industries in international markets, but locally government of Iran will be benefited. Also the environment pollution load would be decreased.

REFERENCES

Abbaspour, M.; Karbassi, A. R.; Khadivi, S. (2006). Implementation of green management concepts in sport complexes. Int. J. Environ. Sci. Tech., 3 (3): 213-220 **(8 pages)**.

Avami, A.; Sattari, S., (2007). Energy conservation opportunities: cement industry in Iran. Int. J. Energy, 1 (3), 65-71 **(7 pages)**.

Barker, D. J.; Turner, S. A.; Napier-Moore, P. A.; Clark, M.; Davison, J. E., (2009). CO_2 capture in the cement industry. Energy Procedia., 1 (1), 87-94 **(8 pages)**.

Barros, C. P.; Assaf, A., (2009). Bootstrapped efficiency measures of oil blocks in Angola. Energ. Policy, 37 (10), 4098-4103 **(6 pages)**.

Chiou, P.; Tang, W.; Lin, C. J.; Chu, H. W.; Ho, T. C., (2009). Comparison of atmospheric aerosols between two sites over Golden Triangle of Texas. Int. J. Environ. Res., 3 (2), 253-270 **(18 pages)**.

Choate, W. T., (2003). Energy and emission reduction opportunities for the cement industry. Industrial Technologies Program, U. S. Department of Energy, BCS Incorporated, Colombia, USA.

Coskun, B. B., (2009). Global energy geopolitics and Iran. Uuslararasi Iliskiler, 5 (20), 179-201 **(23 pages)**.

Farzaneh, H.; Saboohi, Y., (2007). Evaluation of the optimal performance of passenger vehicle by integrated energy-environment-economic modeling. Int. J. Environ. Sci. Tech., 4 (2), 189-196 **(8 pages)**.

Gielen, D.; Taylor, P., (2009). Indicators for industrial energy efficiency in India. Energy, 34 (8), 962-969 **(8 pages)**.

Hustad, C. W., (2000). The Norwegian CO_2-infrastructure initiative: A feasibility study. Paper presented at the 5th. International conference on greenhouse gas control technology. Cairns, Australia (13-16th. August).

Karbassi, A. R.; Abduli, M. A.; Abdollahzadeh, M. E., (2007). Sustainability of energy production and use in Iran. Energ. Policy, 35 (10), 5171-5180 **(10 pages)**.

Karbassi, A. R.; Abbasspour, M.; Sekhavatju, M. S.; Ziviyar, F.; Saeedi, M. (2008a). Potential for reducing air pollution from oil refineries. Environ. Monit. Assess., 145 (1-3), 159-166 **(8 pages)**.

Karbassi, A. R.; Abduli, M. A.; Neshastehriz, S., (2008b). Energy saving in Tehran International Flower Exhibition's Building. Int. J. Environ. Res., 2 (1), 75-85 **(11 pages)**.

Mohsenzadeh, F.; Nouri, J.; Ranjbar, A.; Mohammadian Fazli, M.; Babaie A. A., (2006). Air pollution control through kiln recycling by-pass dust in a cement factory. Iran J. Environ. Health Sci. Eng., 3 (1), 5-8 **(4 pages)**.

Nasr, D.; Massoud, M. A.; Khoury, R.; Kabakian, V., (2009). Environmental impacts of reconstruction activities: A case of Lebanon. Int. J. Environ. Res., 3 (2), 301-308 **(8 pages)**.

Nouri, J.; Karbassi, A. R.; Mirkia, S., (2008). Environmental management of coastal regions in the Caspian Sea. Int. J. Environ. Sci. Tech., 5 (1), 43-52 **(10 pages)**.

Panjeshahi, M. H.; Ataei, A., (2008). Application of an environmentally optimum cooling water system design to water and energy conservation. Int. J. Environ. Sci. Tech., 5 (2), 251-262 **(12 pages)**.

Refaat, A. A.; Attia, N. K.; Sibak, H. A.; El Sheltawy, S. T.; El Diwani, G. I., (2008). Production optimization and quality assessment of biodiesel from waste vegetable oil. Int. J. Environ. Sci. Tech., 5 (1), 75-82 **(8 pages)**.

Shafipour, M. M.; Farsiabi, M. M., (2007). An environmental economic analysis for reducing energy subsidies. Int. J. Environ. Res., 1 (2), 150-162 **(13 pages)**.

Tehrani, S. M.; Karbassi, A. R., (2005). Application of E-Commerce in local home-shopping and its consequences on energy consumption and air pollution reduction. Iran J. Environ. Health Sci. Eng., 2 (4), 247-250 **(4 pages)**.

Tehrani, S. M., Karbassi, A. R., Ghoddosi, J., Monavvari, S. M., Mirbagheri, S. A., (2009). Prediction of energy consumption and urban air pollution reduction in e-shopping adoption. J. Food, Agric. Environ. 7 (3-4), 132-137 **(6 pages)**.

Timilsina, G. R.; Shrestha, R. M., (2008). A general equilibrium analysis of potential demand side management programs in the household sector in Thailand. I. J. Energ. Sec. Manage., 2 (4), 570-593 **(23 pages)**.

Utlu, Z.; Sogut, Z.; Hepbasli, A.; Oktay, Z., (2006). Energy and exergy analyses of a raw mill in a cement production. Appl. Therm. Eng., 26 (17-18), 2479-2489 **(11 pages)**.

Zare, D.; Chen, G., (2009). Evaluation of a simulation model in predicting the drying parameters for deep-bed paddy drying. Comput. Electron. Agri., 68 (1), 78-87 **(10 pages)**.

Zerrouqi, Z.; Sbaa, M.; Oujidi, M.; Elkharmouz, M.; Bengamra, S.; Zerrouqi, A., (2008). Assessment of cement's dust impact on the soil using principal component analysis and GIS. Int. J. Environ. Sci. Tech., 5 (1),125-134 **(10 pages)**.

AUTHOR (S) BIOSKETCHES

Karbassi, A. R., Ph.D., Assistant Professor, Department of Environmental Engineering, University of Tehran. Email: *akarbassi@ut.ac.ir*

Jafari, H. R., Ph.D., Associate Professor, Department of Environmental Management, University of Tehran. Email: *jafari@ut.ac.ir*

Yavari, A. R., Ph.D., Associate Professor, Department of Environmental Management, University of Tehran. Email: *yavari@ut.ac.ir*

Hoveidi, H., M. Manag., Ph.D. Candidate, Department of Environmental Management, University of Tehran, Iran. Email: *hoveidi@ut.ac.ir*

Sid Kalal, H., Ph.D., Assistant Professor, Faculty Member in Nuclear Science and Technology Research Institute, Tehran, Iran.
Email: *Hsidkalal@yahoo.de*

How to cite this article: (Harvard style)

Karbassi, A. R.; Jafari, H. R.; Yavari, A.R.; Hoveidi, H.; Sid Kalal, H., (2010). Reduction of environmental pollution through optimization of energy use in cement industries. Int. J. Environ. Sci. Tech., 7 (1), 127-134.