# De-polluting China's cement industry while improving cement quality and the energy and production structure

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## Introduction

China's cement industry:

- has produced 50%-60% of the world's cement in recent decades;
- has accounted for 6.8% of China's total energy consumption;
- contributed about 8% of the total anthropogenic $CO_2$ emissions;

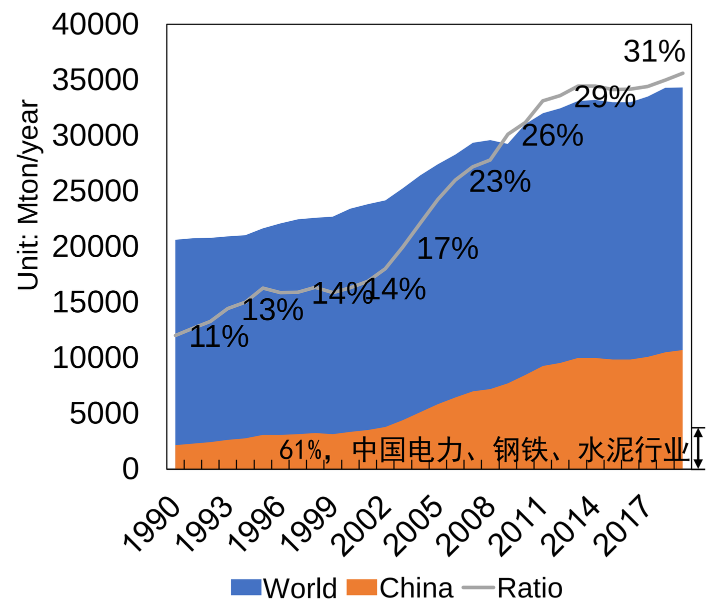



Fig. 1 Anthropogenic $CO_2$ emissions

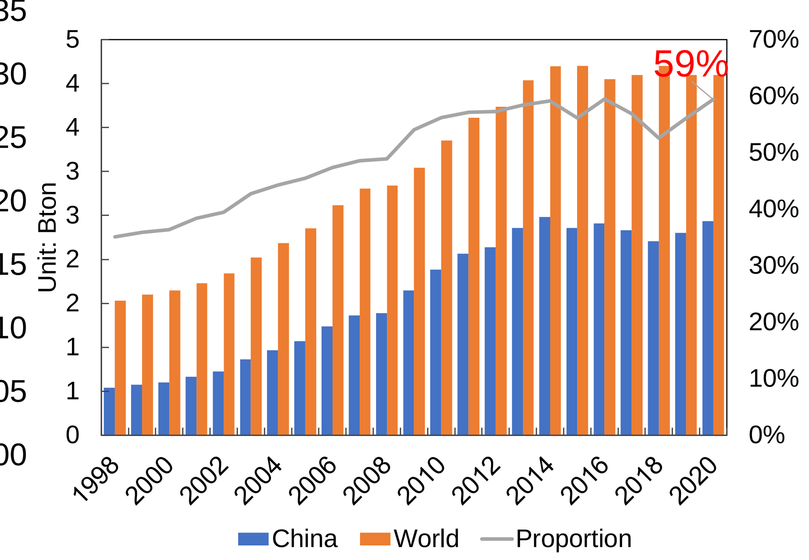



Fig. 2 Cement production

## Research problems

- The future cement demand has usually been estimated based on empirical experiences or the correlations of demand with population and economic development. **More detailed estimates of the future cement demand will have to be realized by categorically considering the end-user demand trends;**
- Differences in the **cement quality** and the corresponding environmental effects will need to be fully considered when analyzing the low-carbon development of cement going forward;
- Detailed estimates of the potentials of **energy and material substitutions** will also be needed;
- Electricity consumption and related **indirect emissions** need to be accounted for when discussing the effects of decarbonization measures.

