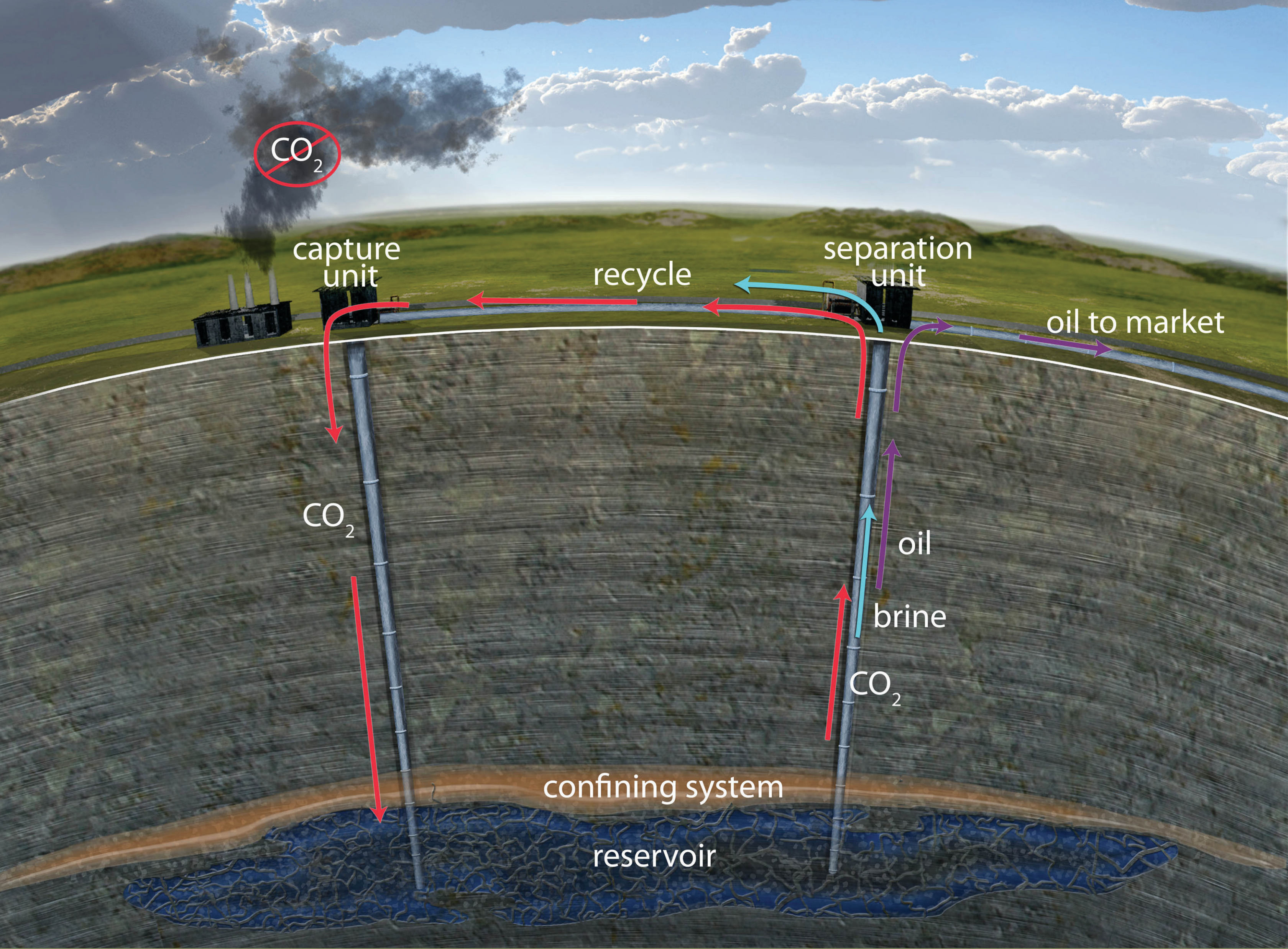


The Carbon Question

By Juli Berwald

The Gulf Coast Carbon Center Has Got Answers

A white van with an orange UT Austin logo drives down a dirt road outside Cranfield, Mississippi and pulls into a clearing. Susan Hovorka, principle investigator of the Gulf Coast Carbon Center at the Bureau of Economic Geology, steps out and surveys the site.

The calm belies two years of intense activity. During that time a massive drill rig occupied the space, boring well holes two miles below the surface. Freight trucks delivered miles of cable and pipe. Technicians labored around the clock, installing sensors, valves, and lines to connect the subsurface to the surface. But all the noise and machinery are gone now. Three red pipes snake their way above ground, a silent indication the test site is ready.

