

Assessment of Energy Use and Energy Savings Potential in Cement Sector in India

1. Cement Production Processes

Cement acts as a bonding agent, holding particles of aggregate together to form concrete. Cement production is highly energy intensive and involves the chemical combination of calcium carbonate (limestone), silica, alumina, iron ore, and small amounts of other materials. Cement is produced by burning limestone to make clinker, and the clinker is blended with additives and then finely ground to produce different cement types. Desired physical and chemical properties of cement can be obtained by changing the percentages of basic chemical components (CaO, Al₂O₃, Fe₂O₃, MgO, SiO₂, etc.).

Most cement produced is Portland cement: other cement types include white, masonry, slag, aluminous, and regulated-set cement. Cement production involves quarrying and preparing the raw materials, producing clinker through pyroprocessing the materials in huge rotary kilns at high temperatures, and grinding the resulting product into fine powder.

1.1 Raw Materials Preparation

Raw materials preparation involves primary and secondary crushing of the quarried material, drying the material (for use in the dry process) or undertaking a further raw grinding through either wet or dry processes, and blending the materials. The energy consumption in raw materials preparation accounts for a small fraction of overall primary energy consumption (less than 5%) although it represents a large part of the electricity consumption.

1.2 Clinker Production

Clinker production is the most energy-intensive step, accounting for about 80% of the energy used in cement production. Produced by burning a mixture of materials, mainly limestone (CaCO₃), silicon oxides (SiO₂), aluminum, and iron oxides, clinker is made by one of two production processes: wet or dry; these terms refer to the grinding processes although other configurations and mixed forms (semi-wet, semi-dry) exist for both types.

In the wet process, the crushed and proportioned materials are ground with water, mixed, and fed into the kiln in the form of a slurry. In the dry process, the raw materials are ground, mixed, and fed into the kiln in their dry state. The choice among different processes is dictated by the characteristics and availability of raw materials. For example, a wet process may be necessary for raw materials with high moisture content (greater than 15%) or for certain chinks and alloys that can best be processed as a slurry. However, the dry process is the more modern and energy-efficient configuration.

Once the materials are ground, they are fed into a kiln for burning. In modern kilns, the raw material is preheated (in four to six stages) using the waste heat of the kiln, or it is pre-calcined. During the burning or pyroprocessing, the water is first evaporated after which the chemical composition is changed, and a partial melt is produced. The solid material and the partial melt combine into small marble-sized pellets called clinker.

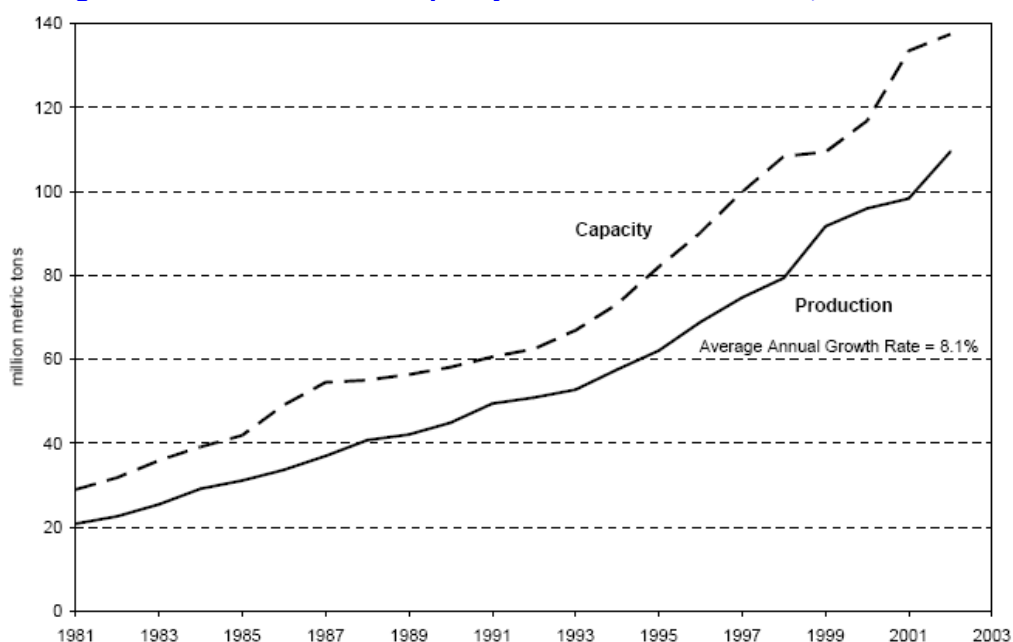
1.3 Finish Grinding

Cooled clinker is ground in tube or roller mills and blended by simultaneous grinding and mixing with additives (e.g., gypsum, anhydrite, pozzolana, fly-ash or blast furnace slags) to produce the cement. Drying of the additives may be needed at this stage.

