Opportunities for Improving Energy Efficiency and Increasing Economic Output in Chinese Cement Kilns

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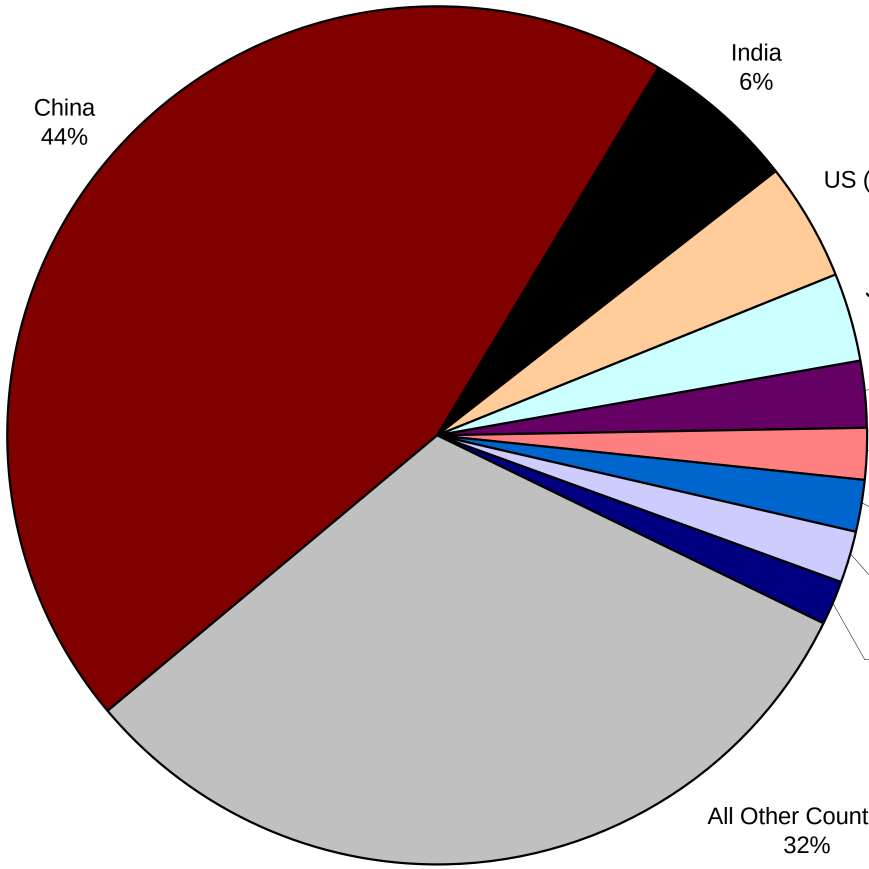
China Dominates World Cement Production

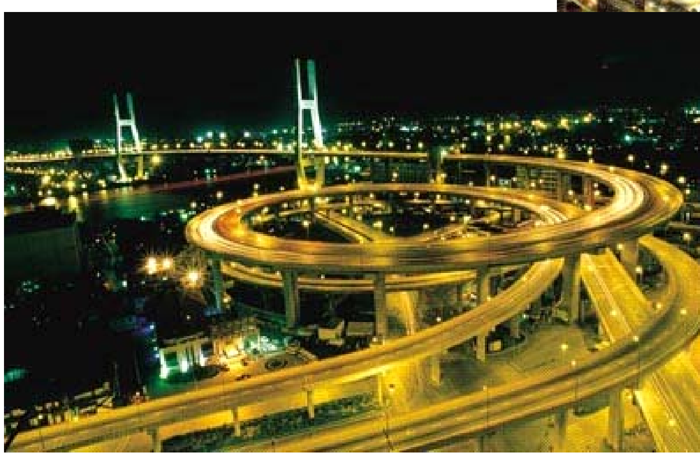
World Cement Production 2004
(Shares by Country)



Source: US Geological Survey, 2005 and Cui, 2005

Building Infrastructure

- **Construction projects:**
  - — **Three Gorges Dam**
  - — **South to North Water Diversion Project**
  - — **Roads, highways, bridges, airports**
  - — **Housing**
  - — **Cities**