Walking toward a shipping container that serves as a nerve center for the project, Hovorka greets David Freeman, a collaborator from Sandia Technologies. They enter a room loaded with computer screens and gauges. Hovorka confirms the wells are operating properly and gives a signal.

A technician from Denbury Resources turns a large wheel opening a valve. Carbon dioxide begins its journey into the same geologic formation that once held thousands of barrels of oil. The loud hiss of compressed gas through the pipes heralds the start of the largest carbon sequestration project funded by the US Department of Energy. But, just two decades ago, the entire field of carbon sequestration was little more than an idea.

Asking the First Question

"Twenty or thirty years ago nobody knew that emitting carbon into the atmosphere from the combustion of fossil fuels was an issue," explains Hovorka.

As geology students learn, carbon, like water, moves between large reservoirs in a global-scale cycle. Plants take up CO_2 from the atmosphere and store it in their own tissues. When the plants die, their carbon is buried deep underground and, with the addition of high temperature, pressure, and a lot of time, converts to fossil fuel. Burning this fuel releases the carbon back to the atmosphere.

If the cycle were running optimally, plants would simply use up the carbon released from burning fossil fuels. But scientists in the 1980s and 1990s found that plants are already growing as fast as they can. The amount of carbon produced from fossil fuels exceeds the ability of vegetation to use it. Along with other greenhouse gases, this excess carbon contributes to a warming of Earth's atmosphere that is altering Earth's climate, ice mass, and living communities.

"So, this idea of helping the cycle close came to my attention," continues Hovorka. "You could augment the natural cycle by capturing the CO_2 and injecting it back into an environment identical or similar to those from which it came and sequester it there for very long periods of time."

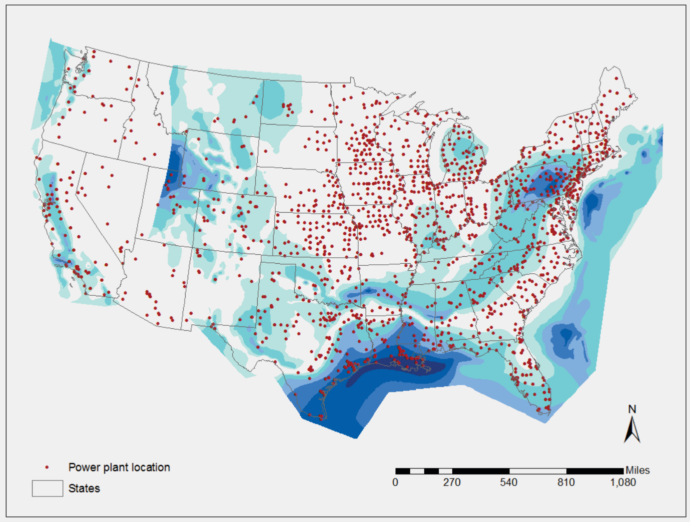
To Hovorka in 1997, this idea, called carbon capture and storage or CCS, dovetailed well with the types of projects already studied at the Bureau of Economic Geology, which has a strong track record evaluating public policy issues related to energy and the environment. Hovorka started talking with people from diverse units at the Bureau, combining her expertise in environmental geology with that of collaborators who had worked on the geology of oil and gas reservoirs. This group of investigators started by asking a lot of questions.

Laying the Groundwork

The first question concerned the economics of the resource, in this case underground space. Would CCS be worth it?

Initial results were encouraging. Early studies focused on enhanced oil recovery (EOR), in which CO_2 is injected into declining oil fields to help force out the residual oil. The work showed the gap between what it would cost to capture CO_2 and use it for EOR would be significant, but small, resulting in an addition to electricity costs, but not an inordinate increase. With a lot of oil fields in decline, especially in Texas, CCS combined with EOR had the potential for economic benefit.

The next set of questions focused on understanding the space. If you don't know the geological characteristics of a reservoir,



Sources and sinks: Red dots show sources of CO_2. Colored zones show places in the U.S. with geological formations appropriate for CCS. Texas, in particular, is well suited for injecting CO_2 into deep underground containment zones.

explains Hovorka, then that space is not really available. "We were trying to be Lewis and Clark of the underground storage reservoirs," she says.

Again, the results were positive. North America, and Texas in particular, contains a lot of underground space with the right characteristics for carbon sequestration. Referred to as containment zones, these geologic formations a mile or two below Earth's surface are also extremely well documented.

Heading into the Field

The time had come to move from paper and computers to the physical reality of CO_2 and rock formations. At about this time, the Department of Energy (DOE) was forming regional partnerships to study carbon sequestration. Hovorka and her collaborators at the Bureau, including Mark Holtz, wrote a proposal to form one of these partnerships.

The proposal was turned down, a decision that had surprising consequences. Rather than acting as a stumbling block, the failure propelled the group forward.

