Energy Conservation Opportunities: Cement Industry in Iran

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Abstract— Growing concerns arise about energy consumption and its adverse environmental impact in recent years in Iran in which cause manufactures to establish energy management groups. Cement production has been one of the most energy intensive industries in the world. Focusing on energy consumption reduction efforts through process improvement, production management and introducing new technologies can achieve significant results. This study, based on conducting on-site energy audits of over 30 cement firms in Iran during 2004–2005, discovered the following energy-saving potentials: electricity savings of $223.5*10^6$ KWh equivalent to 11.3M$, fuel oil savings of $168*10^6$ Lit equivalent to 39.4M$ in FOB prices.

The present paper will study the energy consumption in cement industry in Iran through real auditing and identify technological opportunities in order to decrease energy consumption of the relevant factories, increase the productivity, and improve the production process. Relevant standards planned by government that can provide significant potentials, are discussed too.

Keywords— cement industry, energy auditing, energy conservation, heat recovery

I. Introduction

THE industry sector plays a significant role in global energy consumption. Cement is one of the most energy consuming industries. Since energy production is extensively based on using fossil fuels, the environmental issues will become of great importance. The economical and environmental issues and obligations cause the industry to move toward better design conditions. On the other side, environmental aspects, energy intensity and economical views are integrated to each other which must be thoroughly considered in order to increase efficiency and decrease costs.

Recently, there has been increasing interest in using energy analysis techniques for energy-utilization assessments in order to attain energy saving, and hence financial savings which are related to environmental issues. Schuer et al. [1] gave energy consumption values and described the energy saving methods and potentials for German Cement Industry. The study consisted of two parts, namely electrical energy saving methods and thermal energy saving methods. The results were presented in the form of energy flow diagrams that made the results easy to understand.

Worell et al. [2] performed an energy analysis for the US for the years 1970 and 1997. They reported an in-depth analysis of the US cement industry, identifying carbon dioxide saving, cost-effective energy efficiency measures and potentials between 1970 and 1997. They demonstrated that the use of blended cements is a key cost-effective strategy for energy efficiency improvement and carbon dioxide emission reductions in the US cement industry.

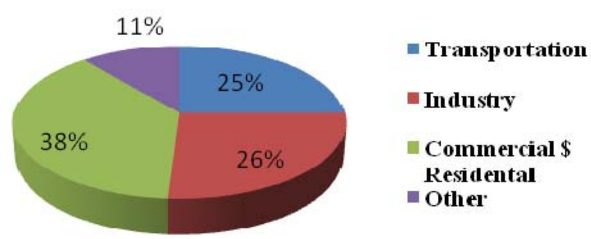
Khurana et al. [3] performed an energy balance of a cogeneration system for a cement plant in Indiana. They found that about 35% of the input energy was being lost with the waste heat streams.

Engin and Ari [4] made an energy audit analysis of a dry type rotary kiln system working in a cement plant in Turkey.

The present paper will study the energy situation in cement production in Iran and its role in the entire energy system. It reviews the production process available in the country and assets the possibilities to improve the efficiency and save energy based on energy auditing programs in which the basic amount of energy required is calculated roughly and compared to real data available from site-visit with regards to Iranian National Standards. Opportunities from the point of energy- and financial- saving will be chosen in order to promote the energy situation of each factory.

II. CURRENT SITAUTION IN IRAN

26 percent of total energy consumption in Iran is contributed to industrial sector that involves 29% petroleum products, 60% natural gas and 11% electricity (Fig. 1) .



