Carbon Capture and Sequestration (CCS) in Florida

JEFFREY CUNNINGHAM
YOGI GOSWAMI
MARK STEWART
MAYA TROTZ

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USF UNIVERSITY OF SOUTH FLORIDA

FESC Florida Energy Systems Consortium
Universities Addressing Florida's Energy Needs

Project Team

- Principal Investigator (PI):
  - Mark Stewart (USF, Department of Geology)
- Co-PIs:
  - Jeffrey Cunningham, Maya Trotz, and Yogi Goswami (USF, College of Engineering)
- Post-doctoral researcher:
  - Dr Shadab Anwar
- Students:
  - *Current*: Saeb Besarati, Arlin Briley, Tina Roberts-Ashby, Mark Thomas
  - *Graduated*: Dru Latchman, Roland Okwen, Douglas Oti

Outline

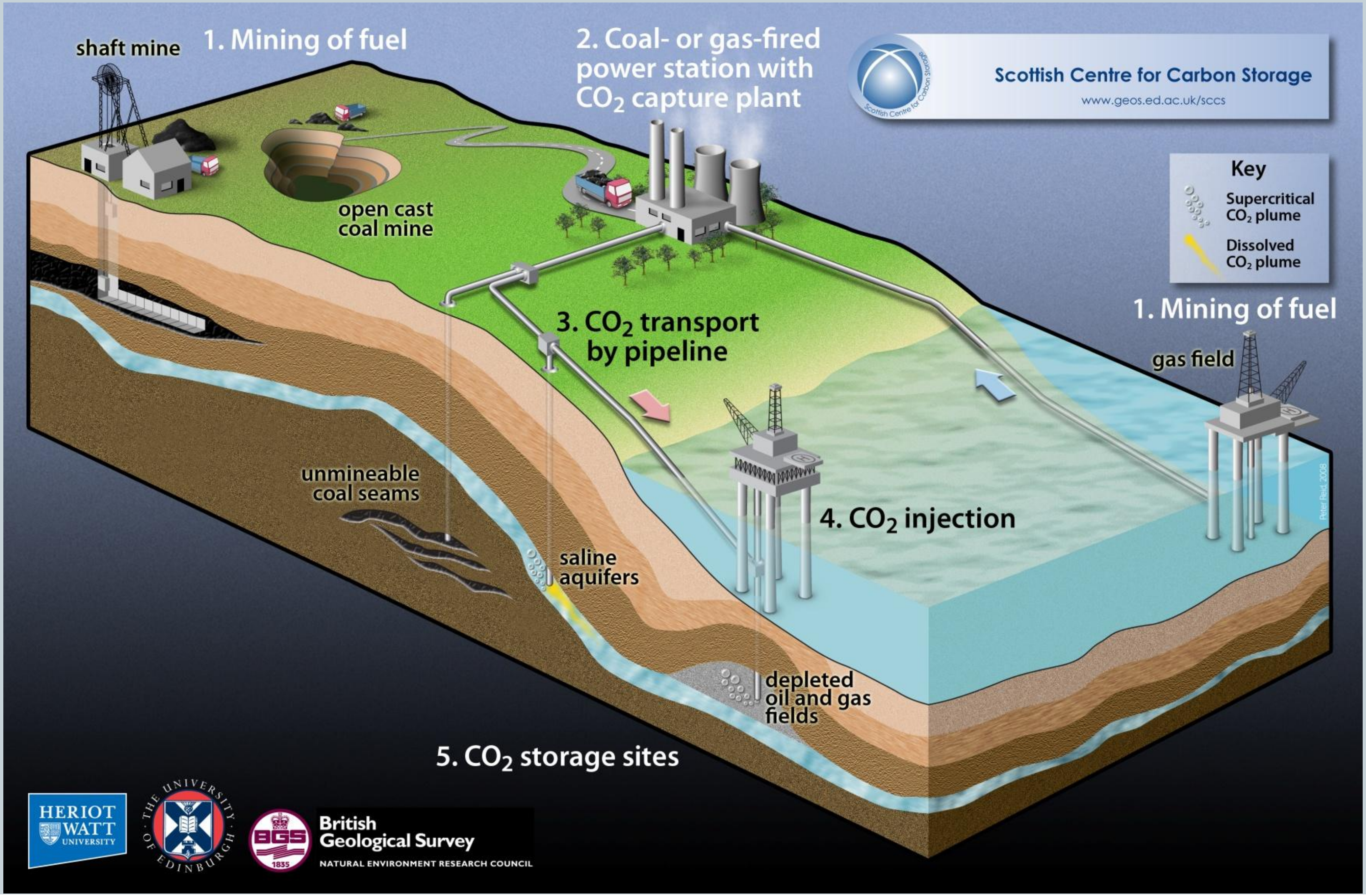
- Introduction to carbon capture and storage (CCS)
- Project goals
- Key results from the last year
- Take-home messages

