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Cement: Background and Low-Carbon Production

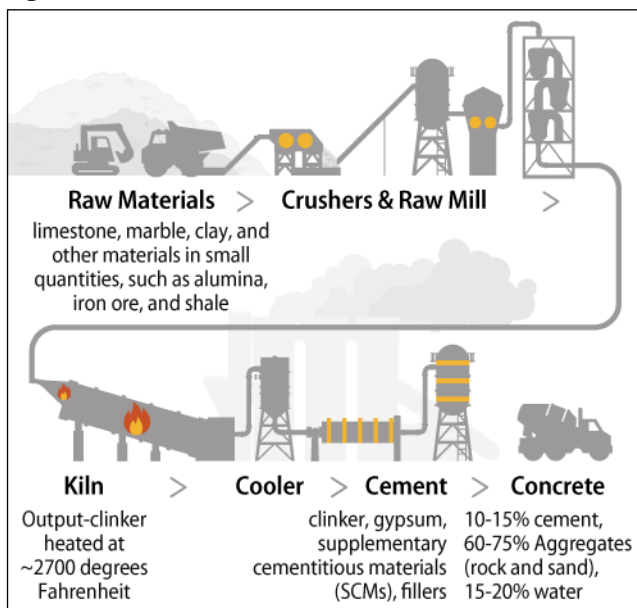
Though *cement* and *concrete* are often used interchangeably, they are two different yet related materials. Concrete is the finished composite that contains cement, along with other ingredients, with extensive use in the built environment in buildings, bridges, dams, and roads. Concrete is the world’s most consumed material after water, and global demand for one of its necessary inputs—cement—is expected to increase from 4.2 billion metric tons (MT) today to 6.2 billion MT by 2050.

Cement manufacturing contributes approximately 7% of global carbon dioxide emissions, making it one of the highest-emitting industrial sectors. Given the size of the global cement sector, its transition to low-carbon production is expected to play an important role in reducing the industry’s global carbon dioxide emissions.

The Cement Manufacturing Process

Cement production begins with the mining of materials, such as iron ore, limestone, and shale. Once quarried, these materials are mixed together, placed in a kiln, and heated at extremely high temperatures (approximately 2700°F), yielding what is called *clinker*—small grey balls roughly the size of marbles. Cement mills then grind clinker down to a fine powder and mix in additives to produce cement. Cement comprises 10%-15% of concrete mix (Figure 1).

Figure 1. Cement Production Chain



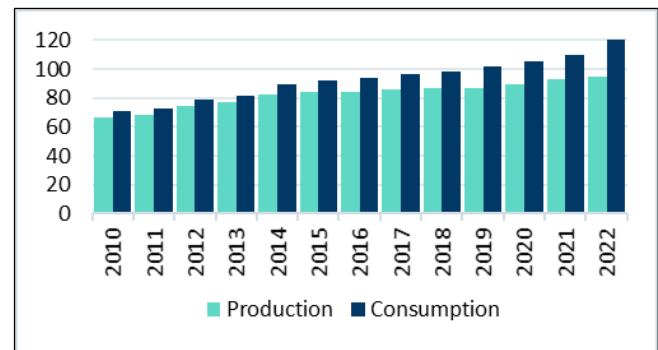
Source: CRS from Ankit Kalanki and Dongyi Wang, “Bringing Low-Carbon Cement to Market,” Third Derivative, June 30, 2022.

U.S. Production, Consumption, and Use

In 2022, the United States produced 95 million MT of cement, making it the fourth-largest producer, representing 2% of the 4.1 billion MT produced globally. China is the world’s largest cement-producing country, accounting for more than 50% of global supply.

In 2022, the United States imported 25.1 million MT of cement, supplying 21% of the U.S. market, which totaled 120 million MT. The U.S. Geological Survey indicates that between 2018 and 2021, the four largest import sources of cement were Canada, Turkey, Greece, and Mexico, in that order, accounting for a combined 75% of total cement imports. Over the past decade, U.S. cement consumption increased each year. U.S. cement production also increased yearly, albeit at a slightly slower pace (Figure 2).

Figure 2. U.S. Cement Production and Consumption
Million metric tons



Source: U.S. Geological Survey, Mineral Commodity Summaries, “Cement Statistics and Information.”

Demand for cement is cyclical and depends on the level of new construction—an interest-rate sensitive sector. Ready-mix concrete producers account for up to 75% of the industry’s annual shipments. Ready-mix concrete is used in varied construction and infrastructure activity (e.g., industrial, residential, and transportation-related). Recent data trends in demand for cement have provided conflicting results. For example, U.S. durable goods shipments of nonmetallic mineral products—an indicator of cement and concrete demand—rose 1.8% year-to-date in September 2023, compared with the same period in 2022. By contrast, the value of U.S. residential construction spending—another determinate of demand for building materials—fell 2.1% year-to-date in September 2023, compared with the same period in 2022.

