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Energy Saving Opportunities in Turkish Cement Sector

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ABSTRACT:The cement industry consumes much energy than the other sectors. The cement industry is also noted for great percentage of the energy cost in the total production cost. In the cement industry, appreciable amounts of energy could be saved or conserved by preventing of leakage in the kilns, modifying the equipment to recover heat from the preheater and cooler in the process of cement-making and effective use of industrial waste materials. These operations dominate the energy consumption and environmental impacts associated with the manufacture of the cement. Improvement of energy efficiency reduces the emission of carbon dioxide from fuel and electricity use and may also reduce the costs of producing the cement. Process improvement may be attained by energy management, applying more energy efficient process equipment and by replacing old installations by new ones or shifting to complete new types of cement production processes, cement kiln optimization process, performing the research and development necessary to prepare and burning the alternative fuels in cement kiln and to develop new cement manufactures.

KEYWORDS: Cement, **e**nergy consumption in cement industry; energy saving potential in cement sector.

I.INTRODUCTION

The cement production is an energy intensive industry with energy typically accounting for 50–60% of the production costs [1]. The escalating costs of cement manufacture over the years and increasing competitiveness have resulted in a focused approach by the cement industry in Turkey to maximize the operational efficiency with respect to retrofitting of energy efficient equipment/systems, technology upgradation, process optimization, effective maintenance management and above all, energy management including energy monitoring and energy audit. This comprehensive approach has resulted in significant reduction in specific energy consumption levels in cement plants. Ministry of Energy and Natural Resources perspectives in the context of energy conservation include energy auditing and management, technological support, research & development, training, consultancy and policy planning. Ministry will carry out studies in the areas of energy management, monitoring and audit during the following years. These studies will help the industry in a variety of ways such as: formulation of policy guidelines for managerial and structural changes in the industry, formulation of specific guidelines for improving energy efficiency in individual / group of plants, as well as for implementation of energy conservation measures in individual plants [2].

II.TURKISH CEMENT INDUSTIRY

Turkey is the fifth largest producer of cement in the world. The Turkish cement industry is a unique combination of very large to very small capacity and very modern to very old technology plants. The share of installed capacity of energy inefficient wet process plants had slowly decreased from 94% in 1960 to 61% till 1980 and thereafter as a result of quantum jump in production capacities through modern dry process plants as well as conversion of some of the wet process plants, the share of old wet process has been reduced to just 5% today.

The Turkish cement industry comprises of 51 large/medium size cement plants including grinding. The annual installed capacity of the industry is about 126 million tons and production was about 75 million tons during 2015 [3]. Cement plays a vital role in infrastructure development, especially in a developing country like Turkey. The industry also provides direct and indirect employment to people. Economic liberalization and favorable industrial policies, including decontrol of cement, has resulted in enormous growth in cement production capacities in Turkey. It is expected that cement production will reach to 100 million tons in 2023.

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Production cost in a cement factory includes raw materials, labor and the sum of operating and energy costs. Typically energy is simply included in the total production costs. The cost can exceed 50%. The highest rate in the cement sector in Turkey is with 55% rate [4].

III.ENERGY CONSUMPTION IN TURKISH CEMENT INDUSTRY

Turkish cement industry is one of the core industries of the country consuming about 9 million tonnes of coal and 7.5 billion electric units annually. Cement industry is highly energy intensive, requiring on an average about 800.K.Cal of thermal energy per tonne of clinker production and about 100 kWh of electric energy per tonne of cement production in the world.

Ministry's energy monitoring studies indicate reducing thermal and electrical energy consumptions. The significant fact is that the best operating levels of energy consumption in cement plants in Turkey are approx. 850 kcal/kg clinkers and 100 kWh/t cement which compare average with world best levels of 650 kcal/kg clinkers and 65 kWh/t cement. Moreover, the older plants can be modernized/expanded by technology upgradation and retrofitting with energy efficient equipment/systems. Some of the cement plants by their pioneering efforts have reduced energy consumption by 25-30% by incorporating/retrofitting energy efficient equipment/systems during the last 7-8 years giving them competitive advantage over others.

