SUSTAINABILITY

Carbon Capture May Be Too Expensive to Combat Climate Change

Every credible plan for reducing global warming hinges on carbon-trapping technology playing a major role. That doesn't seem likely

By David Biello on January 1, 2016

GIANT CONVEYOR (*above*) sits idle inside the coal storage dome at the Kemper power plant in Mississippi, waiting for full operations to begin.
Jeff Wilson

IN BRIEF

Mississippi Power is building the Kemper “clean coal” power plant to generate electricity from the dirtiest form of coal and capture the resulting carbon dioxide emissions instead of sending them into the atmosphere.

Kemper will sell the CO2 to a company that will pump it down into diminishing oil fields to force out more oil; roughly one third of the CO2 emissions is supposed to remain trapped underground there. Burning the oil, however, would send new emissions into the sky.

Costs at Kemper and a few other similar facilities are very high, raising doubt about whether the approach is economically sustainable; to date, 33 carbon capture and storage projects have been shut down or canceled worldwide.

Without effective, affordable carbon capture, nations at this month's Paris climate talks that are committing to cut emissions will not be able to meet their pledges.

Tim Pinkston has built a massive chemistry set in the middle of a longleaf pine forest in eastern Mississippi. “I'm so happy to see it come to fruition,” says Pinkston, a rangy engineer with owlish eyes, during a tour of the Kemper County Energy Facility on a warm summer morning.

Standing on a large expanse of flat land that has been clear-cut and paved with concrete, he is pointing to a vast complex of twisting, turning pipes, hundreds of miles in all, that surges skyward. At the center of this cross between a chemical factory and a power plant are two towering silos more than 300 feet tall. The twin gasifiers, each weighing 2,550 tons, can create the heat and pressure of a volcano. That is what is required to take lignite, a wet, brown coal mined from almost underneath Pinkston's feet, and turn it into gaseous fuel that is ready to burn to generate electricity.

What makes this chemistry set extraordinary is not the fuel it will soon produce but how it will handle the chief by-product: carbon dioxide, the greenhouse gas behind global warming. Rather than send the CO_2 up a smokestack and into the atmosphere, as conventional coal-fired power plants do, Pinkston and his colleagues at Kemper will capture it.

Kemper is the most advanced coal plant in the U.S. And it is key to a worldwide effort to cut back emissions of greenhouse gases, a long-awaited goal embraced by most of the more than 190 nations holding climate negotiations this month in Paris. Coal-fired power plants are the biggest source of the world's CO_2 discharges because the most polluting countries rely on them to produce a large share of their electricity. Few of those nations, including the U.S., which gets 40 percent of its power from coal, are willing to stop the burning. Without closing the plants, the only way these countries can meet their pledges is to keep CO_2 from going skyward, locking it away instead.

There is no credible plan to stave off global warming, whether from individual countries or the Intergovernmental Panel on Climate Change, that does not include such carbon capture and storage, or CCS, technology. Even the scenarios that rely heavily on nuclear power or renewable energy still require carbon capture to clean up emissions from all the necessary cement and steel. There are more than 6,000 large, industrial sources of CO_2 emissions in North America alone. About 1,000 of them are cement kilns or factories that emit 100,000 tons or more of CO_2 a year. Nearly 5,000 of them are power plants that burn fossil fuels, which emit even more. Add thousands of fossil-fuel plants in China, India and elsewhere, and they account for more than 70 percent of the planet's CO_2 pollution. It is easy to see why CCS is central to reducing this pollution.

The trouble is that carbon capture is an expensive fix. The technology itself seems to work, but the cost to build and operate a full-scale plant, which is coming to light as Kemper nears completion and other, smaller facilities gain experience, has been very high. Then there is the question of what to do with the carbon once it has been captured. Storing it deep underground in geologic formations that could hold it for thousands of years adds even more to the cost. Governments are loath to foot the bill. To recover their investments, plant owners would have to raise their customers' electricity rates far above those currently in place.

