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Carbon Capture and Storage: Opportunities in energy-intensive industry

Key Opportunities to Reduce Emissions in China's Cement Industry

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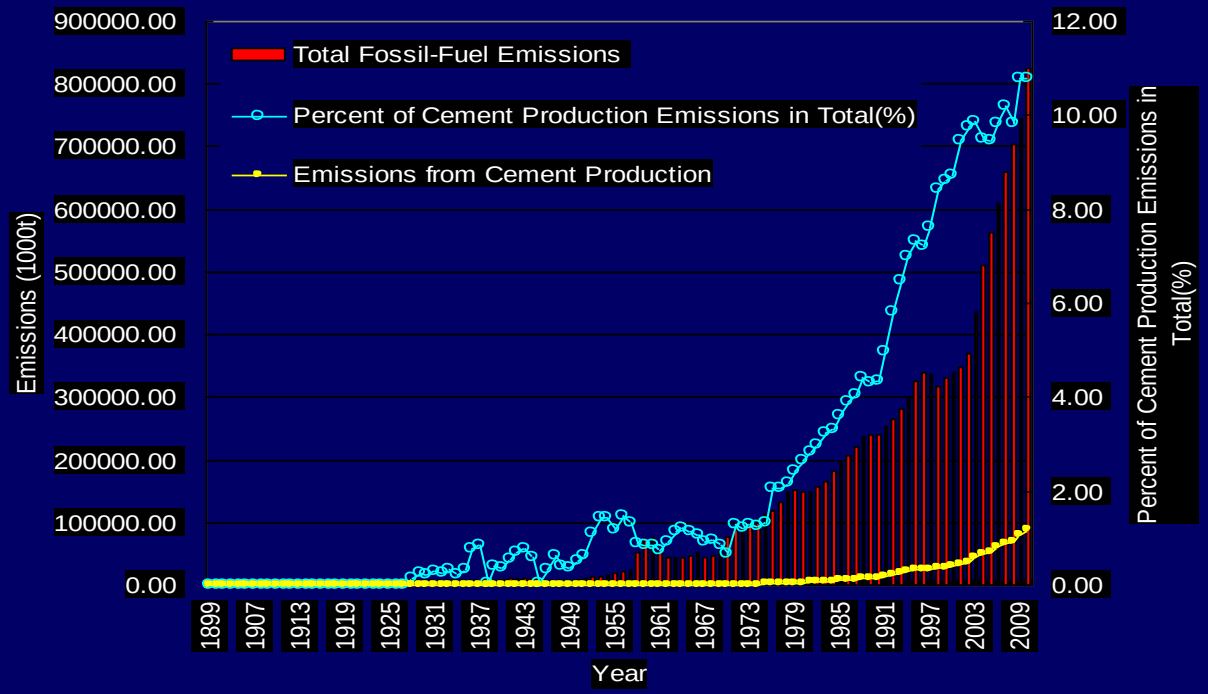
Outline

- Situation of Cement Production in China
- Trend Judgments to Emissions from China's Cement Production
- Forecast on Potentials of Emission Reduction from Cement Production
- Major Approaches to Reduce Emissions from Cement Production

Situation of Cement Production in China

- Apart from coal power and steel industry, the cement industry emits the largest amount of CO_2 in the industrial production.
  - Since 1985, China has been the largest cement producer in the world for consecutive years. It produced 1.63 billion tons of cement in 2009, accounting for more than 50% of the world production. Along with the escalation of cement production, CO2 emission from this process also increases year by year. In 2009, the cement production consumed 153 million tons of standard coal, approximately 6.6% of total energy consumption; the cement production emitted 840 million tons of CO2, approximately 9.85% of China's total coal emission.
  - Various international certification authorities' estimation of China's coal emission from cement production is 15%-45% higher than the actual amount.