(a)

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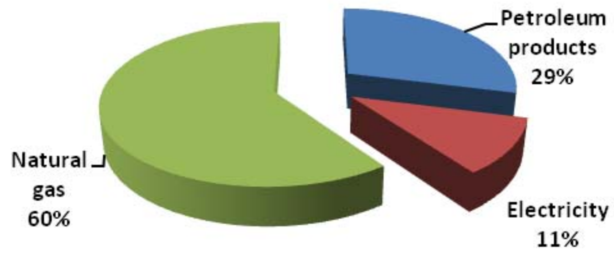


(b)

Fig. 1 (a) Energy consumption in Iran (b) Quantities of different energy carriers using in Iranian Industries (2004)

The following Fig.s show different types of emissions released by industrial factories during recent years.

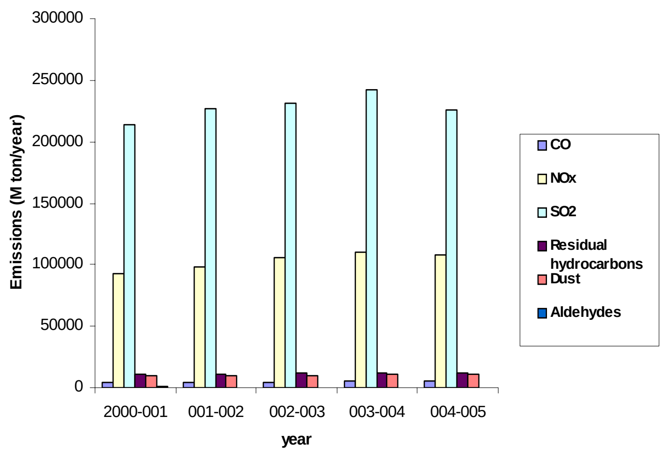


Fig. 2 Emission gases produced by industrial section in Iran

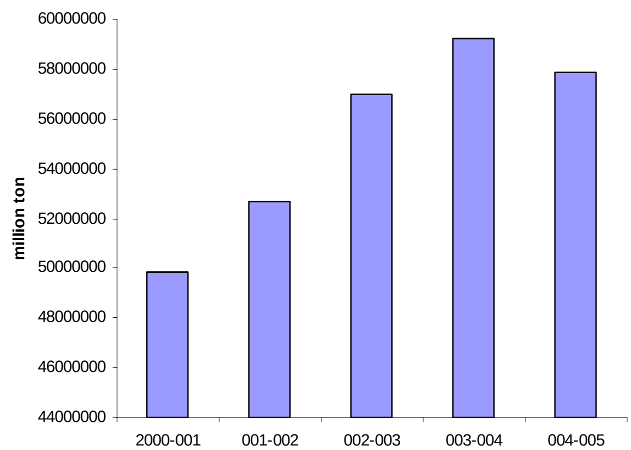


Fig. 3 Total CO2 released by different industries

Cement production, a high energy intensive industry, plays a major role in a country on its way toward sustainable development. The total annual production in Iran is approximately 30 million tons by 33 factories in 2005-2006.

During the last ten years, an increase of 15 million tons in production has been achieved with the average growth rate of 4%. From 1950 up to 2002, the contribution of Iranian factories of total world cement production has increased from 0.04% up to 1.61%.

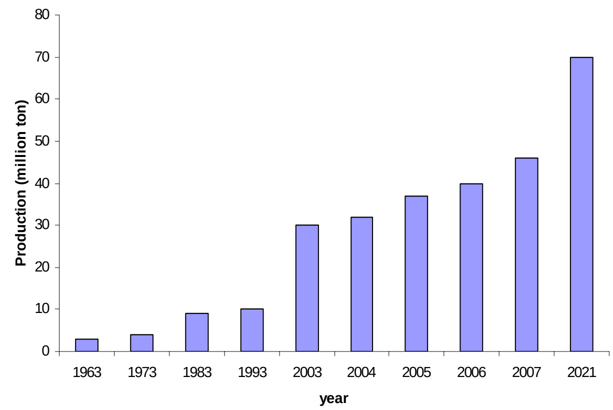


Fig. 4 Total annual cement productions [5]

Cement demand depends on different factors such as population and economical growth. Assuming 10% of annual increase in the demand, the total production must be reached 72.2 million tons in 2021. As illustrated in Fig. 5, plants consume 15 percent of total industrial energy consumption currently.