"It was because we didn't win that proposal that we decided to form the Gulf Coast Carbon Center," says Holtz. "We decided to do it ourselves because we knew as much about carbon sequestration as anyone else."

Coincidentally, Kinder Morgan and BP approached the group in 2002 and asked to form a center of excellence for carbon sequestration. Two years later, the Gulf Coast Carbon Center was a reality.

This newly-minted center was soon funded by DOE's National Energy Technology Laboratory (NETL) to perform a demonstration experiment of carbon sequestration in Texas's Gulf Coast. The Frio Brine Pilot Experiment (named for the formation into which CO_2 was injected) became the first major academic study of carbon sequestration. The Frio project injected 1,600 tons of carbon dioxide 1,500m below the surface. Sophisticated and aggressive monitoring showed the CO_2 behaved exactly as expected in the containment zone. No adverse health, safety, or environmental effects were detected.

But as large as that experiment was, it was still a drop in the bucket compared to the amount of CO_2 emitted by a single power plant in the same time. Hovorka wanted to know if sequestration would be safe on the scale that it would actually be used by industry. Would it interfere with public health by affecting drinking water or causing other environmental damage? Again, the answers were favorable.

In 2009, the Gulf Coast Carbon Center completed an experiment at an oil field in the Texas Panhandle where millions of tons of CO_2 have been injected for EOR since 1972.

"We found no degradation of shallow drinking water resources as a result of more than 35 years of CO_2 injection into deep geological formations," reports Rebecca Smyth, principal investigator of the study.

"Injection is very standard stuff," says Hovorka.

Most people haven't heard of the Safe Drinking Water Act of 1974 or the Underwater Injection Control Program, but they are the pieces of legislation that dictate exactly what needs to be managed when injecting anything underground. Tens of thousands of wells currently inject a variety of fluids underground under the injection program, including thousands of EOR sites.

"The reason people don't know about these programs is because they work," Hovorka explains. It was time to expand again.

Scaling Up

Today, researchers working with the Gulf Coast Carbon Center pump one million metric tons of CO_2 underground every year—the same scale industrial operators will require to make carbon sequestration economically viable.

The project in Mississippi, referred to as Cranfield phase III, is a $34 million multi-year field study of sequestration and monitoring strategies. The Cranfield study "has led the NETL program into a new phase of development, which is the large-scale demonstration project," explains Tip Meckel, a Bureau researcher and major contributor to the project. The Cranfield work is performed in conjunction with the Southeast Regional Carbon Sequestration Partnership (SECARB) with support from DOE/NETL and managed by the Southern States Energy Board (SSEB).

Along with their collaborators, the Gulf Coast Carbon Center decked out two observation wells at Cranfield with some of the most sophisticated scientific instruments ever deployed 3 kilometers (10,000 feet) underground. From electrical resistance tomography to cross well seismic imaging, almost every type of wave signal an instrument can produce is being used to measure carbon sequestration. Fluid samples are conveyed to the surface by means of a state-of-the-art sampler called a U-tube and subjected to a vast array of chemical analyses. The data is still being distilled but, "so far we have a very good history match," says Hovorka.

One significant question remaining is the best way to monitor an injection program.

"We'd like to find the canary in the coal mine," says Hovorka, which means real-time signals that assure managers know it's safe to continue injecting, and warn them if not.

A promising technique is called above zone monitoring. Similar to sneaking spies into the attic of a safe house to collect intelligence from conversations in the rooms below, above zone monitoring involves placing temperature and pressure sensors about 400 meters (1300 feet) above the confinement zone.

"Any pressure or flow communication between those formations due to lack of seal or well integrity will be picked up by the

Concentration on Collaboration

Carbon sequestration is at root a problem that involves a variety of disciplines. When Hovorka started thinking about CCS, she realized she needed information beyond her expertise in subsurface geology—to understand the economics of power plants, the chemistry of coal combustion, and energy regulation.

Today the staff at the GCCC includes stratigraphers who characterize underground containment zones, geochemists who study the chemistry of ground water and rocks, hydrogeologists who work on the movement of water deep underground and in aquifers, and modelers who develop computer programs to validate all of this information. They also include economists who study the market implications of sequestration and environmental geologists studying its risks. Other staff focus on outreach, connecting the information learned at GCCC to the broader scientific community and the public.

"We have much diversity, an abnormal amount of diversity, but it's not nearly enough." says Hovorka. So the carbon center has reached out to a broad spectrum of collaborators.

Within the university, the GCCC works closely with researchers at other units, including Bill Galloway, Patty Gainey-Curry, Matt Hornbach, and Ursula Hammes at the Jackson School and Larry Lake, Gary Pope, and Steve Bryant in the Cockrell School of Engineering, contributing everything from new geophysical techniques for measuring CO2, to characterizing how sands laid down millions of years ago form the perfect compartments for storing the gas.