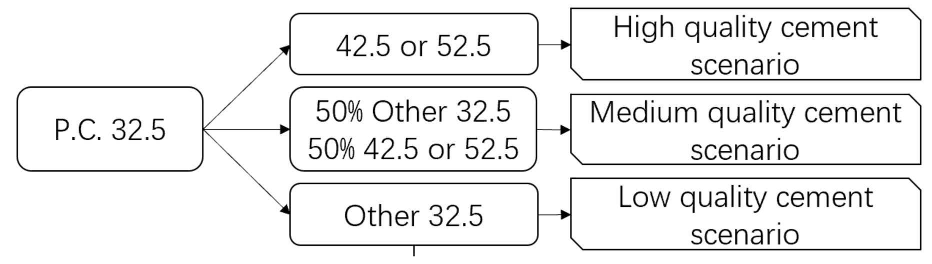
## Research Methodologies

- Provincial demand projection model and provincial bottom-up Integrated Assessment Model, AIM/Enduse[China-Cement],
- Given that construction-related sectors account for most of the cement consumption, we classify the ultimate cement consumers into 13 categories:

$$D_t = C_{BD} + C_{RD} + C_{SP} + C_{RW} + C_{AgI} + C_{TL} + C_{OT}$$

$$C_i = P_i * CUR_i$$

- The cement quality is classified into three levels: high-quality cement (compressive and flexural strength: 52.5 and 62.5), regular-quality cement (C&F: 42.5), and low-quality cement (C&F: 32.5).




## Research results-future demand

The future cement demand is estimated based on the development of downstream industries and the corresponding cement intensity.

- the estimated historical cement consumption rose from 1,332.5 million tons (Mton) in 2007 to 2,484.8 Mton in 2014, then held steady at about 2,400 Mton from 2015 to 2020;
- The differences between the estimated results and statistical data published by the National Bureau of Statistics (NBS) range between -5% and 7.8%;
- In the low-cement-demand scenario, cement production fluctuates up to 2,635.4 Mton in 2060.