The cost of CCS has scuttled once promising efforts. A demonstration project at the Mountaineer coal plant in West Virginia buried more than one million tons of CO_2, then shut down for lack of funds to continue the experiment. In 2015 the U.S. Department of Energy canceled its hallmark FutureGen venture with industry, which was meant to rebuild an old coal plant in Illinois, after spending $1.65 billion. China has quietly changed the name of its flagship GreenGen CCS project—similar to Kemper—and is running the plant to produce power but without capturing CO_2. Only 15 CCS projects are operating worldwide today, with another seven under construction, including Kemper. All have cost billions of dollars to study, design and complete.

Kemper has found a creative way to finance its project, however. It plans to pay for CCS by siphoning off the CO_2 and selling it, an approach known as carbon capture and utilization. Some companies might use CO_2 as an ingredient in baking soda, drywall, plastics or fuel. But emissions from power plants worldwide dwarf even the raw materials that go into the more than four billion tons of cement made every year, one of the largest products that might use the gas. “With the amount of CO_2 we have to deal with, you're not going to turn everything into a valuable material,” says Ah-Hyung “Alissa” Park, a chemical engineer at Columbia University, who works on this challenge.

There is one customer that could use lots of CO_2 and is wealthy enough to pay for it: Big Oil. Petroleum companies need vast amounts of CO_2, which they pump underground to force out oil from wells that otherwise would be running dry. Carbon capture and utilization presents a contradiction: Does it make sense, as a response to climate change, to capture carbon only to use it to obtain more fossil fuels for burning?

The labyrinth

The Kemper project began back in 2006, in the aftermath of Hurricane Katrina, which contributed to a surge in natural gas prices. Mississippi Power was headed toward a future in which 80 percent of its electricity would be generated from natural gas, according to spokesperson Lee Youngblood. Nuclear power was too expensive, and renewable sources such as wind and solar were too intermittent. That left the local lignite.

ettest kind of coal—more than enough for a power plant with Kemper's capacity to burn for 50 years or more.

Conventional coal power plants typically avoid lignite because cleaning the air pollution it creates, much less the CO_2, is daunting. Pinkston and his partners realized that designing a power plant around two towering gasifiers would allow them to use the lignite and still keep pollution below federal limits. They also realized that by adding more equipment they could capture the CO_2, which made strategic sense as plans were laid; Congress was strongly considering legislation to cap greenhouse gas pollution. In 2009 the Magnolia State gave Mississippi Power permission to build Kemper, with a cost limit of $2.88 billion.

Mississippi Power's parent corporation, Southern Company, had already developed the gasifier in the 1990s as part of experiments to turn lignite into a cleaner fuel. Pinkston's team chose an industrial solvent, Selexol, to grab CO_2 from the gas created by pressurizing and heating the dirty coal. Subsequently dropping the pressure would readily release the CO_2 from the solvent, like twisting open the cap on a bottle of seltzer. The approach meant that less of the energy generated from the coal had to be devoted to cleaning up the pollution, lowering the cost. And it seemed like it all could be done with various pieces of technology that had been used in other ways for years. “There's nothing new here but the integration,” says Bruce Harrington, assistant plant manager for Kemper.

That integration has proved trickier than expected. The part of the plant meant to dry the coal had to be torn down and rebuilt as a result of faulty parts. The labyrinth of pipes just kept growing as Kemper got built, stretching to 172 miles, 76 miles more than planned. Workers inside the giant tangle painted some of the machinery a special blue that turns colors if it gets too hot or cold—one of the only ways to see inside the maze to make sure everything is working properly, despite instruments at more than 30,000 points. Engineers with petrochemical expertise had to be imported, and 2,300 miles of electrical cable had to be laid, leading to a doubling of the construction workforce.

All of this complexity inflated the cost: as of October, Kemper was $3.9 billion over budget, up from $2.4 billion when the facility was proposed in 2009 to $6.3 billion. Mounting delays have pushed the start date from May 2014 to at least April 2016; every month of delay costs at least $25 million, according to Southern Company's filings to the U.S. Securities and Exchange Commission. The company had to pay back hundreds of millions of dollars in federal tax credits tied to project milestone dates that were missed.

Mississippi Power has had to turn to its own customers to avoid bankruptcy as it builds a power plant worth more than all the rest of the company's assets put together. In August it raised electricity rates by 18 percent. The big solution, however, is to sell pure, dry CO_2 to the oil industry.