2. Cement Production in India

India is the second largest producer of cement in the world. In 2003, India produced 115 million metric tons (Mt) of cement. India's cement industry – both installed capacity and actual production – has grown significantly over the past three decades, with production increasing at an average rate of 8.1% per year between 1981 and 2003 (see Figure 2-1).

Figure 2-1. Annual Cement Capacity and Production in India, 1981-2003.



Sources: The India Cements, Ltd, n.d.; UNESCAP, 2004.

2.1 Cement Industry Energy Consumption

In 1992, the Indian cement industry produced about 58 million metric tons of cement and consumed approximately 195 PJ of final energy and 261 PJ of primary energy. In 2002, cement production almost doubled to 110 million metric tons but, due to increases in energy efficiency, annual final energy consumption only increased to approx. 352 PJ of final energy and 466 PJ of primary energy.

Energy efficiency improvements are the result of the combined effects of shifting away from inefficient wet kilns toward more efficient semi-dry and dry kilns, as well as adoption of less energy-intensive equipment and practices. Implementation of advanced technology has reduced both energy and materials consumption in Indian cement plants.

Table 2-2 compares the average energy intensity of dry, semi-dry, and wet kilns in India in 1992 to the average for those used in 2002. In all cases, both the thermal and electrical energy required per unit of cement produced declined over this period. In addition, as previously shown in Figure 2-2, the share of production by inefficient wet kilns declined, shifting the bulk of production to the more energy-efficient dry process kilns. Overall, total final energy consumption per metric ton of cement produced in India dropped from 3.6 to 3.1 GJ/t between 1992 and 2002. Similarly, total primary energy consumption dropped from 4.8 to 4.2 GJ/t over this period.

Table 2-2. Energy Use for Cement Production in India, 1992 and 2002.

Process	Thermal Energy		Electricity		Share %	Production Mt	Final Energy PJ	Primary Energy PJ	
	kcal/kg clinker	GJ/t cement	kWh/t cement	GJ/t cement					
1992	Dry	829	2.89	113	0.41	82%	44.4	146.33	201.01
	Semi-dry	944	3.29	116	0.42	2%	1.1	4.01	5.38
	Wet	1359	4.74	107	0.39	16%	8.7	44.37	54.47
	Total						54.1	194.72	260.86
2002	Dry	800	2.68	95	0.34	93%	102.3	309.16	415.15
	Semi-dry	911	3.05	95	0.34	2%	2.2	7.47	9.75
	Wet	1300	4.36	90	0.32	5%	5.5	25.73	31.13
	Total						110.0	342.36	456.03

3 Future Development of the Cement Industry

3.1 Ongoing Changes in the Cement Industry

There have been significant improvements in the Indian cement industry over the past four decades, as more efficient equipment and energy-saving management practices have been adopted. Figure 2-4 and Figure 2-5 illustrate the trends of electrical and thermal energy consumption in the Indian cement industry, respectively, noting the specific technologies that have been incorporated by the industry since 1960.

Figure 2-4. Trend of Electrical Energy Consumption in Indian Cement Industry.

