The Challenges of Carbon Capturing and Sequestration

By Diane Gow McDilda

The concern over increasing levels of carbon dioxide (CO_2) in the atmosphere has increased the interest in research to reduce emissions. One area of study gaining attention is the ability to capture carbon before it escapes into the atmosphere and store it safely underground. There's no better place to capture carbon than at a fixed source, like a fossil fuel power plant. And with Florida's saline aquifers, the state looks to be candidate for carbon storage.

Mark Stewart, a professor in the Geology Department at the University of South Florida (USF), is the lead investigator on a research project that's investigating the efficacy of capturing carbon at fixed sources and sequestering it in the carbonate rocks that run thousands of feet deep beneath Florida's ground surface.

Stewart emphasizes that the project is truly a team effort, with each member bringing their expertise to the table.

"I may be the lead for the CO_2 sequestration research in Florida for FESC, but it wouldn't work without collaborators," says Stewart.

Capturing the Carbon

The project comprises various aspects of the capture and storage process. The removal of carbon from the flue gas is often the most complicated component of the process. For this element, Stewart relies on Yogi Goswami, professor of Chemical Engineering at USF and Co-Director of the Clean Energy Research Center.

Goswami's research involves developing more effective and economic ways to capture CO_2 from flue gas. Technologies include the use of solvents, sorbents, membranes, and cryogenic separation. One method of particular interest utilizes ceramic cloth impregnated with a thin film of calcium or calcium-magnesium. As the flue gas passes through, the carbon is captured by converting the oxide to carbonate. With the carbon secured, flue gas, minus CO_2, escapes. Heating the ceramic converts the carbonate back to the oxide, driving off the CO_2 and making it available for sequestration.

"It's an on-off cycle," explains Stewart. "It's not easy to capture CO_2 and then it requires a lot of energy to separate it. It's possible to use the flue gas to heat the ceramic."

Goswami's research is also focusing on increasing the thermal efficiency of the system and extending the life of the thin oxide film, in hopes of making the solid sorbent technology more cost effective and scalable.

Going underground

Once the carbon is captured, the next challenge is how to most effectively transfer it to Florida's deep saline aquifers for storage. Both the physical and chemical aspects of injecting carbon into the subsurface must be considered. With Stewart's background in geophysical and mathematical modeling, his role is to evaluate the physical aspects of CO_2 storage.

“We use a model the Department of Energy developed, TOUGH, that has the capability of simulating the behavior of three-phase systems, gas, brine, and supercritical CO_2,” says Stewart.

Data were gathered from the Florida Geologic Survey for the study area, the Cedar Key-Lawson formation. The southern half of the Florida Peninsula was selected for study as it’s suitable for both geologic sequestration and enhanced oil recovery (EOR). Stewart and the team evaluated possible injection rates into vertical and horizontal injection wells and determined that rates as high as 8 million tons per year (Mt/y) could be obtained for a single vertical injection well, possibly higher for a horizontal well that isn’t limited by the thickness of the geologic formation.

The proximity of a sequestration site to EOR operations cannot be overlooked. And as surprising as it may sound to some, CO_2 is not solely a combustion by-product, but a useful material.

“Gas and oil companies have been injecting CO_2 into wells for over 40 years,” explains Stewart. “CO_2 is commercially viable.”

Where primary recovery operations generally recover as much as 30-50 percent of the oil and gas originally present, using CO_2 for enhanced recovery can produce an additional 10-20 percent.

“CO_2 under supercritical conditions turns to liquid,” Stewart says. “It acts similarly to trichloroethylene, or TCE, a solvent dry cleaners used. Using supercritical CO_2 is like dry cleaning the oil reserves; it strips the oil off the grains.”

While revenues from enhanced oil recovery do offset the cost of sequestration, the actual sequestration isn’t as effective, as 70-80 percent of the total volume of CO_2 injected is recovered and reused.

While permitting is required for using CO_2 in EOR operations, it’s not an insurmountable hurdle. Permitting for CO_2 sequestration; however, is currently in limbo. The US Environmental Protection Agency (EPA) hasn’t finalized underground injection permitting requirements, primarily over concern of groundwater contamination. This regulatory uncertainty discourages industries from adopting geologic sequestration.

Beyond physical

When injection moves beyond physical into the chemical realm, this is when two more researchers come into play. Jeffrey Cunningham and Maya Trotz, both professors in the Civil & Environmental Engineering at USF, are involved with the chemical reactions that take place in the subsurface as CO_2 is injected. For this the pair relied on TOUGHREACT software to predict the geochemical response to a steady injection of CO_2.

When CO_2 is injected into a brine aquifer it lowers the pH. This in turn dissolves dolomite and calcite, the primary minerals of the limestones of the Florida Peninsula, and precipitates the calcium sulfate mineral gypsum. The concern is that these reactions could decrease the porosity and permeability of the aquifer, possibly clogging the well and limiting its efficiency. Model results from the study indicate that long term effects on well performance would be minimal.

In line with EPA’s concern is the release of contaminants. Previous research as shown that treated wastewater injected into aquifers caused the dissolution of arsenic from subsurface soils into groundwater.

“This is Maya’s specialty,” says Stewart. “She’s working with a consultant and a utility on the effect of injecting wastewater from a city and adding highly chlorinated material. Now we’re asking, ‘what if we pre-dissolve CO_2 or co-inject CO_2?’”

The question of pre-dissolving CO_2 is posed as a matter of storage efficiency. When pre-dissolved, CO_2 stays in solution, allowing a greater volume of carbon to be sequestered, essentially packing more carbon into a unit of storage space.

Where does this leave Florida?

As utilities in Florida, and across the country, anticipate regulatory constraints on carbon, there's no absolute answer as to which regulatory scenario will play out. Regulations can take the form of cap and trade or a carbon tax. Because utilities tend to be conservative in nature, planning 40 years into the future, this puts them in the position of having to prepare where no roadmap exists. This is more difficult for states and utilities that rely almost entirely on coal for electrical power production.

In Florida, electricity production relies heavily on natural gas, which generates half the amount of CO_2 per kW-hour of electricity when compared to coal. This positions Florida well for the near future with regard to avoiding financial impacts from carbon caps or taxes. However, even with a lower CO_2 output, carbon emissions will have to be addressed by Florida utilities.

This may come about through sequestration projects, like Stewart's, or industry changes, such as implementing more CO_2 efficient combined-cycle combustion systems and relying more on natural gas, nuclear and solar power. Mostly likely it will be a combination of the two.