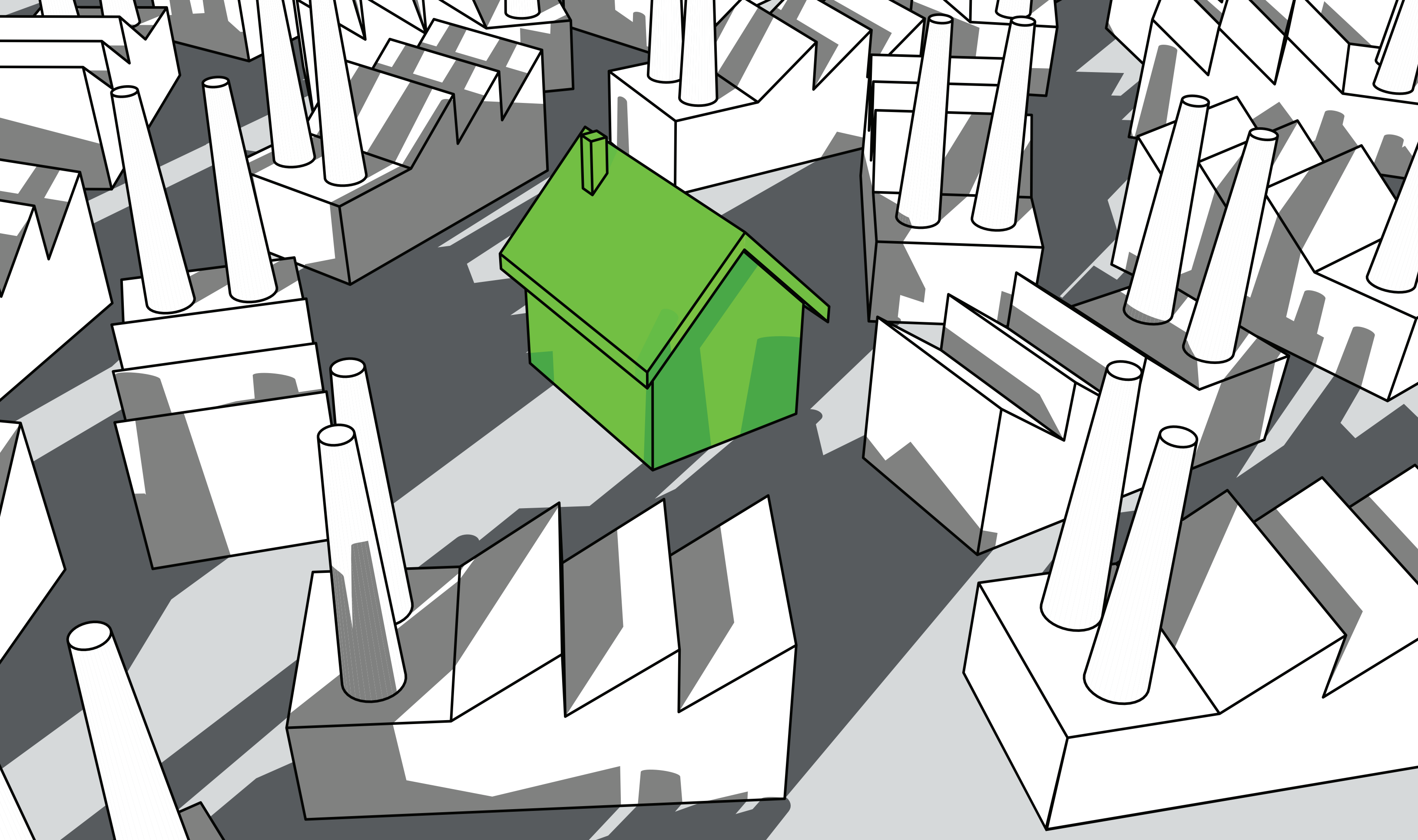

Greening a Ubiquitous Gray

For thousands of years producing cement has also meant producing harmful carbon dioxide. Stuart Licht believes it's time to let in the sun.

By Rachel Kaufman

It's an essential part of the glue that builds cities and much of the space between them. But the process of creating cement, a chief ingredient in concrete, generates nearly as much of the greenhouse gas carbon dioxide as it does cement.

Chemistry professor Stuart Licht thinks he can cut that rate—to zero.

He's developed a solar-powered process that recently was awarded a four-year, $1.7 million grant from the National Science Foundation. Now Dr. Licht and an interdisciplinary team of GW scientists are refining the proof-of-concept.

It may take years, but if perfected and commercialized, Dr. Licht's "solar cement" could go a long way toward greening an industry that he says accounts for around 5 percent of the world's manmade CO_2.

