THE GNCS FACTSHEETS

Mitigating Emissions from Cement

Approximately 5% of global carbon dioxide (CO₂) 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 materials⁴ and high transportation costs,⁵ though there is an international cement trade.⁶ 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 kgCO₂/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 CO₂ as it is heated in the kiln and transformed into clinker, the main component of cement; 50% of emissions).¹¹

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The emissions intensity of cement production varies from 700 kgCO₂ per ton of cement in Western Europe to 900–935 kgCO₂/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

³ IPCC (2007).
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).
2050. 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). While some estimates of potential energy efficiency improvements are as high as 40%, industry analyses suggest this potential may be much more limited. North American producers have voluntarily pledged to reduce emissions intensity by 10% and improve energy efficiency by 20% from 1990 levels by 2020, but these pledges are in fact roughly in line with historical trends of efficiency gains in the industry. 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). Using these substitutes not only reduces emissions from calcination, but can also improve fuel efficiency by enhancing the burnability of raw materials. Blended cement could reduce CO₂ emissions by as much as 20% of total cement emissions. Its potential is highest in countries like China, where cement production is high and substitution materials are plentiful. Barriers to the use of blended cement include other environmental regulations, cement standards and building codes, the limited application of blended cement, the added cost of blending materials ($15–30/t) and their availability.

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%. 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).

<table>
<thead>
<tr>
<th>% CO₂ reduction</th>
<th>5</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>% cost increase</td>
<td>2.9</td>
<td>7.3</td>
<td>17.4</td>
<td>33.2</td>
<td>55.4</td>
</tr>
</tbody>
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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/tCO₂, raising production costs by 40–90%. With enough public and private investment to demonstrate and scale up CCS for cement, it could abate 400–1,400 MtCO₂ emissions per year by 2050.

Concrete can actually serve as a sink for CO₂ through the process of accelerated carbonation. This occurs naturally when CO₂ penetrates concrete in the presence of water and reacts with calcium hydroxide to form calcium carbonate, which results in stable, long-term CO₂ storage. As a mitigation technology, accelerated carbonation is achieved by exposing freshly mixed concrete to flue gases high in CO₂. Research has also begun on using waste concrete to capture CO₂ from ambient air, which has low cost (estimated at $8/tCO₂) but small-scale (up to 4 MtCO₂ per year) potential for early application. Additional research is needed to clarify the global sequestration potential of cement and to estimate costs on a larger scale.

Madeleine Rubenstein; series editor Nico Tyabji

Further resources are available at www.theGNCS.org

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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.
23 Ba-Shammakh et al. (2008), p. 485.
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.
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 CO₂ emissions. See Hamilton. (2008). “A Concrete Fix to Global Warming.” MIT Technology Review. 23 July 2008.
36 Ibid., p. 689.
37 Rehan (2005), p. 112.