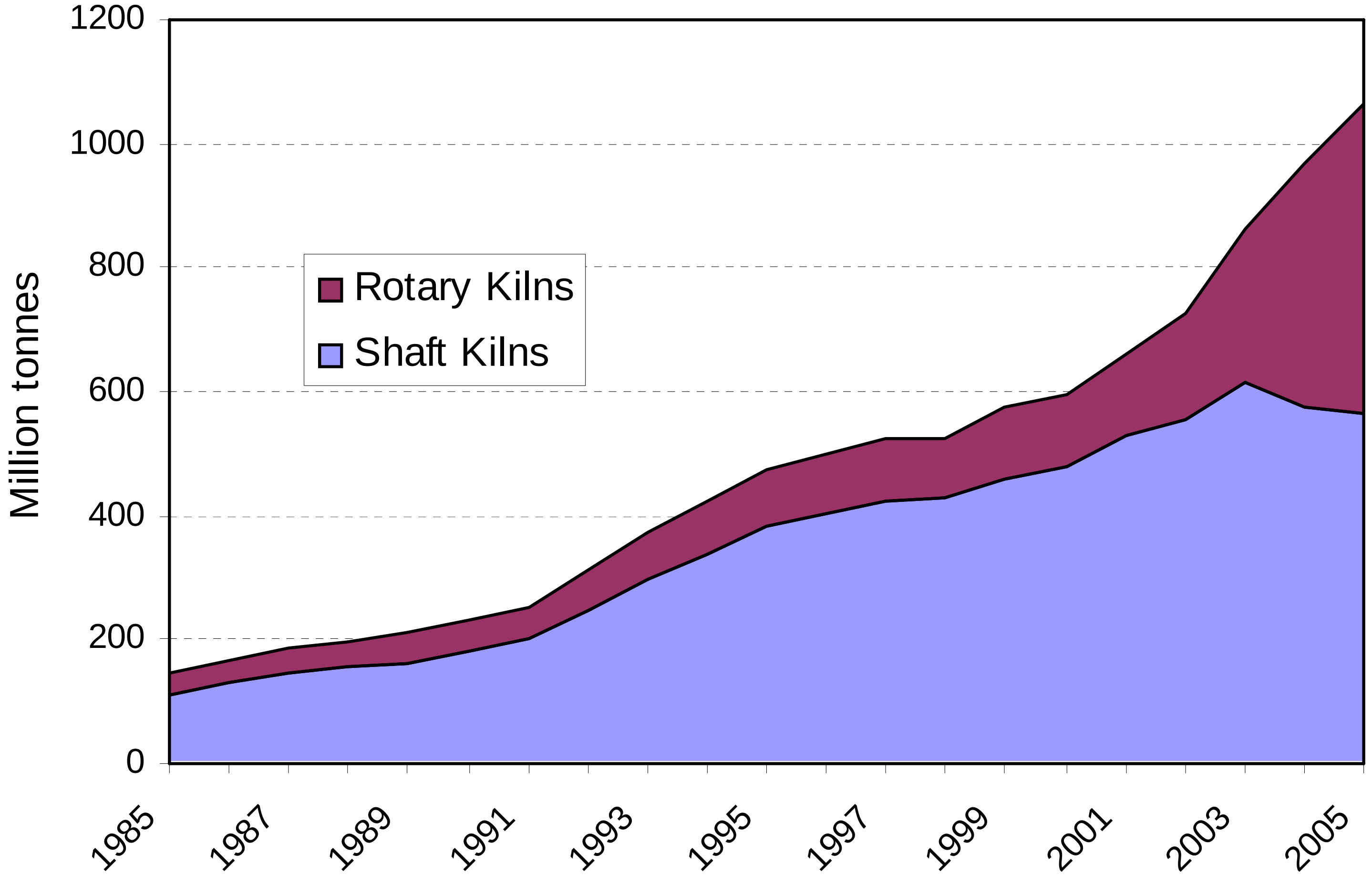


Unique Kilns Prevail in China

- Vertical shaft kilns (VSKs) – dominant cement-making technology
- Not found in most other countries

Pictures from Karstensen, K.H., 2006. *Cement Production in Vertical Shaft Kilns in China: Status and Opportunities for Improvement.* Report to UNIDO.

