# OUT OF THIN AIR

## How a Caltech PhD student and two Institute colleagues turned a carbon capture idea into a start-up that aims to help power plants clean up their toxic fumes.

By Omar Shamout

Climbing a single mountain is a monumental accomplishment. The founders of the carbon capture start-up C-Quester Inc. hope to scale six towering peaks—if only symbolically. The company's metaphorical mountaintops are its scale-up systems, which aim to capture carbon dioxide primarily from the smokestacks of power plants (and potentially from other large point-source emitters like fertilizer-, steel-, or cement-production plants), and to store it safely before it enters the atmosphere. That is why they have named each successive prototype phase after a significant peak. After working on phase A (Annapurna), they are in an advanced stage of phase B (Baldy), a prototype built in the lab that can remove 1 ton of carbon dioxide per year. Concurrently, they are building phase C, Centennial, at the company's new headquarters in a warehouse northeast of Los Angeles, which is designed to remove 100 tons of carbon dioxide per year. Next to come is Denali (1,000 tons), which would be directly connected and retrofitted to a power plant in central California. After that is Everest (100,000 tons) at a commercial demo plant, and Fuji (400,000 tons) at a commercial plant for large point-source emitters.


**From left to right:** C-Quester co-founders **Alan Gu** (MS, PhD '22), **Léopold Dobelle,** and **Clément Cid** (MS '14, PhD '18).

"We spotted a technology that we thought could work really well in the field," says Léopold Dobelle, one of C-Quester's founders, who is also a staff scientist in the lab of Michael Hoffmann, Caltech's John S. and Sherry Chen Professor of Environmental Science. "We are ready to scale it up; we're just looking for more funding."

C-Quester, founded last year by Dobelle and his colleagues Clément Cid (MS '14, PhD '18) and Alan Gu (MS, PhD '22), hopes its gas–solid chemical reactor systems will help slow climate change by neutralizing the carbon footprint caused by flue-gas emissions. But even if the founders manage to reach the top of Fuji in prototype, the problem would be far from fixed.

For some perspective on the enormous challenge of cutting carbon emissions, consider that about 40 million tons of carbon dioxide are already being captured from power and industrial facilities each year. But the International Energy Association estimates that number needs to increase 100 times over to meet the United Nations' energy-related sustainable development goals, meaning the world would need to sequester 4 billion tons annually.

And removing carbon is only the first challenge. "Carbon dioxide is a waste, so how do you handle the waste?" says Cid, the company's CEO, who received his PhD in environmental science and engineering. "We're working to help the client with a turnkey solution for capture, compression, transport, and storage."

Gu, C-Quester's chief technology officer, who received his PhD in chemical engineering, came up with the idea that became C-Quester in 2020 while working in Hoffmann's lab as a graduate student with Cid, the former lab manager, and Dobelle. "I thought maybe I could come up with a carbon-capture solution that is cheaper than all of the existing solutions," Gu says. "What came to mind was, why not use carbonate—bicarbonate chemistry, which has been known for a long time but not done for carbon capture?"

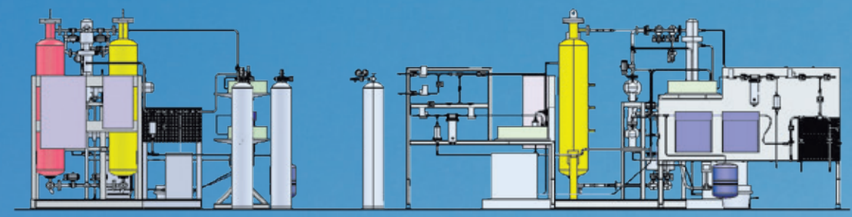
Gu won the 2022 Demetriades-Tsafka-Kokkalis Prize in entrepreneurship from Caltech for this research. The process, Cid explains, is similar to a natural form of carbon sequestration in oceans known as limestone weathering, in which compounds in calcium carbonate (found in shells on the ocean floor), seawater, and carbon dioxide break down and turn into dissolved bicarbonate ions. "What we are doing is making that breakdown happen in the gas phase and turning the bicarbonate into a solid," Cid says, noting C-Quester licenses the intellectual property from Caltech to perform the process commercially. "The real key in the invention is not the chemistry but driving the thermodynamics—forcing the reaction in one direction or the other while making sure to maximize the lifetime of the chemical sorbent."

Gu adds that, compared with other reactors, C-Quester's prototype uses a different type of material to absorb the carbon dioxide, an innovation that serves an economic function. "We have essentially a much larger surface area per volume, so the chemistry can happen in a much smaller reactor," he says. "That's another way for us to cut down the cost and have a patentable technology."

To build the initial protype, the C-Quester team obtained  opportune funding in 2022 from two Caltech sources: the Resnick Sustainability Institute (RSI) and the SanPietro Global Warming Mid-Stage Innovation Fund, which supports decarbonization projects. Stephanie Yanchinski, the Resnick Institute's director of entrepreneurial programs, also helped C-Quester find initial partners to test its reactor, and the company is now collaborating with an industrial partner to scale up its capture system. Caltech also placed Luana Dos Santos, who was part of the Institute's WAVE Fellows research program for students interested in pursuing a PhD, with the team last summer. In addition to Hoffmann, the company is being advised by Melany Hunt, Caltech's Dotty and Dick Hayman Professor of Mechanical Engineering; and Julie Schoenfeld, Caltech's entrepreneur in residence focused on physical sciences, who provided feedback on their investor presentation and general messaging.

"Every time I meet with the C-Quester team, they have advanced the ball," Schoenfeld says. "They have educated themselves; they have taken the feedback, and they have learned from it. They've made substantial progress."

Schoenfeld adds that the market for green-tech firms such as C-Quester is enormous given the scale of the problem. "There are those who say that in order to really get to a meaningful amount of change in the amount of carbon in the air you need something like 100,000 start-ups," she explains. "There's an awful lot of money, and there is a tremendous need to solve the climate problem through innovation."



A schematic of C-Quester's phase C, or "Centennial," gas–solid chemical reactor.

RSI also helped facilitate the company's participation in the National Science Foundation's ZAP and BOOM entrepreneurship programs in 2022. In addition to providing an infusion of grant funding, the programs match company founders with mentors who teach them about customer discovery, how to craft a business plan, and more. C-Quester is now also part of NSF's national Innovation Corps (I-Corps) program, which has allowed Gu, Cid, and Dobelle to meet other start-up founders and a network of investors, alumni, mentors, and potential customers.

Gu says Caltech also provided many resources, including funding, to help him get the business off the ground while he was still a student.

"The Resnick Institute was very supportive in guiding me through what happens in this entrepreneurial world and in helping me gain the general knowledge that I didn't have," Gu says. "And having funding that you don't have to go through too many hoops to get is really helpful. Even though it doesn't seem like a lot of money, it can really change the world." C