- Goal of this talk: “hit the highlights” of our work from the last year
  - Please see the companion presentations for more details

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



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Project Goals

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- 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

Results from 2009-2010

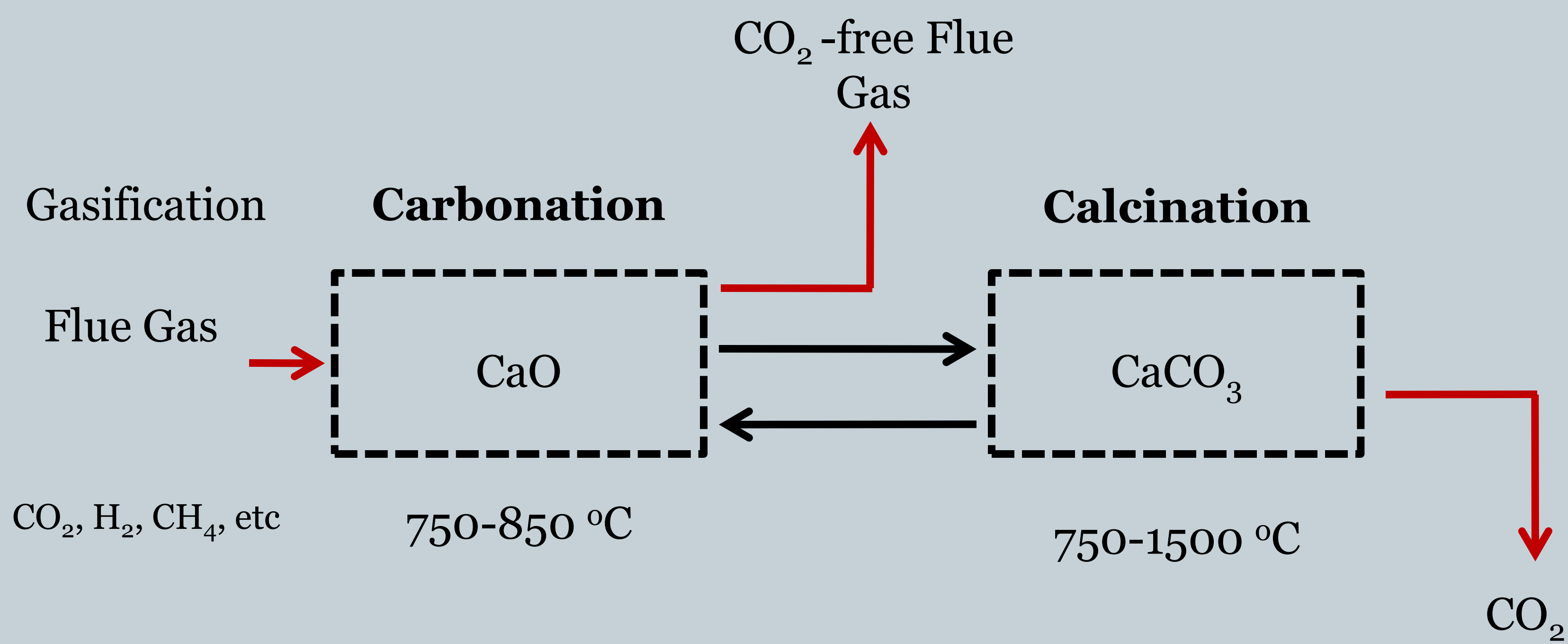
FIRST GOAL:

DEVELOP A SIMPLE AND COST-EFFECTIVE METHOD THAT CAPTURES CO_2 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 CO2, selective for CO2, regenerable, fast diffusion and adsorption
  - Needs further refinement to become viable for full-scale deployment

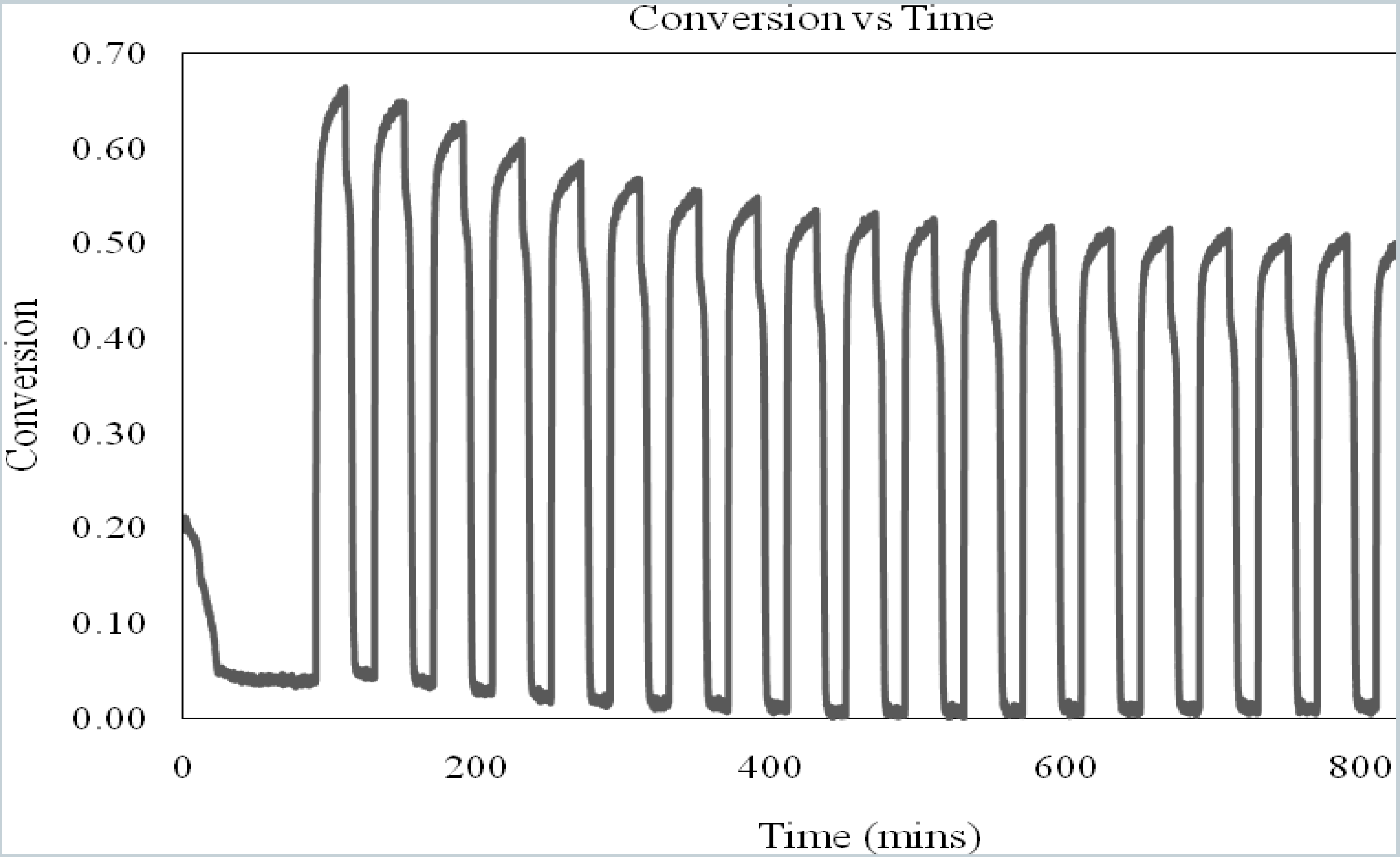
Carbon Capture



- Sorbent: material composite, film of calcium oxide (CaO) impregnated on the fibers of a ceramic fabric
- Also investigating CaO/MgO←→ MgCa(CO3)2

