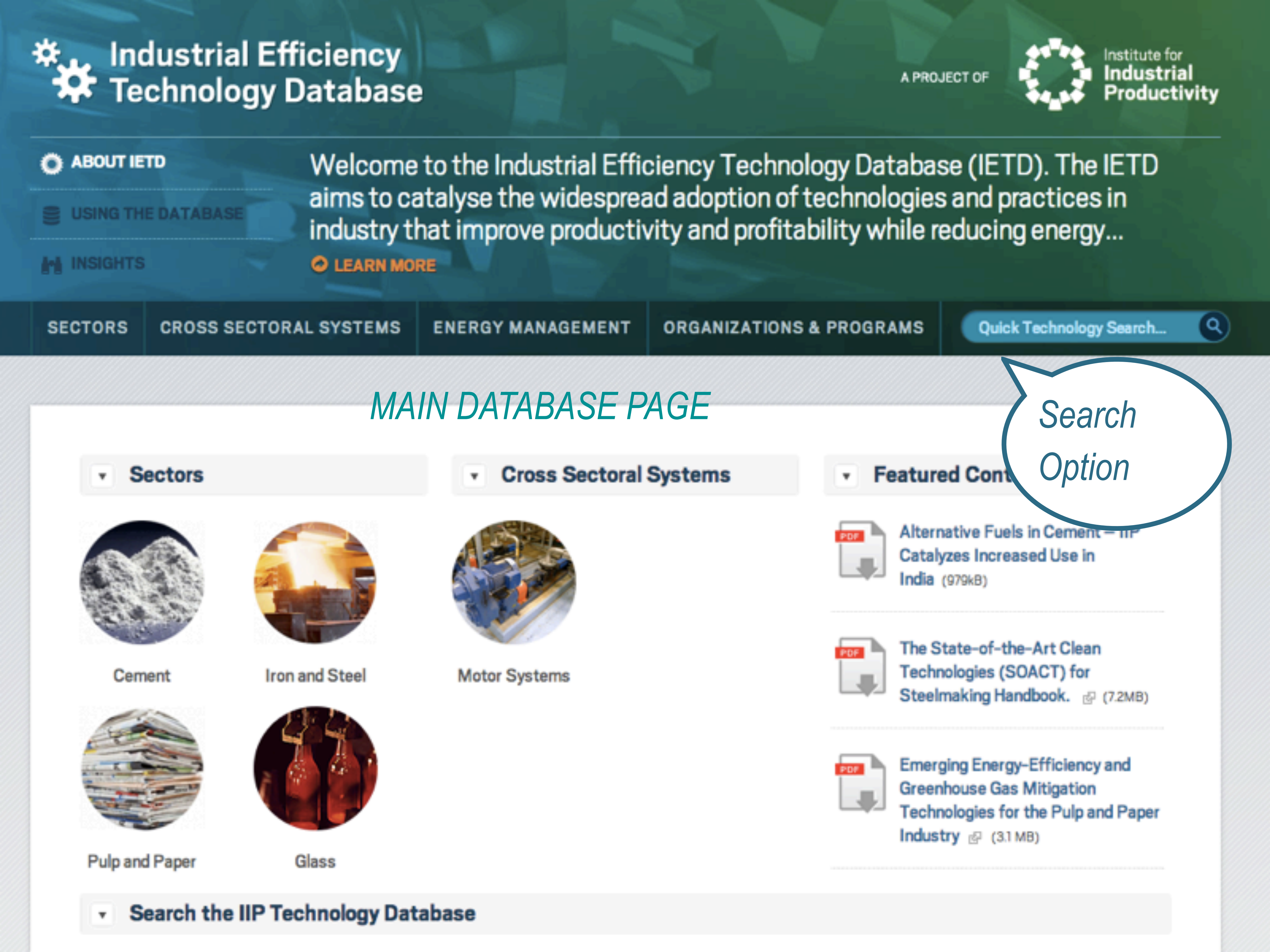
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MAIN SECTOR PAGE

Cement

Cement is a binding agent and is a key ingredient of the most used man-made material: concrete. The demand for cement is strongly correlated to the rate of economic development. Cement manufacturing is the third largest energy consuming and CO_2 emitting sector, with an estimated 1.9 Gt of CO_2 emissions from thermal energy consumption and production processes in 2006.[1] If Best Available Technologies can be adopted in all cement plants, global energy intensity can be reduced by 1.1 GJ/t-cement, from its current average value of 3.5 GJ/t-cement. This would result in CO_2 savings of around 119 Mt.[2]

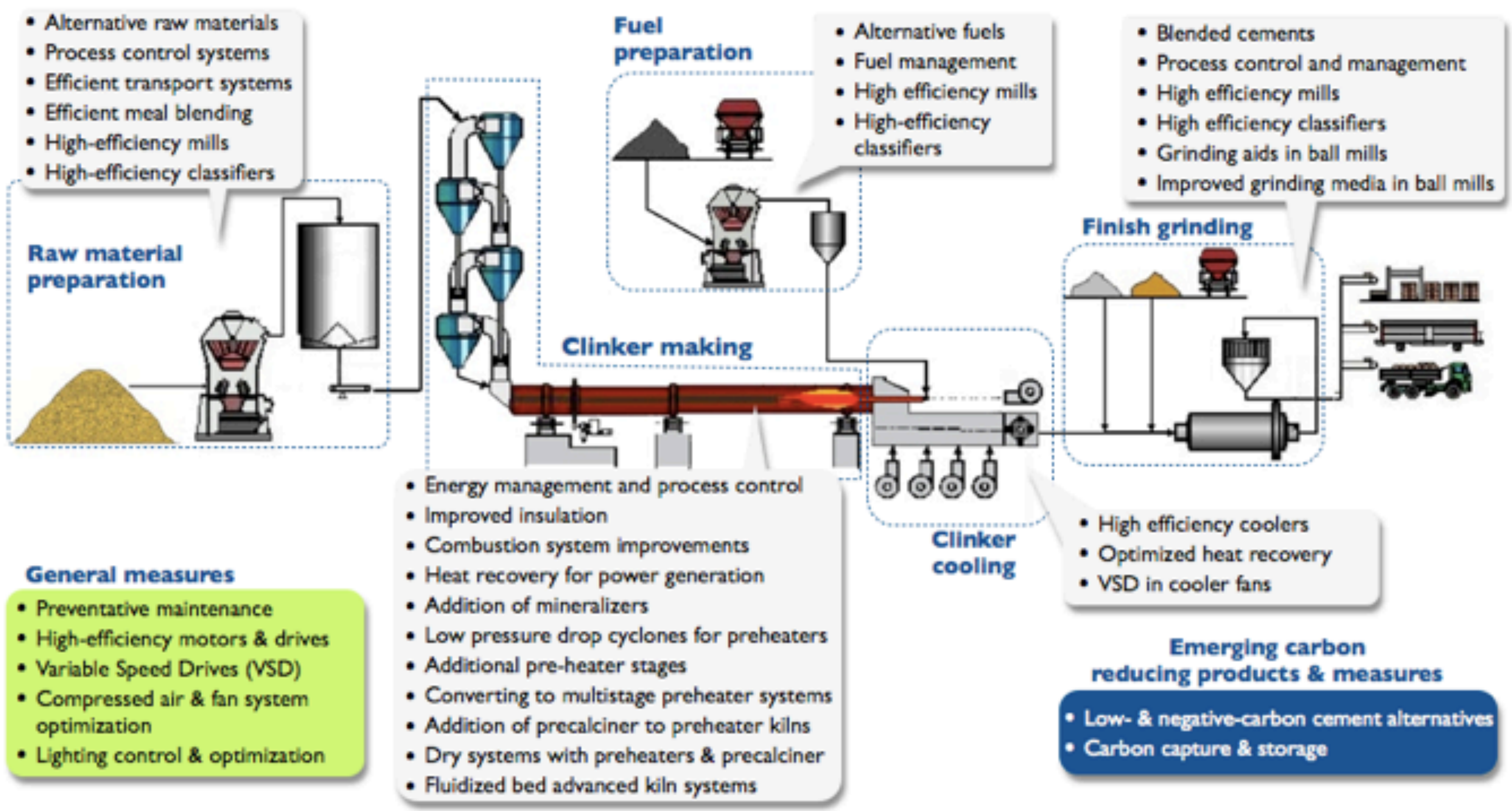
Dry, semi-dry, semi-wet and wet processes are the four main process routes that are used for the production of cement. Dry processes are considerably more energy efficient but the choice of technology mainly depends on the state of raw materials. Thanks to the availability of dry materials a great share of production in the developed world is today converted to dry processes. Dry processes are also the choice for new plants or for those looking for expansions or upgrades. The energy-intensive wet process is still used in some countries (and is a considerable share of production in the Former Soviet Union, Australia, and New Zealand), but is being phased out in many countries.