Situation of Cement Production in China

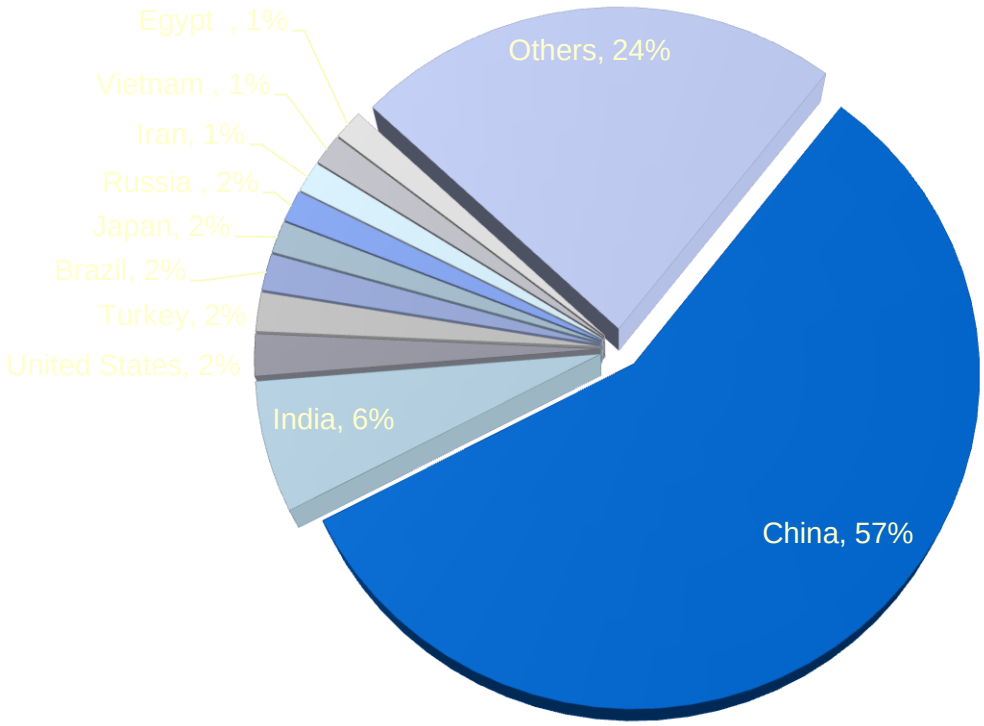


Carbon Emission from China's Cement Production (1950-2010)

Data Source: CDIAC, 2011

In 2009, China produced **1.63 billion tons** of cement, accounting for more than **50%** of the world production. The cement production consumed 153 million tons of standard coal, approximately 6.6% of total energy consumption; the cement production emitted **840 million tons of CO2, approximately 9.9% of China's total coal emission.**

The top 10 cement-producing countries in 2010 accounted for 76% of the total production , in which more than 50% manufactured in China.



List of top 10 countries (Mt)

Rank	country	production
1	China	1880
2	India	210
3	United States	67
4	Turkey	63
5	Brazil	59
6	Japan	52
7	Russia	50
8	Irane	50
9	Vietnam	50
10	Egypt	48

The top 10 countries and its proportion of the world's hydraulic cement production

Data sources: USGS(2010)