The main energy inputs to the cement industry are coal and power. A brief discussion on these energy inputs is as follows:

A. COAL

Coal is predominantly being used in the Turkish cement industry. The quality of indigenous coal supplied is poor with high ash content (30 to 35%) which affects the efficiency of kiln apart from increasing the fuel consumption leading to higher specific Green House Gas emission. Deteriorating and inconsistent quality of coal has become a limiting factor in improving energy efficiency, productivity and clinker quality. The use of these coals results in a number of operationalproblems such as improper and inefficient burning and higher per-unit consumption of coal as well as lower operational efficiencies which tend to further increase the emission of greenhouse gases.

The frequent variations in the quality of coal, inadequate supplies and transportation bottlenecks have rendered it imperative to import coal from countries like Africa, China, Indonesia, India etc. besides going for substitute fuels like lignite, rice-husk petroleum coke etc.However, import of coal is costly and a drain on our national exchequer even though it has helped cement industry getting quality coal. Many cement plants are utilizing lignite blended with coal to the extent possible. Pet coke, which has proved to be an excellent alternate fuel to coal, is a residual product from oil refinery with high calorific value and insignificant ash content but often with high sulphur content as compared to coal. A number of cement plants have attempted successfully using pet coke in varying proportions upto 50% alongwith coal. Pet coke has been used 100% in kiln firing and a few cement plants are using it in the precalciner, too.

B. POWER

Production of cement being a continuous manufacturing process requires stable and reliable power supply. Any power interruption leads to kiln stoppage resulting in loss of production, additional fuel consumption to attain requisite thermal profile and a lot of idle running of equipment leading to wastage of electrical energy. The present power scenario in Turkey is dismal due to shortage of power generation capacity, transmission and distribution losses, poor management of power distribution and low frequency and voltage fluctuation. These factors lead to scheduled power cuts as well as unscheduled power interruptions.
It is estimated that, in a one million tons per annum capacity cement plant, a one-hour power cut (equivalent to 4% downtime) will result in loss of production of about 7% (200 tons). Apart from the production loss, the additional coal requirement would be about 4 tons for a one-hour power cut, amounting to the mere wastage of coal.

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To augment the power requirement, many plants today have their own substation centers and takes power directly from the power transmission lines. In this way, these plants are not affected by the faults from the distribution network.

IV.ENERGY CONVERSATION EFFORTS BY THE INDUSTRY

A brief discussion on these energy conservation efforts is as follows:

A. TARGET SETTING AND ENERGY MONITORING

Most plants have been setting standard/benchmarks; the successes in achieving the targets have been found varying. It is worth noting that the plants are setting targets not only for overall energy consumption levels, but also for section wise energy consumption levels. The monitoring of energy performance by the plants has improved a lot during the last few years. This has also helped in continuous improvement in setting targets and monitoring actual performance.

B. OPERATIONAL CONTROL AND OPTIMIZATION

Process optimization, load management and operational improvement generally involve marginal financial investment and yet found to have produced encouraging results in energy saving. These aspects have been accorded high priority by the plants. The different aspects explored in this direction by the plants are given hereunder:

- Plugging of leakages in kiln and preheater circuit, raw mill and coal mill circuits
- Reducing idle running
- Installation of Improved insulating bricks/blocks in kilns and preheaters
- Effective utilization of hot exit gases
- Optimization of cooler operation
- Optimum loading of grinding media/grinding mill optimization
- Rationalization of compressed air utilization
- Redesigning of raw mix
- Installation of capacitor banks for power factor improvement
- Replacement of over-rated motors with optimally rated motors
- Optimization of kiln operation
- Changing from V-belt to flat belt