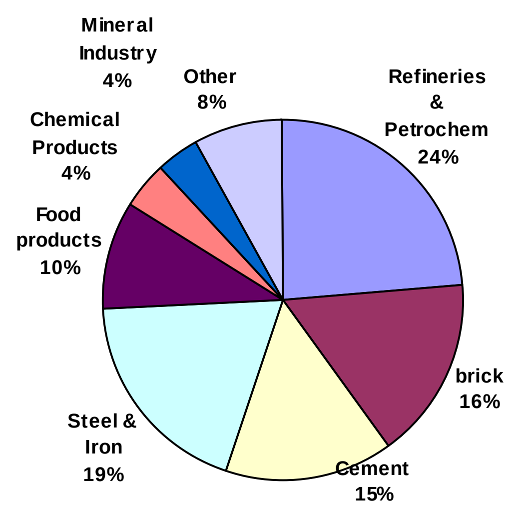
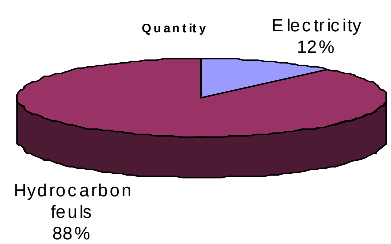


Fig. 5 Energy consumption in different industries (005-006)

Due to different process condition electricity and hydrocarbon fuels (Natural gas and Fuel oil) is used as fuel which 12 percent contributes to electricity and the remainder is hydrocarbon share.



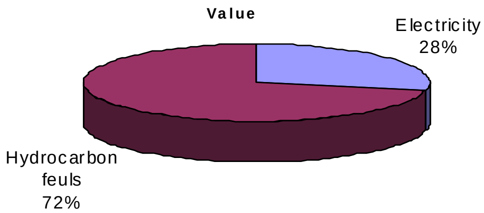


Fig. 6 quantity and value of energy carriers using in cement production (004-005)

The following Fig. shows the amount of different petroleum products used in cement production in Iran.

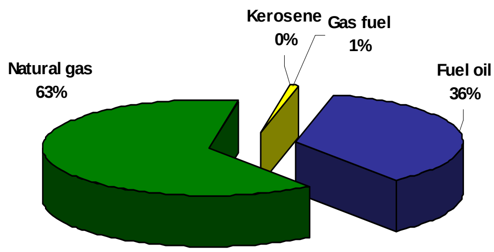


Fig. 7 Different petroleum products used in cement industry in Iran (005-006)

The energy index(SEC stands for Specific Energy Consumption) for cement industry in Iran is currently 105 lit/ton, while this value for the world is 80 and the target for Iran is 95 in 10 years. So saving-potential of 10% can be achieved during this period, equivalent to 29.3 million $ per year[1]. Therefore, there exists a great potential of saving in Iran in comparison with current situation of industry in world by this roughly calculations.

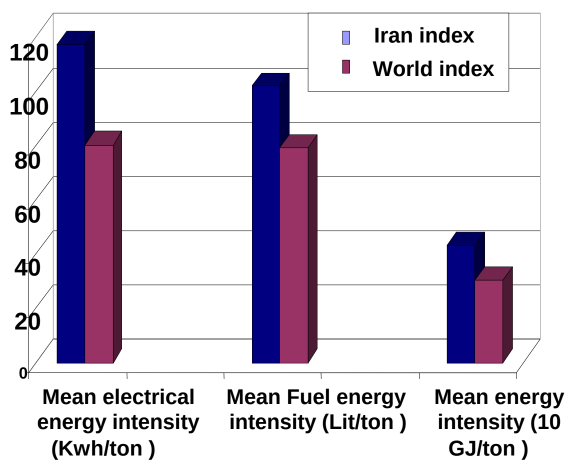


Fig. 8 Energy intensity in cement industry

[1] Based on IFCO reports (Iranian Fuel Conservation Organization; a subsidiary of National Iranian Oil Company(NIOC) established in 2000 with the mission to regiment the fuel consumption in different sectors through review and survey of the current trend of consumption and executing conservation measures nationwide)[6].