In the Department of Geological Sciences, Mark Hesse teaches carbon center students multi-phase flow modeling, key to validating the assumptions of the field tests. Professors Jay Banner and Phil Bennett provide input on groundwater flow patterns ensuring injection projects will not impact aquifers.

In the larger university community, the GCCC collaborates with Gary Rochelle in the chemical engineering who is developing new methods for capturing CO_2 from power plants. David Eaton at the LBJ School looks at legislative policy. Melinda Taylor and Michael Esposito at the Law School study how laws governing sequestration might be written. Ray Orbach at UT's Energy Institute depends on the GCCC to advance solutions to today's energy problems. Mary Wheeler at the Institute for Computational Engineering and Sciences is part of the center's mathematical modeling effort.

"But UT isn't enough" Hovorka asserts. The carbon center's corporate sponsors number in the mid-teens and the center collaborates with six national laboratories, ten universities, a similar number of industries, the USGS, Department of Energy, and the EPA.

The large range of industries involved with the Center bring essential skills and experience to the programs, and in the case of Denbury, Inc. and Kinder Morgan, they act as site hosts in the field.

"We work with the best in the world," summarizes Hovorka.

Work pregresses at a $34 million Department of Energy funded research project evaluating sequestration and monitoring strategies for long-term storage of carbon dioxide at Cranfield field in Mississippi. Here, an observation well is being drilled and fiberglass casing is waiting to be inserted and cemented inside the well.

above zone gauge first," says Meckel. Beginning prior to injection in 2008 and operating continuously through to the present, the above zone monitoring at Cranfield represents the longest continuous data series for any CO_2 injection site.

And so far, assumptions are holding up. CO_2 has remained in the confinement zone. Underground characteristics, like pressure, temperature, and water chemistry, have responded in the ways models predict. The environmental impacts of the injection have been undetectable.

Into the Future

The project at Cranfield is just one of five major projects the carbon center has conducted between 2005 and 2010. More are on the way. Awards of $11 million from state and federal agencies will be used to study the potential for CCS in submerged lands off the Texas coast. The center will receive up to $19 million to conduct a groundbreaking demonstration project in which CO_2 is captured directly from power plants, instead of from naturally occurring geologic reservoirs, and used for EOR. Another project involves assessing effectiveness of diverse monitoring programs.

Overall, the Bureau and the carbon center have received more funding to answer questions about CCS than researchers at any other academic institution in the country.

The carbon center's staff has grown from just two or three members in the 1990s to about two dozen members with expertise in geology, hydrology, chemistry, and economics—and it also includes almost 20 post docs, doctoral candidates, master's students, and undergraduate interns.

At any given time, researchers from the carbon center are working in classrooms on the university's main campus, offices at the Bureau of Economic Geology, field sites in Texas or Mississippi, national laboratories across the U.S., or presenting at conferences all over the world. In all of these places they are looking for answers that will undoubtedly steer the future of carbon sequestration. ✷

The Long (Out)Reach of the Carbon Center

"The first and last mission of the GCCC is outreach." explains Hovorka. The GCCC has long taken an aggressive approach toward sharing information with decision makers, both in industry and government at all levels, state, local, national, international, as well as the public. "In fact, all of the staff, from scientists to students, tend to be outreach enthusiasts."

And the outreach effort just got a major boost. In 2009, the Department of Energy awarded a $1 M grant to the University of Texas to educate the public as well as stakeholders about the recent advances in CCS. Called the Alliance for Sequestration Training, Outreach, Research, and Education or STORE, the program is a collaborative effort between several UT departments. Principle Investigator Hilary Olson explains "We bring together a strong basic research focus from Petroleum Geosystems Engineering and strong outreach from the Jackson School's Institute for Geophysics, and we marry that with the extraordinary applied research and field experience of the GCCC."

STORE has gotten off to a fast start, hosting field trips and workshops for professionals and education programs for K-12 students, with many more events on the horizon. In May, STORE launched its website, which along with basic information about CCS and the Alliance's activities, will include scientists' blogs and video blogs and serve as a major conduit of information for the public and stakeholders involved in carbon sequestration. (See www.storeco2now.com) This fall, several members of STORE and GCCC, including Susan Hovorka and JP Nicot, will teach a new course on carbon sequestration at UT, increasing the exposure of undergraduates and graduate students to the technology.

"What's unique about STORE's collaboration with GCCC," explains Olson, "is that we have the opportunity to launch off the Gulf Coast Carbon Center's scientific successes and transfer that technology, knowledge, and information to the public."