Oil to the rescue

Oil companies have been using CO_2 to scour more oil out of the ground for decades, buying the gas from other companies that ended up drilling into underground deposits of it rather than the oil or natural gas they sought. They build a kind of mini factory atop an oil field that compresses the CO_2 and pumps it down below. The CO_2 mixes with the oil to make it flow easier and restores the pressure underground to force more oil to the surface. As much as two thirds of the CO_2 that gets pumped down returns with the oil. That CO_2 gets combined with fresh supplies and sent back down to push up yet more oil. Each cycle about one third of the gas remains underground, caught in the tiny pores in sandstone like the oil before it. That is the climate benefit—burying the greenhouse gas away from the atmosphere.

The Tinsley oil field near Kemper has produced more than 220 million barrels of oil since its discovery in 1939. Such a big field can warrant the big cost of buying CO_2 from a place like Kemper, along with added roads, truck trips and CO_2 pipelines, to force out another 100 million barrels. Denbury Resources began flooding the field with CO_2 from natural deposits in March 2008. At Tinsley, the company now recycles 670 million cubic feet of CO_2 a year and buys an additional 100 million cubic feet annually, boosting oil production from the field from 50 barrels a day to more than 5,000 barrels daily. When fully operational, Kemper plans to send roughly 60,000 million cubic feet of CO_2 a year through a new 60-mile-long pipeline to Tinsley and other fields in the region.

The catch, of course, is that when the extra oil is subsequently burned as gasoline, home heating fuel or other petroleum fuels, more CO_2 is sent into the atmosphere. The idea that combating climate change depends on a technology that uses CO_2 to produce more oil that then gets burned, producing more CO_2, reliably elicits chuckles from oil field workers.

Nationwide, the U.S. produces roughly 300,000 barrels of oil a day with CO_2, from

Nationwide, the U.S. produces roughly 300,000 barrels of oil a day with CO2, from nearly 140 fields, a number expected to double if low oil prices rebound. The doe estimates there are 72 million barrels of oil in the U.S. (including Alaska) that could be recovered every day with CO2. Already 5,000 miles of pipeline shuttle CO2 from natural deposits such as the Jackson Dome in Mississippi to old oil fields, like a spider's web lurking just underground and occasionally breaking the surface with a valve or pump.

Pricey proposition

Tapping CO2 in deposits currently costs about $0.50 per ton. Carbon dioxide from the complicated Kemper facility, however, may cost up to three times that.

Cost lessons are coming from several places, notably one of the first CCS projects, at the Boundary Dam power plant in Saskatchewan. In October 2014 the “clean coal” power plant began feeding power into the electric grid. SaskPower spent a little more than $1 billion to rebuild one of the plant's three coal-fired boilers to capture its CO2 emissions. The expense worked out to about $11,000 per kilowatt of electric generating capacity, more than three times as much as a typical boiler. Mississippi Power's estimate for Kemper is similar: at least $10,000 per kilowatt.

At those levels, capturing CO2 would add at least $0.04 per kilowatt-hour to the consumer price of electricity, according to doe estimates. That is a 33 percent increase to the average American price of electricity: $0.12 per kilowatt-hour. Without regulations requiring carbon capture or a tax on carbon pollution that power utilities would want to avoid, the companies have little financial reason to pursue the technology. The economics are no better in China, which now consumes roughly four times as much coal as the U.S., or in India, which has declared in its submission to the Paris climate talks that it intends to build many more coal-fired power plants. The new plants are unlikely to have CCS because of the cost.

Even if the expense of carbon capture comes down, the cost of storage may also remain too high. Many of the more than 600 coal-fired power plants in the U.S. are nowhere near geologic formations that might reliably hold CO2 that is simply pumped underground for permanent storage. Many of the power plants are also nowhere near the 1,600 U.S. oil fields that might benefit from CO2 injection, requiring long, expensive pipelines and compressing stations. And scientists cannot say with certainty how much of a climate benefit using CO2 to produce oil would offer. “We don't know the net amount of CO2

stored," says Camille Petit, a chemical engineer at Imperial College London.

