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Eficiência Energética na Indústria de Cimento

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Realização

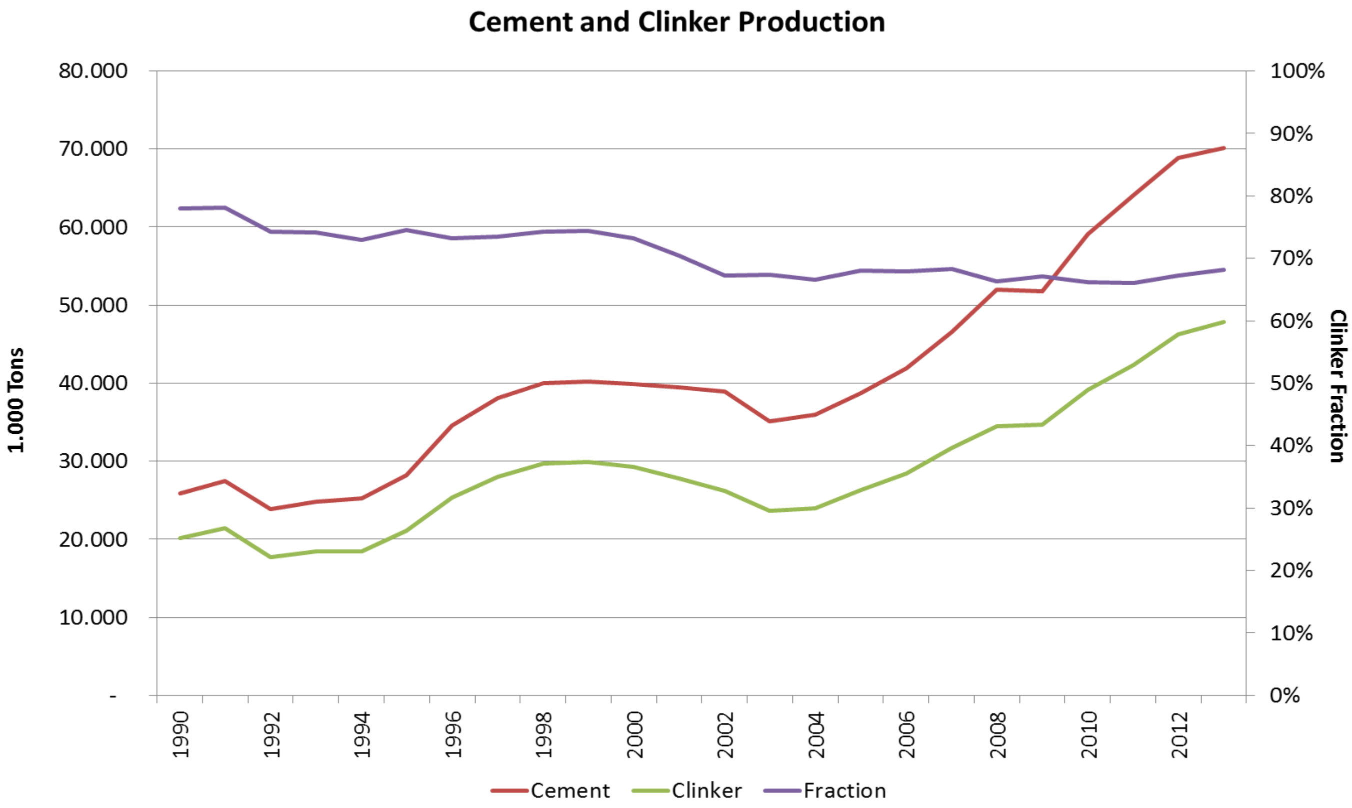
Associação Brasileira de Cimento Portland

SNIC SINDICATO NACIONAL DA INDÚSTRIA DO CIMENTO

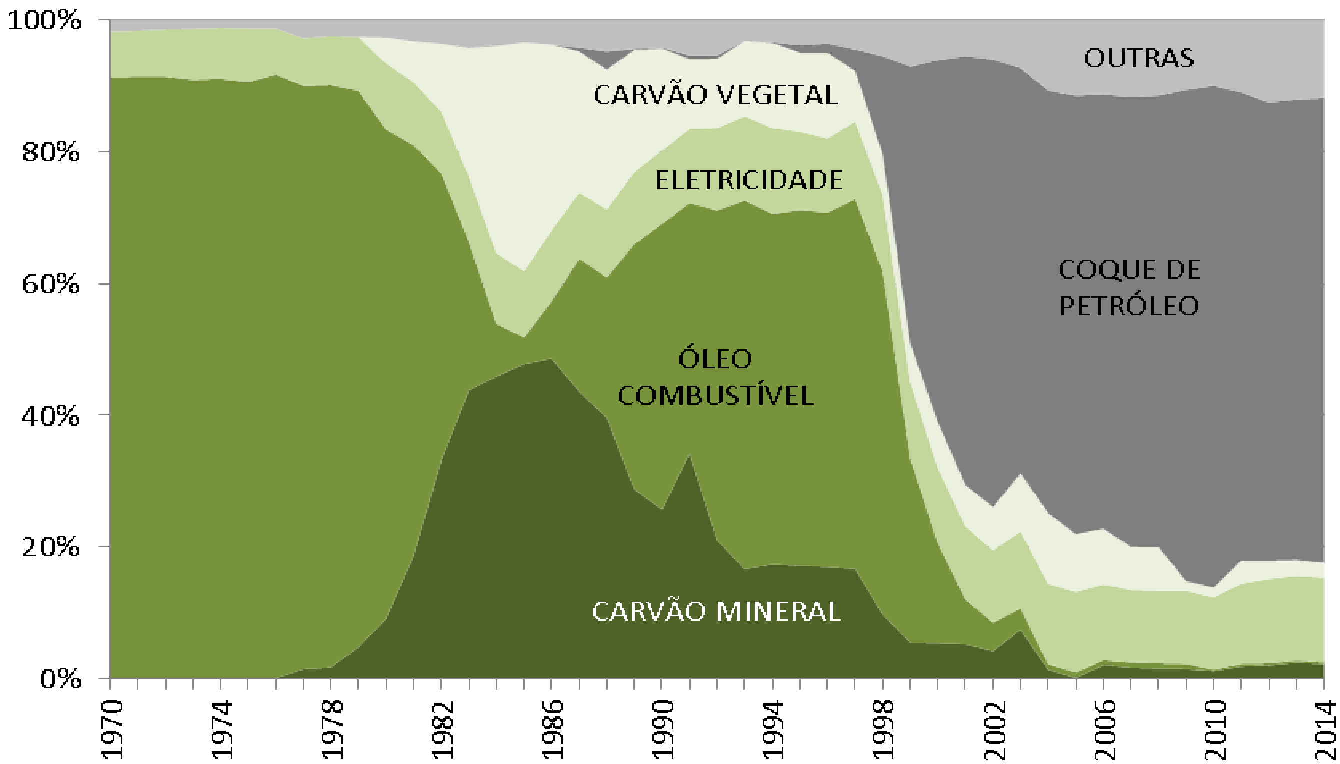
Sumário

- Introdução
- Evolução do uso de energia e do consumo específico no setor
- Comparação internacional
- Tecnologias de uso eficiente de energia (*Best Available Tecnologies)* e discussão de alguns cases
- Compilação das tecnologias aplicáveis no parque brasileiro, e comentário finais

Evolução do uso de energia e do consumo específico no setor

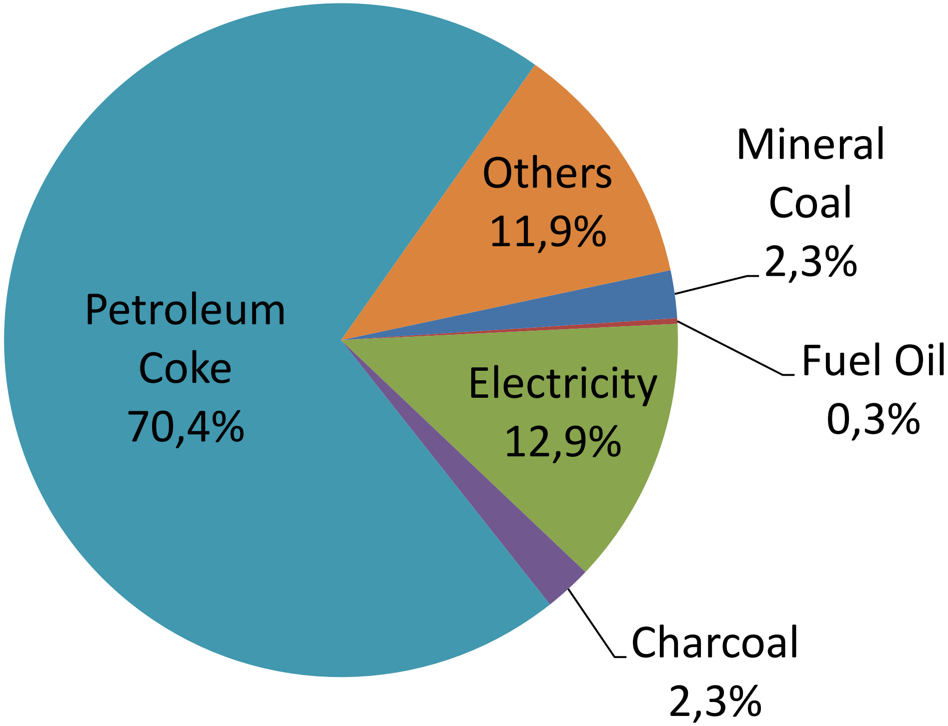


Energy share in cement production



Source: EPE, 2015.