Cement Production in China



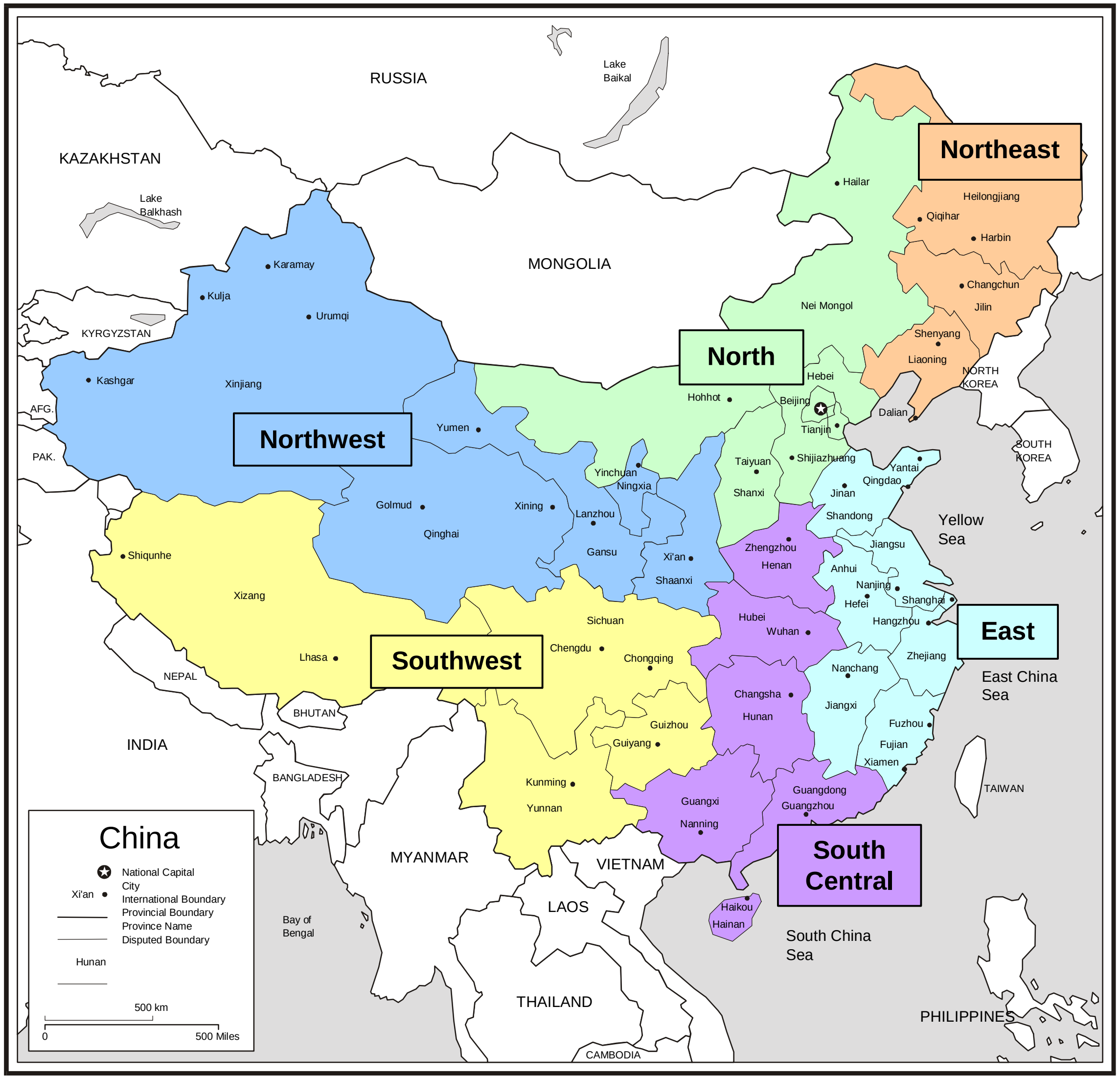
Sources: Cui, 2006a ; Cui, 2005; ITIBMIC, 2004; Soule, et al., 2002

