Cement and Concrete 101

Emissions, Production, and Policy Landscape

Industrial
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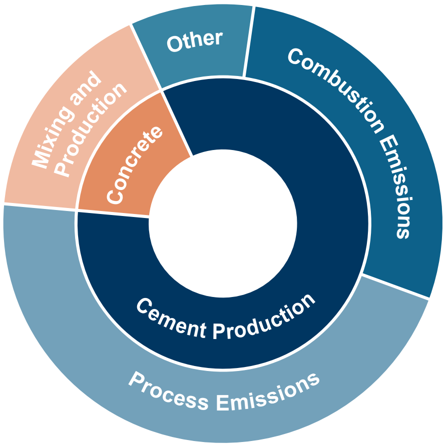
Where do emissions come from in cement and concrete?

From skyscrapers to scraped knees, concrete is foundational in our world. However, the emissions packed into this built environment are less noticeable in our everyday lives. Cement, the key ingredient in concrete, makes up about 7 to 8 percent of carbon dioxide (CO_2) emissions globally, and 1.3 percent of total US emissions. If the cement industry were a country, it would be the third-largest emitter of CO_2 behind China and the United States.

Concrete is the world's most-used human made material.

Figure 1. Breakdown of Emission Sources from Concrete Production

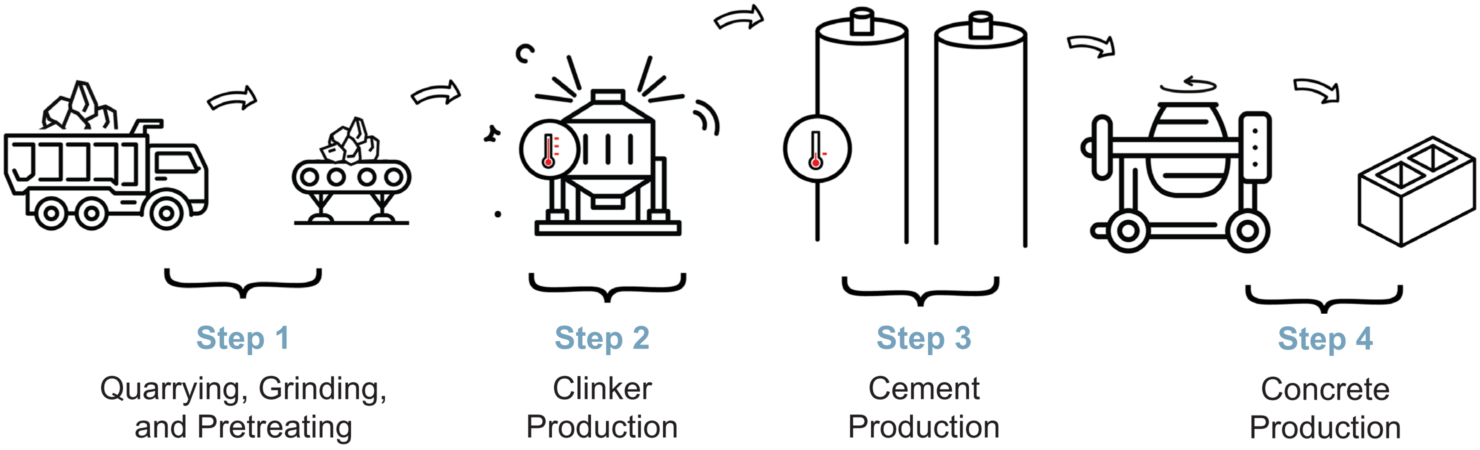


Most industrial sector emissions originate from fossil fuels that are combusted for heat. Emissions can also come from chemical reactions that release CO_2 as a byproduct called "process emissions." Because these emissions result from the chemical transformation of the materials, they are inherent to the production process.

Cement production accounts for 80 percent of emissions in concrete. This is predominantly a mix of process (about half) and combustion (about a third) emissions from the kiln as explained in Step 2 of the production process outlined on the next page. The other 20 percent comes from the energy needed for activities across the value chain, including quarrying, transport, grinding, etc.

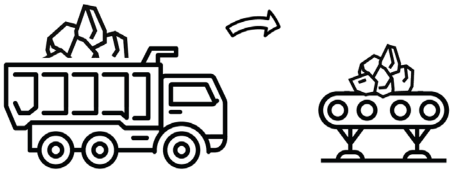
Data for Figure 1 is from the 2018 Energy Transitions Commission's [Mission Possible Cement Report](#).

What is the production process?



The production process can be simplified to four major steps. These include: quarrying, grinding, and pretreating, the production of clinker, the production of cement, and finally, the creation of the end product, concrete.

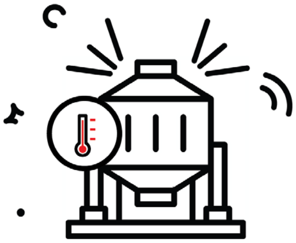
Step 1. Quarrying, Grinding, and Pretreating



The first step in the cement process is the **quarrying and grinding of raw materials,** primarily limestone. The materials are ground into a fine powder. Depending on the facility, these materials undergo various **pretreatments** before entering the kiln for calcination.