C. ENERGY EFFICIENT EQUIPMENT

Use of energy efficient equipment gives very encouraging results even at the cost of some capital investment. More and more plants are now going for this available energy saving equipment to improve the energy performance of the units. The energy efficient equipment being used by the cement industry is highlighted below:

- Slip Power Recovery System
- Variable Voltage & Frequency Drive
- Efficient Motor System
- Energy Efficient Lighting
- Grid Rotor Resistance
- Soft Starter for Motors
- High Efficiency Fans
- High Efficiency Separators
- Vertical Roller Mill
- Pre-Grinder/Roller Press
- Low Pressure Preheater Cyclones
- Multi-channel Burner
- Bucket Elevator in place of pneumatic conveying
- Fuzzy Logic/Expert Kiln Control System
- Improved Ball Mill Internals

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- High Efficiency Grate Cooler
- Waste Heat Recovery

D. ACTIVE PARTICIPATION OF EMPLOYEES AND MANPOWER TRAINING

The cement plants are realizing the need for active participation of employees in energy conservation efforts. The suggestions box schemes, quality circles, brain-storming sessions and cash rewards for good suggestions etc. are some of the schemes, the plants are adopting for ensuring active participation of employees.

Setting up of an energy conservation cell for monitoring and controlling energy performance of the plant is gaining its significance in the plants.

Cement units are also giving importance to manpower training by deputing their employees at different levels; for seminars, workshops, training courses to enhance their knowledge and to create awareness among the employees towards energy conservation.

V.TECHNOLOGICAL DEVELOPMENTS

The last two decades have experienced major technological advances in cement plant equipment/systems such as single stage crushers, On-line- Bulk Material Analyzers, Vertical Roller Mills, High Pressure Roller Presses, High Efficiency Grate Coolers and 5/6 Stages Low Pressure Cyclone Pyroprocess Systems. The economic necessity for high productivity and energy efficient plants has been the motivating force for their development/adoption.

VI.A SURVEY ON CEMENT PLANT EFFICIENCY

This section is made of a cement energy audit in 2015-2016. Cement factory, has been formed with three sub-units, including administrative offices as production manager in charge of the plant manager, general manager and maintenance teams. Depending on the general maintenance directorate, Factory Energy Management program it is being implemented even partially. It's about a care manager depends on the overall electrical engineer, has served as energy manager.

The main production at the cement factory, CEMI 42.5A, CEMIIA / CEMI 42.5B / SDC 32.5 cement types are produced. In addition, clinker is as the intermediate production.

The types of energy used in the production of cement and clinker in the plant are given in table 1 and table 2 for the last 3 years.

Energy consumption that occurs depending on the scope of the current operating conditions at the factory carried out a detailed energy audits examined, determining the energy efficiency potential and aimed to develop productivity-enhancing projects. This was carried to the goal the following works:

- Production and energy consumption were examined and calculated for some part of the plant.
- Based on the calculated energy consumption targets it has been proposed and some are determined based on the theoretical savings potential target.

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Table 1. Energy used in clinker production

Explanation / Years	2013	2014	2015
Clinker production (net ton)	1,476,405	1,407,530	1,391,400
Electric energy (MWh/year)	115.8	109.2	107.9
Electric cost (TL/kWh)	0.22	0.22	0.24
Electric (TL)	25,130,082	23,521,706	25,612,209
Specific Energy Consumption (MWh/net T)	0.078	0.077	0.077
Fuel (ton/year)	215,337	215,438	229,212
Fuel (TL/ton)	213	210	205
Fuel (TL)	45,854,459	45,136,424	46,945,081
Specific Coal Consumption (ton/net ton)	0.146	0.153	0.165
TOTAL (TL)	70,984,542	68,658,131	72,557,291
% Electric (Cost basis)	35	34	35
% Fuel (Cost basis)	65	66	65
TOTAL (TSE)	134,904	132,245	125,154
% Electric (energy basis)	7	7	7
% Fuel (Energy basis)	93	93	93
Total Specific Energy (TSE/product.)	0.091	0.094	0.089