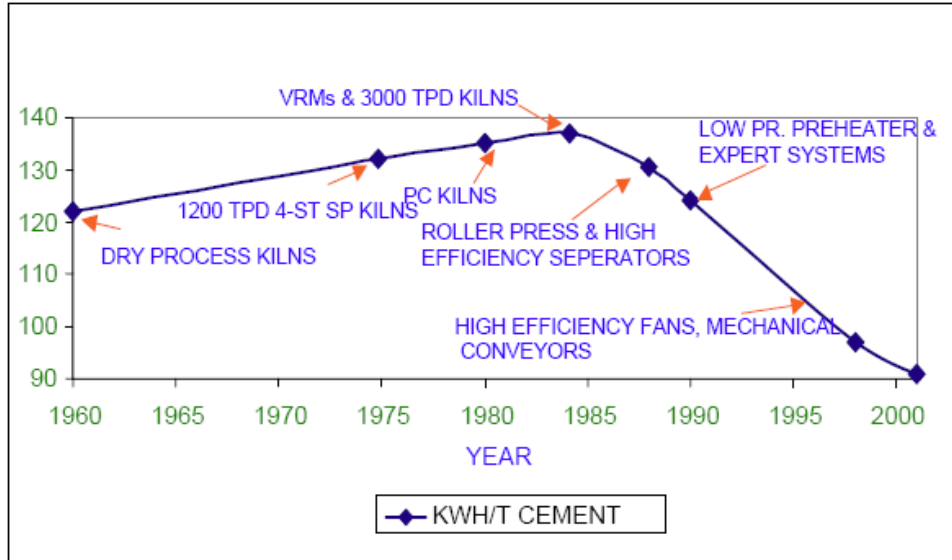
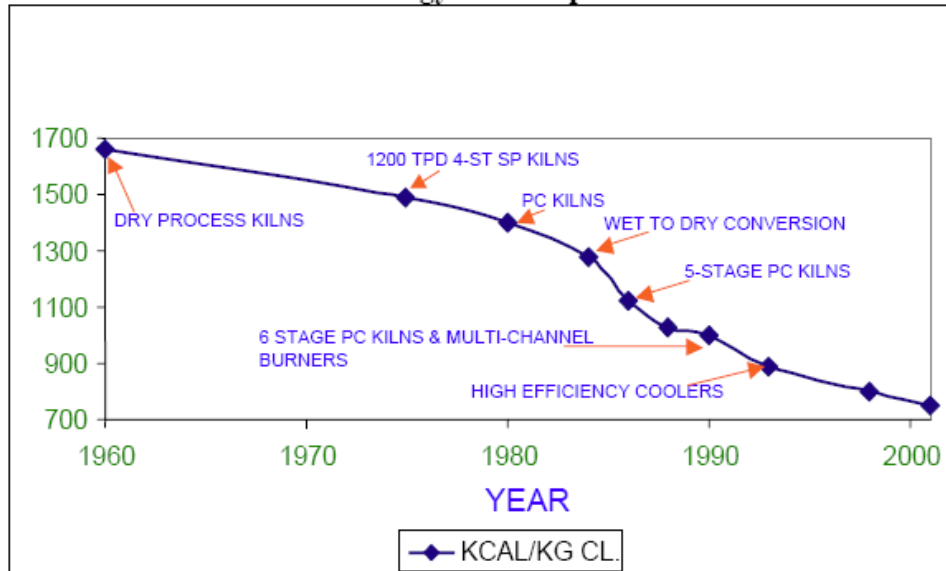


Figure 2-5. Trend of Thermal Energy Consumption in Indian Cement Industry.



3.2 Potential for Energy Efficiency Improvement

While a number of cement plants in India approach world best practice levels in terms of energy efficiency, average Indian cement plants are relatively inefficient (Engineering Staff College of India, 2003). Table 2-3 provides average energy consumption values by process for Indian cement plants. In almost all cases, the average energy consumption efficiency value is significantly higher than the best practice value, indicating a strong potential for energy efficiency improvement in many plants.

Table 2-3. Average and Best Practice Energy Consumption Values for Indian Cement Plants by Process.

Process	Unit	India Average	World Best Practice
Raw Materials Preparation			
Coal mill	kWh/t clinker	8	2.4
Crushing	kWh/t clinker	2	1.0
Raw mill	kWh/t clinker	28	27
Clinker Production			
Kiln & cooler	Kcal/kg of clinker	770	680
Kiln & cooler	kWh/t clinker	28	22
Finish Grinding			
Cement mill	kWh/t cement	30	25
Miscellaneous			
Utilities: mining & transportation	kWh/t clinker	1.6	1.5
Utilities: packing house	kWh/t cement	1.9	1.5
Utilities: misc.	kWh/t cement	2.0	1.5
Total Electric	kWh/t cement	95	77

India's National Council for Cement and Building Materials reports that "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." In addition, sponsored energy audits of about 50 cement plants in India have found savings of up to 164 kcal/kg clinker and 16.4 kWh/t cement on average, leading to potential cost savings Rs. 4.40 million to Rs 66.20 million annually.