Energy Share in Cement Production - 2014



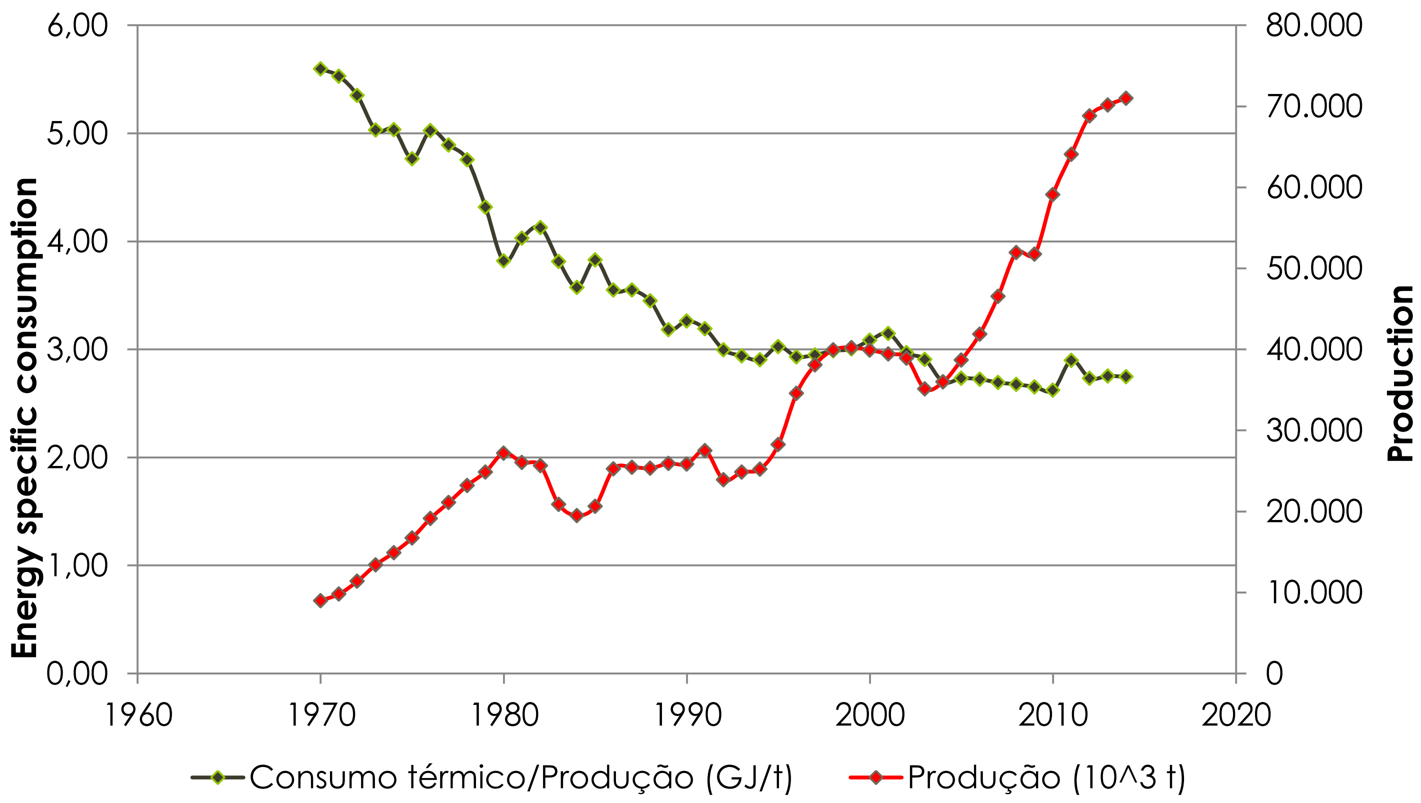
Source: EPE, 2015.

Fuel share in Cement Production - 2013

2013	
Conventional Fossil Fuels	**82,5%**
Coal + anthracite + waste coal	1,5%
Petcoke	80,5%
(ultra) Heavy fuel	0,2%
Diesel oil	0,2%
Biomass Fuels	**9,6%**
Dried sewage sludge	0,0%
wood, non impregnated saw dust	0,1%
Agricultural, organic, charcoal	4,7%
Other biomass	4,8%
Fossil Waste	**7,9%**
Waste oil	0,3%
Tyres	4,6%
Plastics	0,1%
Impregnated saw dust	0,3%
Mixed industrial waste	1,6%
Other fossil based wastes	0,9%

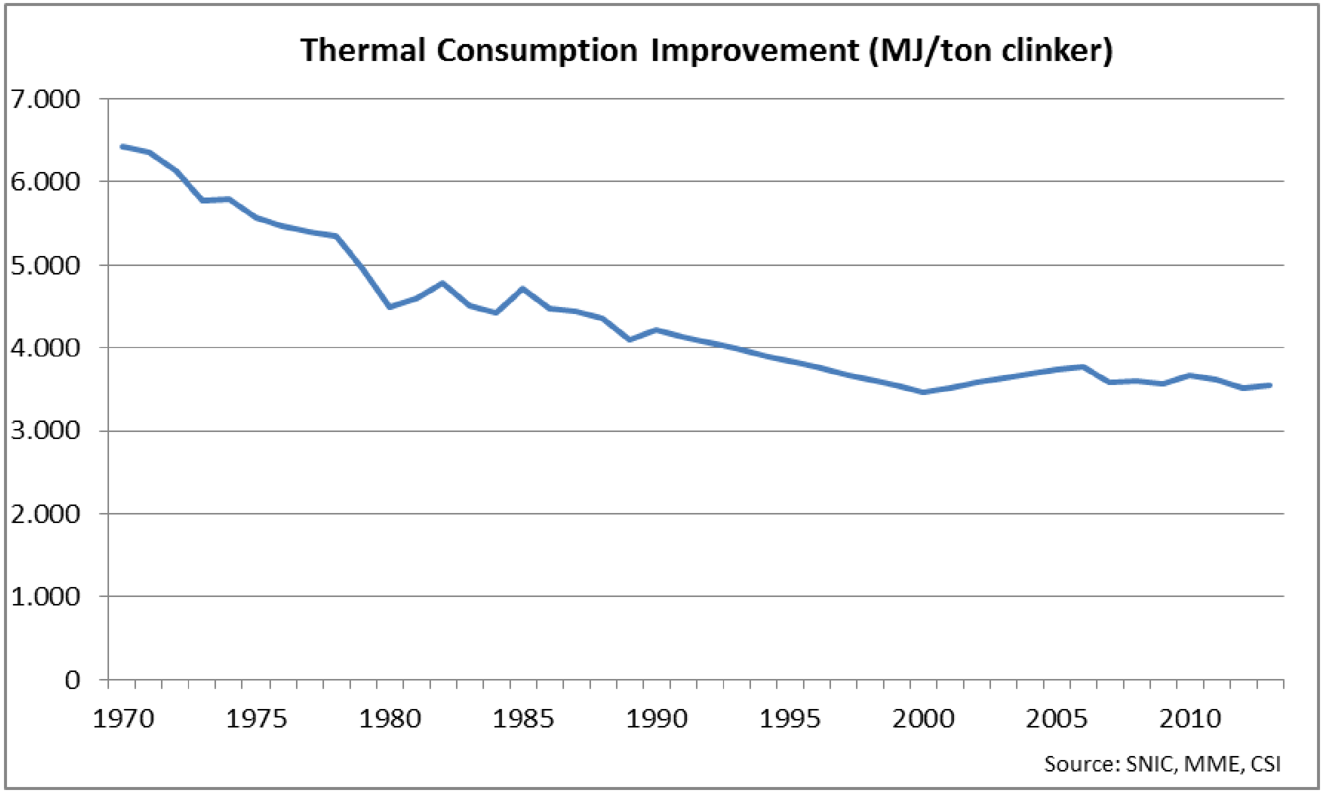
Source: CSI

Specific thermal energy consumption (GJ/t cement)

