POTENTIAL FOR CARBON CAPTURE AND SEQUESTRATION (CCS) IN FLORIDA

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### Project Team

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Why CCS?

- Reduces CO$_2$ emissions from large stationary sources
  - Especially fossil-fuel-fired power plants
  - Also petrochemical plants, refineries, cement production
- Mitigates effects of energy production on climate
  - Allows us to continue using fossil fuels until new technologies are ready for full-scale deployment
- Florida has one of only two “capture-ready” coal-fired power plants in the United States
  - Integrated gasification / combined cycle (IGCC)
How CCS Works

1. Mining of fuel
2. Coal- or gas-fired power station with CO₂ capture plant
3. CO₂ transport by pipeline
4. CO₂ injection
5. CO₂ storage sites

Key
- Supercritical CO₂ plume
- Dissolved CO₂ plume

Scottish Centre for Carbon Storage
www.geology.ed.ac.uk/acs
Project Goals

- Develop a simple and cost-effective method that captures CO$_2$ from power-plant flue gas
- Determine if there are suitable repositories in Florida to store captured CO$_2$
- Estimate/predict what will happen if CO$_2$ is injected into the candidate repositories
  - Physical effects of CO$_2$ injection
  - Chemical effects of CO$_2$ injection
  - Long-term storage capacity / sequestration potential
Recent Results

FIRST GOAL:
DEVELOP A SIMPLE AND COST-EFFECTIVE METHOD
THAT CAPTURES CO₂
FROM POWER-PLANT FLUE GAS
Carbon Capture

- Several technologies potentially suitable for carbon capture
  - Solvents (liquid amines)
  - Sorbents (metal oxides)
  - Membranes
  - Cryogenic separation
- Technologies available currently (mostly with liquid amines) are expensive, energy-intensive
- Solid sorbents:
  - Promising technology
  - High capacity for $\text{CO}_2$, selective for $\text{CO}_2$, regenerable, fast diffusion and adsorption
  - Needs further refinement to become viable for full-scale deployment
Carbon Capture

- Sorbent: material composite, film of calcium oxide (CaO) impregnated on the fibers of a ceramic fabric
- Also investigating CaO/MgO $\leftrightarrow$ MgCa(CO$_3$)$_2$
Carbon Capture

- Results: carbonation/calcination cycles are reversible for many cycles
Carbon Capture

- Conversion is a function of pressure
• Conversion is a function of temperature
Carbon Capture

• Based on the experimental data, a “shrinking core model” is obtained

![Graph showing temperature and pressure data](image)

- For reaction control:
  \[ X = 1 - \left(1 - \frac{kt}{3}\right)^3 \]
  where \( k = 0.044 \).

- For diffusion control:
  \[ -3(1 - X)^{\frac{2}{3}} + 2(1 - X) = 2kt - 1 \]
  where \( k = 0.00051 \).
SECOND GOAL: DETERMINE IF THERE ARE SUITABLE REPOSITORIES IN FLORIDA
Geologic Sequestration

Overview of Geological Storage Options
1. Depleted oil and gas reservoirs
2. Use of CO₂ in enhanced oil and gas recovery
3. Deep saline formations — (a) offshore (b) onshore
4. Use of CO₂ in enhanced coal bed methane recovery
5. Deep unmineable coal seams
6. Other suggested options (basalts, oil shales, cavities)

Source: Intergovernmental Panel on Climate Change (IPCC)
In Florida?

- Sunniland Trend
- Oil and gas fields
- Viable, but probably relatively low storage capacity
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- Cedar Keys / Lawson Formation
- Deep saline aquifer
- Approximately 3000-5000 ft (1000-1500 m) below ground surface – deep enough for CO2 to be supercritical
- Not considered a potential “underground source of drinking water” (USDW) – too salty
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Lawson Formation

- Diagrammatic cross-sections through wells from southern Georgia to Columbia County, Florida (Applin and Applin, 1967)
- Predominantly porous dolomite, smaller amounts of calcite and gypsum
- Appears to have sufficient porosity, permeability, chemistry to store CO2
- Appears to have adequate seals so CO2 will not leak back to surface
Recent Results

THIRD GOAL:
ESTIMATE/PREDICT EFFECTS OF CO$_2$ STORAGE IN CANDIDATE REPOSITORIES
Proposed CO$_2$ Injection
Questions: Physical

- Will CO₂ leak out of the formation?
  - Can’t answer that one without expensive geologic investigation
  - First check if there are any “red flags” before conducting this expensive investigation

- Can we inject enough CO₂ (say, 1 million tons per year) without increasing the pressure too high in the formation?