Most of the energy use and CO_2 emissions of the cement industry is linked to the production of clinker, which is the main component of cement and produced by sintering limestone and clay. Electricity needed for crushing and grinding raw materials, fuel, and the finished products represents another important energy demand. Proven technical options with potential to enable considerable reductions in energy use and CO_2 emissions can be categorized into: use of energy efficient technologies; use of alternative raw materials and fuels, and reducing the clinker content of cement via increased use of other blends. There are also emerging options in the form of alternative cementitious materials and carbon capture and storage.

into: use of energy efficient technologies, use of alternative raw materials and fuels, and reducing the clinker content of cement via increased use of other blends. There are also emerging options in the form of alternative cementitious materials and carbon capture and storage.

IMAGE MAP FOR QUICK ACCESS TO SELECTED TECHNOLOGIES/MEASURES

CementSchematic



CementProcesses

Compressed Air Systems
Finish Grinding
Blended Cement Alternatives
Raw Material Preparation
Alternative Raw Materials
Low-Carbon or Carbon-

Cross-Sectoral Systems

Motor Systems

MAIN TECHNOLOGY/MEASURE PAGES

Waste Heat Recovery for Power Generation

Waste heat from cement kilns is usually used for drying of raw materials and fuel. Depending on the humidity of the raw materials and the cooler technology, additional waste heat is available from the kiln gases (preheater exit gas) and cooler exhaust air. This heat can be used for electricity production. Power can be produced by using a steam cycle, an organic rankine cycle, or the KALINA process. The low temperature level of the waste heat in cement plants (200 – 400 ºC) limits the efficiency to a maximum of 20 – 25%. However, 25 to 30% of plant's power demand can be met through generating power from waste heat.

Heat recovery for power is most economical for long dry kilns but long dry kilns with preheaters in China and Europe have power production installations. Heat recovery for power production may not be feasible in plants where the waste heat is used in raw mills to extensively dry the raw material - which offers a more efficient and economic option (US EPA, 2010. p22).

It has been reported that there are at least 33 cogeneration units in various cement plants with total capacity about 200 MW in Japan. In China about 24 kilns having capacity of 2000 ton per day and above have cogeneration units with supplementary fired boilers to meet about 22 – 36 kWh/t clinker.

Development Status	Products
Commercial	clinker

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Waste Heat Recovery for Power GenerationCosts & Benefits

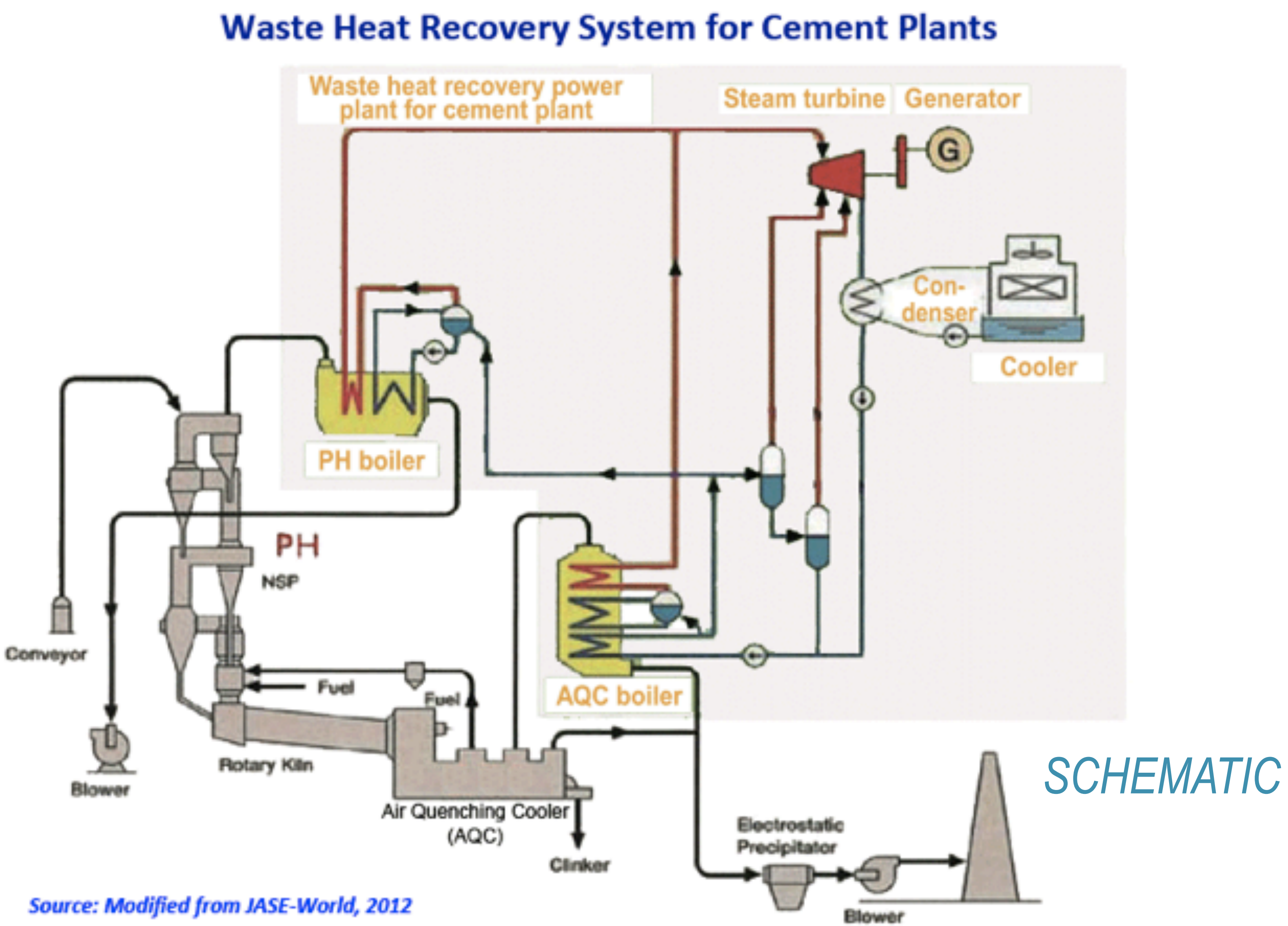
Waste Heat Recovery for Power GenerationCosts & Benefits