Diverse Kiln Technologies and Energy Intensities

	2001		2002		2003		2004		2005
Rotary Kilns	Mt	#	Mt	#	Mt	#	Mt	#	Mt
Large & medium NSP/SP kilns	71	151	121	228	199	326	319	566	473
Small NSP/SP kilns	7	101	8	101	6	101	4	66	
Cyclone pre-heater kilns	2	72	2	72	2	64	1	34	
Shaft pre-heater kilns	10	290	9	280	5	236	3	148	
Semi-dry process kilns	5	12	6	14	7	16	7	16	
Cogenerative kilns	13	113	14	115	14	121	17	150	
Lepol kilns	3	20	3	20	3	19	3	19	
Small dry-process hollow kilns	8	330	8	320	8	320	4	170	
Wet-process kilns	34	206	40	250	40	250	40	250	
Rotary Kilns Sub-Total	***153***	***1295***	***211***	***1400***	***282***	***1453***	***397***	***1419***	***564***
Shaft Kilns									
Improved shaft kilns	91	850	115	885	145	1150	155	1240	
Mechanical shaft kilns	312	8400	339	8350	372	9280	363	9060	
Ordinary shaft kilns	64	3000	55	2800	64	3150	48	2400	
Shaft Kilns Sub-Total	***467***	***12250***	***509***	***12035***	***581***	***13580***	***566***	***12700***	***500***
Total	**620**	**13545**	**720**	**13435**	**863**	**15033**	**963**	**14119**	**1064**

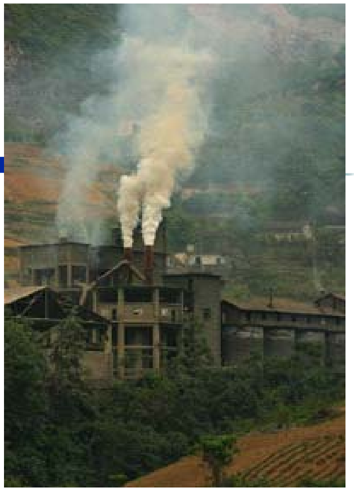
Sources: Cui, 2006a ; Cui, 2005; ITIBMIC, 2004

Geographical Production (2004 in Mt)



Region	Production
North Region	*125.96*
Northeast Region	*49.76*
East Region	*376.71*
South Central Region	*234.03*
Southwest Region	*94.53*
Northwest Region	*52.69*

Policy Environment



NDRC's 2004 *China Medium and Long Term Energy Conservation Plan:*

— "by 2010, China's products as a whole are expected to reach or approach the advanced international level of the early 1990s…by 2020 China is expected to reach or approach the international advanced level"

— Target for energy consumption for 2010 is 148 kgce/t (4.3 GJ/t) cement and for 2020 is 129 kgce/t (3.8 GJ/t)

— China's 2004 overall cement intensity was 4.9 GJ/t while international best practice for dry process cement kilns is around 3.0 GJ/t (final energy)

— Plan specifically promotes the adoption of low temperature waste heat recovery technology for production of electricity in cement plants with production of 2,000 tonnes per day or greater, stating "we should every year establish 30 power generating units using medium and low temperature residual heat, and thus 3 million tce will be saved per year"

Policy Environment

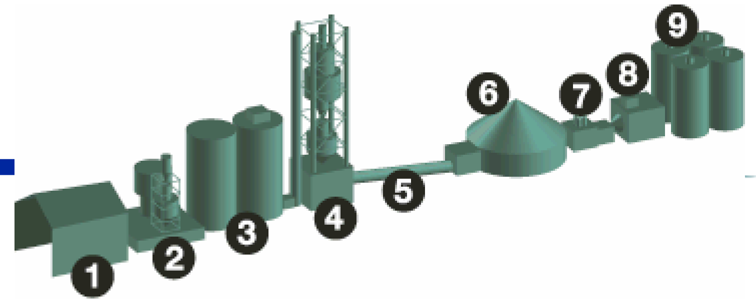
In 2006, NDRC further outlined goals for structural adjustment of the cement industry between 2005 and 2010:

- — Increase in the share of new dry process cement kiln production from 40% to 70%
- — Closure of 250 Mt of inefficient production capacity
- — Increase in scale and reduction of the total number of cement enterprises to 3500
- — Annual production capacity of the top 10 cement enterprises should be at or above 35 Mt
- — Energy consumption reduced from 130 kgce/t (3.8 GJ/t) clinker to 110 kgce/t (3.2 GJ/t) clinker
- — Integrated energy consumption should decrease by 25% and emissions of air pollutants should decrease by 50%