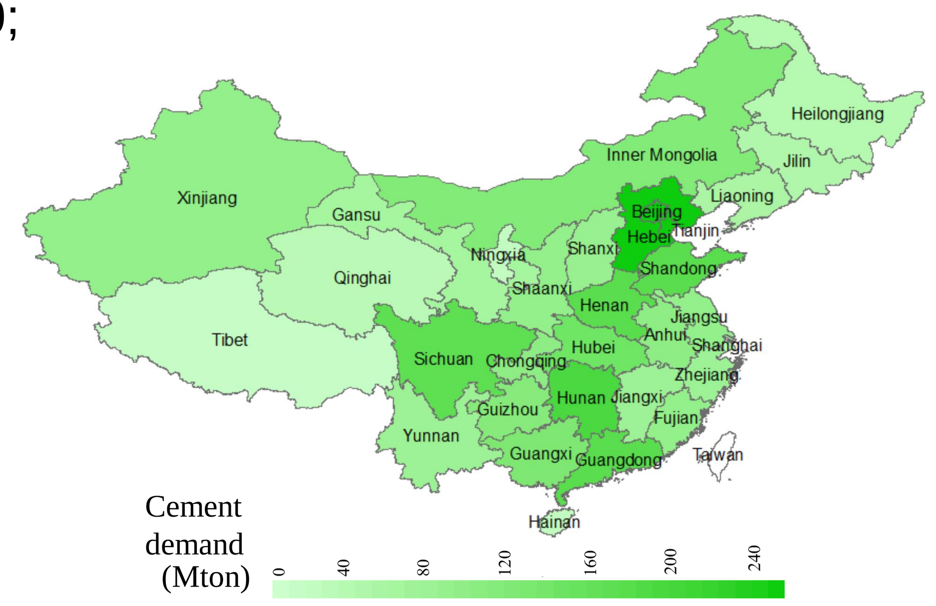


Fig. 3 Provincial cement demand in 2060

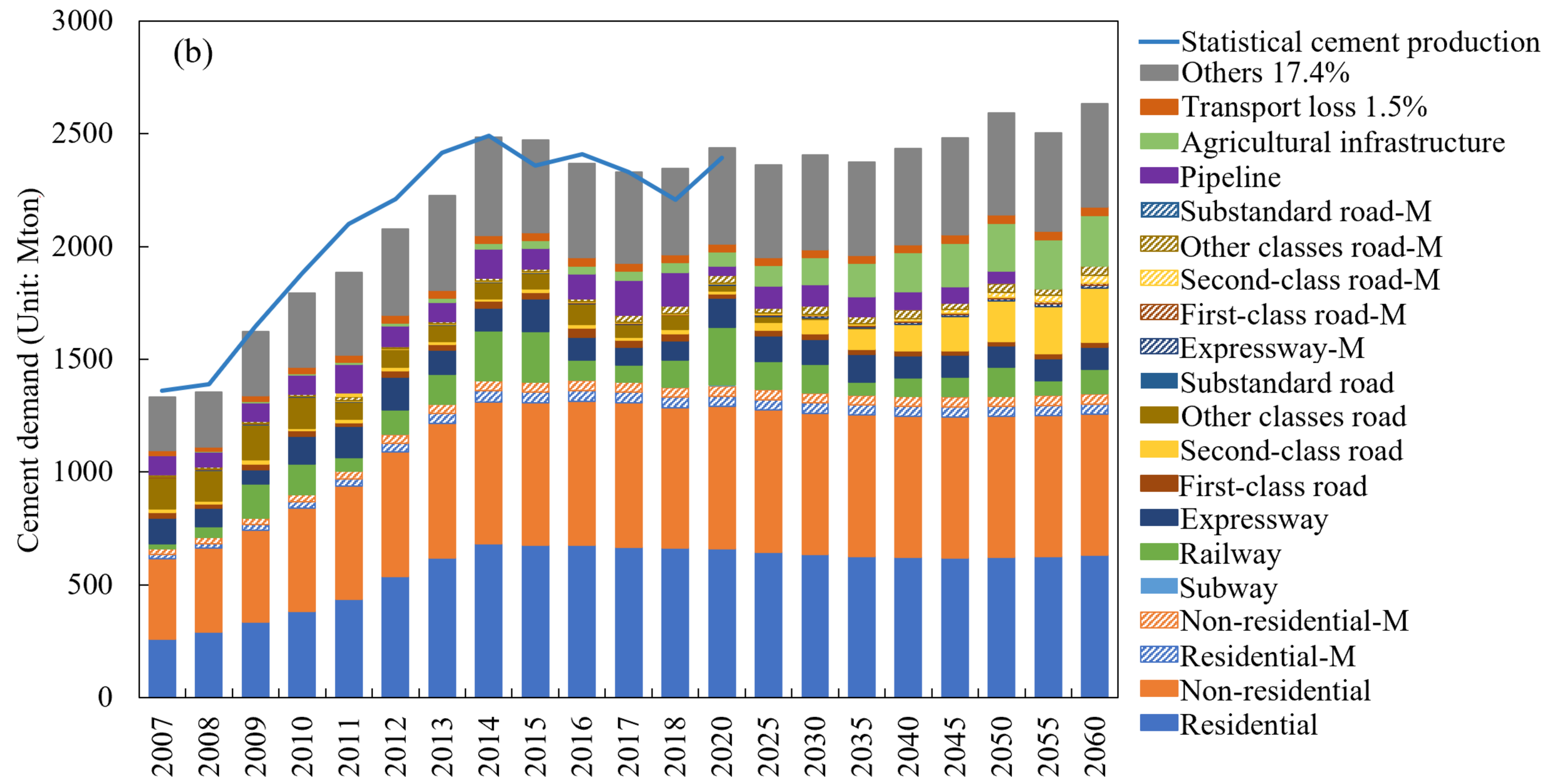



Fig. 4 Historical and future cement demand estimates for different categories under the low-cement-demand scenario (Note: M stands for "maintenance")

The best practice measures can reduce energy consumption and emissions of high-quality cement production faster than low-quality cement production.

