Build a Better Carbon Trap and ...

By PAUL VOOSEN of
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To capture the carbon dioxide generated by coal plants, chemical companies like Dow Chemical Co. and energy giants like Alstom SA have been betting big on liquid solvents like amine, a corrosive derivative of ammonia that has a thirst for binding with CO2.

Problem is, once the two are bound, they never want to part.

In an attempt to circumvent the huge energy demands needed to separate amines from CO2, which can take up to 25 percent of the energy generated by a coal plant, scientists -- many funded by the Department of Energy -- are developing a new generation of porous solids that can trap CO2 and then, almost as easily, let it go.

Such solids come in various forms: carbon derived from sugars and tattooed with microscopic holes; molecular sieves that sift and separate chemicals; and elaborate, Tinkertoy-like molecules that form massive skeletons capable of trapping and holding specific chemicals.

At the forefront of this last field is the laboratory of Omar Yaghi at the University of California, Los Angeles, which over the past decade has helped create a new realm of massive, crystalline molecules called metal organic frameworks, or MOFs. With an acronym that sounds like the name of a fuzzy rodent, different species of MOFs may become the basis for hydrogen fuel tanks, drug-delivery devices and CO2 scrubbers.

Now, the lab has created a new generation of MOFs that have close to the same storage capacity and preference for CO2 as amines do, while only weakly bonding with the molecule. The research will be published later this year; the lab's previous reports on the subject have appeared in *Science* and *Nature*.

To the naked eye, MOFs look "kind of like a rock," said Bo Wang, a researcher in Yaghi's lab. But at the molecular level, these seeming solids look like a massive series of circular cages, almost like a honeycomb or molecular sponge, he said.

Amines, once they have chemically reacted with CO2, must be cooked at 120 degrees Celsius for one to two hours before they let go of their load. According to Wang, it takes two minutes at 60 degrees Celsius for 1 gram of the new MOFs to drop their CO2 and be ready for further use.

The MOFs' secret is that their frameworks -- which are built out of metal ion clusters connected by organic links -- are easily modified. Yaghi's lab has made thousands of different versions of the molecules, testing to see which had the proper shape to selectively admit CO_2.

"The genius of the materials that Professor Yaghi has developed is their enormous capacity for CO_2," said Joseph Hupp, a chemist at Northwestern University who has developed MOFs that separate CO_2 from methane.

Carbon dioxide has a moment where its electrons are not distributed evenly among the molecule, called its quadropole moment, Hupp said. This signature is distinctive from many other gases and allows MOFs, through their arrangement of atoms, to be selective.

Hupp is uncertain that MOFs will easily be applied to the steamy industrial environment of the coal plant. "I think it's conceivable, but I'm not so sure," he said.

Wang thinks he has a molecule that will be ready to scale up to industrial levels in an affordable way. Already, Yaghi's lab has partnered with the chemical giant BASF SE to mass-produce three simple MOFs, called Basolite, which are used to absorb a wide range of chemicals.

Once you have the recipe down, MOFs are simple to assemble, Wang said.

"It's easy as shake and bake," he said. You have these metals and organic linkers, and you "dump these into the solvent and cook it. And when it cools down you will see crystals. ... It's more like self-assembly."

It remains to be seen if MOFs will be able to compete commercially with liquid solvents, which offer a less complicated chemistry. Wang points out that BASF has already lowered the price of its Basolite line to about €10 per kilogram. "That's already competitive," he said.

Takes one to know one

The Department of Energy is spreading its bets on porous solids and recently announced funding support of $2 million for a research project at TDA Research Inc., a private firm based in Wheat Ridge, Colo., in the shadow of the National Renewable Energy Laboratory.

TDA has proposed using a proprietary form of activated carbon for capturing CO_2. Typically, activated carbon, which is hugely porous -- 1 gram contains almost the surface area of a basketball court -- is used to absorb poisons and in groundwater remediation or sewage treatment.

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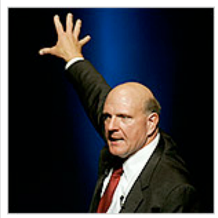

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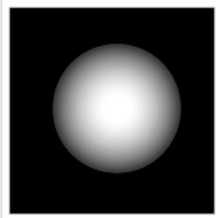

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