THE GNCS FACTSHEETS

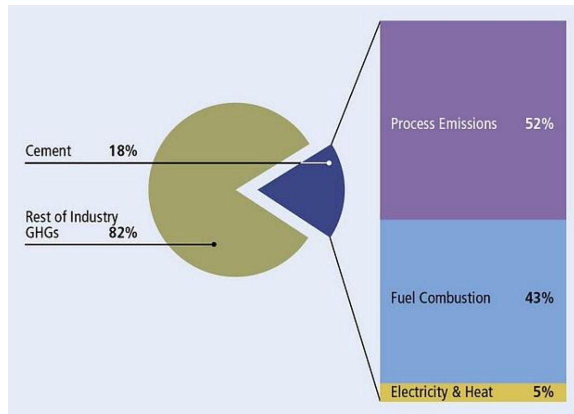
Mitigating Emissions from Cement

Approximately 5% of global carbon dioxide (CO_2) emissions result from cement production.[1] The second-most consumed substance on Earth after water,[2] cement is the primary component of concrete and is required globally for construction and transportation infrastructure. China is the world's largest producer of cement (47% in 2005), followed by India and the US.[3] Cement production is largely driven by domestic consumption due to the ready availability of materials[4] and high transportation costs,[5] though there is an international cement trade.[6] Cement consumption is growing at 2.5% annually,[7] and at current technological levels and efficiency rates, CO_2 emissions from the cement industry are expected to rise from 2,297 million tons (Mt) in 2005 to 3,486 Mt by 2020.[8]

Emissions from Cement Production

Cement production is both energy and emissions intensive: 60–130 kg of fuel and 110 kWh of electricity are required to produce a ton of cement,[9] leading to emissions of around 900 $kgCO_2/t$.[10] Emissions result from *direct energy-related emissions* (from fossil fuel combustion used to heat the kiln; 40% of emissions); *indirect energy-related emissions* (from electricity consumption used to power machinery; 5–10% of emissions); and *process-related emissions* (due to calcination, whereby limestone releases CO_2 as it is heated in the kiln and transformed into clinker, the main component of cement; 50% of emissions).[11]

GHGs from Cement Manufacture



Source: WRI (2005), p. 74

The emissions intensity of cement production varies from 700 $kgCO_2$ per ton of cement in Western Europe to 900–935 $kgCO_2/t$ in China, India and the US.[12] This variation is due to the fuel used for combustion (most commonly coal and petroleum coke);[13] the efficiency of the plant and type of kiln; the clinker-to-cement ratio (higher clinker content results in more emissions from calcination); and the carbon intensity of electricity inputs.[14]

Mitigation Potential and Challenges

Emissions from direct energy use (fossil fuel combustion to heat the kiln) can be reduced through fuel switching and efficiency measures. Alternative fuels include natural gas, biomass and waste-derived fuels such as tires, sewage sludge and municipal solid wastes.[15] The use of alternative fuels has the potential to reduce overall cement emissions by 18–24% from 2006 levels by

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[1] IPCC. (2007). *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report*. Intergovernmental Panel on Climate Change. Section 7.4.5.1: Minerals – Cement.
[2] WBCSD. (2009). *Cement Technology Roadmap 2009: Carbon Emissions Reductions up to 2050*. World Business Council for Sustainable Development. p. 2; UNEP. (2010). *Greening cement production*. United Nations Environment Programme.
[3] IPCC (2007).
[4] Worrell *et al*. (2001). "Carbon Dioxide Emissions from the Global Cement Industry." *Annual Review of Energy and Environment*, 26. p. 304.
[5] Akashi et al. (2010). "A projection for global CO_2 emissions from the industrial sector through 2030 based on activity level and technology changes." *Energy*: 1-13. p. 3.
[6] An estimated 6–7% of total cement production enters the world market (Ocean Shipping Consultants, 2010); China exported less than 1% of its cement in 2002 (Cement Trade, n.d.).
[7] IPCC (2007).
[8] Akashi *et al*. (2010), p. 5.
[9] UNEP (2010).
[10] Ba-Shammakh *et al*. (2008). "Analysis and Optimization of Carbon Dioxide Emission Mitigation Options in the Cement Industry." *American Journal of Environmental Sciences*, 4(5): 482-490. p. 482.
[11] WRI. (2005). *Navigating the Numbers: Greenhouse Gas Data and International Climate Policy*. World Resources Institute. p. 74.
[12] IPCC (2007). Kim and Worrell. (2002). "CO_2 Emission Trends in the Cement Industry: An International Comparison." *Mitigation and Adaptation Strategies for Global Change*, 7: 115-133. p. 120.
[13] Ba-Shammakh *et al*. (2008), p. 483; WBCSD (2009), p. 9.
[14] See IPCC (2007) and Kim and Worrell (2002).
[15] Ba-Shammakh *et al*. (2008), p. 485; IPCC (2007), Section 7.4.5.1. Waste derived fuels have numerous limitations, including other negative environmental impacts: see Worrell *et al*. (2001), p. 319; Ba-Shammakh *et al*. (2008), p. 485; and Garza. (2009). "CO2 Mitigation Opportunities and Challenges in the Cement Industry." Presentation. Sept 2009. Slide 9.