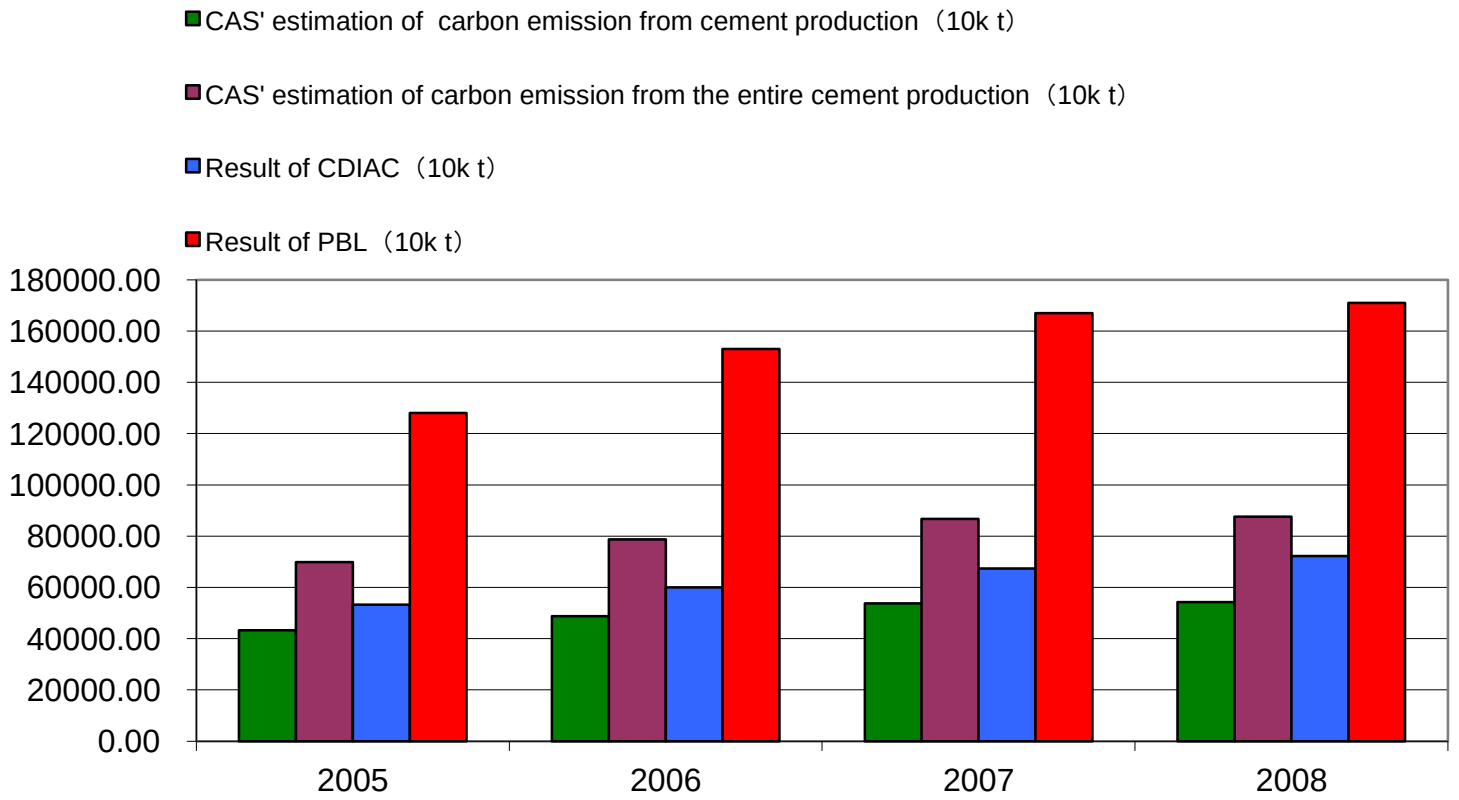
Estimate Differences of Various Agencies to China's Cement Production Emission

Year	2005	2006	2007	2008
Cement Production (10k t)	106884.79	123676.48	136117.26	142011.00
Clinker Production (10k t)	77900.00	87300.00	96200.00	97701.00
Export (10k t)	1078.49	1672.26	1781.41	1280.57
Import (10k t)	34.27	34.59	11.25	5.10
Carbon emission from material's carbonate decomposition (10k t)	41619.39	46887.94	51649.87	52180.39
Carbon emission from kiln dust's calcination in the cement kiln (10k t)	7104.98	8004.39	8817.31	8907.88
Carbon emission from the burning of organic carbon (10k t)	947.33	1067.25	1175.64	1187.72
Carbon emission from the burning of traditional fossil fuel (10k t)	18378.21	20704.69	22807.45	23041.72
Carbon emission from cement production's power consumption (10k t)	8233.88	9276.20	10218.29	10323.25
CAS' estimation of carbon emission from cement production (10k t)	43277.22	48755.63	53707.24	54258.90
CDIAC's result (10k t)	53300.13	60044.97	67320.02	72306.68
Deviation from the result of CDIAC (%)	18.80	18.80	20.22	24.96

The huge estimation difference is due to the inaccurate carbon emission factor, activity level and the conflicting research boundaries.

The data inversion (2005-2008) shows that CDIAC's result is **18.80%-24.96% higher** than our calculation of carbon emission from cement production.

PBL's result is **45.40%-48.76% higher** than our estimation of carbon emission from the entire cement production.