Parent Process: Clinker Making	
Energy Savings Potential	Typically, 8–22 kWh/t-clinker can be produced without changes to kiln operation. Generation up 45 kWh/t clinker is possible by modifying kiln operations (e.g. less cyclone stages or by-passing upper stage(s) (CSI/ECRA, 2009. p. 31) In China, production potential of 24-32 kWh/t clinker using domestic technology and 28-36 kWh/t clinker using foreign technogly. 39 kWh/t clinker is achieved in a Chinese plant using Japanese technology Japanese technologies are reported to be able to produce 45 kWh/t clinker. The potential for Indian plants are reported to be 20-24 kWh/t clinker. 48.5 GWh/y of net electricity will be produced by a 8 MW WHR unit installed at a 4500 tpd plant in China (UNFCC, 2008).
CO2 Emission Reduction Potential	The 8 MW power plant installed by the Indian Cements Ltd. (for their 4500 tpd plant) has been reported to reduce the CO_2 emissions by 45 000 tons per year (PCA, 2008). With the installation of a 9 MW WHR plant to a plant with 5000 tpd capacity, annual CO_2 emission reductions in excess of 52 000 ton year is planned (UNFCC, 2007) 41 000 t CO_2/y reduction is expected with the installation of an 8 MW waste heat recovery unit in a 4500 tpd plant in China.
Costs	For a plant with 2 millon t-clinker/y capacity, installation costs are estimated to be between € 15-25 million. Operational costs are estimated to decrease by €0.3–1.2/t-clinker (CSI/ECRA, 2009. p.32). Investment per kW are estimated to be about 6000-10000 RMB (US $ 940 - 1570) for Chinese technology and 16,000 - 22 000 RMB (US $2500 to 3400) for foreign technology for China. Estimated payback periods are usually less than 3 years. For China it was estimated that for a 2000 ton per day (730,000 annual ton) kiln capacity, about 20 kWh/t clinker of electricity could be generated for an investment of 20 to 30 million RMB (US $ 3.1 to 4.7 million). For India, investment costs are given to be around $2.25 million per MW capacity. Indian Cements Ltd. has put up an up to 8 MW power plant using Japanese technology for its 4500 tpd plant for a total investment of US $ 18.7 million (PCA, 2008). The installation cost of the 8 MW WHR unit in a 4500 tpd plant in China is reported to be RMB 58.8 million. The project is reported to have an IRR of 6.65% (the IRR value is stated to be 17.08% with carbon credits) [2008 values]. (UNFCC, 2008)

ENERGY, COST & CO2 PERFORMANCE INFORMATION

Waste Heat Recovery for Power GenerationSchematic

▾ Waste Heat Recovery for Power GenerationSchematic



▾ Waste Heat Recovery for Power Generation Publications

Energy Efficiency Improvement Opportunities for the Cement Industry

Waste Heat Recovery for Power Generation Publications

Energy Efficiency Improvement Opportunities for the Cement Industry

Date: Jan 2008 | **Source:** LBNL | **Format:** PDF | **Type:** Publications

The U.S. Environmental Protection Agency's (EPA) energy guide, Energy Efficiency Improvement and Cost Saving Opportunities for Cement Making, discusses energy efficiency practices and technologies that can be implemented in cement manufacturing plants. This ENERGY STAR guide provides current real world examples of cement plants saving energy and reducing cost and carbon dioxide emissions.

http://www.energystar.gov/ia/business/industry/LBNL-54036.pdf?5d92-a6b3

Page Number: 14-16

ADDITIONAL RESOURCES

Development of State of the Art Techniques in Cement Manufacturing: Trying to Look Ahead

Date: Jun 2009 | **Source:** CSI | **Format:** PDF | **Type:** Publications

The report represents the independent research efforts of the European Cement Research Academy (ECRA) to identify, describe and evaluate technologies which may contribute to increase energy efficiency and to reduce greenhouse gas emissions from global cement production today as well as in the medium and long-term future.

http://www.wbcsdcement.org/pdf/technology/Technology%20papers.pdf

Page Number: 31-32

Carbon Dioxide Control Technology Review

Date: 2008 | **Source:** PCA | **Format:** PDF | **Type:** Publications

This report by Portland Cement Asssociation provides an extensive review of technologies for controlling CO_2 emissions. This report summarizes several of those control methods including: conventional, pre-combustion, oxyfuel, and post combustion technologies; and hybrid systems.

http://www.cement.org/bookstore/download.asp?mediatypeid=1&amp%3Bid=16705&amp%3B...

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Waste Heat Recovery for Power Generation Reference Documents

Hebei Quzhai Cement 9000kW Waste Heat Recovery Project - CDM Project Design Document

MAIN PROCESS PAGES

Clinker Making

Clinker is produced by sintering limestone (calcium carbonate) and clay (alumino-silicate) at elevated temperatures. The production of clinker involves the feeding of the raw meal into the kiln, where first the calcination of calcium carbonate takes place and then the resulting calcium oxide is burned at high temperatures together with silica, alumina and ferrous oxide to form clinker.

