Turning Carbon Dioxide Into Rock, and Burying It

Henry Fountain, New York Times, 2-9-15

HENGILL, Iceland — In a cramped work trailer not far from Iceland's largest geothermal power plant, a researcher pored over a box of core samples — cylinders of rock that a drilling rig had pulled from deep underground just a few minutes before.

In a test that began in 2012, scientists had injected hundreds of tons of water and carbon dioxide gas 1,500 feet down into layers of porous basaltic rock, the product of ancient lava flows from the nearby Hengill volcano. Now the researcher, Sandra Snaebjornsdottir, a doctoral student at the University of Iceland, was looking for signs that the CO_2 had combined with elements in the basalt and become calcite, a solid crystalline mineral.

In short, she wanted to see if the gas had turned to stone.

“We have some calcites here,” she said, pointing to a smattering of white particles in the otherwise dark gray rock samples. “We might want to take a better look at them later.”

Ms. Snaebjornsdottir and her colleagues are certain that the process works, but the cores — eventually hundreds of feet of them — will undergo detailed analysis at a laboratory in Reykjavik, Iceland's capital, to confirm that the calcites resulted from the CO_2 injection.

The work is part of a $10 million project called CarbFix, which is developing an alternative way to store some of the carbon dioxide emitted by power plants and industries. When that carbon dioxide is released into the atmosphere, it traps heat, making it the biggest contributor to global warming. So to help stave off the worst impacts of climate change, experts say, billions of tons of CO_2 may have to be captured and stored underground.

But doing so is costly. And with little in the way of economic incentives to spur carbon storage, there are only about a dozen large-scale projects operating around the world, storing a total of less than 30 million tons a year, according to the Global CCS Institute, which promotes the technology. Only one of these is at a power plant — the Boundary Dam project in Saskatchewan, Canada, which started capturing and storing emissions from one of its coal-fired boilers last fall.

Boundary Dam and the other projects operate roughly the same way: Carbon dioxide gas, highly compressed so that it acts like a liquid, is injected into a formation, usually sandstone and often an old oil or gas field. Impermeable rock layers above the storage zone should, in theory, keep the CO_2 trapped indefinitely, but because the gas remains buoyant, there is a risk that it will move upward through cracks and eventually bubble back into the atmosphere.

The CarbFix project differs from this conventional approach by using water along with carbon dioxide, and by injecting them into volcanic rocks. The technique is designed to exploit the ability of CO_2 to react with the rocks and turn into solid minerals.

“Basically we're using a natural process and engineering it for climate-change mitigation,” said Juerg Matter, a geochemist at the University of Southampton in Britain and one of the lead researchers on the project. Until last year, Dr. Matter was at the Lamont-Doherty Earth Observatory at Columbia University, a CarbFix partner.

But whether the approach will prove to be commercially viable and lead to wider adoption of carbon storage, particularly on the huge scale that will be required to help stem the forces of climate change, remains uncertain.

In the CarbFix process, the injected water and CO_2 mix inside the well as if it were a giant geological soda machine. The resulting carbonated water, which is acidic, helps break down the rock, releasing calcium and other elements that combine with the carbon and oxygen from the CO_2.

Because the gas, in effect, disappears, “we don’t like to call it storage,” said Edda Aradottir, who manages the project and works for Reykjavik Energy, the utility that runs the geothermal plant and is another CarbFix partner. The preferred term, she said, is mineral carbonation.

But injecting huge amounts of water along with the CO_2 — 25 tons of liquid for each ton of gas — adds to the cost. CarbFix scientists have estimated that transportation and injection could cost about $17 per ton of CO_2, about twice the cost of transporting and injecting the gas alone. (These costs are on top of the much higher costs of capturing and separating CO_2 from a power plant smokestack.)