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III. Cement Process Discription

Cement production involves the chemical combination of Calcium carbonates (limestone), silica, alumina, iron ore, and small amounts of other materials, which are chemically altered through intense heat to form a compound with binding properties.

After raw materials including limestone, chalk and clay are treated, they will be passed through crusher. Then they convert to a fine powder in the proper portion in mills. Producing clinker from treated raw materials by heating consists of three parts: pre-heaters, furnace and cooler. The produced clinker will be grinded and mixed with gypsum and sent for packing.

There are two different production systems categorized as wet process which is an old technology that even used in some factories in Iran and dry type. In the dry process, the raw materials are ground, mixed, and fed into the kiln in their dry state. Fig. 9 illustrates a typical flow diagram in a dry process. The choice among different processes is dictated by the characteristics and availability of raw materials.

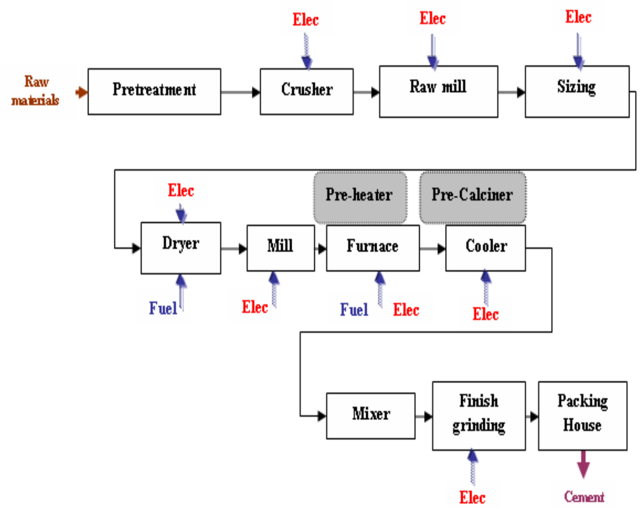

Fig. 9 Flow diagram of typical wet process in cement production

Table 1 contains the energy requirement for operational equipments in a typical process.

Table 1 Energy required by different process sections

Process sections	Dry	Wet
Electricity(KWh/ton)		
Raw material treatment & Crushing	4	3
Meshing	44	10
Fans & coolers	23	25
Dust collector	6	8
Cement milling	45	45
Transportation	8	58
Total electricity required (KWh/ton)	130	99
Fuel burned in Furnaces(lit/ton)	112.5	156

Fig. 10 shows the contribution of electricity consumption among process sections.

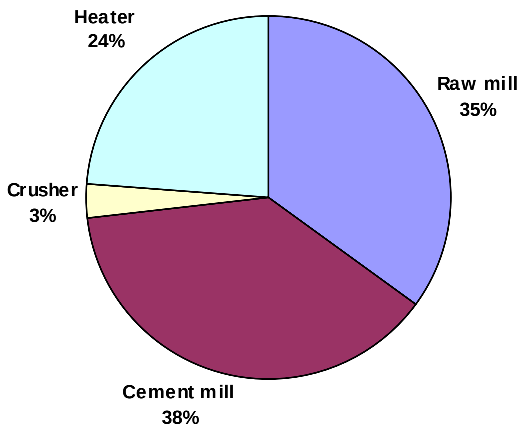

Fig. 10 quantity of electricity used by different sections of cement processes

Fig. 11 is the comparison between two processes in which total energy consumption in wet and dry processes are equal to 6.8 and 4.6 GJ/ton cement respectively(wet process uses 30% more energy).