Table 2.Energy used in cement production

Explanation / Years	2013	2014	2015
Cement production (net ton)	1,888,500	1,787,000	1,788,000
Electric energy (MWh/year)	67,059	64,502	61,906
Electric cost (TL/kWh)	0.22	0.22	0.24
Electric (TL)	15,605,260	15,064,615	16,011,788
Specific Energy Consumption (MWh/net T)	0.036	0.036	0.035
TOTAL (TSE)	5,766	5,547	5,324
Total Specific Energy (TSE/product.)	0.0031	0.0031	0.0030

- Potential determination to ensure the reduction of energy consumption in production volumes increased efficiency in the use of energy is made.
- The new generation of highly efficient application technologies, waste heat potential common points and loss and leakage points are determined.
- By lowering the intake temperature, energy savings is calculated for compressed air compressors center.
- Pressurized leakages of air leakage points aremeasured and energy provision iscalculated.
- Instead of the raw water pump and transfer pump tower, it is recommended to work more efficient pumps.

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According to these projects and improvements potential energy savings are shown in table 3.

Table 3.Potential energy saving for electrical power

Projects	Potential energy saving (kWh)
High efficiency motor renewing	225,457
Using VFD's for the bag filterscompressors	245,179
Stopping the blower running idleunder raw meal silo	165,900
Modifications at the pump system	152,696
Using VFDs in F1-07 & F1-08blowers	129,300
Preventing leaks of compressedair	71,491
Lowering the compressor inlet airtemperature	43,854
TOTAL	1,033,877

VII.WASTE HEAT RECOVERY SYSTEM (WHR)

Cement clinker is manufactured primarily from limestone, clay, sand and iron oxide-bearing as raw materials. These materials are blended and finely comminuted to form the raw meal [5]. The process of manufacture of cement consists essentially of crushing and grinding of the raw materials, mixing them intimately at certain proportions and burning them, usually in a rotary kiln at a temperature of approximately 1450 ºC. The material sinters and partially fuses to promote the formation of the clinker phases. The principal phases in the cement clinker are tri-calcium silicate, di-calcium silicate, tri-calcium aluminate and calcium alumina-ferrite. The clinker is then cooled and ground to fine powder with the addition of a few percent of gypsum. The resulting product is so called commercial Portland cement [6]. During the heating up and burning process, decomposition reactions, phases transformations and formation of new phases occur. These phenomena influence each other. Regarding, the energy consumption in the kiln plant, the important aspects are the enthalpies of the reactions, which may be endothermic or exothermic [7].

The cement production ranks among the most energy intensive industrial processes. Although new cement plants almost uses dry process with lower energy consumption than that in a wet process, the cement production process still require large amounts of energy. The calcinations and drying processes, as well as the kiln, require large quantities of thermal heat. The grinding mills, fans, and other motor driven equipment rely on electric energy. Although cement burning process has been optimized [8], significant heat loss, mainly caused by the waste gases, still occurs. It was found that about 40% of the total input energy was being lost through hot flue gases, cooler stack and kiln shell [9].

In order to reduce energy consumption in cement production process, the cogeneration power plant can recover the waste heats to generate electrical energy with no additional fuel consumption and thus reduce the high cost of electrical energy and CO_2 emissions for cement production. Since the waste heats in cement plant are classified as middle and low temperature waste heat, several power plants are particularly well suited for these waste heats available, such as single flash steam cycle, dual-pressure steam cycle, ORC and the Kalina cycle.

Waste heat source in the existing cement plant includes the suspension preheater (SP) exhaust gas and the hot air from the clinker cooler discharge. These heat sources may be used separately or in combination for cogeneration power generation. These two heat sources have different temperature levels. Two heat recovery vapor generators are provided to recover the two waste heat sources, respectively. One for the preheater exhaust is called SP boiler, and the other for

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the clinker cooler exhaust is called air quenching cooler (AQC) boiler. Frequently, the SP exhaust gas is used in the cement plant for drying raw materials, which limits the available heat for power generation.