Clinker making is responsible for 90% of the total energy consumption in cement plants. In modern plants, hot exhaust gases are used for pre-calcination, for pre-heating the raw meal and may also be used for additional energy recovery, thereby helping to reduce energy consumption.

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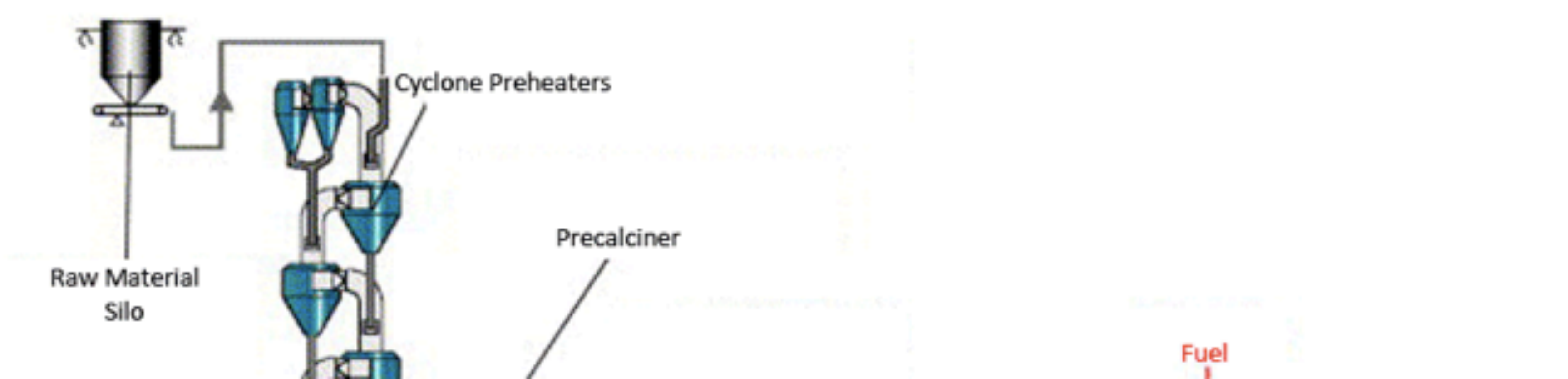
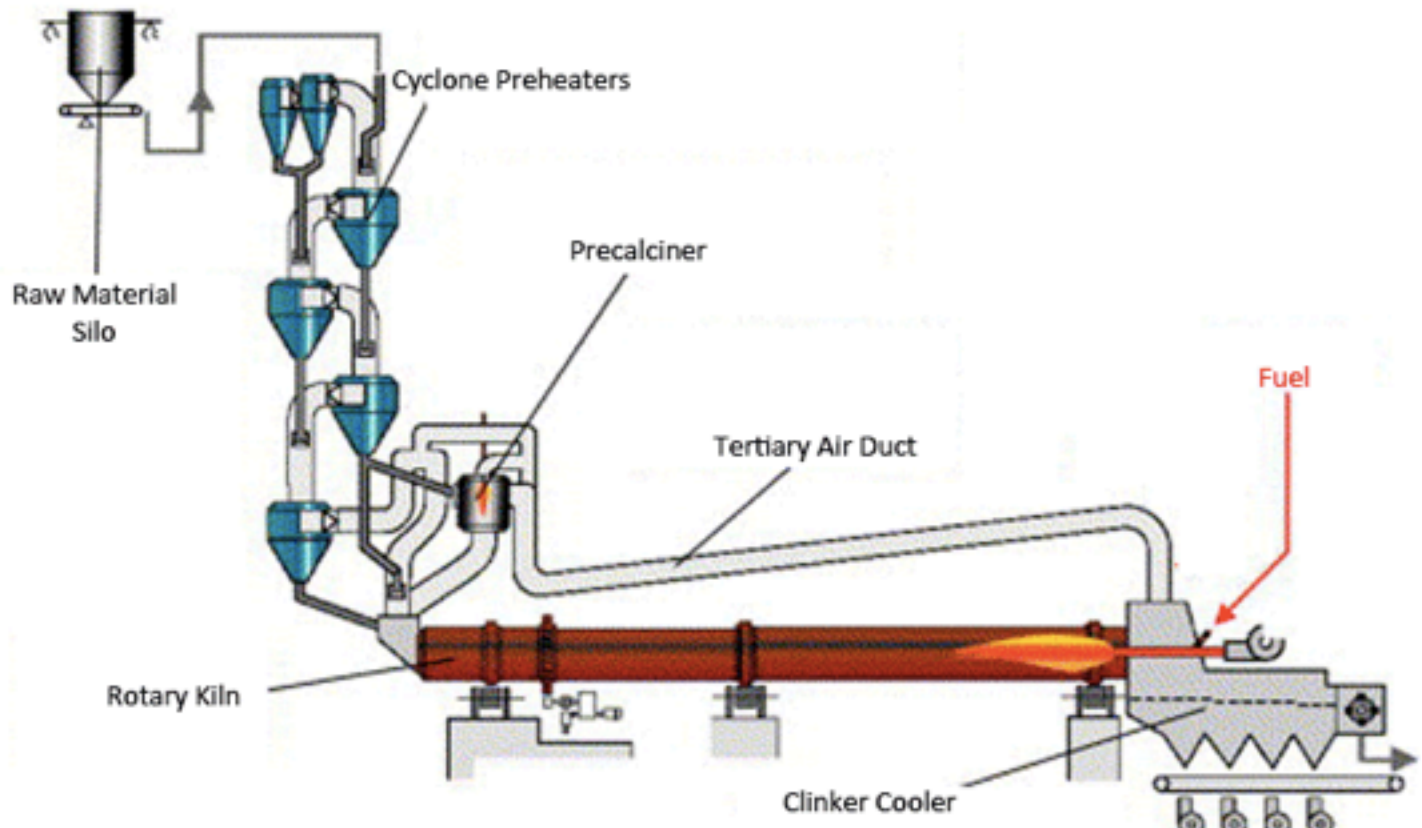
Clinker MakingSchematic



Clinker MakingSchematic



Source: Modified from Giannopoulos et al, 2006

Clinker MakingTechnologies & Measures

Technology or Measure	Energy Savings Potential	CO2 Emission Reduction Potential Based on Literature	Costs	Development Status
Dry Kilns with Multistage Pre-heaters and Pre-calcination	Fuel savings up to 3.0 GJ/t-clinker can be realized. Electricity consumption can increase by around 9 kWh/ton clinker.	Emission reductions are estimated to be: 284 kg CO_2/t-	Cost of converting wet plants can be between US $50 to 100 per annual ton clinker capacity. Conversion costs can reach up to US $135 million.	Commercial