3.3 Categories of Energy Efficiency Improvement

Numerous technologies and measures exist that can reduce the energy intensity of the various process stages of cement production. Table 2-4 provides a list of a number of these technologies and practices by process stage, the associated typical specific fuel and electricity savings, the primary energy savings, the simple payback period, and the level of penetration of these technologies and measures in Indian cement kilns. Numerous case studies exist illustrating the energy and cost savings from adopting energy-efficient technologies and measures in Indian cement plants.

Trends in adoption of energy-efficient equipment in India cement kilns were shown in Figures 2-4 and 2-5. These trends continue today and some types of energy-efficient equipment currently being adopted in India include slip power recovery systems, variable voltage and frequency drives, grid rotor resistance, soft starter for motors, high efficiency fans, high efficiency separators, vertical roller mills, pre-grinder/roller presses, low pressure preheater cyclones, multi-channel burners, bucket elevators in place of pneumatic conveying, fuzzy logic/expert kiln control system, mechanical seals in kilns, improved ball mill internals, and high efficiency grate coolers.

In addition to adoption of energy-efficient technologies, energy management and process control optimization, which often require little financial investment, can lead to significant energy savings. Various Indian cement plants are exploring the following management and optimization techniques: 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; and changing from V-belt to flat belt.

The use of waste heat from the exit gases of preheaters and grate coolers can be used for on-site cogeneration of electricity. A recent analysis by the National Council for Cement and Building Materials found a potential for generation of 3 to 5.5 MW in 20 surveyed cement plants and concluded that in 45 plants producing 1 million tons per year or more, the total cogeneration potential is about 200 MW.

The use of blended cements, in which blast furnace slag, fly ash from thermal power plants, or other agents are inter-ground with cement clinker, is an important option for further reducing the energy required for clinker production. Blended cements are commonly used in Europe and produce the same quality of cement while using less clinker, leading to reductions in energy consumption, costs associated with energy, and emissions of greenhouse gases. It appears that blended cements are being used by the more modern cement facilities in India and the share of blended cement was 43% in 2002. While significant increases in blended cement capacity may not be realistic due to distances from sources of blending materials as well as technical limits, it is a viable option for improving energy efficiency in some plants and promotion of blended cements has been recommended by the Bureau of Energy Efficiency as a proposed energy policy for India.

Indian cement plants are also beginning to explore the use of alternative and waste fuels, such as lignite, pet coke, tires, rice husks, groundnut shells, etc., to replace the use of coal in cement kilns. The Central Pollution Control Board has proposed that the Indian cement industry increase its use of high calorific value hazardous wastes as fuels in cement kilns. The cement industry has requested further information on the instrumentation required to monitor emissions from waste fuel burning as well as details of the location of such wastes. CMA is pressing the government to allow the cement industry to use waste-derived fuels and its recent international seminar for the cement industry highlighted alternate and hazardous waste derived fuel.

4. Scenarios of Future Energy Use

4.1 *Future Trends in Cement Production*

Historically, cement production in India grew at an average annual rate of 8.1% between 1981 and 2003. Despite some significant single-year jumps, such as the 11.4% growth that was experienced b/w 2001 & 2002, annual growth since 1990 was 7.5% per year and since 2000 was 6.2% per year.

The Indian Planning Commission's Working Group on Cement Industry predicts cement production in India to grow at a rate of 10% during the tenth five year plan (2002-2007). The India cement industry itself projects a growth rate of 8% to 10% over the 2003 to 2007 period.

Growth of 8% per year from 2003 to 2020 would result in cement production of 425 million metric tons in 2020; 10% growth would lead to production of 580 million metric tons that year. China, the world's largest producer of cement, has seen sustained cement production average annual growth of 10% since 1980, mostly due to the enormous infrastructure development that country has experienced over this period. Similarly, India has plans to lay 13,000 kilometers of roads for the Golden Quadrilateral and North South East West projects, as well as to use cement for the Rural Road Scheme, rail projects, construction of power plants, coastal ports, rural housing, etc. In addition, it is reported that almost 50 million homes and 24,500 kilometers of new roads are currently needed and over 22,000 kilometers of single-lane highways need to be widened, 2000 kilometers of expressway needs to be constructed and 635 bridges need to be constructed or repaired.