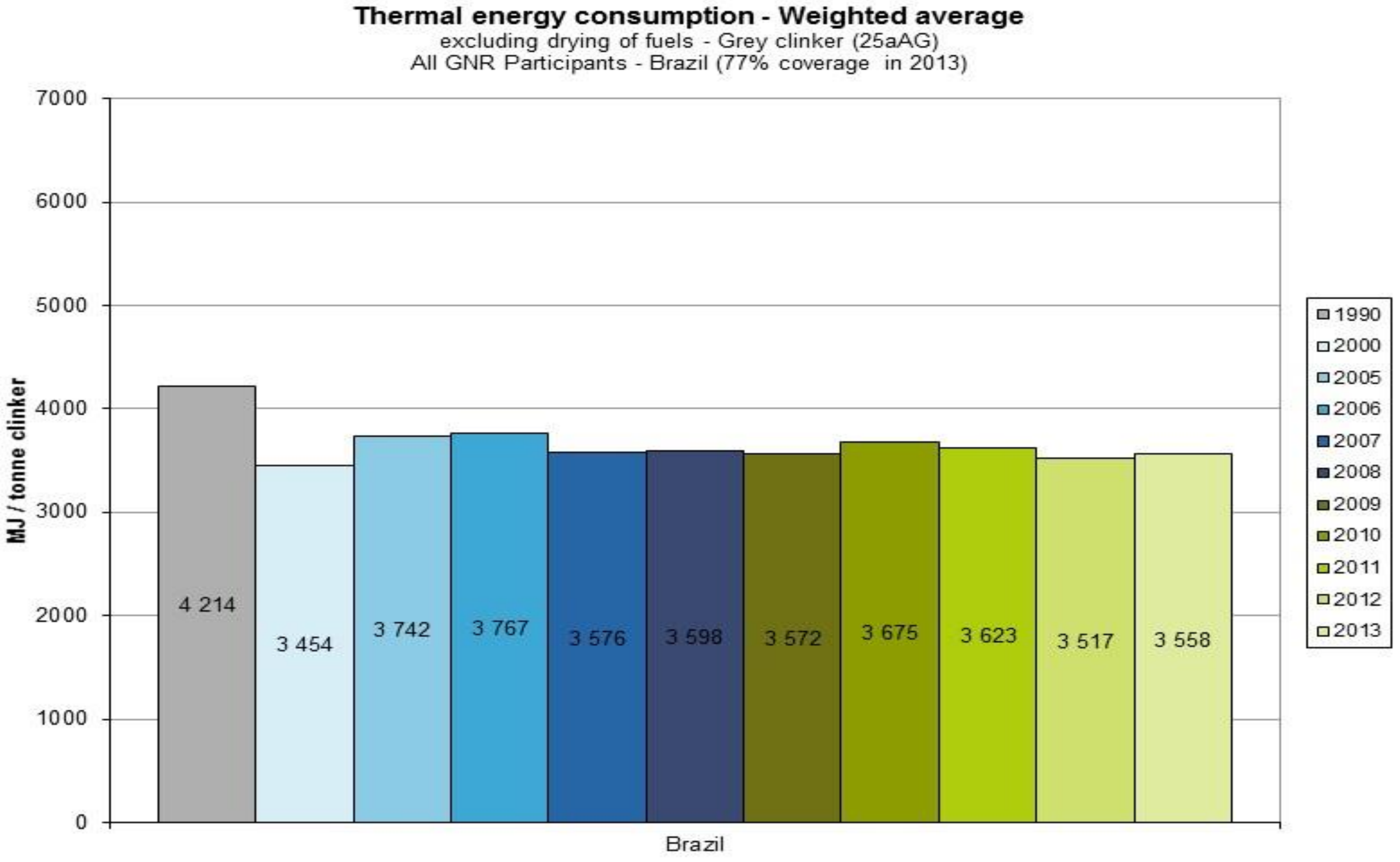


Source: EPE, 2015.

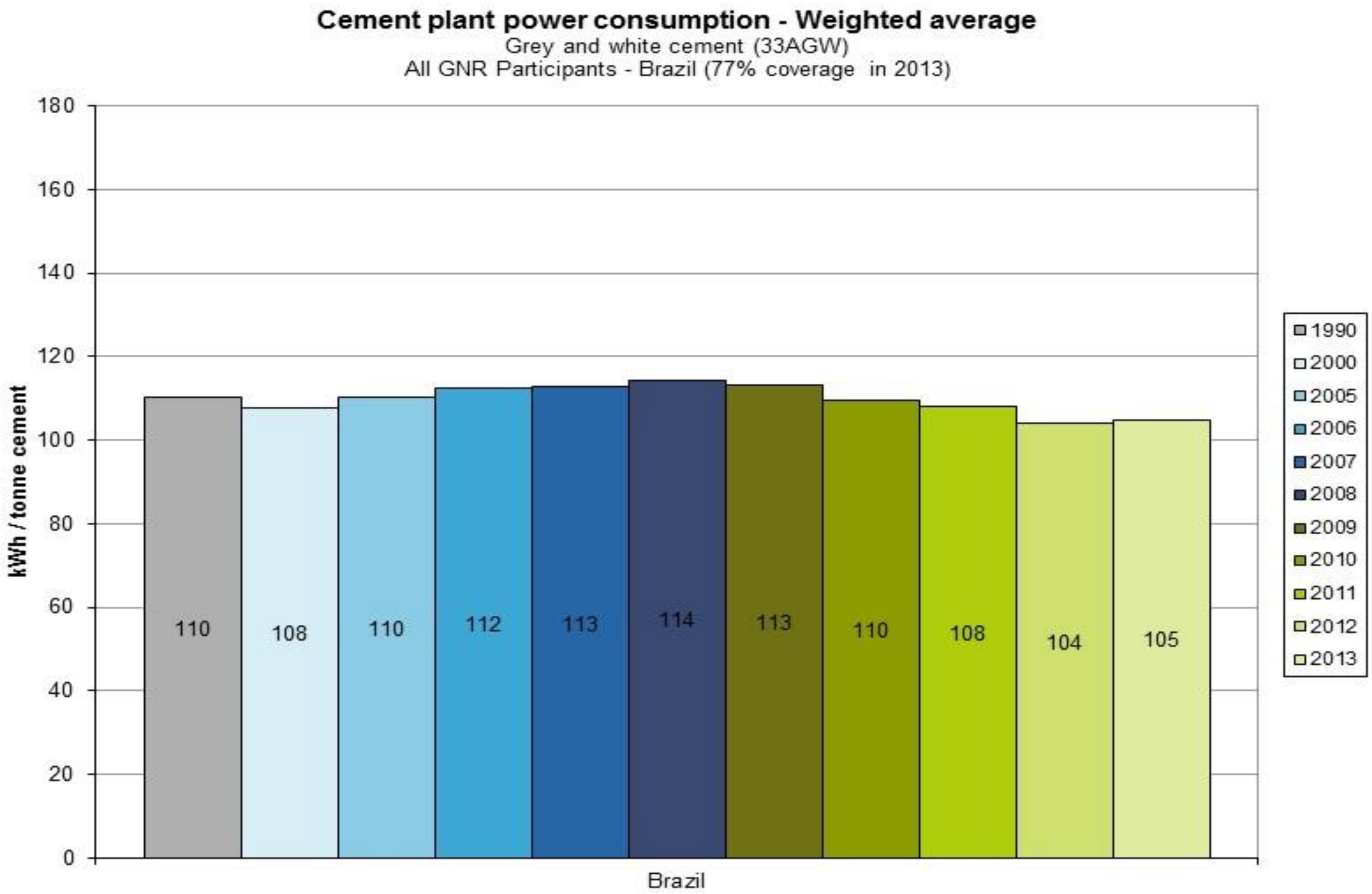
Specific termal consumption



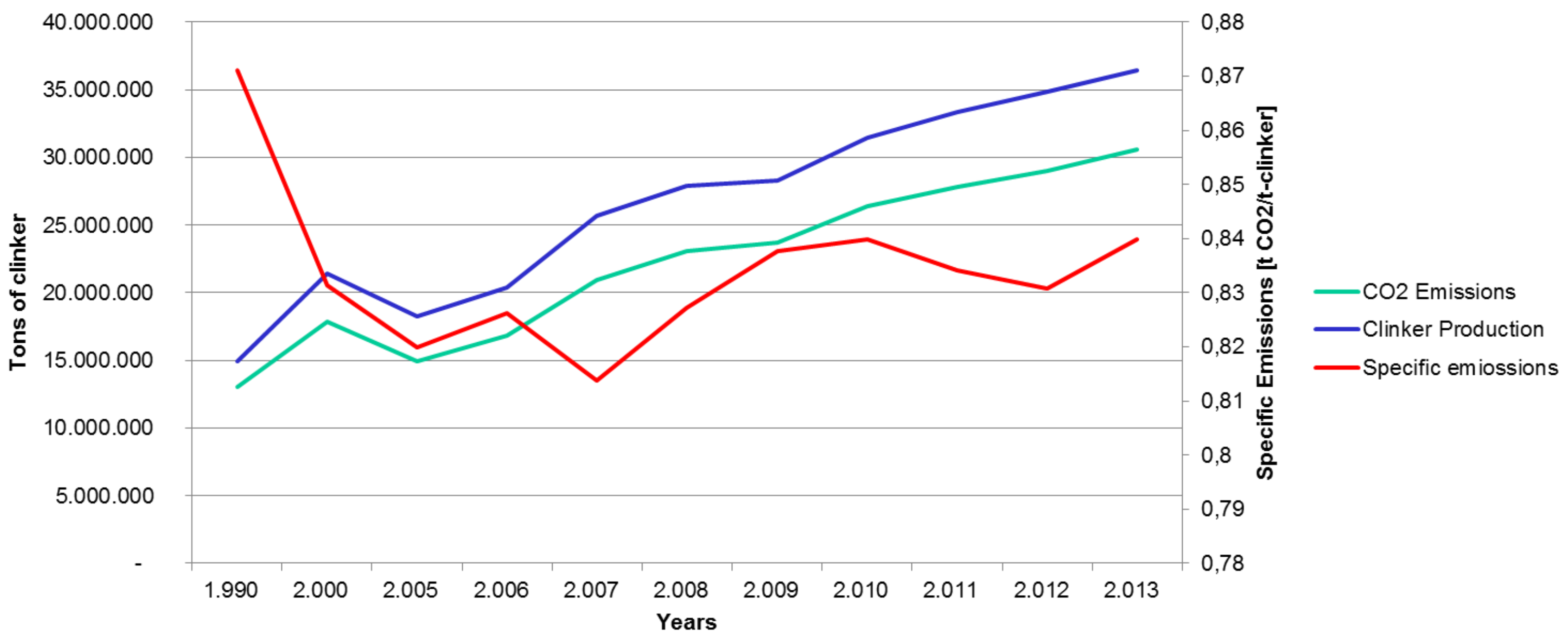
Thermal energy intensity – cement industry in Brazil