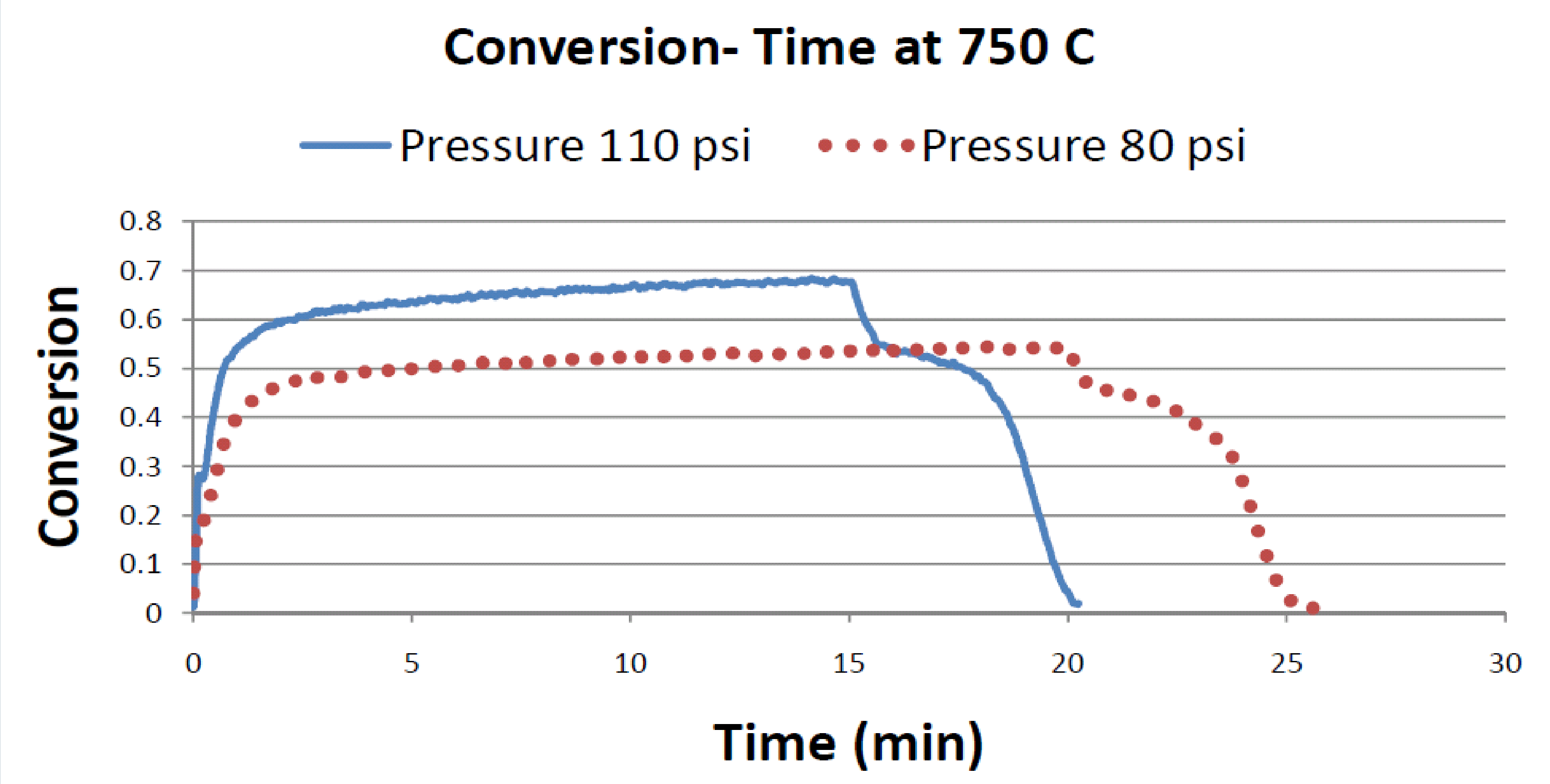
Carbon Capture

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



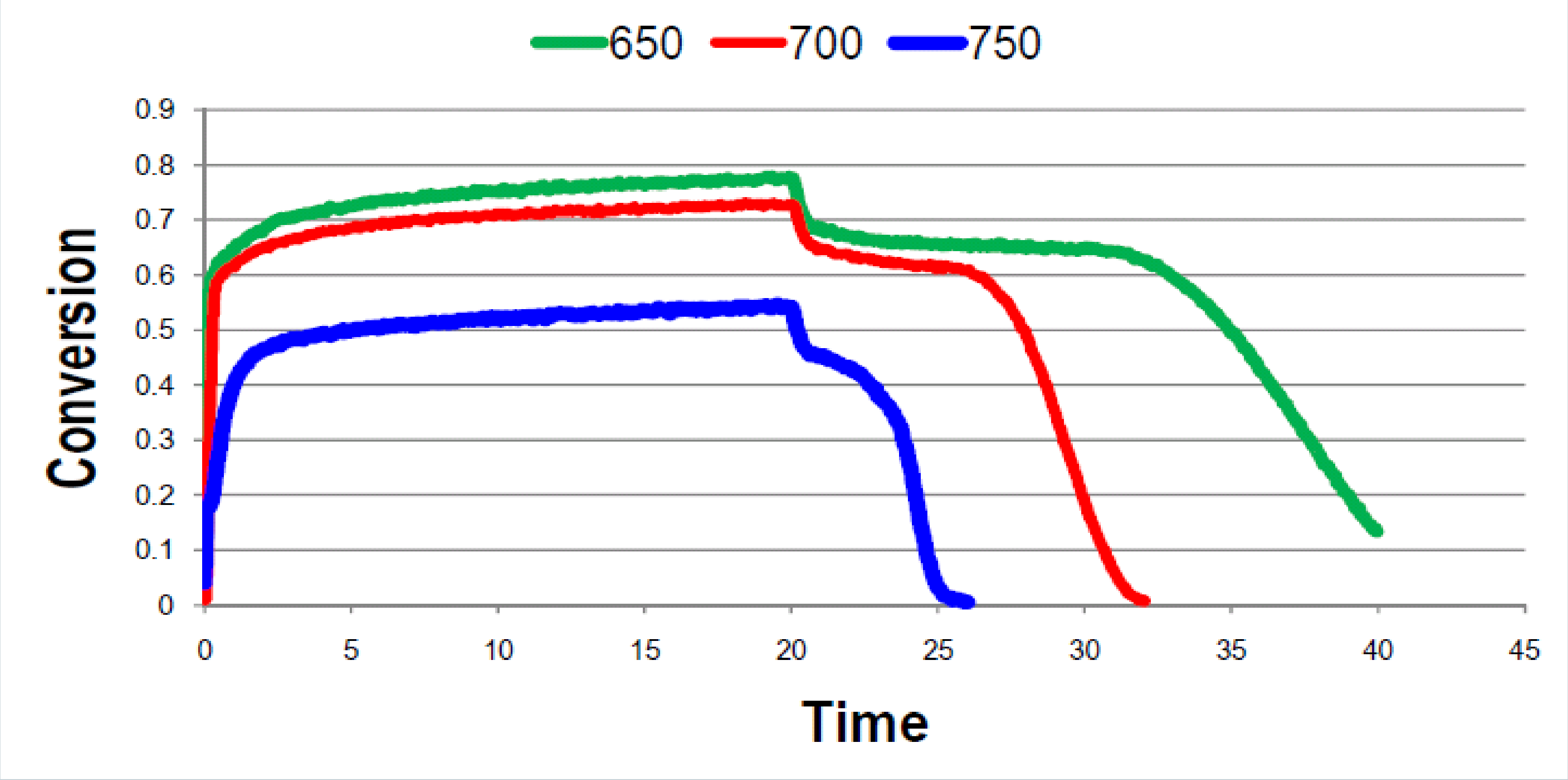