NDRC also Initiated "Top-1000"Energy-Consuming Enterprise Program

- — Includes ~90 cement plants

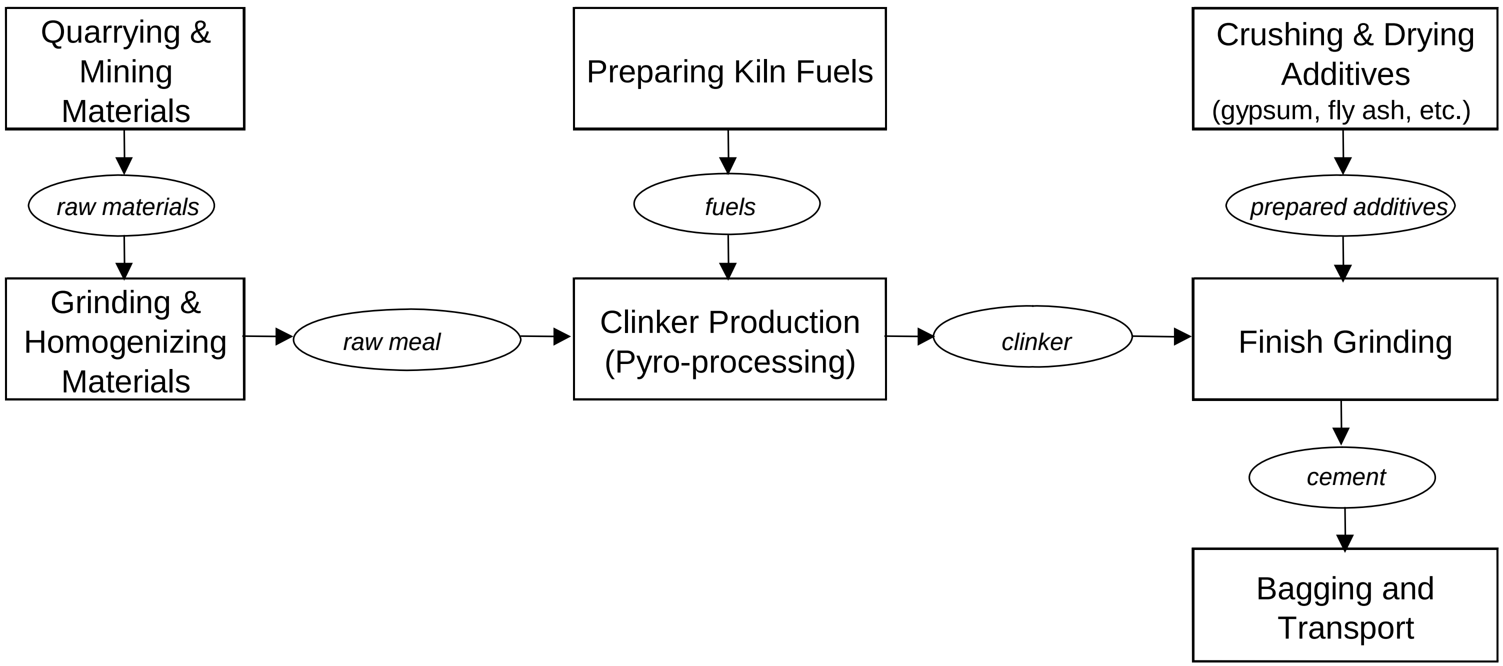
Cement Manufacturing



Raw Material Preparation (1-3)

Clinker Making (4-5)

Finishing (6-9)



Energy Use for Cement Manufacturing

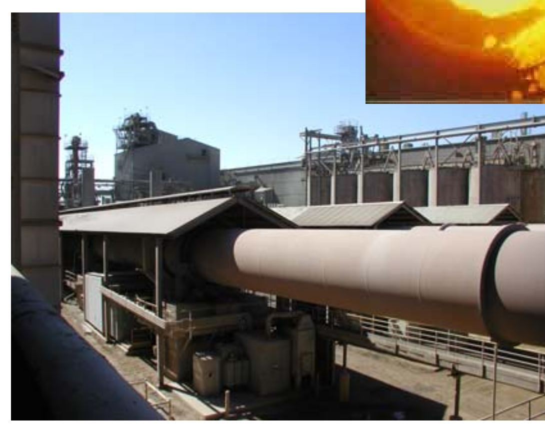
Wide variation in energy consumption depending upon technologies used

	Fuel Use (GJ/t product)	Electricity Use (kWh/t product)	Primary Energy Use (GJ/t cement)
Raw Material Preparation			
Crushing		0.3-1.6	0.02-0.03
Raw Meal Grinding		12-22	0.21-0.39
Clinker Making			
Wet kiln	5.9-7.0	25	6.2-7.3
Lepol kiln	3.6	30	3.9
Long dry kiln	4.2	25	4.5
Short dry kiln – suspension preheater	3.3-3.4	22	3.6-3.7
Short dry kiln – preheater & precalciner	2.9-3.2	26	3.2-3.5
Shaft kiln	3.7-6.6	N/A	3.7-6.6
Finishing			
Finish Grinding		28-55	0.31-0.60

Worrell, E., Price, L., Martin, N, Hendriks, C. and Ozawa Meida, L., 2001. “Carbon Dioxide Emissions from the Global Cement Industry,’ *Annual Review of Energy and the Environment*. 26:303-329.