Electricity intensity – cement industry

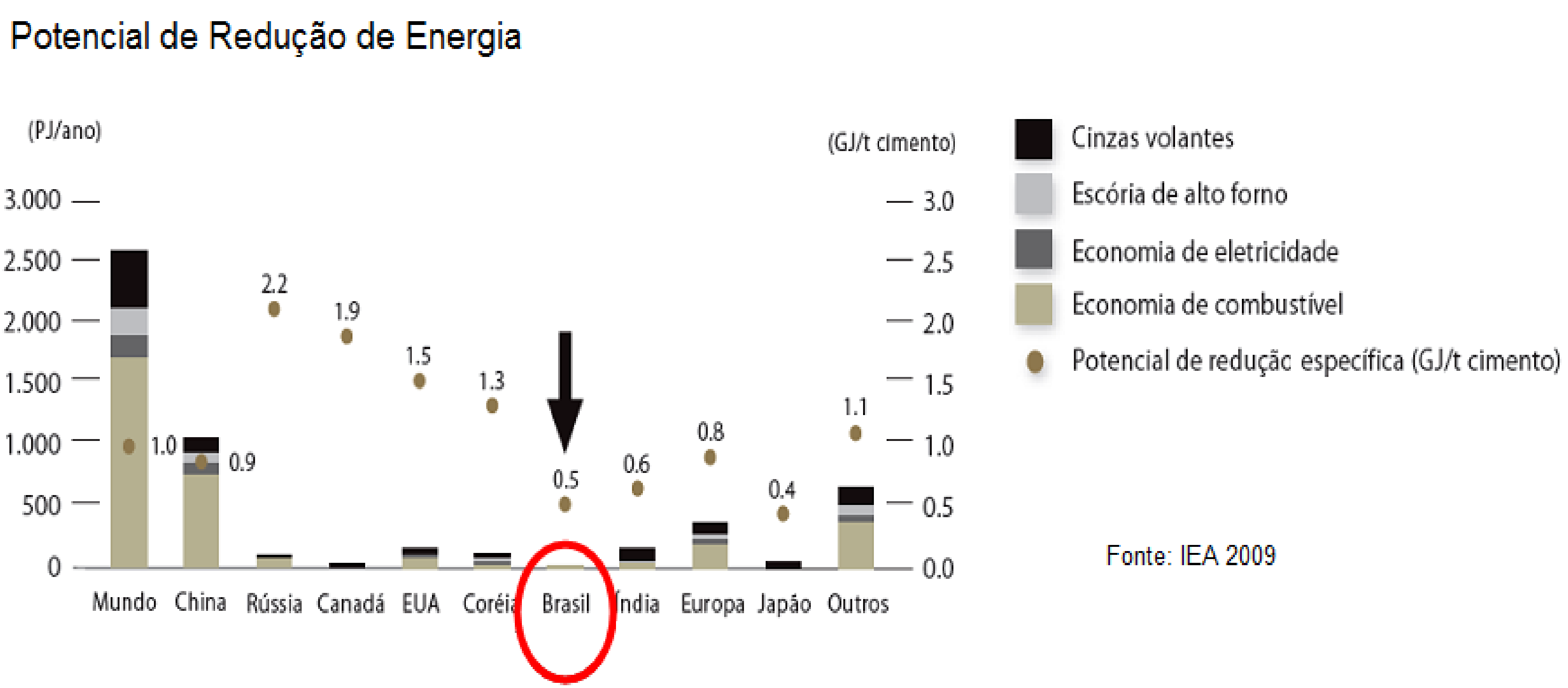


CO2 Emissions – CSI (77% of total Prod.)

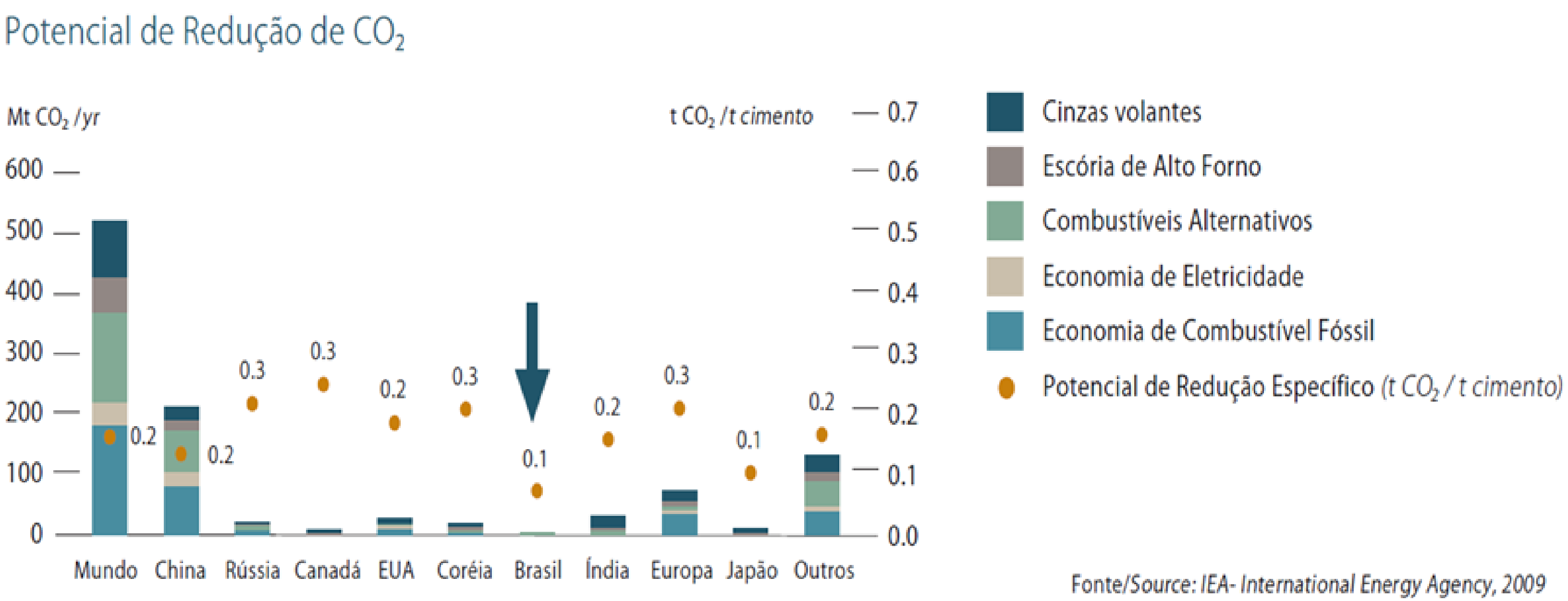


Source: CSI (2014)