Situation of Cement Production in China

- During the eleventh five-year plan period, the industrial restructuring of China’s cement industry has reaped fruitful result. The new type of dry clinker production has accounted for 80% of the total capacity. Recently, the cement industry majorly transformed from eliminating the outdated capacity to improving the proportion of the non carbonate raw materials and enhancing the comprehensive utilization ration of fuel.
- In 2010, China produced 1.152 billion tons of cement clinker and 1.868 billion tons of cement. The per capita of cement production is 1.34 ton, far surpassing that of the developed countries in the industrialization phase. From 2005 to 1020, China’s ratio of cement clinker dropped from 0.73 to 0.62. It is estimated that China will emit 63.85185 million tons ofCO_2 by production and will comprehensively release 103.1157 million tons of CO_2 .

CO_2 Emission Estimates from Cement Production in China since 2005

Year	2005	2006	2007	2008	2009	2010
Cement production (10k t)	106884.8	123676.5	136117.3	142011	164558.5	186800
Clinker production (10k t)	77900	87300	96200	97701	103282.1	115200
Clinker ratio	0.73	0.71	0.71	0.69	0.63	0.62
Carbon emission from cement production (10k t)	43277.22	48755.63	53707.24	54258.9	57318.46	63851.85
Carbon emission from comprehensive cement production (10k t)	69889.32	78736.52	86732.98	87623.87	92564.82	103115.7

Trend Judgments to Emissions from China's Cement Production

- Judged by analyzing trends of industrialization and urbanization in China, the national cement production in 2010 has approached the maximum and it will not exceed 2 billion tons in 2020.
- The absolute amount of national cement production will probably drop in 2020, keeping the level of 2010.
- Due to the technology improvement, the clinker ration will decrease to 0.55, with the clinker scale in 2020 lower than that in 2010.
- Because of the higher proportion of the new dry method and the optimized production line, the power consumption per cement has further descended. In 2020, the total consumption of cement production will decrease to 110kg/t of standard coal.

Forecast on Potentials of Emission Reduction from Cement Production

- The estimated CO_2 emission reduction from 2008 to 2012 is above 3.3 billion tons; it will be 12.8% in 2020, if replaced by furnace slag, improving thermal efficiency, and using alternative fuels.

Forecast on Potentials of Emission Reduction from Cement Production

- Assumed the national cement production is 2 billion tons in 2020, the potentials of the emission reduction will be as follows:
- First, reduce the emission from cement production. The CO_2 emission from per unit cement will descend 300-350kg. The proportion of low-carbon cement will be 5% in 2020 and CO_2 emission will decrease by 30-35 million tons.
- Secondly, the clinker ratio will drop from 62% to 55%, and the CO_2 emission will descend 49.28 million tons.
- Thirdly, the comprehensive power consumption per ton of cement will descend 40kg standard coal, 30-35kg of which is from fossil fuel. CO_2 emission will drop by 192-224 million tons.
- In conclusion, the estimated emission reduction of China's cement industry will be 271.3-308.3 million tons in 2020.

Major Approaches to Reduce Emissions from Cement Production

1. Alternative materials

- Industrial waste. Both blast furnace slag and coal ash contain CaO. Replacing 1t CaCO with 1t blast furnace slag reduces 35kg CO2 emission. China produces 1.2~1.5×108t blast furnace slag a year, and therefore 4.2~5.25×106 t of CO_2 can be reduced.
- Carbide slag in chemical industry mainly contains $Ca(OH)_2$. CO_2will not be emitted if replacing CaCO with carbide slag. Despite carbide slag's good performance in reducing emission, it will be restricted and impacted by the supply.

Carbide Slag Replace CaCO to Reduce CO_2 Emissions

Project	1000t / d Production line	2000t / d Production line	2500t / d Production line
Clinker production (10^4 t / a)	30	60	75
CO_2 emission reduction per ton of clinker (t / tCli.)	0.511	0.511	0.511
Annual CO_2 emission reduction (10^4 t / a)	15.33	30.66	38.33

Major Approaches to Reduce Emissions from Cement Production

2. Change the Chemical Composition of Clinker

- CaO is the main ingredient of ordinary portland cement clinker, accounting for about 65%. If the clinker's CaO content can be reduced, the $CaCO_3$ required by clinker's production can be decreased accordingly. Therefore, it will effectively reduce the CO_2 emission. Saturation factor and silica modulus adjust the chemical composition of the cement clinker. If the saturation factor is reduced from 0.95 to 0.88, the ratio of CaO in the clinker will drop from 68% to 64%, and the CO_2 emission per ton of cement clinker's production will descend 30 kg.
- Adding C_2S to belite minerals as raw materials would reduce the sintering temperature. In addition, the low calcium silicate cement added with belite minerals has higher resistance to stress than the ordinary portland cement. It will also reduce the CaO in clinker to 45%. Producing per ton of clinker will reduce 16 million tons of CO_2 emission less than the ordinary portland cement clinker.