Carbon Capture

- Conversion is a function of pressure



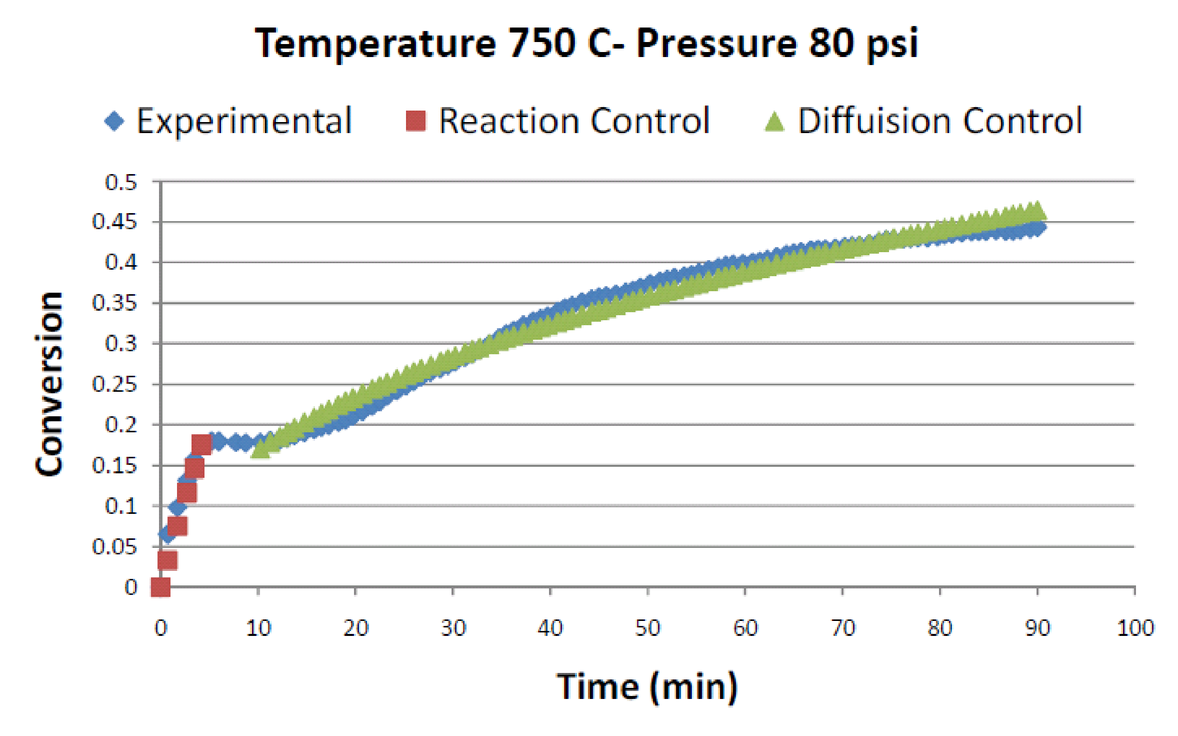
Carbon Capture

- Conversion is a function of temperature



Carbon Capture

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



- For reaction control :

$$X = 1 - (1 - \frac{kt}{3})^3$$

where k = 0.044.