CO2 emissions reductions possibilities

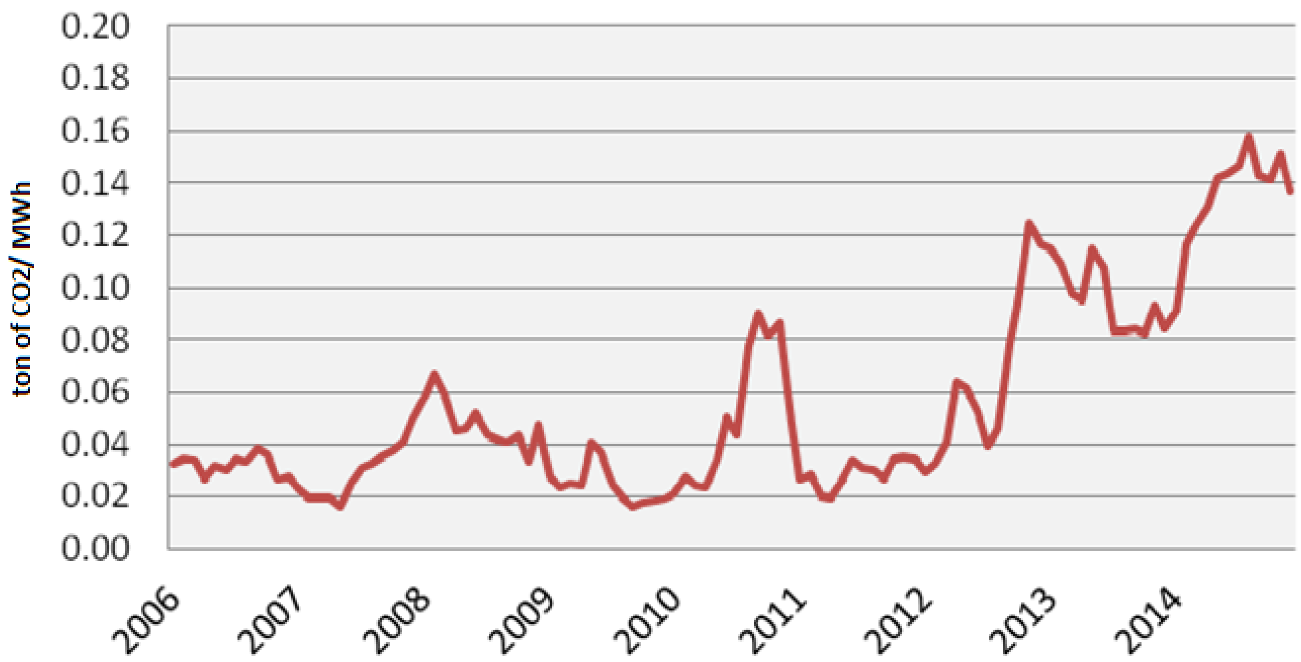


CO2 emissions reductions possibilities



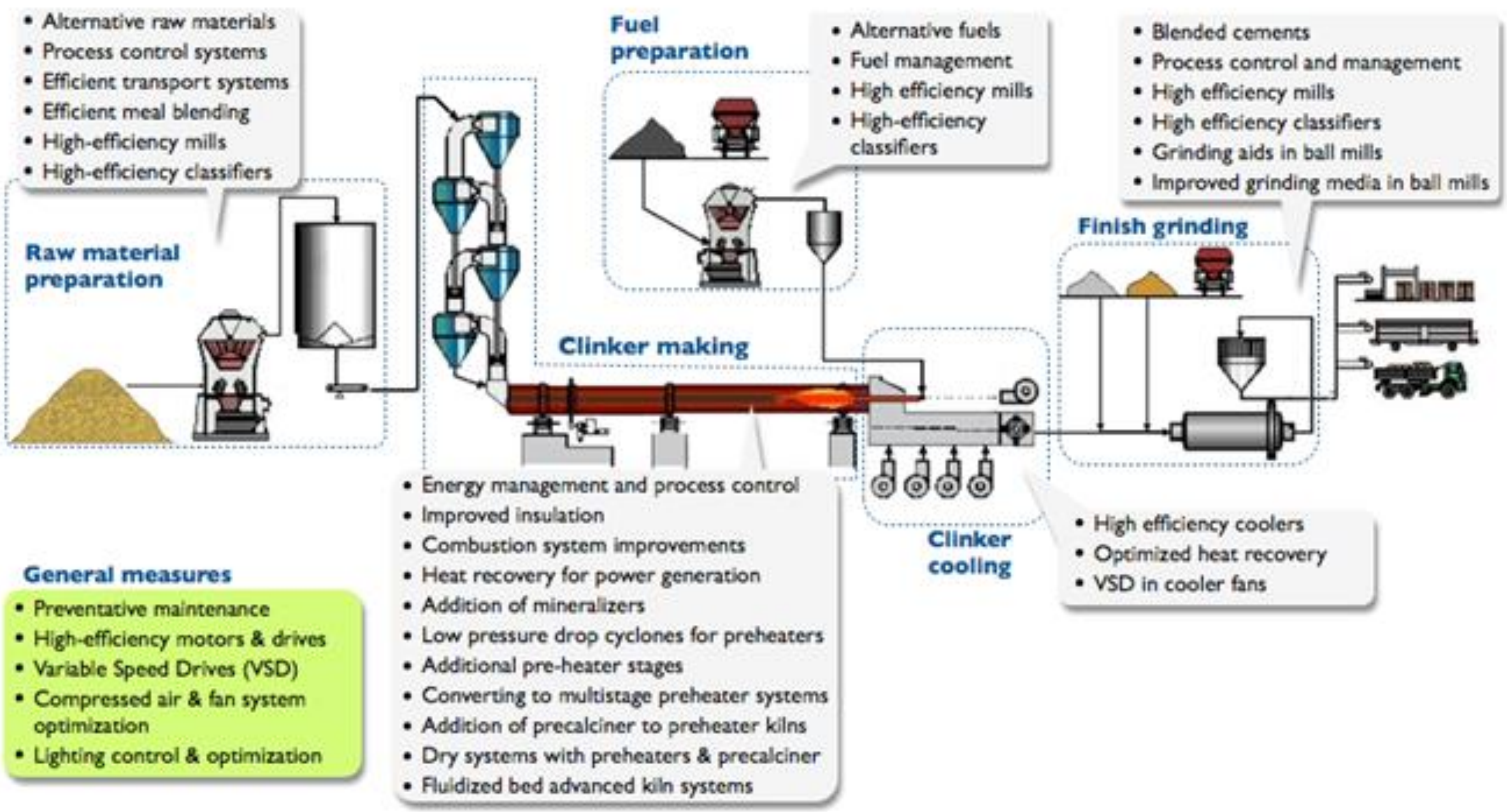
CO2 emissions – electricity in Brazil

Emission factor of the Brazilian energy grid



Source: MCTI 2016

Cement Production Process Flow Schematic and Typical Energy Efficiency Measures



Source: Industrial Energy Technology Database, Institute for Industrial Productivity, http://ietd.iipnetwork.org/content/cement

Specific Thermal Energy Consumption by Rotary Kiln Type

Kiln Type	Heat Input, MJ/ton of clinker
Wet	5,860 – 6,280
Long Dry (LD)	4,600
1 Stage Cyclone Preheater (SP)	4,180
2 Stage Cyclone Preheater (SP)	3,770
4 Stage Cyclone Preheater (SP)	3,550
4 Stage Cyclone Preheater plus Calciner (PC)	3,140
5 Stage Cyclone Preheater plus Calciner (PC) plus high efficiency cooler	3,010
6 Stage Cyclone Preheater plus Calciner (PC) plus high efficiency cooler	<2,930

Source: Based on Madlool 2011

Energy saving measures and technologies (selected)

1- High efficiency fan and VSD for mill vent
2- Pre-grinding to ball mills
3- Variable speed drive & high efficiency fan
4- Process controls and optimization
5- Waste Heat Recovery for power production
6- Low pressure drop cyclones for suspension preheater
7- Improved burnability using mineralizers
8- Optimizing heat recovery
9- VSD for cooler fan
10- Process control and management in finish grinding
11- Replacing ball mill with vertical roller mill, HPGR or Horizontal mill
12- Optimizing the operation of a cement mill
13- High pressure roller press as a pregrinding to ball mill
14- High-efficiency classifiers

Summary – energy and CO2 reductions

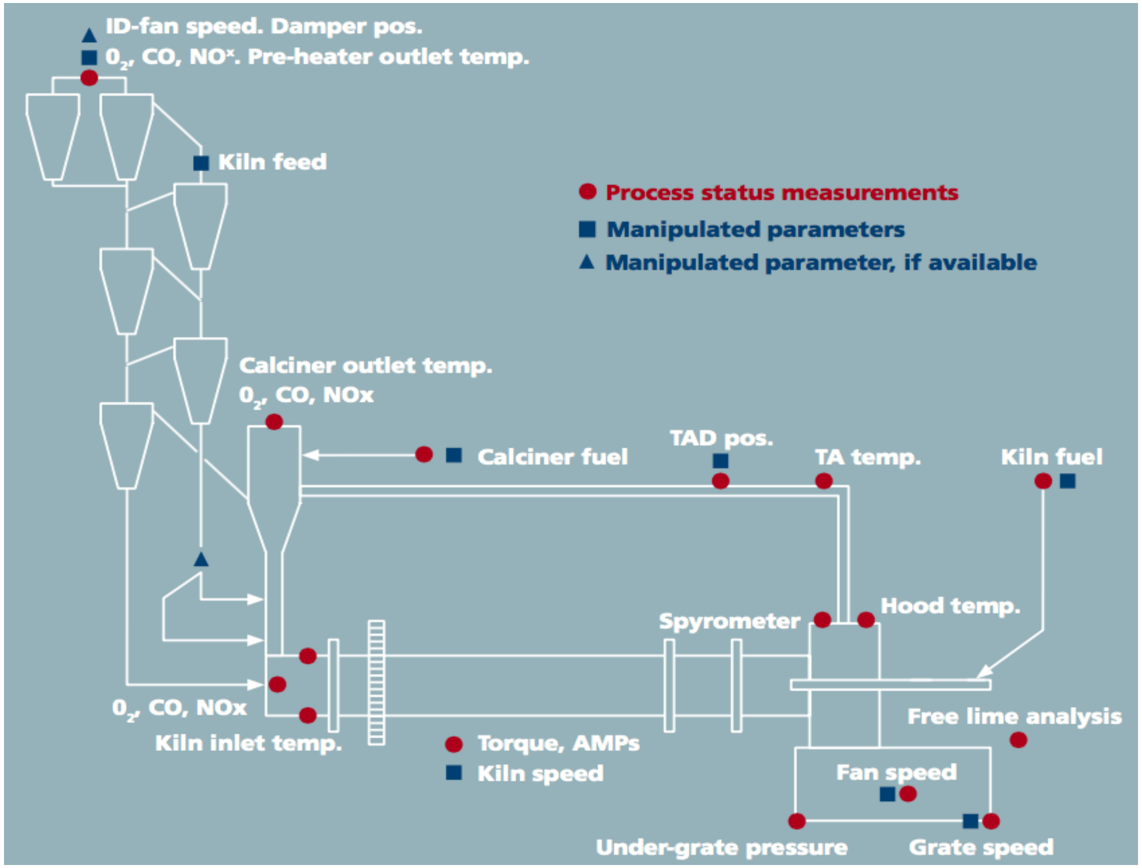
En. Eff. Measures	Electricity Reduction	Unit	Thermal reduction	Unit	GHG Reduction	Unit
High efficiency fan and VSD for mill vent	0,36	kWh/t-clinker	-		0,04	kgCO2/t-clinker
Pre-grinding to ball mills	0,8	kWh/t-raw mat.	-		0,10	kgCO2/t-raw mat.
Variable speed drive & high efficiency fan	0,16	kWh/t-clinker	-		0,02	kgCO2/t-clinker
Process controls and optimization	-		0,111	GJ/t-clinker	9,22	kgCO2/t-clinker
Waste Heat Recovery for power production	25	kWh/t-clinker	-		3,12	kgCO2/t-clinker
Low pressure drop cyclones for suspension preheater	0,13	kWh/t-clinker	-		0,02	kgCO2/t-clinker
Improved burnability using mineralizers	-		0,115	GJ/t clinker	9,55	kgCO2/t-clinker
Optimizing heat recovery	-		0,065	GJ/t clinker	5,40	kgCO2/t-clinker
VSD for cooler fan	0,10	kWh/t clinker	-		0,01	kgCO2/t-clinker
Process control and management in finish grinding	3,5	kWh/t cement	-		0,44	kgCO2/t-cem.
Replacing a ball mill with vertical roller mill, HPGR or horiz.mill in finish grinding	9	kWh/t cement	-		1,12	kgCO2/t-cem.
Optimizing the operation of a cement mill	2	kWh/t cement	-		0,25	kgCO2/t-cem.
High pressure roller press as a pregrinding to ball mill	10	kWh/t cement	-		1,25	kgCO2/t-cem.
High-efficiency classifiers	5	kWh/t cement	-		0,62	kgCO2/t-cem.