Cement Kiln Energy Efficiency Improvement Opportunities

- Report prepared by LBNL at request of U.S. EPA and the Asian Development Bank
- Relied on both international and China-specific case study information
- Significant assistance from Institute of Technical Information for Building Materials Industry of China
- For each technology, the following information is provided:
  - — Capital costs ($/t)
  - — Operations and maintenance costs ($/t)
  - — Simple payback period (years)
  - — Fuel savings (GJ/t)
  - — Electricity savings (kWh/t)
  - — CO2 savings (kgC/t)
  - — Lifetime of measure (years)
- Report is still in review process



Cement Kiln Energy Efficiency Improvement Opportunities

Options evaluated:

Improved refractories	Low temperature heat recovery for power
Energy management & process control	High temperature heat recovery for power
Convert VSK to NS preheater/precalciner	Low pressure drop cyclones
Long dry kiln upgrade to preheater/precalciner	Efficient kiln drives
Preheater kiln upgrade to precalciner	Kiln shell heat loss reduction
Old dry kiln upgrade to multi-stage preheater	Adjustable speed drive for kiln fan
Convert to reciprocating grate cooler	Blended cements
Kiln combustion system improvements	Use of waste-derived fuels
Indirect firing	Limestone cement
Optimize heat recovery/upgrade clinker cooler	Low alkali cement
Seal replacement	Use of steel slag

Convert VSK Kilns to NSP/SP Kilns

— Rapid growth in construction of NSP kilns in China

— About 10-20% are imported, remainder are domestic technology

- Domestic technology costs 1/3 to 1/5 that of imported technology, but has a shorter lifetime and is not yet available for kilns over 5000 tpd
- Ordinary, mechanical, and improved vertical shaft kilns in China consume about 105 kWh/t clinker and between 4.7 and 6.5 GJ/t clinker
- Hejiashan Cement Company in Zhejiang Province replaced two mechanical shaft kilns with two 5-stage cyclone preheater, precalciner kilns
  - — Electricity consumption = 86 kWh/t clinker
  - — Fuel consumption = 3.5 GJ/t clinker
- Beijing Liulihe Cement Factory installed a 5-stage cyclone preheater, precalciner kiln
  - — Electricity consumption = 60 kWh/t clinker
  - — Fuel consumption = 3.0 GJ/t clinker ("domestic advanced level")

Low Temperature Heat Recovery for Power Generation

- 1995: demonstration project Anhui Ningguo cement plant for the installation of Japanese equipment on a 4000t/d kiln
  - — Capacity of the generator is 6.48MW**;** electricity generated per ton of clinker reached 35kWh
  - — Cost of 18,000 to 22,000 RMB per kW for installation capacity over 6MW
- Domestic technology developed in 1996
  - — Three Chinese companies now provide this technology domestically
  - — Domestic technology demonstration project utilizes the waste heat from two clinker kilns of Taishan Cement Ltd. (capacities of 5000t/d and 2500t/d).
  - — Recently registered as a CDM project
- Domestic technology compared to foreign technology:
  - — Domestic technology now producing 35 kWh/t clinker; foreign technology producing 45 kWh/t clinker
  - — Domestic investment = 6000 to 10,000 RMB ($50K-$80K); foreign investment = ~16,000 RMB ($130K)

Blended Cement

- Roughly 50% of total CO_2 emissions from cement production are from process emission related to clinker making

- Clinker can be partially be replaced by blending in other materials
  - Ground limestone
  - Blast furnace slags
  - Fly ash
  - Natural pozzolans

- Potential constrained by
  - Limits on application (cement grade)
  - Availability of blending material:
    - Slags: iron production
    - Fly-ash: coal-fired power stations
    - Natural pozzolans: volcanic material