But Sigurdur Gislason, a geochemist at the University of Iceland and the project’s chief scientist, said the CarbFix approach might have a cost advantage over the long term. Because of the risk of leakage, a conventional storage site would have to be monitored, potentially for hundreds of years, at a cost that is difficult to estimate. A CarbFix site, with its stable minerals, could be left alone.

“No one ever talks about monitoring,” Dr. Gislason said. “This is where we score very highly.”

Mineral carbonation can occur in many kinds of rock, but often it is extremely slow. The CarbFix approach accelerates the process by injecting into basalt, a very reactive rock. And few places in the world can top Iceland for basalt; the country is made almost entirely of it. The island sits atop the Mid-Atlantic Ridge, the boundary between two of the planet’s largest tectonic plates, where basaltic magma rises from deep within the earth to form new crust.

What Iceland lacks, however, are significant CO_2 emissions. Geothermal generating stations, like the Hellisheidi plant across a road from the CarbFix site, do emit some CO_2 — it and other gases bubble up naturally along with the hot water and steam used to generate electricity — but the amounts are only about 5 percent of the emissions from an equivalent natural-gas plant.

“We can never do large-scale CO_2 injection” in Iceland, Dr. Aradottir said. But because of the geology, the country is an ideal place to demonstrate to potential users like power companies that the process works. (Since the initial test, CarbFix has scaled up its process and is now injecting 10,000 tons of gas per year from the plant at a nearby site.)

Large basalt deposits are found in other locales, including the Pacific Northwest in the United States. There, at a site in the Columbia River basin near Wallula, Wash., a similar test project — the only other one in the world — is also in an analysis phase, having completed the injection of 1,000 tons of carbon dioxide in 2013.

The project, a partnership of several companies and Battelle Memorial Institute, a nonprofit research and development organization that operates the Pacific Northwest National Laboratory, might best be described as a hybrid between conventional CO_2storage and the CarbFix approach.

Only carbon dioxide is injected, said Pete McGrail, a research fellow at the laboratory who leads the project. That helps to keep costs in line with conventional CO_2storage. And the basalt has dense, impermeable layers that keep the buoyant gas contained.

But because basalt is so reactive, after a relatively short time — a matter of years, not centuries — most of the CO_2 should be mineralized, making long-term monitoring unnecessary. (With the CarbFix process, once the CO_2 is dissolved in water, it is no longer buoyant, so there is no need for an impermeable layer.)

Like the CarbFix researchers, Dr. McGrail was surprised by how reactive basalt was when he conducted some initial experiments in the early 2000s.

“We had a conventional view that reactions would be slow,” he said, as they are in sandstone and other rocks. “But much to our surprise, when we cracked open those samples, it was one of those game-changer moments.”

In Iceland, the detailed analyses of the core samples should conclusively determine if the CarbFix approach works. But already the researchers have a strong indication that their technique is successful. A submersible pump installed at the bottom of a nearby well to monitor the injection process broke down twice. Both times when it was hauled up for repairs it was covered in calcite. “That’s basically the proof,” Dr. Aradottir said.

But it remains an open question whether the mineralization approach will be adopted when and if carbon storage becomes more widespread. While there is more than enough basalt around the world — Ms. Snaebjornsdottir has calculated that the Mid-Atlantic Ridge alone could handily store every last bit of emitted CO_2 — getting the gas to the storage sites would be impractical in many cases.

And given that the economics of carbon storage are already poor, it is difficult to see many companies taking on the added expense of injecting water, too.

“If you’re looking at it from the point of view of, ‘Would a fossil-fuel power plant choose to sequester CO_2 by carbonating water?’ — no, that doesn’t make any sense,” said Elizabeth Burton, general manager for the Americas of the Global CCS Institute. But if the plant has to re-inject wastewater anyway, “maybe the economics would work out,” she said.

Dr. Matter and the other CarbFix scientists are confident that mineralization will be an answer, at least for some efforts to fight climate change.

“The problem is big enough,” Dr. Matter said. “We need many solutions.”