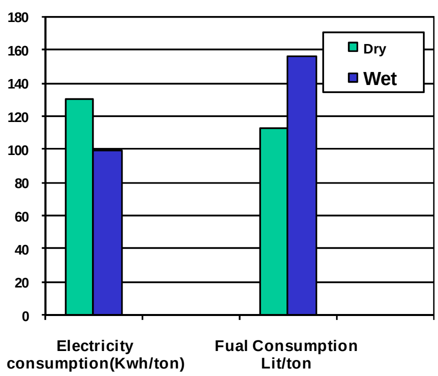

Fig. 11 Comparison of energy carriers used in wet and dry cement production

IV. Energy Auditing Methodology

Energy audits are the most comprehensive approaches to improving an existing system's energy efficiency. These audits can identify specific opportunities for improving energy efficiency and lowering atmospheric emissions including carbon dioxides (CO_2), nitrous oxides (NO), and sulfur oxides (SO) and particulate.

There exist 42 dry, 5 wet, and 2 semi-dry production lines. New dry process kilns have been developing at a high speed in recent years.

During 2004-2006, energy audits of approximately all cement production units have been conducted by IFCO in Iran.

The energy auditing team does their job in two levels: primary and final auditing. At first, they study the historical consumption trends and technological information of the factory; identifying the potential of saving opportunities roughly and preparing the primary report. In the final stage they measure the electrical and thermal characteristics', plan the necessary experiments, calculate the intensity according to national standards for cement energy usage. They provide mass and energy balance in different sectors, identify waste streams and find the solution in order to descend these wastes. Finally, the possibility studies and economical calculations are done and the final report will be prepared.

A cement manufacturing energy auditing team should address the energy use areas and recommend potential actions listed in Table 2.

V. Results and Discussion

In Iranian cement factories, the intensity of electricity and fuel oil are 117 KWh/ton and 105 lit/ton respectively. Altogether the energy intensity in cement will be 4.319 GJ/ton. (1.31 greater than mean world energy intensity in cement production). The significant shift in fuel sources is occurred over recent years. Cement manufacturers have switched fuel oil to natural gas. Fuel switching is costly in terms of capital costs. This switch was initially a result of environmental issues and value of fuel oil. Opportunity cost from this replacement is high for the country and it provides the feasibility of fuel oil export.

Factories that consume more energy than the determined index by the government must pay 20 percent extra for price of energy usage (which is equal to 824 Kcal/kg calinker in 2005-2006 for cement plants). The Energy Standard for the cement from the point of electrical and thermal specific energy consumption is more rigid and may be categorized as: high energy intensive, medium energy intensive and low energy intensive processes. The government laws compelled the factories to consider these standards. In 2000, IFCO conducted comparative study of cement plants in Iran considering both electrical and thermal specific energy consumptions with respect to the average index through out the world. The first potential of 4.3 $/year*ton have been identified, in aggregate.