- How far will the CO₂ plume travel from its injection well in, say, 50 or 100 years?

- How does CO₂ displace the brine?
  - Need to examine phenomena at the pore scale
• Brine is wetting fluid
• Brine is 10 times more viscous and 1.65 times denser than supercritical CO$_2$
## Pore-scale Model

- Numerical model based on lattice-Boltzmann technique to describe physics of fluids at the pore scale
- Can simulate the displacement of brine by injected $\text{CO}_2$
- Will use this model to determine how displacement depends upon pore-scale morphology
- Can couple the physical model to chemical models

[Play movie of brine displacement](#)
Questions: Chemical

- **Will CO\textsubscript{2} injection cause the rock matrix to dissolve?**
  - CO\textsubscript{2} dissolves into brine, forms carbonic acid
  - Carbonate minerals typically dissolve at low pH
  - Could threaten the integrity of the formation

- **Will CO\textsubscript{2} injection cause new minerals to precipitate?**
  - Introduction of additional carbonate into the system
  - System may be super-saturated, will precipitate carbonates to reach new equilibrium
  - Could plug the formation near the injection well, rendering the well useless – huge waste of $$
Coupled Modeling: Physical/Chemical

- Couple the physical flow model to a geochemical model that describes CO$_2$ dissolution, chemical speciation, diffusion within the brine, and reaction.
- Still developing/perfecting algorithms and code for the coupled model ... almost there.

Play movie of pH change during brine displacement
Mineral Precipitation and Dissolution

- Calcite and Dolomite will dissolve and Gypsum will precipitate
- Quantities are not highly sensitive to choices of appropriate sub-models for estimating CO\(_2\) thermodynamic parameters
  - Activity, fugacity, solubility
- Quantities are relatively sensitive to temperature and salinity
  - Activity coefficient is a strong function of temperature & ionic strength
  - Solubility is a function of temperature
- Quantities are surprisingly insensitive to initial pH and CO\(_2\) injection pressure
  - Solution buffering
  - CO\(_2\) fugacity does not increase linearly with pressure
• In all models, porosity is predicted to increase (net dissolution of minerals)

• Ignoring advective effects, the increase in porosity is very small \((10^{-6} - 10^{-4})\)
  ○ Proportional to initial porosity and residual brine saturation

• So far, no reason to believe that CCS won’t work
Carbon capture and storage may mitigate global climate change by allowing us to continue using fossil fuels in the short-term.

Important for Florida’s energy supply

Requires us to be able to

- Capture CO₂ efficiently
- Identify a location in Florida where the CO₂ can be stored (without leaking)
- Demonstrate that injection is technically feasible

So far, all indications are that the Lawson formation (deep saline aquifer) may be a viable repository.

- No “red flags” from physical or chemical modeling studies
- Detailed geologic characterization will be required.
Future Work

- Continue scientific investigations
  - Longevity of carbon-capture technology
  - Geologic characterization of repositories in Florida
  - Pore-scale models of CO\textsubscript{2} flow and geochemistry

- Work with industrial partners
  - Especially with electric power utilities in Florida

- Ultimate goal: pilot-scale CCS demonstration project in Florida
  - Might be coming soon!
TECO EXPERIMENT
Power plant set to test method of pumping gas underground

Mark Hornick, director of planning, engineering & construction for Tampa Electric, shows where warm gas clean up and CO₂ capture equipment will go for an experimental plan for carbon sequestration that involves pumping the greenhouse gas deep underground at the Polk Power Station south of Mulberry.

Thursday, August 18, 2011
Scott Wheeler / NYT Regional Media Group
By TOM PALMER
NYT Regional Media Group

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MULBERRY - A novel but expensive way to keep greenhouse gases like carbon dioxide out of the atmosphere is poised for a test at a Polk County power plant.
The plan, which is under permit review by state officials, is to send 300,000 tons of carbon dioxide per year deep underground, where scientists say the gas won't seriously affect the climate or anything else.