The plant has 72.9 Gcal/h at both preheater outlet and coolers outlet. The hot gas is needed for raw mills, cement mills, climate and coal mills.
There are two hypotheses for the plant:

- Bad conditions: The calculated based on full running all departments, with most humidity raw meal, winter time, and low WHR efficiency. It means minimum WHR capacity.
- Normal conditions: The calculated based on existing situations with winter time, estimated running time of raw mill 1.(12 hour/day), low WHR efficiency. It means estimated WHR capacity. Capacity will increase at eh summer time.

Bad Conditions:
The total measured hot gas is 72.9 GKal/h. Demand for raw mill 1 is 8.9 GKal/h (water input is 15 tons/h). Demand for raw mill 2 is 17.8 GKal/h (water input is 30 tons/h). Demand for coal mills and drier is 4.1 GKal/h (water input is 7.3 tons/h). Demand for climate and hot water is 3 GKal/h. Demand for cement mills is 9.5 GKal/h (water input is 16 tons/h). So the remaining thermal power will be 29.6 GKal/h.

1 calorie is equal to 0.001163 watt. So 29.6 GKal/h is equal to 34.4228 MWh thermal power.

Most WHR system power turbine efficiency is changing between%17 to %25. When the minimum efficiency is taken, generated electrical power will be 5.85 MWh. It means the plant can produce min 5.85 MWh at the worst condition.

Normal Conditions:
The total measured hot gas is 72.9 GKal/h. Demand for raw mill 1 is 7.7 GKal/h (water input is 13 tons/h). Demand for raw mill 2 is 16.6 GKal/h (water input is 28 tons/h). Demand for coal mills and drier is 3.7 GKal/h (water input is 6.7 tons/h). Demand for climate and hot water is 3 GKal/h. Demand for cement mill is 7.6 GKal/h (water input is 12.9 tons/h). So the remaining thermal power will be 34.3 GKal/h. This is equal to 39.8909 MWh thermal powers.When the minimum efficiency is taken, generated electrical power will be 6.78 MWh. It means the plant can produce min 6.78 MWh at the normal condition.

The power range is between 5.85– 6.78 MWh. It should be chosen 10 MWh design capacity for the plant..

Investment Cost is changing between 1,150 k€/MWh and 1,800 k€/MWh according to WHR and ORC system choosing.

Waste heat recovery from the hot gases in thesystem has been recognized as a potential option to improve energy efficiency [10].

It has been suggested that the process be modified forenhanced waste heat recovery by replacing the preheater system with the waste heat recoverysystem [11], however considering the process specifications and the high efficiency, it is desirable tolook at the option of recovering heat from the existing streams rather than modify the system.Exergy analyses on the preheater cyclones have indicated that the second law efficiency of thepreheater is high [12], hence it is not proposed to make modifications on the preheater instead aretrofit to the existing components is suggested.

VIII.CONCLUSION

The cement industry is an energy intensive industry and Turkish Cement Industry has been continuously striving to reduce energy consumption in cement manufacture at each step. The increased consciousness for energy conservation and the steps taken towards effective monitoring, better operational control & process optimization, retrofitting of energy efficient equipment etc. have contributed greatly in energy conservation efforts. Energy conservation measures are cost effective and can bring about considerable improvement in cost-economics of cement manufacture.

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Successful reduction of fuel consumption contributes to lower fuel cost, higher clinker production, lower electricity consumption and lower greenhouse gas emission. Internationally, the cement industry is moving toward the use of alternative fuels such as tires, lubricants and oils. The use of alternative fuel can save cost and contribute to solution of the environmental problems.

The cogeneration power plants in cement plant can recover the waste heat available from the preheater exhaust and clinker cooler exhaust gases and generates electricity on a continuous basis without interfering with the core, clinker production process.

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