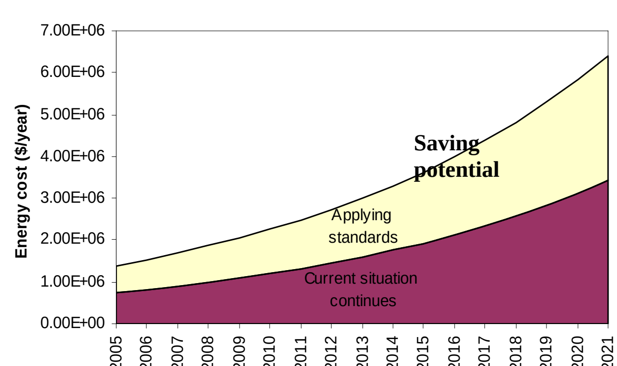

Fig. 12 The saving potential via applying the standard

Table 2 Energy-efficient opportunities in cement production

Raw material preparation	Replace traditional mills with Roller mills and high pressure pressing mills Improve ball mills Applying efficient separators Insulating the hot piping entering mills in order to dry materials Utilizing pre-crusher Continuous control of raw material level in mills Adjusting raw material size
Clinker production	Combustion system improvement Heat loss reduction by insulation Improve cooler operation and substituting satellite coolers by grate ones Using mechanical transportation system (elevator instead of airlift) Adding (multi stage) pre-heater and pre-calcinator Support developing the dry type and semi dry type Low pressure cyclones Efficient fans Recycle waste heat Use secondary fuels as waste tires Complete tighten of system Utilizing variable speed drivers in order to control air inlet
Finish grinding	Improve ball mills Replace traditional mills with Roller mills and high Continuous control of cement level in mills Control the size of input clinker and softness of the cement according to standards Apply grinding-aid materials in order to increase the capacity and reduce the energy intensity Using the high-efficiency separators Introducing pre-crusher
Preventive maintenance	Correct maintenance in order to operate in optimal point

Following the present methodology, they determine $1.5*10^{12}$ Kcal/year thermal saving equivalent to 39.4 million dollars per year and $223.5 * 10^6$ KWh/year electrical saving equivalent to 11.3 million dollars annually during 2005-2006. Fig. 13 show the percentage of financial savings due to electrical and thermal saving options.

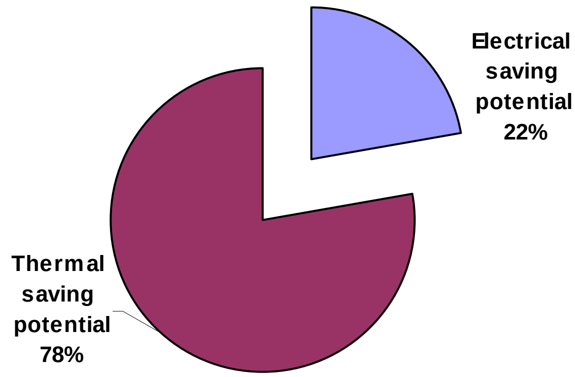

Fig. 13 Financial saving potential

Altogether, there exists 50.6 million $ saving potential in cement plants through real auditing in 2005-2006. Most of this value is relevant to improve the existing technologies and process conditions.

The following discussion recommends energy efficiency strategies for some of the largest industrial facilities across the country (25 factories including 35 production lines).

A. *Electrical saving potential*

Although electricity is using widely during the cement plant, milling is the most electrical consuming section (See Fig. 10). So any modification will result in significant savings. These modifications in Iranian factories include:

- Leak reduction in different part such as furnace and mills (raw and cement), pre-heater and side-equipments
- Modify capacity in order to increase the equipment capacity which greatly affects on the required electricity.
- Cooler: Adjust the amount of inlet air, heat recovery, change the cooler
- Mechanical systems: Install elevator instead of airlift**.**
- Electrical motors and drives**:** motors can be accurately predicted to run at less than 33% of the rated output by reconfiguring the motor from Delta to Star connection. VSD will also allow motors to run at the required speed to save energy. Other VSD benefits are: reduced demand on the hydraulic system means that the hydraulic oil runs at a lower temperature and requires less cooling - an additional cost saving measure, reduced noise, lower maintenance costs.
- optimizing compressor operations, improving compressed air quality, reducing compressed air use.
- Introducing pre-crusher in raw and cement mill

The electrical saving- potentials which has been identified by the energy-audits teams are summarized in Table 3.

Table 3 Electrical saving potentials

Option	Electrical saving potential (KWh/year)	Financial saving ($/year)
Monitoring	4E+06	2E+05
Leakage reduction	4E+07	2E+06
Modify the capacity	3E+07	1E+06
Compressor	370260	18513
Cooler	534400	26720
Transportation material	3E+06	1E+05
Pre-crusher	3E+07	2E+06
Motors & drives	1E+08	6E+06
Total	2E+08	1E+07

The following figures illustrates contribution of each solution in cement factories. Correct operation of motors and drives, leakage reduction, and modify capacity have the largest saving-potential respectively. Most of the proposed solutions have low rate of return.