- For diffusion control:

$$-3(1-X)^{\frac{2}{3}} + 2(1-X) = 2kt - 1$$

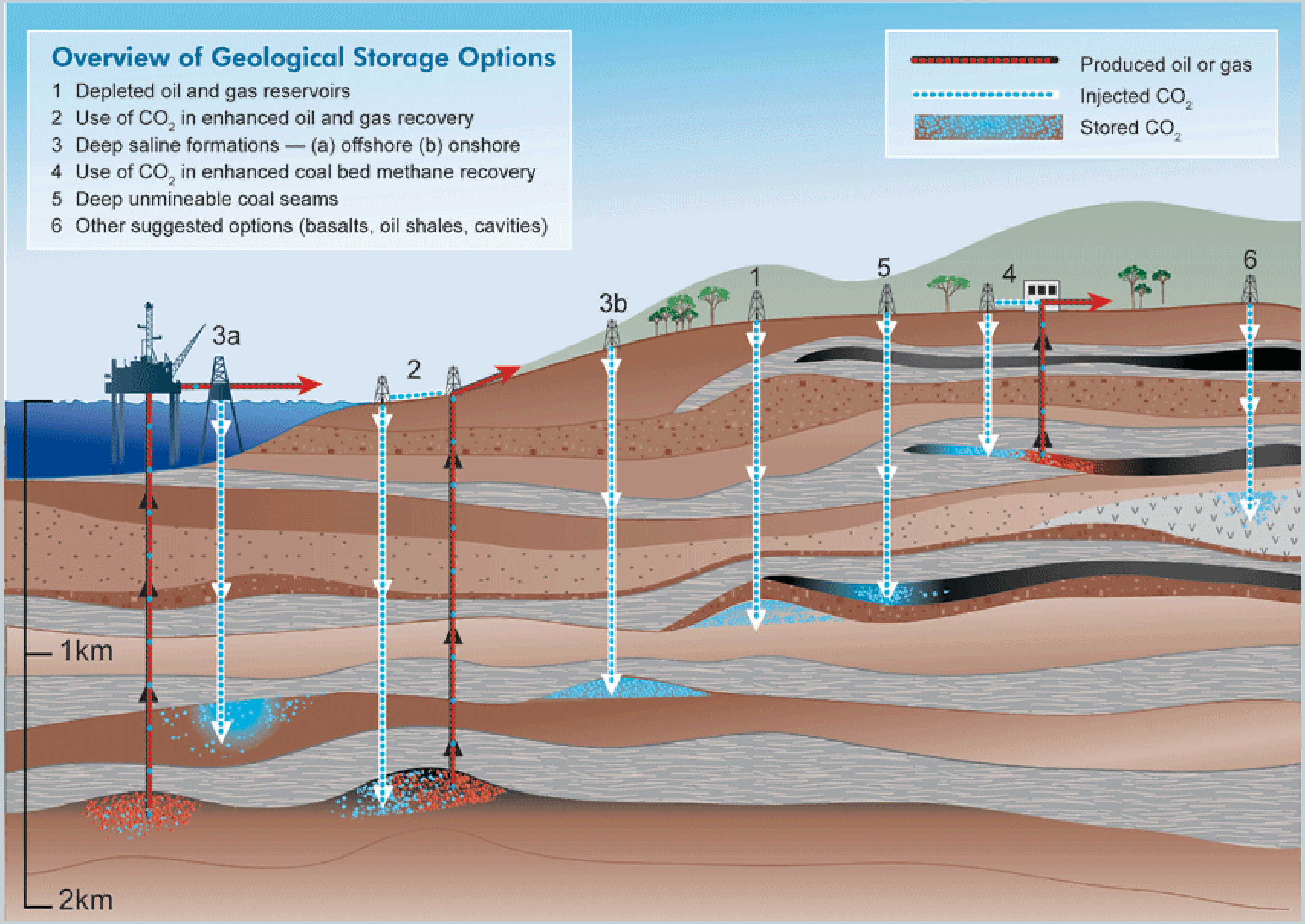
where k = 0.00051.