Process controls and optimization - Clinker Making

- (On-line) Monitoring & analyses of physical & chemical characteristics
- Automated weighing & blending control
- Combustion management – fuel grinding, air & mass flow, exhaust gas management, burner management, cooler operation
- Expert control (fuzzy-logic, rule-based-control) and model-predictive systems.

Potential Benefits - Improved product quality; improved heat recovery; lower refractory consumption; reduced maintenance; higher productivity

Process controls and optimization - Clinker Making



Schematic depiction of control points and parameters in a kiln system control and management system. Source: FLSmidth

Process controls and optimization - Clinker Making

Typical savings of 2.5–5 percent (up to 10 percent recorded);
For kilns w/o management systems, 50–200 MJ/t-clinker reduction

Up to 1 kWh/t-clinker

US$ 0.34–0.47 million (for 2 million tpa plant)

Operational saving of 0.3–1 US$/t-clinker (for 2 million tpa plant); Payback often < 2 years (can be as low as 3 months)

Source: Institute for Industrial Productivity (IIP) and ECONOLER (2016).

- **Estimated energy saving in Brazil: ~ 3%**
- **Tech. penetration in BR**

  2014: 38%
  2030: 66%
  2050: 99%

Waste Heat Recovery for power production- Clinker Making

- Potential to generate up to 1/3 of plant power requirements (reducing purchased/captive power needs)
- Reduces operating costs
- Protects against rising electricity prices
- Enhances power reliability
- Lowers specific energy consumption, reducing overall greenhouse gas emissions
- Heat recovery potential
  - 750–1050 MJ/t clinker at 300-400ºC from preheater
  - 330 to 540 MJ/t-clinker at 200 to 300ºC from cooler

Implementation Factors:

- The amount of heat available in (exhaust gas volume and temperature) and conditions of the waste gases determine the size, the technology, and overall generation efficiency
- The amount of heat available and temperature is a function of the size and configuration of the kiln (i.e., tpd and number of preheater stages) and the raw material moisture level.
- Capital cost of the heat recovery system is generally a function of size, technology and supplier.
- System installation costs (design, engineering, construction, commissioning and training) are functions of the installation size, technology, complexity, supplier and degree of local content.
- System operating and maintenance costs are a function of size, technology, site-specific operational constraints - costs are influenced by staffing, operating hours of the kiln and availability of the heat recovery system

Waste Heat Recovery for power

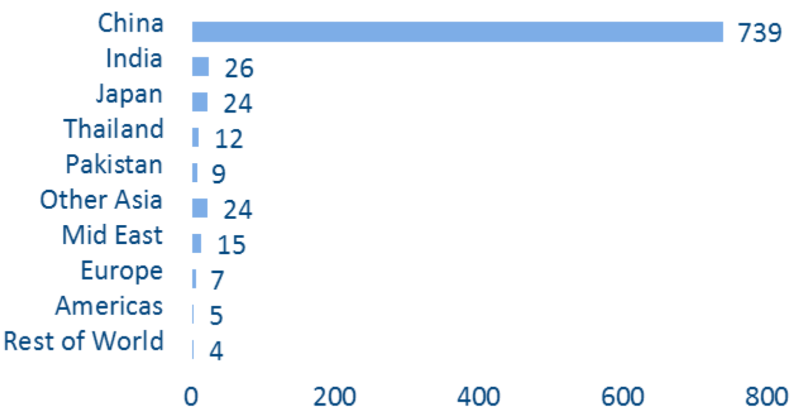
Up to 22 kWh/t-clinker electricity production
22–36 kWh/t-clinker reported in large-scale Chines plants
45 kWh/t-clinker with additional fuel firing or kiln system modification

Costs are very system specific
Range from 7,000 US$/kWe for 2 MW systems (ORC) to 2,000 US$/kWe for 25 MW systems (steam)

Status: Initially introduced by Japanese suppliers

China is now the leader in WHR deployment and sales for cement applications

WHR Systems in Cement – Number of Units - 2012



Source: Institute for Industrial Productivity (IIP) and ECONOLER (2016).

- **Tech. penetration in BR**

  2014: 0%
  2030: 33%
  2050: 33%

Improved burnability using mineralizers – Clinker Making

Mineralizadores (fluoretos) são substâncias que promovem a formação de compostos de clinquer sem participar nas reacções de formação. São particularmente eficazes e promovem a formação de silicato tricálcico. Possibilitam uma menor demanda de energia uma vez que reduzem a temperatura na sinterização do clínquer.

O potencial desta tecnologia é limitado. Enquanto a adição de mineralizadores em quantidades menores pode melhorar a qualidade do produto, quantidades maiores podem ter impactos adversos na qualidade do produto e na operação do forno devido à formação de revestimentos.

Main Influencing Parameters

- Chemical properties of the raw mix and mineralizers
- Mineralogy of its component materials and its fineness
- Raw mix control and kiln feed homogenization
- CO2 intensity of fuel mix

Conditions, Barriers and Constraints

- Costs of mineralizers
- Grindability of clinker can deteriorate
- Increased coating formation in the sintering zone
- Impact on clinker quality
- Impact on kiln operation and product properties
- Health problems given fluor emission of the kiln

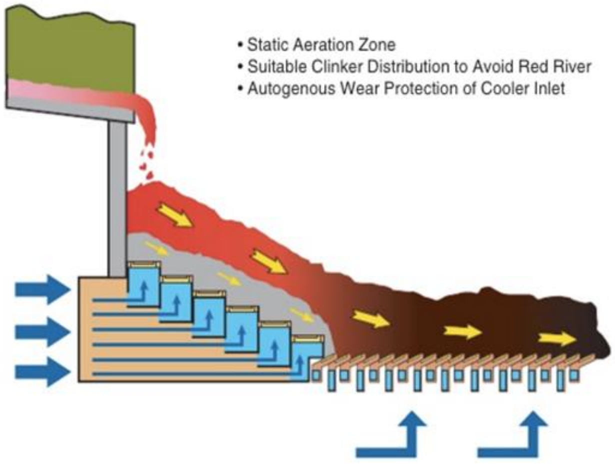
- **Tech. penetration in BR**

  2014: 5%
  2030: 5%
  2050: 5%

Optimizing heat recovery- Clinker Making

- Clinker cooler optimization aims to maximize heat recovery, minimize clinker temperature and reduce specific fuel consumption.
- This may also improve product quality and emission levels.
- Heat recovery can be improved through reduction of excess air volume, control of clinker bed depth and new grates such as ring grates.
- A recent innovation in clinker coolers is the installation of a static grate section at the hot end of the clinker cooler. Additional heat recovery results in reduced energy use in the kiln and precalciner, due to higher combustion air temperatures.

Fixed static inlet section for a clinker cooler



Source: Institute for Industrial Productivity (IIP) & ECONOLER (2016).

Optimizing heat recovery- Clinker Making

➢ **Energy Performance**

0.05 to 0.08 GJ/t-clinker savings are reported through the improved operation of the grate cooler, and savings of 0.16 GJ/t-clinker are reported for retrofitting a grate cooler.