Table 2-4. Cement Production Energy Efficiency Technologies and Measures: Energy Savings, Simple Payback Period, and Penetration in Indian Cement Plants.

Energy Efficiency Technology or Measure	Specific Fuel Savings	Specific Electricity Savings	Primary Energy Savings	Simple Payback Period ⁵	Penetration in Indian cement plants
	GJ/t cement	kWh/t cement	GJ/t cement	years	# of plants
Raw Materials Preparation					
Raw meal (slurry) blending and homogenizing systems	-	1.5 - 3.9	0.02 - 0.04	N/A	
Fuel preparation: roller mills	-	0.7 - 1.1	0.008 - 0.012	N/A	
Raw meal process control - vertical mill	-	0.8 - 1.0	0.009 - 0.011	1	<10
Switch from pneumatic to efficient mechanical transport systems	-	3.2	0.04	> 10	
Replace ball mills with high efficiency vertical roller mill (VRM) (dry)	-	10.2 - 11.9	0.11 - 0.13	> 10	>20
High efficiency classifiers/separators (dry)	-	4.3 - 5.8	0.05 - 0.06	> 10	>20
Clinker Production					
Indirect firing	0.13 - 0.19	-	0.14 - 0.20	N/A	
Kiln shell heat loss reduction	0.09 - 0.31	-	0.095 - 0.327	1	
Efficient mill (kiln) drives	-	0.8 - 3.2	0.009 - 0.035	1	
Use of waste-derived secondary fuels	> 0.5	-	> 0.53	1	
Seal replacement	0.02	-	-	< 1	
Optimization of heat recovery/upgrade clinker grate cooler	0.06 - 0.12	-1.8 - 0.0	0.044 - 0.127	1-2	>20
Conversion to reciprocating grate cooler	0.23	-2.4	0.22	1-2	
Energy management and process control systems	0.1 - 0.2	1.2 - 2.6	0.12 - 0.24	1-3	10-206
Kiln combustion system improvement	0.1 - 0.4	-	0.1 - 0.4	2-3	>20
Heat recovery for power generation (cogeneration)	-	18	0.2	3	
Installation or upgrade of a preheater to a preheater/precalciner kiln	0.12 - 0.54	-	0.13 - 0.57	5	>20
Low-pressure drop cyclones for suspension preheaters	-	0.5 - 3.5	0.01 - 0.04	> 10	>20
Conversion of long dry kiln to multi-stage preheater	0.36 - 0.73	-	0.38 - 0.77	> 10	
Conversion of long dry kiln to preheater/precalciner kiln	0.55 - 1.10	-	0.58 - 1.16	> 10	
Improved refractories ⁷					>20

⁵ Simple payback periods are calculated on the basis of energy savings alone. In reality many investments may be driven by other considerations than energy efficiency (e.g. productivity, product quality), and will happen as part of the normal business cycle or expansion project. Under these conditions the measure will have a lower payback period depending on plant-specific conditions.

⁶ Expert systems.

⁷ Energy savings are difficult to quantify, as they will strongly depend on the current lining choice and management (Worrell and Galitsky, 2004).

Table 2-4. Cement Production Energy Efficiency Technologies and Measures: Energy Savings, Simple Payback Period, and Penetration in Indian Cement Plants (continued).