Clinker MakingTechnologies & Measures

Technology or Measure	Energy Savings Potential	CO2 Emission Reduction Potential Based on Literature	Costs	Development Status
Dry Kilns with Multistage Pre-heaters and Pre-calcination	Fuel savings up to 3.0 GJ/t-clinker can be realized. Electricity consumption can increase by around 9 kWh/ton clinker. In a case in UK, two wet process kilns with a total heat requirement of 5.65 GJ/t-clinker were replaced with a single pre-heater/pre-calciner kiln resulting in energy saving of 36% (down to 3.5 GJ/t-clinker).	Emission reductions are estimated to be: 284 kg CO2/t-clinker in Chinese context. 297 kg CO2/t-clinker in Indian context 233 kg CO2/t-clinker in the United States.	Cost of converting wet plants can be between US $50 to 100 per annual ton clinker capacity. Conversion costs can reach up to US $135 million.	Commercial
Conversion of Long Dry Kilns to Preheater/Precalciner Kilns	Up to 1.4 GJ/t-clinker can be saved.	For every ton of clinker, following amounts of CO_2 reductions are estimated: 132.4 kg in Chinese context; 138.5 kg in Indian context; 108.8 kg in the United States.	Upgrading costs are reported to be between US $8.6 to $29 per annual ton of clinker capacity.	Commercial
Addition of Pre-Calcination to Kilns with Preheaters	In an Italian plant, the conversion reduced specific fuel consumption from 3.6 to 3.1-3.2 GJ/t clinker, resulting in savings of 11 to 14%, and enabled a capacity increase of 80 to 100% (from 1100 tpd to 2000 to 2200 tpd).	For Chinese context, this option holds the potential to reduce CO_2 emissions by 38 to 47 kg for every ton of clinker produced.	Investments in the range of US $9.4-28 per annual ton clinker may be required. Payback times are usually less than 5 years. In India, the payback times are reported to be less than 3 years.	Commercial
Replacing Vertical	Savings up to 2.4 GJ/t-clinker can	In China, CO	Costs of such conversions can be between US $28-41 per	Commercial

PROVIDES A FULL RANGE OF APPLICABLE MEASURES WITH SUMMARY INFO ON ENERGY, COST & CO2 PERFORMANCE

Addition of Pre-Calcination to Kilns with Preheaters	In an Italian plant, the conversion reduced specific fuel consumption from 3.6 to 3.1-3.2 GJ/t clinker, resulting in savings of 11 to 14%, and enabled a capacity increase of 80 to 100% (from 1100 tpd to 2000 to 2200 tpd).	For Chinese context, this option holds the potential to reduce CO_2 emissions by 38 to 47 kg for every ton of clinker produced.	Investments in the range of US $9.4-28 per annual ton clinker may be required. Payback times are usually less than 5 years. In India, the payback times are reported to be less than 3 years.	Commercial
Replacing Vertical Shaft Kilns	Savings up to 2.4 GJ/t clinker can be obtained. Savings of 1.6-2.0 GJ/t clinker are reported from India depending on pre-heater/pre-calcination system configuration	In China, CO_2 emissions can be reduced by 227 kg/t clinker by converting VSKs to pre-heater/pre-calciner kilns.	Costs of such conversions can be between US $28-41 per annual ton of clinker production.	Commercial
Kiln Shell Heat Loss Reduction	Fuel consumption is estimated be reduced by around 0.12 to 0.4 GJ/t of clinker.	in China, switching to better refractories may reduce CO_2 emissions by 11 to 38 kg per ton of clinker.	Switching to higher quality refractories may cost around US $0.25/annual tonne clinker capacity. Estimated payback period is approximately 1 years.	Commercial
Process Control and Optimization in Clinker Making	Savings vary between 2.5 to 10% and typical values are estimated to be 2.5 to 5%.		The costs of process control optimization measures/techniques vary widely and can be up to $6.8 million [1€=$1.35 US] The economics of advanced process control systems are very good and estimated payback periods can be as short as 3 months. In general, estimated payback period is less than 2 years.	Commercial
Waste Heat Recovery for Power Generation	Typically, 8–22 kWh/t-clinker can be produced without changes to kiln operation. Generation up 45 kWh/t clinker is possible by modifying kiln operations (e.g. less cyclone stages or by-passing upper stage(s) (CSI/ECRA, 2009. p. 31) In China, production potential of 24-32 kWh/t clinker using domestic technology and 28-36 kWh/t clinker using foreign	The 8 MW power plant installed by the Indian Cements Ltd. (for their 4500 tpd plant) has been reported to reduce the CO_2 emissions by 45 000 tons per year (PCA, 2008). With the	For a plant with 2 millon t-clinker/y capacity, installation costs are estimated to be between € 15-25 million. Operational costs are estimated to decrease by €0.3–1.2/t-clinker (CSI/ECRA, 2009. p.32). Investment per kW are estimated to be about 6000-10000 RMB (US $ 940 - 1570) for Chinese technology and 16,000 - 22 000 RMB (US $2500 to 3400) for foreign technology for China. Estimated payback periods are usually less than 3 years. For China it was estimated that for a 2000 ton per day (730 000 annual ton) kiln capacity, about 20 kWh/t	Commercial