Fixed static inlet section for a clinker coolered by an increase in electricity use of 2.0 kWh/t clinker.

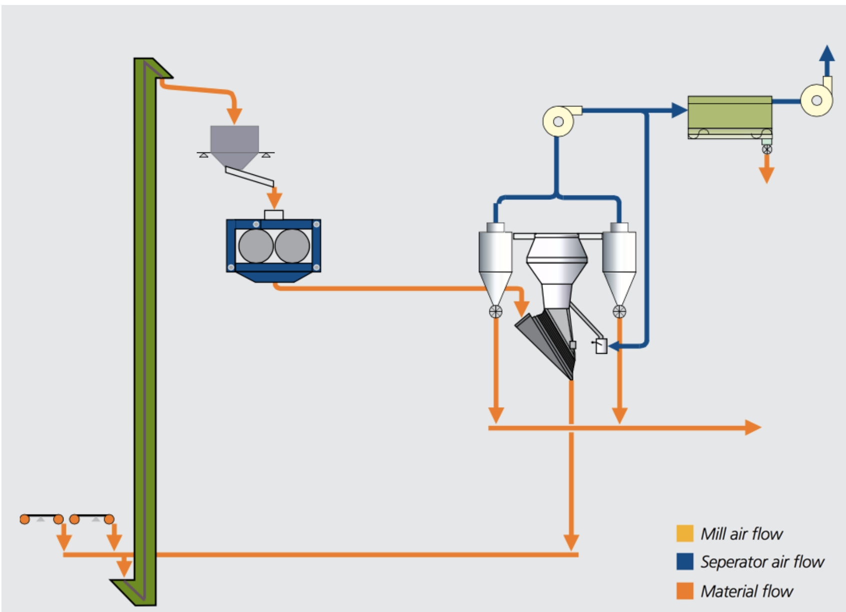
Installation of a static grate section could improve the heat recovery rates by 2 to 5 percent.

- **Tech. penetration in BR**

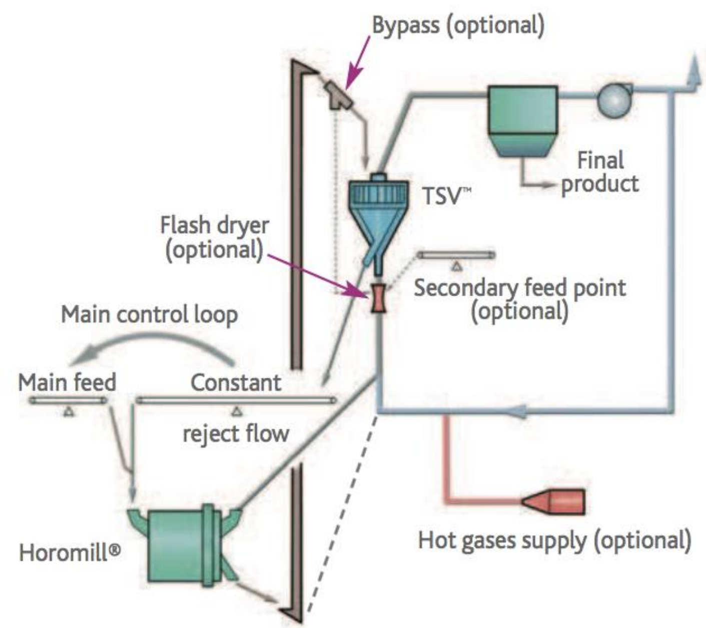
  2014: 64%
  2030: 99%
  2050: 99%

Replacing a ball mill with vertical roller mill, HPGR or horizontal mill in finish grinding

Vertical Roller Mills (VRM), High-Pressure Roller Press (HPGR) and Horizontal Mills offer more efficient grinding



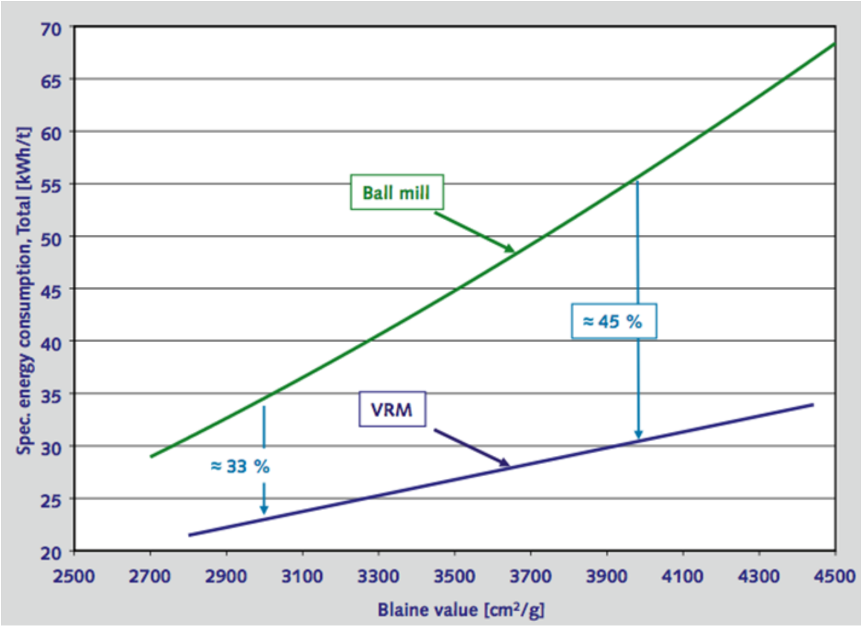
High Pressure Roller Press in finish grinding.
FLSmidth, 2010

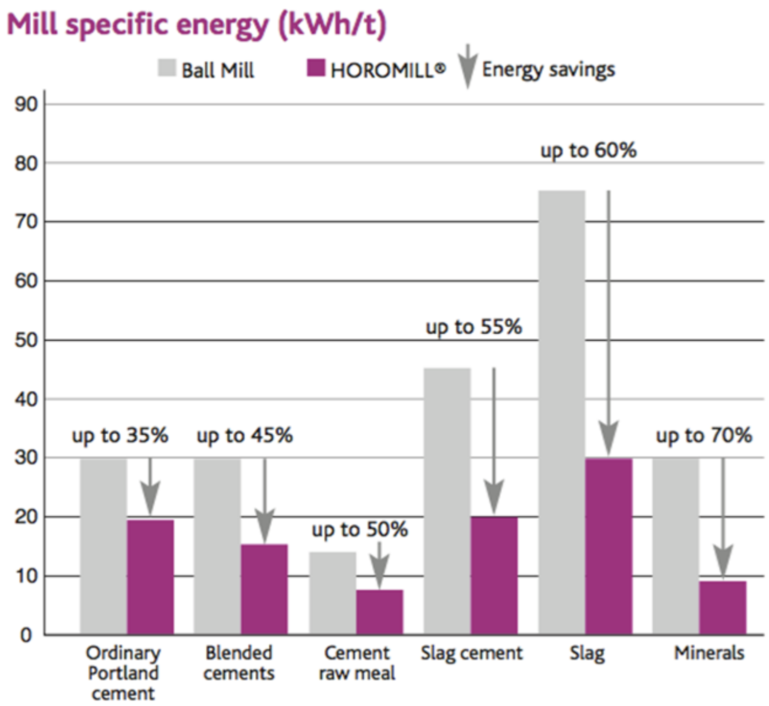


Basic layout of cement grinding using horizontal mill.
Fives Fcb

Source: Institute for Industrial Productivity (IIP) and ECONOLER (2016).

Replacing ball mill with more efficient technologies





Source: Institute for Industrial Productivity (IIP) and ECONOLER (2016).

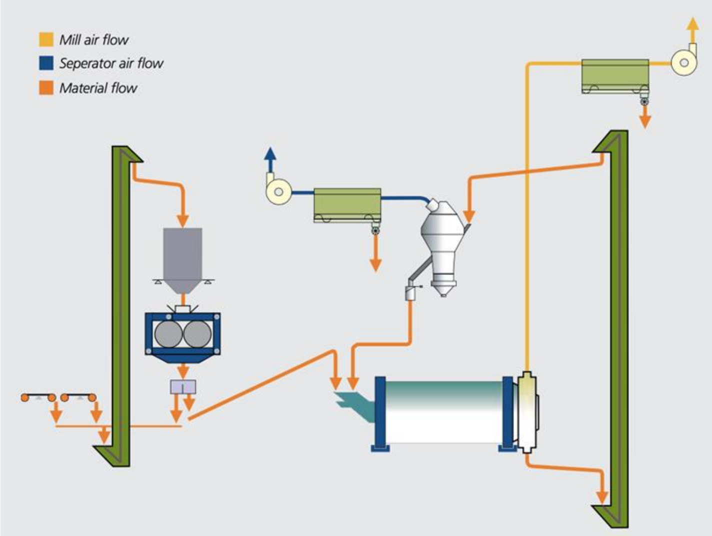
Replacing ball mill with more efficient technologies

- **In Brazil - power savings are estimated in 9 kWh/ton cement using roller mill**
- **Costs (Brazil): US$ 70/t cement capacity**
- **Tech. penetration in BR**
  - **2014: 13%**
  - **2030: 13%**
  - **2050: 13%**

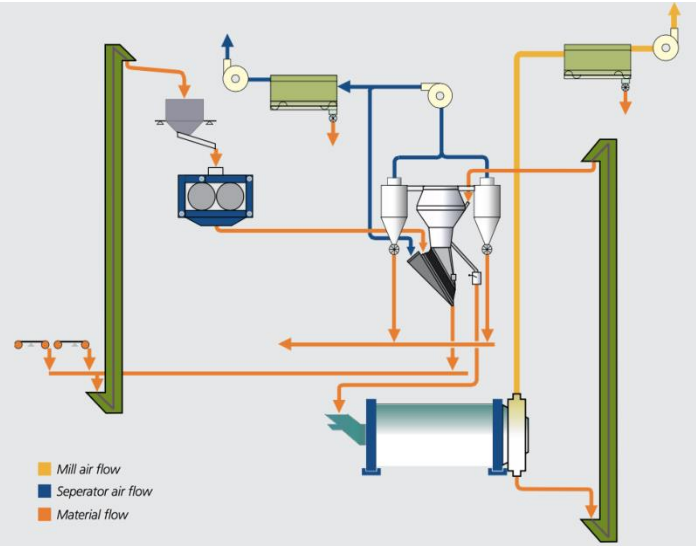
Source: Institute for Industrial Productivity (IIP) and ECONOLER (2016).