Energy Efficiency Technology or Measure	Specific Fuel Savings	Specific Electricity Savings	Primary Energy Savings	Simple Payback Period ⁸	Penetration in Indian cement plants
	GJ/t cement	kWh/t cement	GJ/t cement	years	# of plants
Finish Grinding					
Energy management and process control - grinding mills	-	1.6	0.02	<1	10-209
Improved grinding media in ball mills	-	1.8	0.02	8	
High pressure roller press	-	7 - 25	0.08 - 0.27	>10	10-20
High-efficiency classifiers	-	1.7 - 6.0	0.02 - 0.07	>10	
General Plant-Wide Measures					
Preventative maintenance	0.04	0 - 5	0.04 - 0.06	<1	
High efficiency motors and drives	-	0 - 5	0.06	<1	
Adjustable or variable speed drives	-	5.5 - 7	0.06 - 0.08	2-3	
Optimization of compressed air systems	-	0 - 2	0.02	<3	
Efficient lighting	-	0 - 0.5	0.01	N/A	
Product Changes					
Blended cement	1.21	-15	1.11	<1	
Limestone Portland cement	0.30	3.0	0.35	<1	
Low alkali cement	0.16 - 0.4	-	0.17 - 0.42	<1	
Reduced fineness of cement for selected uses	-	0 - 14	0.15	<1	
Use of steel slag in clinker (CemStar)	0.16	-	0.17	<2	

Sources: Martin et al., 1999; Raina, n.d.; Worrell and Galitsky, 2004.

⁸ Simple payback periods are calculated on the basis of energy savings alone. In reality many investments may be driven by other considerations than energy efficiency (e.g. productivity, product quality), and will happen as part of the normal business cycle or expansion project. Under these conditions the measure will have a lower payback period depending on plant-specific conditions.

⁹ Expert systems.

India's 2003 per capita cement production of 0.1 tonne/capita is significantly below the world average of 0.3 tonne/capita and China's production of 0.58 tonnes/capita. If India's per capita production increases to world average levels by 2020, then - based on the United Nation's medium variant population projection - total cement production would increase to 390 million metric tonnes. If India's per capita production increases to China's current level then total cement production in India in 2020 would rise to 765 million metric tonnes.

4.2 Future Trends in Energy Consumption for Cement Production

From the above discussion, it appears that cement production in the range of 400 to 600 million metric tonnes in India by 2020 is likely. Assuming average energy intensity values reach today's best practice levels, this leads to energy consumption for production of cement in India of between 1,100 and 1,700 PJ of final energy and 1,500 to 2,100 PJ of primary energy in 2020.

5. Summary and Future Directions

The Indian cement industry has grown rapidly over the past few decades and there have been significant investments in new cement kilns and associated production equipment. This has led to a situation where India's cement industry is made up of both some of the world's most energy-inefficient plants as well as some of the world's best practice facilities. The challenge for the Indian cement industry is to modernize or phase out the older, inefficient plants while acquiring the best possible cement production technology as production inevitably expands in the coming decades.

The Bureau of Energy Efficiency is currently leading the Indian Industry Programme for Energy Conservation. The activities of this project related to the cement industry include formation of a Cement Task Force, energy audits, identification of best practices, and development of energy consumption norms. A benchmarking tool being developed through the Indo-German Energy Efficiency & Environment Project will provide cement manufacturers with information regarding their relative energy consumption level compared to their peers and to industry average. A number of cement plants have set their own targets for energy efficiency improvement.

Once a cement plant has participated in a benchmarking exercise, it requires more detailed information about the energy savings and costs of specific energy-efficiency improvement measures that can be adopted in order to set ambitious, yet achievable, targets. Information from the Indian case studies and best practice examples, combined with international information on energy-efficiency technology energy savings and costs, could be provided to Indian cement manufacturers in the form of an energy management guide or could be integrated into a benchmarking tool in order to provide projected savings for an individual cement plant given the adoption of a chosen set of energy-efficient technologies and practices.

Policy-related recommendations for increasing energy efficiency of the Indian cement industry include 1) institutional reforms in which there is demonstrated commitment to energy conservation by senior cement company management, 2) establishment of a dedicated "energy management cell" within a cement company that includes a full-time energy manager with regular reporting, monitoring, training, and auditing responsibilities, 3) establishment of realistic short term and long term targets for reducing energy consumption, accompanied by a budget for reaching the targets, 4) initiation of employee awareness programs to involve the plant operators and foremen in energy efficiency activities, and 5) increased promotion of blended cements through incentives to manufacturers for producing blended cements, education of cement consumers, awareness campaigns for the general public, developing categorization scheme for blended cements, and promoting the use of blended cement in large construction project through such mechanisms as government procurement.

Reference:

Jayant Sathaye, Lynn Price, Stephane de la Rue du Can, and David Fridley Energy Analysis Department Environmental Energy Technologies Division Lawrence Berkeley National Laboratory Berkeley, CA 94720

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