Economic forecasts from the Portland Cement Association (PCA) estimate cement demand to decline 2.9% through 2023—the first time in over a decade—as the U.S.

economy is gradually weakening based on a tightening of monetary policy. PCA expects cement consumption to rebound by 1.4% in 2024 and continue to rise consecutively each year through 2028.

Cement is a basic commodity product, which means the industry's customers are generally price-sensitive. Prices fluctuate due to changes in supply and demand and are also affected by general economic conditions. Cement prices, on a tonnage basis, have increased in recent years in the United States from \$121 in 2018 to \$142 in 2022, a 17% rise. High production costs and increased demand have contributed to rising cement prices.

Low-Carbon Cement

The chemical reaction inherent in cement making—*calcination to produce clinker*—accounts for about 60% of the industry's carbon emissions. The remainder comes from direct and indirect processes (e.g., fossil-fuel combustion and energy use). Kilns and precalciners consume around 90% of the energy used in cement manufacturing.

Several present strategies aim to reduce emissions in cement manufacturing. One strategy involves innovative chemistry, which seeks to increase the share of supplementary cementitious materials (SCMs) in cement production and the use of less carbon-intensive alternative binding materials. Globally, the clinker-to-cement ratio is more than 70% and higher in the United States. Reducing the clinker-to-cement ratio is one aspect of cement decarbonization. For example, blended cements reduce the clinker-to-cement ratio by substituting clinker with SCMs, to include calcined clay, limestone, fly ash, blast-furnace slag, or silica fume. Availability of some of these industrial byproducts—notably fly ash and blast-furnace slag—may decline should these industries decarbonize themselves.

LC3—limestone calcined clay cement—is blended from limestone, clinker, and calcined clay. LC3 technology developers assert it could reduce carbon emissions in the cement production process by up to 40%. The developers also assert that LC3 is cost-effective and would require minimal capital investments at existing cement mills.

Potential technical challenges to decarbonizing cement and concrete production remain. For cement that incorporates a higher share of SCMs and alternative binding materials, questions remain about meeting durability and performance requirements in certain construction applications, cost-effectiveness of the process, and costs of conversion of existing facilities.

Another strategy that may help decarbonize cement manufacturing—specifically in addressing process-related emissions—is carbon capture, utilization, and storage (CCUS). Although CCUS is deemed a mature technology in certain contexts, its current use in cement manufacturing is limited by economic challenges, namely high capital and operating costs for individual U.S. plants.

Cement decarbonization is likely to require capital investments in processes and technologies that reduce fuel-related and process emissions. An analysis by the

consultancy firm McKinsey & Company estimates that expanding low-carbon cement production capacity, combined with CCUS equipment, could increase the cost of the average ton of cement by 45% in 2050 relative to today.

Government Initiatives and Programs

P.L. 117-169, commonly referred to as the Inflation Reduction Act of 2022 (IRA), contains several provisions that seek to reduce the carbon intensity of U.S. manufacturing. For instance, IRA provisions support federal government plans to leverage its buying power to help establish a market for low-carbon construction materials. Other IRA provisions support efforts to decarbonize several energy-intensive industrial processes, including for cement and concrete.

IRA provided funding for a \$2.15 billion pilot procurement program to purchase low-carbon materials in federal projects. In May 2023, the U.S. General Services Administration (GSA) announced this six-month pilot, the Low Embodied Carbon (LEC) Material Requirements Pilot Program. The pilot program will apply GSA's interim LEC material requirements into procurement for 11 GSA construction and modernization projects. GSA's interim requirements are based on the Environmental Protection Agency's interim determination, which set global warming potential limits for four LEC products: asphalt, concrete (and cement), glass, and steel.

IRA also created a new Department of Energy venture, the Advanced Industrial Facilities Deployment Program, that is to provide funding (up to \$5.8 billion) for producers to retrofit and upgrade their operations. Cement producers are one of several industrial manufacturers that are eligible to receive financial assistance.

The federal government and some state governments have cooperated to promote low-carbon construction materials. In March 2023, as part of the Federal Buy Clean Initiative, the Federal-State Buy Clean Partnership was created with commitments from 12 states. These states have committed to prioritize efforts that support the procurement of low-carbon construction materials (including cement and concrete) in state-funded projects and to collaborate with the federal government to help establish demand for such goods.

As cement manufacturing is both a carbon- and energy-intensive industrial process, Congress may also consider creating a federally led research program designed for low-carbon cement. For example, the CHIPS and Science Act (P.L. 117-167), enacted in August 2022, established a research and development program specific to low-emissions steel manufacturing. The program—led by the Department of Energy in collaboration with partners across academia, industry, and government—is in its early stages of deployment. Lessons learned from any economic or technical successes arising from the steel program might be applied to cement, such as incentivizing alternative fuels for heat combustion and studying the effectiveness of CCUS use.

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