UC SANTA BARBARA

THE Current

May 14, 2026

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Basalt could be the key to greener and cheaper cement

Ideas to reduce carbon emissions often revolve around renewable power, electric vehicles and energy efficiency. But there's another, less colorful character that's often overlooked: cement.

"Cement barely registers in the public mind as a major driver of climate change, but the CO_2 emissions from cement production are similar to all the world's passenger cars," said Jeff Prancevic, a geologist at UC Santa Barbara. Overall, the industry accounts for around 4.4% of global greenhouse gas emissions.

A study led by Prancevic and Cody Finke, of Brimstone Energy, Inc., proposes a pathway to reducing the carbon footprint of Portland cement, the most widely used type. Producing cement from calcium-rich silicate rocks such as basalt, instead of limestone, could lower both the energy requirements and carbon dioxide emissions associated with production. The researchers found that silicate-derived Portland cement could require less than 60% of the energy used to process limestone while reducing associated carbon dioxide emissions by more than 80%, which could improve the economics of cement production.

According to the paper, published in Communications Sustainability, the switch is possible with existing technologies, and could even provide feedstock for steel and aluminum production, potentially improving the material and energy efficiency of industrial production writ large.

Better, cheaper, cleaner

Portland cement is used in almost all modern construction. It binds together the sand and aggregate used to make concrete. The calcium in cement is currently sourced from limestone because the refining process is simple, although it's very energy intensive. "But limestone is half CO_2," Prancevic said, "which is released into the atmosphere during cement production."

The current method requires heating limestone to over 1,500°C to produce the key ingredient quicklime (calcium oxide). The liberated carbon and oxygen escape as carbon dioxide — approximately 500 kg per metric tonne of cement produced, not including additional emissions from the energy used in the process.

Prancevic, Finke and their colleagues investigated whether calcium-rich silicate rocks, such as basalt or gabbro, could be a practical replacement for limestone in Portland cement production. They first assessed the availability of these rock types at the surface for mining, using existing geological maps, and found that there are sufficient quantities to supply cement production for several hundred thousand years at current production levels. "Not all of that basalt is easily accessible," Prancevic said, "but the numbers suggest that calcium from basalt is virtually inexhaustible."

The authors then estimated the energy requirements and carbon dioxide emissions of manufacturing cement using silicate rocks. They found that the theoretical minimum energy requirement is less than 60% compared to processing limestone. Using natural gas as an energy source, the minimum carbon dioxide emissions per tonne of cement produced decreased from 609 kg to around 50 kg, depending on the specific type of rock used. These theoretical baselines highlight the immense opportunity for silicate-sourced calcium to reduce both the energy intensity and emissions associated with cement production.

Finally, the authors investigated how silicate rocks could be used to produce Portland cement using technologies borrowed from other industries. They identified a viable process and found that even without optimization, and using average grid electricity, it would reduce carbon dioxide emissions by more than 25% compared to the current standard process using limestone.

Displacing the incumbent

On the one hand, it makes a lot of sense to source calcium from a rock that's not full of carbon. "I'm surprised that it's taken so long for this solution to be considered," Prancevic said. On the other hand, purifying calcium from silicate minerals is simply a much greater engineering challenge than purifying calcium from limestone, which is high in calcium. "So I'm fairly surprised that there seem to be viable, energy-efficient processes to experiment with."

The authors note that silicate rocks typically contain a variety of valuable metals that could be recovered as by-products during industrial cement production. In fact, the ratio of calcium and iron in basalt is almost exactly the ratio that society consumes for cement and steel production, so we could produce these materials from the same rock without excesses of either. Basalt also has around 20 times more aluminum than we currently consume, so this surplus could open up new opportunities, the researchers said. Producing several products from the same feedstock minimizes wasted material and energy, which is a major reason this approach is so much more efficient than the limestone route.

Despite its advantages, sourcing cement from silicates may be a tough sale. Cement is cheap (around $150 per tonne), and the process to make Portland cement from limestone has been optimized over more than a century. "The construction industry is built around Portland cement, from design to placement to maintenance," Prancevic said. "Even subtle changes in standards are painstakingly considered and are slow to be adopted. This is exactly why we've focused on technology to make the same Portland cement builders are used to."

Indeed, lower-carbon alternative cements have existed for decades, but without a push to decarbonize, companies may not consider it worth the financial risk to pursue them. The fact that the team's approach produces Portland cement enables it to slot into existing supply chains, but it will need to demonstrate significant savings to dislodge the production methods entrenched in the industry.

Prancevic's co-authors at Brimstone Energy are working to bring this solution to market, and there is plenty of room for experimentation. For instance, more research could improve the efficiency of the process and the refining of valuable by-products. "This paper is really a call for other researchers to experiment with new

technologies to accelerate cement decarbonization," Prancevic said, "because there is the potential to solve a climate problem as big as cars simply by sourcing calcium from a different rock."

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Climate Change
Energy Efficiency

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