Energy Efficiency: Investment in upgraded equipment during the quarrying and grinding, or equipment for pretreatments, such as preheaters, and precalciners can improve the energy efficiency at the plant.

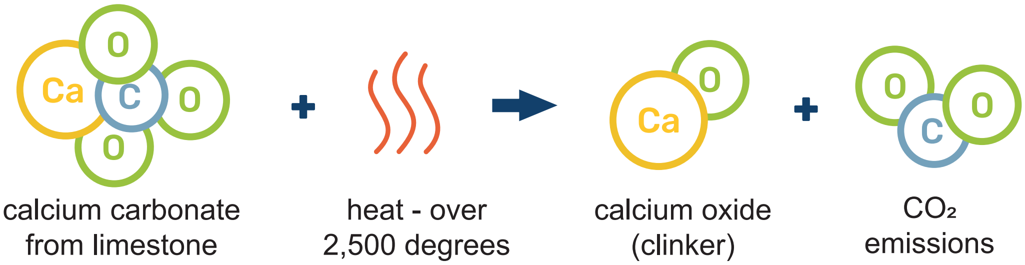
Step 2. Clinker Production



In a rotary kiln, the limestone mixture is heated to over 2,500 degrees Fahrenheit to produce **clinker**, the main, and most critical, ingredient in cement. This process is called calcination.

As the mixture is heated, it breaks down into calcium oxide (clinker) and CO_2. The equation below shows how this transformation occurs. This step in the production process accounts for roughly 90 percent of the emissions associated with cement production, which is a mix of process and combustion emissions.

Calcination:

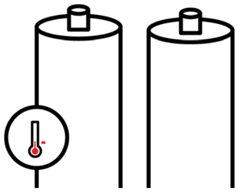


Carbon Capture Technologies: To address process emissions, carbon capture technologies can play a critical role. Because these carbon emissions are released during the chemical transformation of the material, they are unavoidable. However, cement production facilities can be retrofitted with carbon capture equipment that captures the emissions from the precalciner or the kiln before they are released into the atmosphere. This captured CO_2 is then transported to where it can be used beneficially in another product or process, such as concrete curing, or permanently stored underground.

Fuel Switching: The high temperature needed in the kiln to produce clinker presents a challenge to reducing combustion emissions. Currently, many facilities use coal and natural gas to achieve high heat. Substituting these fossil fuels with lower-carbon feedstocks can reduce these emissions. However, some alternatives have difficulty reaching those high temperatures—which is why biofuels, hydrogen, or waste feedstocks could be the most feasible options.

Energy Efficiency: Improving the efficiency of kilns and clinker coolers can maximize energy productivity throughout the clinker production process, requiring less energy overall.

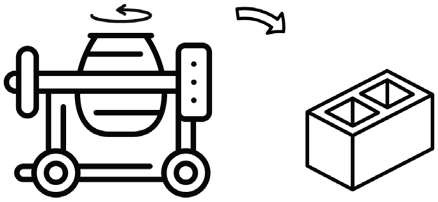
Step 3. Cement Production



The clinker is cooled before being blended with a small amount of gypsum, limestone, or other additives. The mixture is then ground to a powder to form **cement.** Cement produced in this manner is called Portland cement and is the most commonly used cement worldwide.

Novel & Blended Cements: Novel, low-carbon alternatives to traditional Portland cement are being explored, such as alkali-activated cements. These cement types have different ingredients and can potentially lower process and combustion emissions during cement production. Another type of low-carbon cement, known as blended cement, is produced by lowering the clinker content with supplementary cementitious materials. However, many of these mixes face barriers to deployment, such as a lack of demand, prescriptive standards, and low public awareness. A supportive policy and regulatory landscape is needed for these novel cements to scale up commercially.

Step 4. Concrete Production



Last, the cement is mixed with water, aggregates, and sand to form the end product, **concrete**. This is the product we see in everyday life in sidewalks, roads, and bridges.

Materials Substitution: Reducing the carbon intensity of concrete typically starts with reducing the cement content and replacing it with supplementary cementitious materials. Cement acts as the binding agent, or glue, in concrete. When the amount of cement is reduced, it needs to be replaced with another glue. This can include materials such as natural pozzolans or some industrial waste materials, including fly ash or steel slag. Pozzolans are a type of material that, when mixed in water, react to form a cementitious compound, similar to Portland cement. Alternative aggregates can also be substituted to reduce the carbon intensity of the material. This can include recycled concrete, agricultural waste, or synthetic aggregates.

What is the policy landscape for decarbonization?

Each of the decarbonization solutions for the cement and concrete sector described above is often dependent on the local context of a facility, such as age, the availability of alternative fuels and materials, and the proximity of infrastructure for transport, use, or storage of captured CO_2. Since many of the solutions described have various levels of technological readiness and cost considerations, a supportive policy landscape is crucial for spurring deployment and innovation. Learn more about key cement and concrete decarbonization policies by visiting industrialinnovation.org.