## Research results-energy consumption

- Cement is produced by mixing clinker with gypsum and other materials. More clinker is consumed to produce cement of higher quality, which results in higher emissions and incurs higher costs for consumers.
- The clinker-to-cement ratio (C2Cr) increases from 59.3% in 2020 to 59.5%, 63.8%, and 68.0% by 2060 in the low-, medium-, and high-cement-quality scenarios, respectively.

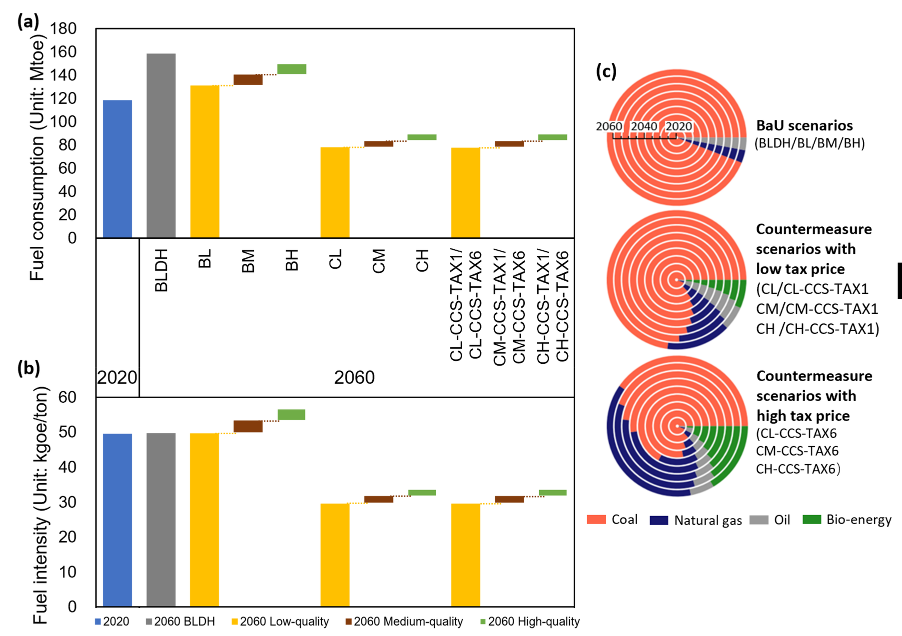


Fig. 6 Time series fuel consumption (a), fuel intensity (b), and fuel structure (c) of the cement industry under different scenarios up to 2060

- Kilns and preheating devices are the major consumers of fossil fuels in cement production.
- Electricity consumption of the kiln process surges by 263.7% in tax scenarios compared to the BaU scenarios in 2060, as CCS is installed in the kilns.

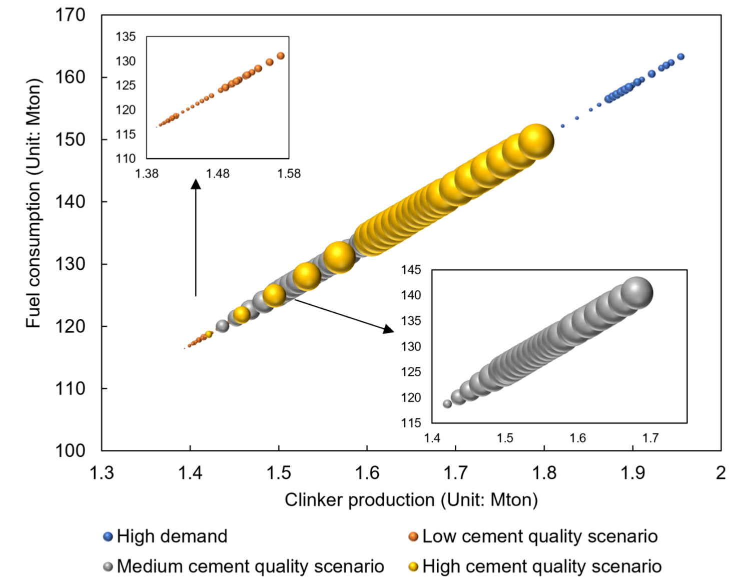


Fig. 5 Clinker production under different crude steel demands (x axis) and corresponding fuel consumption in the BL-DH, BL, BM, and BH scenarios (y axis), the bubble size indicates the clinker-to-cement ratio (C2Cr) (the range is 59.0%-68.1%)

- Fuel consumption is 40.5% lower in the countermeasure scenarios with technological development (CL, CM and CH) than in the corresponding BaU scenarios in 2060. Tax policy alone has less impact on energy conservation than the non-tax scenarios.