Dr. Licht has already applied the process to the CO_2-free production of iron, bleach, and other materials. The effort is part of a broader vision for what he has called a "renewable chemical economy"—one that produces commodities through sustainable processes, shedding fossil fuel-intensive ones.

"Rising carbon dioxide levels, and the associated climate consequences, provide one of the most daunting challenges of our time," says Dr. Licht.

The most carbon dioxide-intensive part of the cement-making process is heating limestone to create lime.

Limestone's chemical formula is $CaCO_3$, or one atom of calcium, one of carbon, and three of oxygen. Heating the limestone splits the rock into lime (CaO), leaving one carbon atom and two of oxygen, or CO_2. All that carbon dioxide is released into the atmosphere—not to mention the carbon dioxide generated from the fuel used to heat the limestone.

Dr. Licht's system produces lime with no emissions whatsoever.

Dubbed Solar Thermal Electrochemical Production, or STEP, the process uses solar concentrators to heat a lithium salt to melting and beyond—1,382 degrees Fahrenheit, the temperature of lava. A secondary concentrator and solar cell generates an electric current.

Into this electrified sludge you add limestone. The heat and jolt of electricity melts the limestone and separates the lime from the molecules of CO_2, just as in traditional production.

But the electrolysis also splits the CO_2 further, into valuable materials like graphite (a form of solid carbon) and carbon monoxide. Graphite is used in manufacturing strong, lightweight products like fishing rods, bicycle frames, tennis rackets, and lithium-ion batteries. Carbon monoxide can be mixed with hydrogen to create synthetic diesel and jet fuels.

After accounting for the value of the byproducts, Dr. Licht says his process is cheaper than using a traditional lime kiln. It's also quite different than the way lime has been made for millennia.

That's why Dr. Licht's new team also includes Peter LaPuma, an expert in life-cycle assessments, and social scientist Sabrina McCormick. Dr. LaPuma will be studying the environmental impacts of such a system—and how they compare to those from traditional cement production—as well as the economics of it, while Dr. McCormick researches how to convince the industry to embrace it.

"The [cement] industry is super conservative," Dr. McCormick says. "They're kind of an old-boys network. They want to do what their friends are doing, and they don't want to do what their friends aren't doing."

Tarek El-Ghazawi, an expert in high-performance computing and another member of the team, is more optimistic. "The industry should be excited about the potential of this project," he says.

Dr. El-Ghazawi will be designing software to model the chemical reactions in the molten salt and will simulate the processes using "George," GW's 10.6-trillion-calculations-per-second supercomputer. The models are necessary because while the basic process—solar power, heat, and electric current—seems simple, the intermediate chemical reactions undergone by the limestone and lithium salt are still rather mysterious.

Dr. El-Ghazawi will spend three years developing a working model. "In the first year we will look at modeling the chemical reactions and the electric field, in the second year we will be looking at thermal exchanges." In the third year, he will combine the various models together to make a full simulation. Finally, the team will be able to use the model to test different conditions to try to improve the lime-making process.

Geochemist Henry Teng is another team member looking forward to the model. As far as understanding the properties of lithium salt at high temperatures, he says, "we are starting from scratch."

"Geologists study [limestone and lithium salt] all the time, but most of the studies are not done above—let's call it room temperature," Dr. Teng says. "We don't know anything about the molten salt. We don't know the properties. We don't know the density, we don't know the viscosity. Nobody's studied that."

Dr. Teng adds that further studies, both in the lab and on the supercomputer, will help the team figure out what will happen when the technology leaves the lab and goes into the real world.

For example, limestone typically contains impurities "and we have to see whether that will be a nuisance or useful to us."

While selling the cement industry on a whole new process might be tough, the team members point out that the process can be added in stages.

"We can retrofit old plants," Dr. Teng says. "Instead of modifying the oven where you bake limestone we would add an additional conduit and direct the carbon dioxide that is released from the oven into a chamber where we have molten salt" and electrodes.

That sort of retrofit would still capture all the carbon dioxide released from the chemical reactions, but wouldn't rely on solar heat to warm the limestone.

In fact, despite its name, the STEP process doesn't even need solar at all.

Dr. Licht's graduate student Jason Lau explains that the energy to melt the lithium salt and bake the limestone could come from anywhere—other renewables, preferably. But even burning fossil fuels for heat and electricity would result in a carbon savings, since the biggest emissions come from the conversion of limestone to lime.

Besides, "it takes a lot of energy to heat up [the lithium salt], but not much to keep it up. It holds on to heat well," he says. This is an important consideration for commercialization—plants can't shut down operations at the first hint of a cloud.

If the STEP team can convince manufacturers to sign on, it could be a win-win: higher profits for the manufacturers and less pollution for everyone else.