Reckoning deferred

As Kemper shows, carbon capture makes for big, expensive power plants, much like nuclear power. As a result, the list of defunct projects such as FutureGen is long. Worldwide, 33 CCS projects have been scrapped since 2010, according to the Global Carbon Capture and Storage Institute. Most consumed hundreds of millions of dollars before failing. Those that still exist, such as Summit Power's Texas Clean Energy Project, are struggling. Boundary Dam is having trouble meeting its own carbon capture targets.

Nevertheless, CCS projects continue because of the compelling need to combat climate change. NRG Carbon 360 is building one in Texas called Petra Nova. The utility plans to make money from selling electricity and the oil obtained by pumping 1.6 million tons of CO_2 a year into the West Ranch Oil Field near Houston. Petra Nova, scheduled to come online in late 2016 at the earliest, will capture CO_2 from only 10 percent of the power plant's total capacity, however, at a cost of $1 billion.

"Cleaning up coal plant emissions is a good goal," says Al Armendariz, a Sierra Club activist and former Environmental Protection Agency official. "But the costs of the Petra Nova project, especially compared with the low costs of renewables in Texas like wind and solar, make it questionable if CCS is the most effective way to reduce carbon emissions."

Therein lies the fallacy. Unless the U.S. starts to shut down more coal power plants and even natural gas power plants, it must find a way to convert CCS from an expensive luxury to a viable fix. Otherwise the country will not meet its long-term target of 80 percent cuts in greenhouse gas pollution by 2050.

Kemper does not provide much hope that carbon capture can be a cheap and easy solution. Two bulging stockpiles of dark coal rise beside the behemoth, baking under the Mississippi sun, waiting for the gasifiers to start up. The nine-million-pound, all-electric strip-mine machine that dug it up, renamed the Liberty Belle after being imported from the U.K., sits idle. So do the big Caterpillar 789D trucks that haul the coal, which burn 28 gallons of diesel an hour, a CO_2 source not likely to be captured anytime soon.

When Kemper finally operates as designed, it will capture 65 percent of the CO_2 it would otherwise emit. It is not clean coal, just 21st-century coal, which is cleaner than its predecessors. The advanced power plant will emit formaldehyde, toluene and a long list of heavy metals, in addition to tons of acid-rain-causing sulfur dioxide, smog-forming nitrogen oxides and soot, among other forms of air pollution. It will emit 91,000 tons annually of greenhouse gases other than CO_2. There will still be toxic coal ash to deal with somehow. Ultimately Kemper will send at least 800 pounds of CO_2 into the sky for every megawatt-hour of electricity it generates. That is roughly the same as a power plant that burns natural gas, though less than half of what a typical coal-fired power plant belches.

The world stands at the threshold of finally acting to solve another garbage problem in a long list of them. Just as our forebears started paying to move trash to a landfill or to treat sewage, we will have to pay to minimize the use of the atmosphere as a dump. Kemper represents the best effort yet to clean up coal, although it is perhaps not good enough. “We would like to be making larger progress and faster progress,” says Julio Friedmann, the doe's principal deputy assistant secretary for fossil energy.

The harsh economic math shows CCS costs more than just burning coal. That may make the necessary technology impossible to develop in a world without a price on such pollution.

To generate needed revenue, Kemper has been producing electricity for more than a year now—without Pinkston's gasifiers. The turbines burn natural gas from a pipeline connected to underground deposits. None of the CO_2 exhaust is captured. It simply wafts up the smokestack, adding to the invisibly thickening blanket in the atmosphere, trapping yet more heat that Mississippi—and the rest of the world—does not need.

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MORE TO EXPLORE

Carbon Storage Atlas. Fifth edition. U.S. Department of Energy, 2015. www.netl.doe.gov/research/coal/carbon-storage/atlasv

The Global Status of CCS: 2015, Summary Report. Global CCS Institute, 2015. http://status.globalccsinstitute.com

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Can Captured Carbon Save Coal? David Biello; June 2009.

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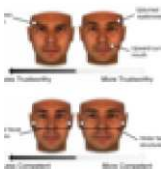
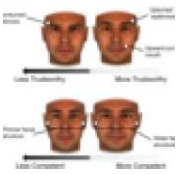

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