High pressure roller press for pre-grinding (as a coarse grinding prior to fine grinding in a ball mill)

- Efficiency of ball mills is low, and there is limited opportunity to improve both coarse and fine grinding performance by ball selection
  - ✓ Install vertical mill for coarse grinding before ball mill – existing ball mill used exclusively for fine grinding
  - ✓ Potential for productivity increase between 50 – 100 percent
- *Implementation Factors:*
  - ✓ More applicable to plants where the total replacement of ball-mills is not feasible and capacity increases are desirable



High pressure roller press as a pre-grinding to ball mill (FLSmidth, 2010)



High pressure roller press as a semi-finish pre-grinder with two stage separator (FLSmidth, 2010)

High pressure roller press for pre-grinding

Electricity savings of 7-24 kWh/t-cement reported;
Savings can reach 30%

Savings of 8 – 12 kWh/t-cement reported in China

US$ 2.7 million in a Japanese plant with 100 t/h capacity;

In India, US$ 10 - 20 million, or between US$ 55,000 – 65,000 per tph system capacity

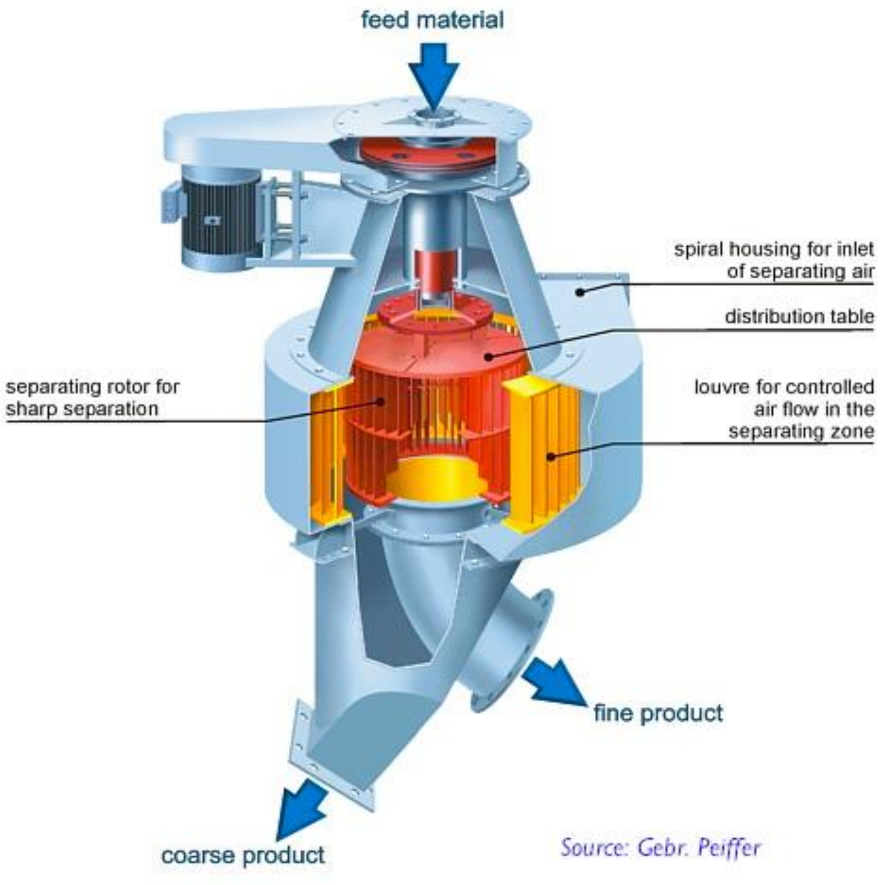
Production capacity can be increased by up to 100%

- **Tech. penetration in BR**

  2014: 0%
  2030: 0%
  2050: 0%

High-efficiency classifiers – Finish Grinding

- High-efficiency classifiers featuring optimized air ducts and additional external air circuits separate the material more cleanly.
- High separation efficiency leads to higher proportion of classifier fines.
- The number of circulations of the mill feed declines
- Throughput increases (by up to 15%)



Source: Institute for Industrial Productivity (IIP) and ECONOLER (2016).

High-efficiency classifiers – Finish Grinding

Overall power demand can be reduced by 10-15 % (up to 7 kWh/t-cement reductions reported);
Savings typically around 5 kWh/t-cement in China

2.0 US $/annual ton of finished material;
2.5 million ECU for installation and retrofitting (for 2 mtpa capacity);
In India, installation reported at 2,000 US$ per tonne hourly capacity

- Tech. penetration in BR

  2014: 70%
  2030: 80%
  2050: 80%

Source: Institute for Industrial Productivity (IIP) and ECONOLER (2016).

General energy savings measures (house keeping)

- ✓ High efficiency motors
- ✓ Use of variable speed drives (VSD):
  - *Mill vent – raw material*
  - *Fuel Preparation*
  - *Preheaters*
  - *Cooler fans*
  - *Cement mill vent*
- ✓ Preventative maintenance
- ✓ Compressed air system maintenance and optimization
- ✓ Reducing leaks in comp air system
- ✓ Compressor controls

Energy Savings: 1% or 2% of the electricity consumption of the cement plant

Tech. penetration in BR

2014: 13%
2030: 33%
2050: 66%

Summary – energy and CO2 reductions

Energy Efficient Measures	Electricity Reduction		Thermal Reduction		GHG Reduction	
Pre-grinding to ball mills	0.8	kWh/t-raw mat.	-		0.10	kgCO2/t-raw mat.
Process controls and optimization	-		0.111	GJ/t-clinker	9.22	kgCO2/t-clinker
Waste Heat Recovery for power production	25	kWh/t-clinker	-		3.12	kgCO2/t-clinker
Low pressure drop cyclones for suspension preheater	0.135	kWh/t-clinker	-		0.02	kgCO2/t-clinker
Improved burnability using mineralizers	-		0.115	GJ/t clinker	9.55	kgCO2/t-clinker
Optimizing heat recovery	-		0.065	GJ/t clinker	5.40	kgCO2/t-clinker
Process control and management in finish grinding	3.5	kWh/t cement	-		0.44	kgCO2/t-cement
Replacing a ball mill with vertical roller mill, HPGR or Horizontal mill in finish grinding	9	kWh/t cement	-		1.12	kgCO2/t-cement
Optimizing operation of a cement mill	2	kWh/t cement	-		0.25	kgCO2/t-cement
High pressure roller press as a pregrinding to ball mill	10	kWh/t cement	-		1.25	kgCO2/t-cement
High-efficiency classifiers	5	kWh/t cement	-		0.62	kgCO2/t-cement
General E.Ef. measures	1	kWh/t cement	-		0.12	kgCO2/t-cement

Source: IIP & ECONOLER (2016) and INT.

Summary table - costs and technology penetration

En. Eff. Measures	Costs (Brazil)	Penetration (%) 2014	Penetration (%) 2030	Penetration (%) 2050
Pre-grinding to ball mills	US$ 18,6 million	2%	2%	2%
Process controls and optimization	US$ 0,6 a 1,7 t/clinker	38%	66%	99%
Waste Heat Recovery for power production	US$ 3.000/kWe	0%	33%	33%
Low pressure drop cyclones for suspension preheater	US$ 26,8 million	60%	60%	60%
Improved burnability using mineralizers	US$ 0,6 a 3 t/clinker	5%	3%	3%
Optimizing heat recovery	US$ 0,47 t/clinker	64%	99%	99%
Process control and management in finish grinding	US$ 1,2 t/clinker	61%	66%	66%
Replacing ball mill with vertical roller mill, HPGR or horizontal mill	US$ 70 t/cement-cap	13%	13%	13%
Optimizing the operation of a cement mill	US$ 0,39 t/cement	33%	50%	66%
High pressure roller press as a pregrinding to ball mill	US$ 30 million	0%	0%	0%
High-efficiency classifiers	US$ 4 t/year	70%	80%	80%
General measures	0,30 US$/t-cement	13%	33%	66%

Source: IIP & ECONOLER (2016) and INT.

Muito Obrigado

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