Waste Heat Recovery for Power Generation	Typically, 8–22 kWh/t-clinker can be produced without changes to kiln operation. Generation up 45 kWh/t clinker is possible by modifying kiln operations (e.g. less cyclone stages or by-passing upper stage(s) (CSI/ECRA, 2009. p. 31) In China, production potential of 24-32 kWh/t clinker using domestic technology and 28-36 kWh/t clinker using foreign technogly. 39 kWh/t clinker is achieved in a Chinese plant using Japanese technology Japanese technologies are reported to be able to produce 45 kWh/t clinker. The potential for Indian plants are reported to be 20-24 kWh/t clinker. 48.5 GWh/y of net electricity will be produced by a 8 MW WHR unit installed at a 4500 tpd plant in China (UNFCC, 2008).	The 8 MW power plant installed by the Indian Cements Ltd. (for their 4500 tpd plant) has been reported to reduce the CO_2 emissions by 45 000 tons per year (PCA, 2008). With the installation of a 9 MW WHR plant to a plant with 5000 tpd capacity, annual CO_2 emission reductions in excess of 52 000 ton year is planned (UNFCC, 2007) 41 000 t CO_2/y reduction is expected with the installation of an 8 MW waste heat recovery unit in a 4500 tpd plant in China.	For a plant with 2 millon t-clinker/y capacity, installation costs are estimated to be between € 15-25 million. Operational costs are estimated to decrease by €0.3–1.2/t-clinker (CSI/ECRA, 2009. p.32). Investment per kW are estimated to be about 6000-10000 RMB (US $ 940 - 1570) for Chinese technology and 16,000 - 22 000 RMB (US $2500 to 3400) for foreign technology for China. Estimated payback periods are usually less than 3 years. For China it was estimated that for a 2000 ton per day (730,000 annual ton) kiln capacity, about 20 kWh/t clinker of electricity could be generated for an investment of 20 to 30 million RMB (US $ 3.1 to 4.7 million). For India, investment costs are given to be around $2.25 million per MW capacity. Indian Cements Ltd. has put up an up to 8 MW power plant using Japanese technology for its 4500 tpd plant for a total investment of US $ 18.7 million (PCA, 2008). The installation cost of the 8 MW WHR unit in a 4500 tpd plant in China is reported to be RMB 58.8 million. The project is reported to have an IRR of 6.65% (the IRR value is stated to be 17.08% with carbon credits) [2008 values]. (UNFCC, 2008)	Commercial
Low Pressure Drop Cyclones for Suspension Preheaters	Power savings in the range of 0.7-4.4 kWh/t clinker depending upon feasibility of cyclone modification and fan efficiency. In India, average savings are reported to be 1.5 kWh/t clinker.	Use of this option may reduce CO_2 emissions by 0.5 to 3.5 kg per ton of clinker produced. Based on the average savings of 1.5 kWh/t clinker, use of this technology reduces CO_2 emissions by 1.2 kg per ton of clinker produced.	The cost of a low-pressure drop cyclone system is assumed to be US $3 per annual ton clinker capacity. Installation of the cyclones can be expensive, since it may often entail the rebuilding or the modification of the preheater tower, and the costs are very site specific.	Commercial

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Additional Preheater Cyclone Stages	Moving from 4 stage to 5 stage, or from 5 stage to 6 stage can reduce the specific heat energy consumption between 0.08 to 0.1 GJ/t clinker In India reductions between 0.06 to 0.1 GJ/t clinker are reported.	CO_2 emissions can be reduced by 7.6 – 9.5 kg/t-clinker. CO_2 emissions can be reduced by 7.9 – 9.9 kg/t-clinker.	Investment cost for retrofit in 2015 is estimated to be € 5-8 millions ($6.8-10.88 million) The operational cost for retrofit in 2015 is estimated at 0.23-0.26 €/t clinker ($0.31-0.35) less. The cost estimation covers 2 new cyclone stages (1 stage replaced, 1 additional stage, 2 string preheater) including construction and installation. A site specific cost estimation needs also to include a new fan and/or preheater tower modification/rebuilding (etc.) as required. Therefore, costs can increase significantly. Against this background, additional electricity costs can be neglected, provided that low pressure drop cyclones are used. In India, total costs of $2.8 million are reported.	Commercial
Combustion System Improvements	Specific fuel savings up to 8% have been realised in plants using Gyro-Therm technology. Another technique developed in the UK for flame control resulted in fuel savings of 2 to 10% depending on the kiln type.		The payback times for Gyro-Therm technology is expected to be less than one year. Costs are estimated to be around $1.0/annual ton clinker capacity, with estimated payback periods of 2-3 years.	Commercial
High Efficiency Fans for Preheaters	0.7 kWh of electricity can be saved for each ton of clinker produced. In India savings in the range of 0.3-.0.5 kWh/ton clinker are reported depending on generation	CO2 emissions can be reduced by: 0.55 kg CO_2/t-clinker 0.57 kg CO_2/t-	Capital costs of US $0.01 per annual ton of clinker capacity are reported.	Commercial

High Efficiency Fans for Preheaters	0.7 kWh of electricity can be saved for each ton of clinker produced. In India savings in the range of 0.3-.0.5 kWh/ton clinker are reported depending on generation of existing fan.	CO2 emissions can be reduced by: 0.55 kg CO_2/t-clinker 0.57 kg CO_2/t-clinker	Capital costs of US $0.01 per annual ton of clinker capacity are reported.	Commercial
Bucket Elevators for Kiln Feed	Following savings in electricity consumption are reported in literature: • 2.26 kWh/t-clinker (UNFCC) • 2.5 kWh/t-portland cement (US-EPA) In India savings in the range of 1.0-1.3 kWh/t of clinker are reported.		Following cost informatin is provided in the literature: • US $0.23 per annual ton clinker capacity (UNFCC) • US $3.43 per annual ton portland cement capacity (US-EPA) In India Installation costs of this technology is reported to be US $4000-5000 per meter. US-EPA reports a US $0.17/ton-portland cement reduction in operating costs.	Commercial
Fluidized Bed Advanced Cement Kiln System	Thermal energy use can be decreased by around 0.4 GJ/t-clinker (NEDO, 2006), while the electricity consumption increases by around 9 kWh/t-clinker (ECRA, 2009) 20% more heat can be recovered in the cooling system, as compared to conventional methods (APP, 2009)	CO_2 reductions in the range of 10% can be realized (NEDO, 2006).	Construction costs are expected to be around 30% lower.	Demonstration
Efficient kiln drives	0.5 – 1% reduction in electricity use of the kiln drive can be achieved by replacing a DC motor with AC motor. Using high-efficiency motors to replace older motors, or instead of re-winding old motors, may reduce power costs by 2 to 8%. Electricity savings are 0.55-3.9 kWh/t clinker		The capital cost for single pinion drive with an air clutch and a synchronous motor is around 6% higher than standard kiln drive.	Commercial

Improved Burnability Using Mineralizers	Based on the modelling results, thermal energy consumption can be reduced by between 0.05 to 018 GJ/t clinker.	CO_2 emissions can be reduced by 4 to 16 kg per ton of clinker	Additional costs of mineralizers has to be considered and may outweigh the fuel cost savings. Espeically CaF2, which is commonly used, is an expensive material. Use mineral wastes containing flourides can be economically viable, however, such materials have a limited availability.	Commercial
Alkali bleed (alkali by-pass) systems			Investments of US $4.54-6.39 million are reported in Japan for a plant with 5 000 ton per day clinker capacity. Investment costs of $2-3 million are reported for a similar sized plant in India.	Commercial
Oxygen enrichment technology	Thermal energy use can be decreased by 0.1 - 0.2 GJ/t clinker but electricity use increases by 10 - 35 kWh/t clinker	While this technology may reduce direct CO_2 emissions by 10 to 20 kg per ton of clinker due to reduced fuel consumption, the indirect emissions are estimated to rise by 15 to 25 kg/t clinker due to increased electricity use.	Economic viability of this option still remains to be established. However, for a plant with 2 M t/y clinker capacity the investment costs for both new installation and for retrofitting, using cryogenic air separation unit, are estimated as € 5 to 10 million for 2015. The operational costs, on the other hand, are estimated to be between € 0.5 to 2.3 per ton of clinker - taking into consideration both fuel saving and additonl costs.	Demonstration
Retrofitting to modern multi-channel burner	Depending on the secondary air temperature, reduction of the primary air ratio by 5-10% will lead to a fuel energy saving of 0.05-0.08 GJ/t-clinker at conventional kilns and about half of this at precalciner kilns. The electrical energy demand will remain almost unchanged as the higher consumption for control fittings and air delivery channels can be offset by the reduction of the primary air.		Investment cost for retrofit in 2015 is estimated to be € 0.4 to 0.5 million (US $0.54 -0.68 million). The operational cost for retrofit in 2015 is estimated to decrease by 0.08 to 0.25 €/t clinker ($0.11 - 0.34/t-clinker). Investment cost is based only on price for new burner and the reference precalciner kiln. Investment costs are reported to be in the range of US $40-65 per "ton per day" capacity in India.	Commercial
Stabilization of kiln coating	Radiation heat losses will be reduced leading to energy savings.		Kiln shell air-cooling equipment costed about $0.129 million (1US$=¥77.4)	Commercial