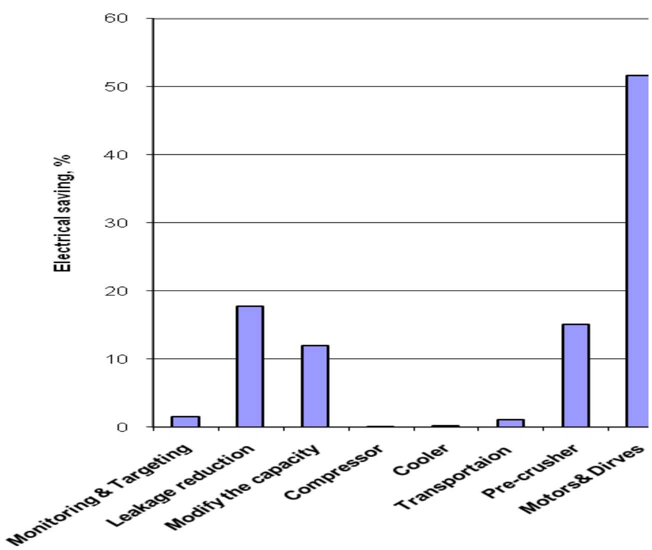

Fig. 14 Electrical saving potential

B. *Thermal saving potential*

Some alternatives for thermal energy conservation are as follows:

- Avoid leakage in clinker production & Raw material treating, close unnecessary openings, provide more energy efficient seals, ...
- Modify capacity
- Cyclones: Increase efficiency
- Combustion process: monitoring the combustion process, modify burners, check the furnace envelope, change bricks, heat recovery techniques by reduction of stream temperature or using the heat capacity of the stream in preheating sections, fuel reduction, lower kiln exit gas losses, install devices to provide better conductive heat transfer from the gases to the materials (e.g., kiln chains), operate at optimal oxygen levels (control combustion air input), optimize burner flame shape and temperature, lower kiln radiation losses by using the correct mix and more energy efficient refractory's to control kiln temperature zones
- Grinding and milling: adjustment of ball charges, modifying particle size distribution, controlling gypsum dehydration
- Cooler: adjust the zero point of cooler, remove operational damages of cooler , reduce vent air of fan and correct the distance of plates and distribute air correctly, adjust pressure, lower clinker cooler stack temperature, recycle excess cooler air, reclaim cooler air by using it for drying raw materials and fuels or preheating fuels or air
- Pre-heater: improve or add additional capacity
- Dust collectors: Lower dust in exhaust gases by minimizing gas turbulence.

Table 4 The thermal energy saving-potential in a typical cement production lines in Iranian factories

Option	Thermal saving (Kcal/year)	Financial saving ($ /year)
Monitoring & Targeting	1.141E+09	30139.62
Leakage reduction	5.96E+11	15754182
Modify the capacity	1.89E+11	4998270
Cyclones	6.386E+10	1686529
Furnace & Combustion process	3.99E+11	10531462
Cooler	1.99E+11	5258573
Filtration	9.092E+09	240123.4
Calciner	3.828E+09	101104.6
Material transportation system	2.746E+09	72516.38
Pre-heater	1.09E+11	2881960
Raw material composition	2.167E+10	572397.7
Total	1.595E+12	42127257

As shown in Fig. 16, leakage is the most source of thermal wastes that can be easily avoided. Also combustion process in furnace has great improvement potential.