Major Approaches to Reduce Emissions from Cement Production

3. Reduce the amount of clinker and add mineralizer

- Improve the proportion of non-carbonate material and reduce the amount of clinker, such as fly ash, coal gangue, tailings, water granulated slag, steel slag, urban garbage;
- Use mixed materials to improve the quality of clinker. 1% increase in the amount of mixed material will reduce 1% of cement clinker and 1% of CO_2 emissions per ton of cement;
- Add active material such as fly ash when mixing concrete. It will not produce emissions, because it can't reach the CO_2 decomposition temperature;
- Adding mineralizer can control the generation process of clinker, which reduces the decomposition temperature of $CaCO_3$, the coal consumption and carbon emissions.

Major Approaches to Reduce Emissions from Cement Production

4. Use alternative fuels and reduce the consumption of fossil fuels

- Main alternative fuels: waste tires, plastic, polymer fabrics, waste wood, animal bones, urban burnable garbage;
- Replacing coal with combustible industrial waste is highly effective. After the replacement, the annual CO_2 emission reduction of each 1000t/d production line is 0.93 million tons, with emission reduction ratio of 9.17%; the annual CO_2 emission reduction of each 2000t/d production line will be 19.8 thousand tons, with emission reduction ratio of 9.38%; the annual CO_2 emission reduction of each 5000t/d production line is 46.5 thousand tons, with emission reduction ratio of 9.37%;
- Directly using cement rotary kiln to incinerate municipal solid waste will reduce 2.25% of CO_2 emissions, with a poor effect. Setting a garbage incineration system next to the cement rotary kiln can reduce emissions by 6.3%, with an obvious effect.

Major Approaches to Reduce Emissions from Cement Production

CO2 emissions reduction comparison on the rotary garbage burned in rotary kiln directly and installed system near the garbage incineration

Project	1000t / d Production line		2000t / d Production line		5000t / d Production line	
	Method1	Method2	Method1	Method2	Method1	Method2
CO_2 emission reduction, 10^4 t / a	0.24	0.63	0.48	1.26	1.05	3.45
CO_2 emission reduction ratio, %	2.37	6.21	2.27	5.97	2.11	6.95

Method1: Direct incineration

Method2: Set a waste incineration system next to the rotary kiln

Major Approaches to Reduce Emissions from Cement Production

5. Further raise the recycling levels of cement kiln waste heat
   - Optimize the scale of the cement production line, improve power generation capacity of the waste heat, and enhance the proportion of waste heat in the precalciner stage;
   - Reduce grinding power consumption, improve the two grinding equipment and be committed to the research and development of the grinding equipment with low power consumption.

The effect of CO_2 emissions in using waste heat power to different scale cement production line

Project	2500t / d	5000t / d
Installed capacity (MW)	4.5	7.5
Genaration power (Kw)	3.4~3.8	6.8~8.8
Annual power production(10^4 kWh)	2520	5400
Annual decrease of standard coal (t)	8971.2	19234
annual CO_2 emission reduction (t)	21344.4	45738

Major Approaches to Reduce Emissions from Cement Production

6. CO_2 Capture, Storage and Subsidence (CCS)

- Pre-combustion capture is not easy to achieve, and only 10% of CO_2 can be captured after the combustion. So capture during the combustion is the best choice;
- Carbon can be sequestrated in oil and gas fields, traps without hydrocarbon, and deep saline aquifers;
- Carbon subsidence includes absorption by the oceans, forests and agricultural soils through photosynthesis, and carbonation (CO_2 in the atmosphere seeps into the concrete, reacts with the moisture $Ca(OH)_2$ and forms $CaCO_3$).

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Thank you!