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Stabilization of kiln coating	Radiation heat losses will be reduced leading to energy savings.		Kiln shell air-cooling equipment costed about $0.129 million (1US$=¥77.4)	Commercial
Indirect firing	Assuming a reduction of excess air between 20% and 30%, indirect firing may lead to fuel savings of 0.015 -0.022 GJ/t clinker. The advantages of improved combustion conditions will lead to a longer lifetime of the kiln refractories and reduced Nox emissions. These co-benefits may result in larger cost savings than the energy savings alone.		US $5 million for an annual production capacity of 680,000 ton clinker, or US $7.4/t annual clinker capacity.	Commercial
Proper Sealing and Seal Replacement	In a Japanese plant, air leakage at the kiln outlet was reduced by 160 Nm3/min with proper sealing, resulting in energy saving of 0.042 MJ/t-clinker.		For a 5000 tpd plant, the implementation costs are reported to be US $50 thousand [1 US$ =¥110]	Commercial

The Institute for Industrial Productivity welcomes information on relevant industrial efficiency technologies or measures that are not currently included in the database or if information in this database is incorrect or out-of-date.

Please address your input to info@iipnetwork.org.

The Institute for Industrial Productivity acknowledges Fraunhofer ISI, IREES, LBNL-China Energy Group, E3M Inc., ISR-UC and Holtec for their valuable contributions.

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Cement

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Depending on the employed production technology, characteristics of raw materials, and the composition of final products cement manufacturing can show significant variations in energy consumption and CO_2 emissions. In the following, best attainable values for different production processes and for different cement products are presented.

OTHER IMPORTANT INFORMATION IS PROVIDED ON MAIN SECTOR PAGES

▾ CementBenchmarks

International Benchmarks for Thermal Energy Consumption in Clinker Making with Different Technologies[1]

Production Process	Energy Consumption (GJ/t Clinker)	
	Min	Max
Dry, multistage cyclone pre-heater and pre-calciner kilns	2.85	3.0
Dry process rotary kilns with cyclone pre-heaters	3.1	4.2
Semi-dry/semi-wet processes (Lepol kiln)	3.3	4.5
Dry process long kilns		5.0
Wet process long kilns	5.0	6.0
Shaft kilns (up to 100 t/d capacity)	3.1	4.2

World Best Practice Final Energy Intensity Values for Portland Cement[2]

Process	Energy carrier	Product unit	kWh/t product	GJ/t prduct	kWh/t clinker	GJ/t clinker	kWh/t cement	GJ/t cement
Raw materials preparation	Electricity	t raw meal	12.05	0.04	21.3	0.08	20.3	0.07
Solid fuels preparation	Electricity	t coal	10	0.04	0.97		0.92	
Clinker making	Fuel	t clinker				2.85		2.71
	Electricity	t clinker			22.5	0.08	21.4	0.08
Additives preparation	Fuel	t additive						
	Electricity	t additive						
Finish grinding								
325 cement	Electricity	t cement					16	0.06
425 cement	Electricity	t cement					17.3	0.06
525 cement	Electricity	t cement					19.2	0.07
625 cement	Electricity	t cement					19.8	0.07
Total								
325 cement							**59**	**2.92**
425 cement							**60**	**2.92**
525 cement							**62**	**2.93**
625 cement							**62**	**2.93**

Assumptions: Ratio of "t of raw materials per t of clinker "is 1.77; ratio of "t of coal per ton of clinker" is 0.97; clinker to cement ratio in Portland cement is 0.95; additives to cement ratio in Portland cement is 0.05.

World Best Practice Final Energy Intensity Values for Fly Ash Cement[2]

Globally, more than 3.3 billion tons of cement was produced in 2010. Graphs below show the global distribution of production and the shares of top 10 cement producing nations.

Globally, the cement sector is dominated by a small number of large companies. Largest cement companies, and their capacities and sales are also provided below.

Cement production is an energy intensive process, with energy costs representing 20-40% of production costs (IEA, 2007. p. 145).

Since 1990s, globally there has been a gradual reduction in the "clinker ratio" – the ratio of clinker to cement in the final product – which reflects in reduced specific energy consumption. China is believed to have the lowest clinker ratio in 2010, due to extensive use of granulated blast furnace slag, fly-ash, boiler bottom-ash and a variety of other substitutes.

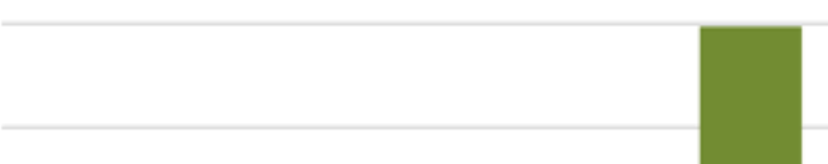
The table below provides an overview of the availability of materials that can be used as clinker substitutes and their current consumption levels.