Use of Waste-Derived Fuels

- Waste-derived fuels can replace commercial fossil fuels, resulting in net energy and cost savings
- Currently only a few cement plants in China burn any significant amount of waste fuels
  - — Beijing Cement Plant
    - Capacity to dispose of 10 kt per year of 25 types of waste
    - Burning solid waste from the chemical industry, some paints, solvents, and waste sludge from nearby water treatment facility
  - — Shanghai Jinshan Cement Plant
    - Burns sludge dredged from Huangpu Rivier
  - — Hong Kong Cement Plant
    - Purchases waste from other provinces
- Significant stockpiles of industrial waste in China

Summary

- Cement is a very important sector in China
  - Large and still growing
  - Both energy and process-related CO_2 emissions
- Many energy efficiency and CO_2 reduction opportunities
- Savings potentials vary by cement facility and region, as well as policy environment
  - Alternative fuels: availability
  - Blended cement: availability of blending materials, market for cement grade
  - Energy efficiency: facility equipment (kiln type, age etc.)
- 22 energy efficiency measures identified for cement kilns
  - 14 have payback periods of 3 years or less

For Further Information…

LBNL industrial website: industrial-energy.lbl.gov
LBNL China Energy Group website: china.lbl.gov

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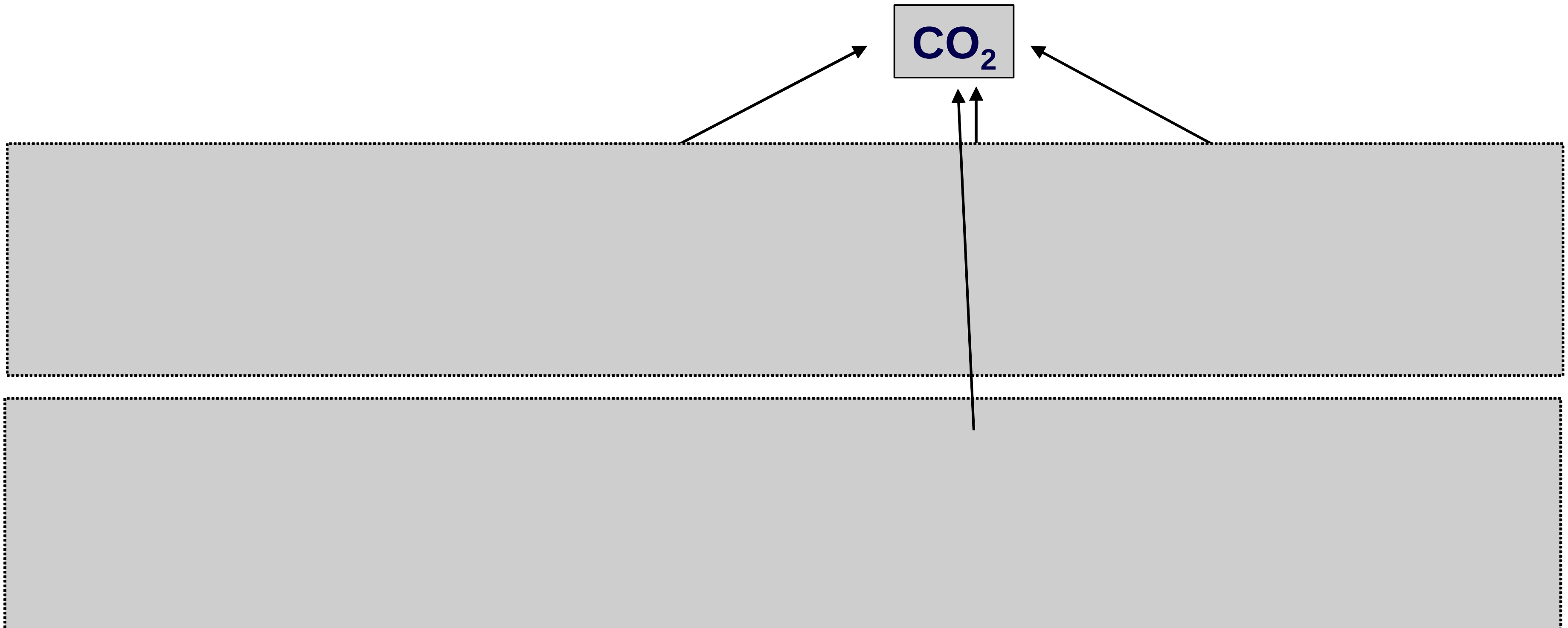
CO2 Emissions from Cement Production



Raw Materials Clinker Cement