2050.[16] Efficiency improvements can reduce emissions by addressing the production process (e.g., switching from inefficient wet to dry kilns, adjusting fan speed for greater efficiency) and through technical and mechanical improvements (i.e., preventative maintenance to repair kiln leaks, more efficient motors, updating fuel systems to accept alternative fuels).[17] While some estimates of potential energy efficiency improvements are as high as 40%,[18] industry analyses suggest this potential may be much more limited.[19] North American producers have voluntarily pledged to reduce emissions intensity by 10% and improve energy efficiency by 20% from 1990 levels by 2020,[20] but these pledges are in fact roughly in line with historical trends of efficiency gains in the industry.[21]

Emissions from the calcination process can be addressed through the use of blended cement, whereby some of the limestone-based clinker is replaced by other "cementitious" materials (primarily coal fly ash and blast furnace slag).[22] Using these substitutes not only reduces emissions from calcination, but can also improve fuel efficiency by enhancing the burnability of raw materials.[23] Blended cement could reduce CO_2 emissions by as much as 20% of total cement emissions.[24] Its potential is highest in countries like China, where cement production is high and substitution materials are plentiful.[25] Barriers to the use of blended cement include other environmental regulations,[26] cement standards and building codes, the limited application of blended cement, the added cost of blending materials ($15–30/t)[27] and their availability.[28]

Mitigation Costs

A study analyzing cost optimization for different emissions reduction targets found that reducing emissions by up to 50% would increase the cost of producing cement by around 55%.[29] Notably, the model optimized costs through efficiency improvements for emissions reduction targets up to 10%, adding in fuel switching to meet targets of 20–30%, and beyond that by also employing carbon capture and storage (CCS).

Production cost increases for CO_2 reduction targets

% CO_2 reduction	*5*	*10*	*20*	*30*	*50*
% cost increase	2.9	7.3	17.4	33.2	55.4

Source: Ba-Shammakh *et al.* (2008), p. 488

Future Mitigation Potential

As in other industries, CCS could reduce emissions from cement production. The cost of CCS for cement would be roughly $75–100/t$CO_2$, raising production costs by 40–90%.[30] With enough public and private investment to demonstrate and scale up CCS for cement, it could abate 400–1,400 MtCO_2 emissions per year by 2050.[31]

Concrete can actually serve as a sink for CO_2 through the process of accelerated carbonation. This occurs naturally when CO_2 penetrates concrete in the presence of water and reacts with calcium hydroxide to form calcium carbonate,[32] which results in stable, long-term CO_2 storage.[33] As a mitigation technology, accelerated carbonation is achieved by exposing freshly mixed concrete to flue gases high in CO_2.[34] Research has also begun on using waste concrete to capture CO_2 from ambient air,[35] which has low cost (estimated at $8/t$CO_2$) but small-scale (up to 4 MtCO_2 per year) potential for early application.[36] Additional research is needed to clarify the global sequestration potential of cement and to estimate costs on a larger scale.[37]

Madeleine Rubenstein; series editor Nico Tyabji
Further resources are available at **www.theGNCS.org**

[16] WBCSD (2009), p. 11.
[17] Ba-Shammakh *et al.* (2008), p. 484.
[18] Worrell *et al.* (2009), p. 14. WBCSD (2009: 6) says that state-of-the-art technologies can improve thermal efficiencies by up to 3.5 GJ/ton.
[19] Garza (2009), slide 7.
[20] US and Canada industry pledges through the Portland Cement Association. See Portland Cement Association. (2009). *Report on Sustainable Manufacturing.* Portland Cement Association. p. 3.
[21] See Kim and Worrell (2002), p. 126.
[22] Worrell *et al.* (2001), p. 324.
[23] Ba-Shammakh *et al.* (2008), p. 485.
[24] Worrell *et al.* (2001), p. 324.
[25] Worrell *et al.* (2001), p. 325.
[26] Some by-products contain traces of heavy metals and other volatile materials. *Ibid.*, p. 324.
[27] *Ibid.*, p. 325.
[28] Garza (2009), slide 10.
[29] Ba-Shammakh *et al.* (2008), p. 488.
[30] For an overview of CCS for the cement industry see: IEA. (2008). *CO_2 Capture and Storage*. Paris: International Energy Agency. p. 69.
[31] Ibid. and WBCSD (2009), p. 14.
[32] Rehan. (2005). "Carbon dioxide emissions and climate change: policy implications for the cement industry." *Environmental Science and Policy* 8: 105-114. p. 112.
[33] In the field, storage potential varies according to humidity level, temperature, and the permeability of the concrete. *Ibid*., p. 112.
[34] Although the magnitude of sequestration potential is still uncertain, some estimates place it at close to 20% of all cement-related CO_2 emissions. See Hamilton. (2008). " A Concrete Fix to Global Warming." *MIT Technology Review*. 23 July 2008.
[35] Stolaroff *et al.* (2005). "Using CaO- and MgO-rich industrial waste streams for carbon sequestration." *Energy Conversion and Management*, 46: 687-699. p. 688
[36] *Ibid*., p. 689, 697.
[37] Rehan (2005), p. 112.