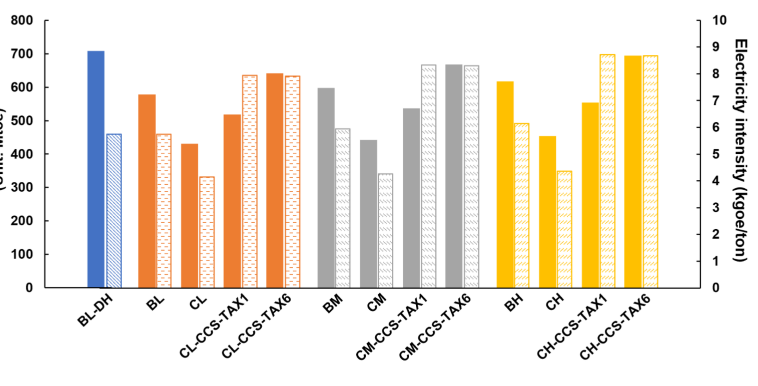


Fig. 7 Cumulated electricity consumption of the cement industry from 2020 to 2060 (solid bar, left axis) and electricity intensity of the industry in 2060 (shaded bar, right axis)

## Research results-emissions

- Direct emissions from fuel combustion and indirect emissions from electricity consumption are both considered in this research.
- With technological progress in the countermeasure scenarios without tax (CL, CM, CH), CO2 emissions fall by 19.2% from 2020 to 2060. With the incentives from the carbon and environmental tax policies in place, the widespread adoption of CCS leads to CO2 emission reductions of 71%-74% and 75%-78% during the research period in the low-tax scenarios
- Because of the increased biomass consumption, CH4 emissions increase by up to 343.1% from 2020 to 2060 under the high-quality-cement-and-high-tax scenario (CH-CCS-TAX6).
- N2O, NOx, PM, and CO emissions fall by 32.5%, 59.1%, 53.8%, and 53.6%, respectively, during the research period.
- Deployment of advanced technologies can provide sustained incentives to reduce emissions.