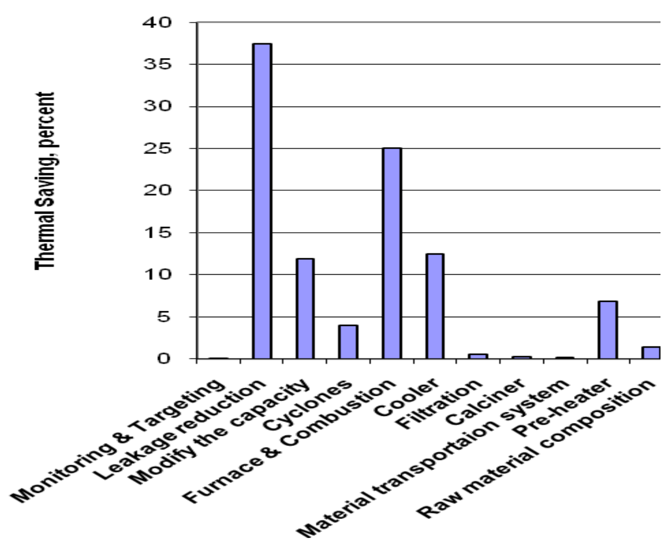

Fig. 15 Thermal-saving potential

C. Production schedueling and planning

Stopping the production line will affect the production efficiency, increase wastes, change operating condition, change the quality of product, and therefore waste energy, money and time. Stopping the raw mill will cause stopping of all relevant equipments. There are possibility of 42075 KWh electrical saving equivalent to 841500 $ and 495*107 Kcal thermal saving equivalent to 130738.6 $ in the plants under study annually.

As a result of these efforts, they amount to more than 50 million dollars in energy costs savings and a significant reduction in process emissions will be achieved. Most of the above solutions are about upgrading the existing technologies. But there is a great opportunity in introducing new technologies and correct maintenance of system operation. These suggestions are discussed as below.

D. Introducing new technologies

- Installing air filtration in Oromieh factory will save 8-11 Kcal/Kg thermal energy.
- Installing new design high-efficiency crushing, grinding, and milling equipment cyclones. High efficiency separators will reduce required electricity up to 8 %.
- Replacing high-carbon fuels by low-carbon fuels (e.g. shifting from fuel oil to natural gas)
- Utilizing the vertical grinding mills on existing ball grinding mills will reduce 30% of energy consumption. Traditional ball mills used for grinding certain raw materials (mainly hard limestone) can be replaced by high-efficiency roller mills, or ball mills combined with high pressure roller presses. The use of these advanced mills saves energy without compromising product quality.
- Efficient transport systems
- Applying high efficiency burners and coolers
- Utilizing CHP systems in cement plant
- Using oxygen enrichment in burner
- Utilizing alternative fuels such as: biomass, tires, solvents, oils, solids…
- The addition of pre-heater and pre-calcination sections
- Changing cement product formulations, applying a lower clinker to final cement mixture ratio (i.e., increasing the ratio of cement additives that do not require pyroprocessing)
- Sequestering CO2 from the gas streams

E. Plant operation and maintenance

Repairing a failed motor may appear to be a cost-effective action but repair can reduce energy efficiency by up to 1% and may not be the most economical long-term action.

VI. Conclusion

The aim of this study was to determine energy situation in cement industry in Iran and the possible energy and financial saving potentials. Energy auditing is a powerful tool, which has been successfully and effectively used in the design and performance evaluation of energy-related systems.

In order to reach this purpose, there will be done energy audit on-site visit on almost all factories and the production process is analyzed by considering energy consumption. The main conclusions drawn from present study may be summarized as follows:

Leakage, furnace and the drives have the greatest opportunities to save energy

Waste air also transfers a very important amount of energy, so the inlet air should be controlled and dust and stack gases can be used in pre-heater or other sections.

Dry process will reduce the energy consumption (30% less than wet process). So programs for supporting the development of new dry process kilns must be continued.

Promoting recycle economy, facilitating technological progress reduce consumption and protect the environment.

Applying standards will help the industry to reduce energy costs in coming years.

VII. Conclusion

A conclusion section is not required. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

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