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For Carbon Emissions, a Goal of Less Than Zero

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IF the world is going to sharply reduce the amount of carbon dioxide pumped into the atmosphere by midcentury, then many businesses will have to go carbon neutral, bringing their net emissions of the greenhouse gas to zero.

But some could go even further by removing more CO_2 than they produce. Instead of carbon neutral, how about carbon negative?

In academic and industrial labs worldwide, researchers are working on technologies to reach that goal. Success could create the ultimate green business — for example, one that produces fuel whose emissions are more than offset by carbon dioxide stored during production. The businesses would be successful if, as anticipated, Congress puts a tax on emissions or starts a trading plan that makes carbon credits valuable.

For some experts, it's not a question of whether businesses will go carbon negative but when.

Carbon-negative technologies of some sort will be essential, said Daniel M. Kammen, director of the Renewable and Appropriate Energy Laboratory at the University of California, Berkeley. The world is facing the certainty of massive emissions for decades to come from plants already running, he said, adding that atmospheric concentrations must be stabilized. "We've got such a carbon overshoot looming in the future that this is going to have to happen," he said.

The United Nations Intergovernmental Panel on Climate Change said that an 80 percent cut in carbon dioxide emissions was necessary to avoid the worst consequences of climate change. But capturing the gas from coal plant smokestacks or switching to fuels that produce less of it when burned goes only so far.

"The great problem is actually removing carbon dioxide from the atmosphere," said Geir Vollsaeter, an environment expert and former general manager of carbon dioxide at Shell International, a subsidiary of the oil giant.

While much engineering work would have to be done to make a business carbon negative, the outlines are clear.

Take the concept of building a coal plant that captures and stores carbon dioxide. Such a plant could have zero emissions, because the coal would be turned into gas and processed to produce hydrogen and carbon dioxide. The hydrogen, a pollution-free fuel, would be burned, and the CO_2 pumped underground for permanent storage.

But Robert Williams, a research scientist at Princeton University, said that not only coal could be gasified;

you could also make the same fuel by starting with plant matter or other biomass.

And then, he said, "if you put any CO2 underground that is derived from biomass, that's negative CO2 emissions." That is because plants or trees — the raw material for the fuel —pull carbon dioxide from the atmosphere as they grow, and the gasification and storage takes that carbon out of circulation.

Mr. Williams said the more likely route would be to gasify a mixture of coal and biomass to keep the process carbon neutral. But the balance depends on the cost of separation and storage versus what kind of tax or other fee Congress might put on emissions.

More audacious is a plan by two professors at Columbia University to suck carbon dioxide out of the air, using waste heat from a solar plant, which has no smokestack.

Peter M. Eisenberger, a professor of earth and environmental sciences whose résumé includes positions at Exxon and other major companies, and Graciela Chichilnisky, an economist and mathematician, have proposed a "global thermostat strategy," which would adapt a chemical process for capturing carbon dioxide from smokestacks.

Ordinarily, the process requires a large amount of energy. But the professors noted that McMahan L. Gray, a scientist at an Energy Department laboratory, has modified the process so that the relatively small amount of waste heat from a solar-generating plant could do the job. They estimate that they could remove about five pounds of carbon dioxide per kilowatt-hour of electricity produced. (A coal plant emits about two pounds when it makes that much electricity.)

"If you want to solve the global warming problem, you can't do that by staying even," Dr. Eisenberger said.

It will probably take a bounty on a ton of carbon, though, before anyone will do tests to see how well the chemistry will work on a practical scale.

A carbon-based process that may be a step closer to commercialization was created by George A. Olah, a Nobel laureate in chemistry, and G. K. Surya Prakash, a fellow faculty member at the University of Southern California. To recycle carbon dioxide, they developed a kind of reverse fuel cell, which makes methanol by mixing the gas with water and applying a jolt of electricity.

If the source of the electricity is carbon-neutral — from a windmill or a nuclear reactor, for example — the process would be carbon negative. (Although if the methanol is used as vehicle fuel, the carbon would be released back into the environment, making the process carbon neutral.)

UOP, a subsidiary of Honeywell, announced in December that it had acquired rights to the technology, a sign somebody thinks it could be profitable.

The Department of Agriculture is considering carbon storage as a new crop, so to speak. "It's one of the many, many ways the agriculture community is going to be a viable player in the renewable-energy field as we go forward," said Edward T. Schafer, the secretary of agriculture, at a renewable-energy conference this month.

The method is called agrichar, in which some biological material — grass or trees grown specifically for the purpose; or a cornstalk or other agricultural waste — is cooked at a very high temperature in the absence of oxygen. That produces an oil that, with a little chemical work, can be used as a vehicle fuel.

But in a world focused on carbon, the important part may be the leftovers, a charcoal-like material that retains most of the carbon. It also has useful minerals, like potassium and phosphorus. Plowed back into a field, it helps the soil retain water and nutrients, which also enhances plant growth, said Robert C. Brown, director of the Bioeconomy Institute at Iowa State University.

Senator Ken Salazar, Democrat of Colorado, has introduced legislation that would pay for more research. If it works, he said, farmers would have a new crop. “You’d be growing allowances,” he said.

If being carbon negative becomes important, then some existing industries may try to describe themselves that way. In some cases, it may even be true.

For example, Covanta Energy of Fairfield, N.J., operates plants that make electricity by burning municipal solid waste, which is about 80 percent paper and other organic materials. But Anthony J. Orlando, Covanta’s president and chief executive, says he is hoping to collect carbon credits, because each ton burned, he said, would have otherwise been buried in a landfill where bacteria digest garbage to make methane, a potent greenhouse gas. The company is building plants in China that will qualify for credits, issued by the European Union, which companies in Europe can buy to offset their own carbon output, Mr. Orlando said. As for the United States, he said, “it depends on the legislation.”

A Washington company, the Solena Group, also has a carbon-negative plan, which emerged from the decision by regulators in Kansas last year to turn down a permit for two new coal-burning power plants because of the millions of tons of carbon dioxide they would produce. The regulators insisted that the builder of the plants, an electric co-op called Sunflower, had to permanently remove the carbon from circulation. Gov. Kathleen Sebelius and the Kansas State Legislature are still arguing over whether the plants should be built.

Solena says it can use the carbon. The company employs a high-temperature process to break up anything organic into a flammable gas. The organic material could be algae, which have an extremely high energy value per pound. And algae eat carbon dioxide.

Solena is in discussion with Sunflower to build a 40-megawatt power plant that would run on gasified algae; the algae would be grown in thousands of clear plastic cylinders, 3 feet wide by 10 feet tall, sitting in the Kansas sun and fertilized with sodium bicarbonate, made with carbon captured from Sunflower’s coal plant. For each 1.8 tons of carbon dioxide, the columns would yield a ton of algae.

A Solena subsidiary has been growing algae at a facility in Alicante, Spain.

If built, the system would make double use of the carbon from the coal and avoid digging more coal for more power. Alternatively, the gas could be turned into diesel fuel or other vehicle fuel, if prices favored that.

For the truly adventurous, there is the plankton ocean digester, the brainchild of Mark E. Capron, an

American civil engineer. His idea is to take a natural process, the bacterial breakdown of algae in the ocean, and carry it out in an underwater tank without air. The process would produce methane, which could be piped to shore for use as fuel, and carbon dioxide, which could be pumped to the ocean depths, where it would stay.

Since the system would replace the need for oil or natural gas, it would reduce carbon loading in the atmosphere. And it would run on plants or anything else that came into the digester. “Fish, octopuses, we’re not picky,” Mr. Capron said.