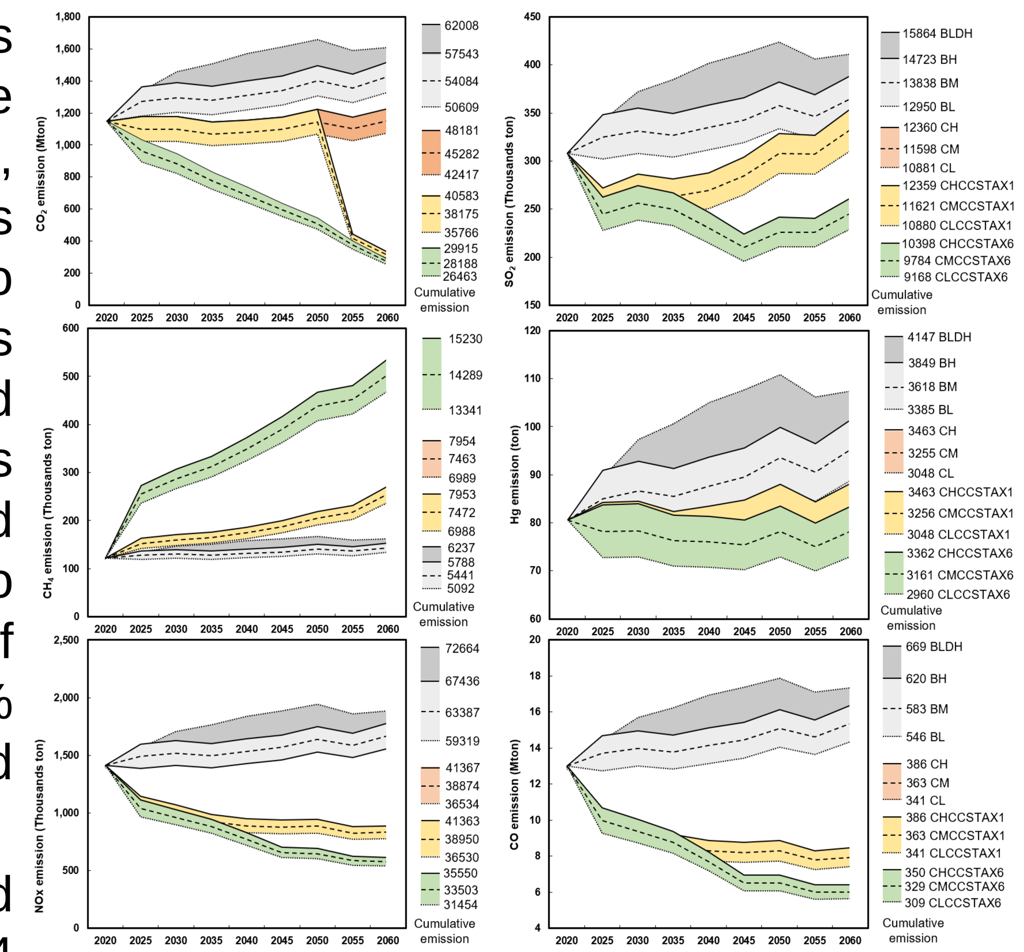


Fig. 8 Time series (line graph) and cumulative emissions (bar chart) of $CO_2$ and air pollutant during the research period (unit: thousands ton) from the cement industry under different scenarios

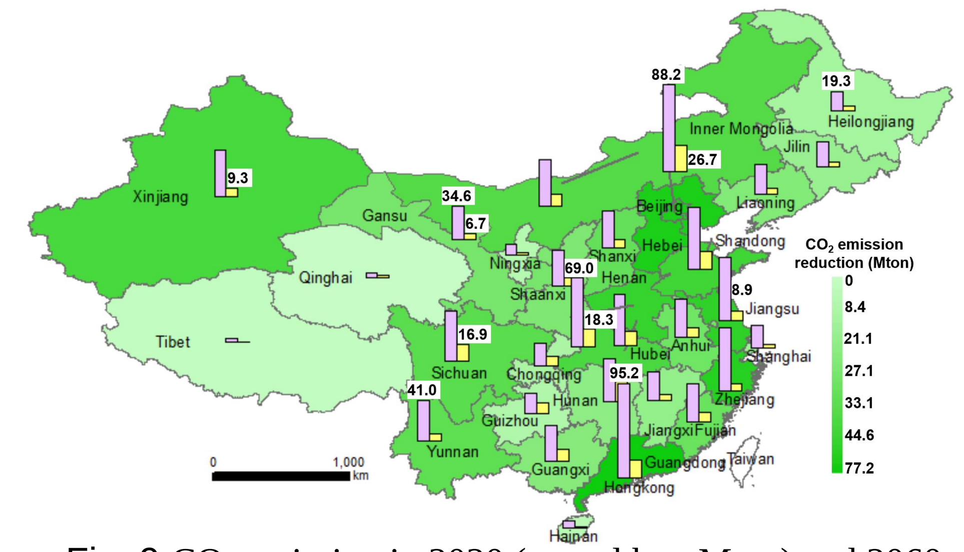


Fig. 9 $CO_2$ emission in 2020 (purpal bar, Mton) and 2060 (yellow bar, Mton), and $CO_2$ emission reduction from 2020 to 2060 (gradient green, Mton) in CH-CCS-TAX6 scenario