Current Use and Availability of Clinker Substitutes (IEA, 2007. p150)

Clinker Substitute	Use in 2004 *(Mt)*	Availability *(Mt)*
Total blast furnace slag	n.a.	180 – 220
Granulated blast furnace slag	90	110
Fly ash	222	445
Pozzolona	50	n.a

General Industry Characteristics

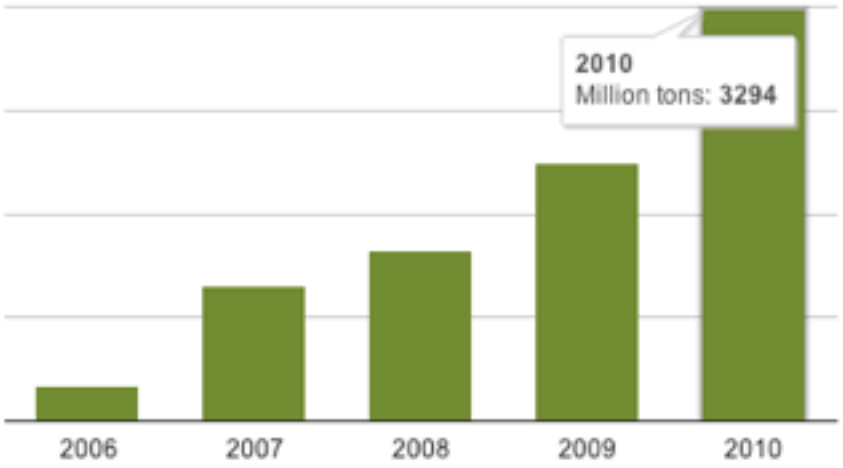
Global Cement Consumption



Global Cement Consumption by Region in 2010

General Industry Characteristics

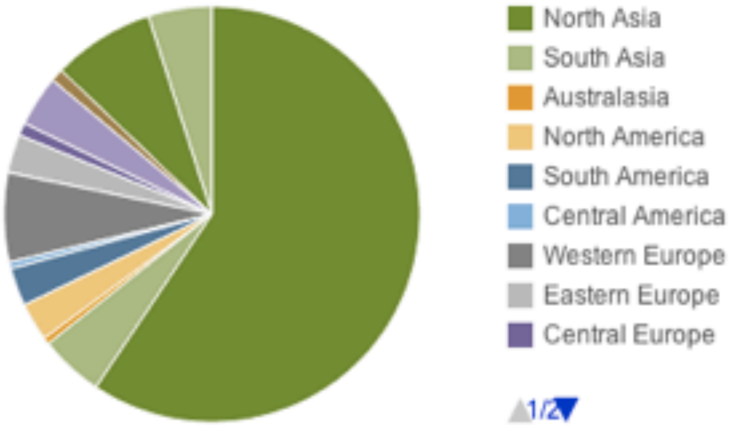
Global Cement Consumption



SEE SOURCE DATA

2011 [1]

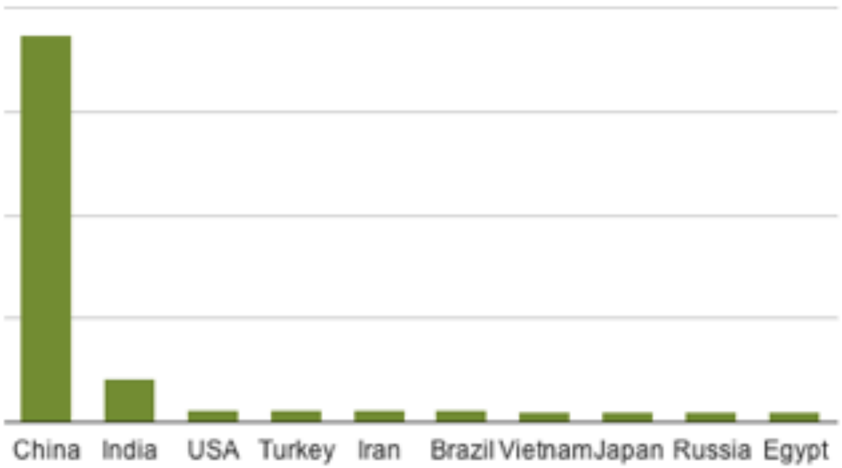
Global Cement Consumption by Region in 2010



SEE SOURCE DATA

2010 [2]

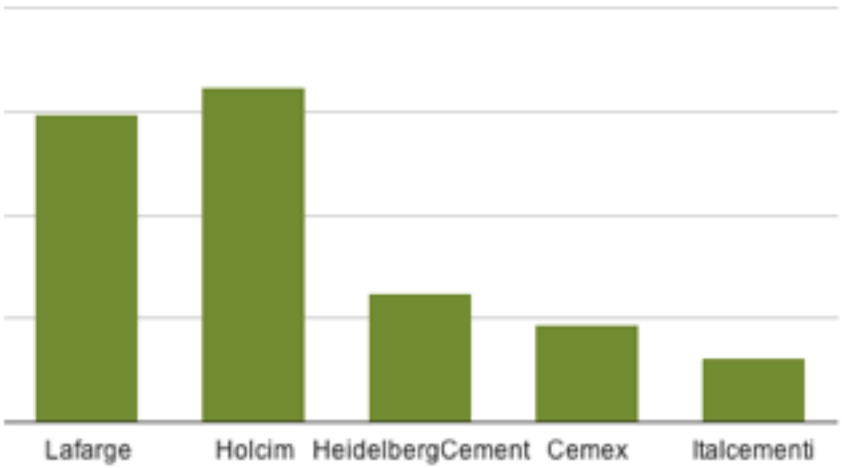
Top ten cement producing nations in 2010



SEE SOURCE DATA

2010 [3]

Capacities of leading cement companies



SEE SOURCE DATA

2010 [4]

There are numerous organizations working at global, regional, national levels with improving the resource productivity and reducing the environmental impact of cement manufactuing. Some of the major ones are listed below:
Original research for this section is performed by Lawrence Berkeley National Laboratory's China Energy Group.

Cement Organizations Global

Cement Sustainability Initiative (CSI)

Description: Developed under the umbrella of World Business Council for Sustainable Development (WBCSD), the Cement Sustainability Initiative (CSI) is a global effort by 24 major cement producers with operations in more than 100 countries. A key purpose of the Initiative is to identify actions and facilitate steps cement companies can take, individually and as a group, to accelerate progress toward sustainable development. CSI have developed various materials and tools on energy efficiency, CO2 accounting and reporting.

Global Superior Energy Performance Partnership - Cement Working Group (GSEP)

Description: Global Superior Energy Performance Partnership (GSEP) was established by government and corporate leaders in 2010 in Washington DC. The purpose of the initiative is to accelerate energy efficiency improvements throughout industrial facilities and large buildings and to significantly cut global energy use by encouraging industrial facilities and commercial buildings to pursue continuous improvements in energy efficiency. The initiative also aims at promoting public-private partnerships for cooperation on specific technologies or in individual energy-intensive sectors.

International Energy Agency (IEA)

Description: The International Energy Agency (IEA) is an autonomous organization, which works to ensure reliable, affordable and clean energy for its 28 member countries and beyond. IEA has been a key partner in various studies on energy efficiency, energy technologies, and energy policies. It also offers a wealth of information on energy and CO2 emission statistics. Examples of IEA's work related to Cement Industry

The World Bank

Description: The World Bank has funded various studies/projects, and programs on energy efficiency in industry including the cement industry in