Results from 2009-2010

SECOND GOAL:

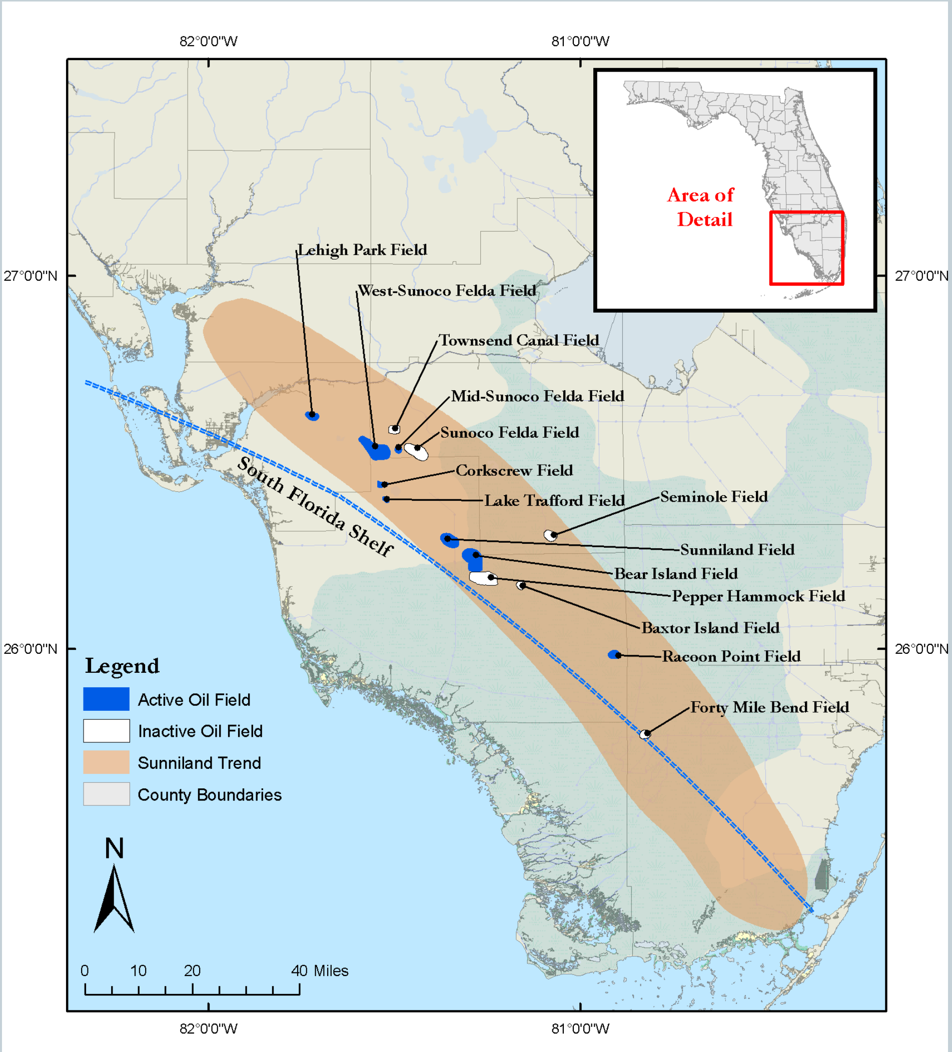
DETERMINE IF THERE ARE SUITABLE REPOSITORIES IN FLORIDA

Geologic Sequestration



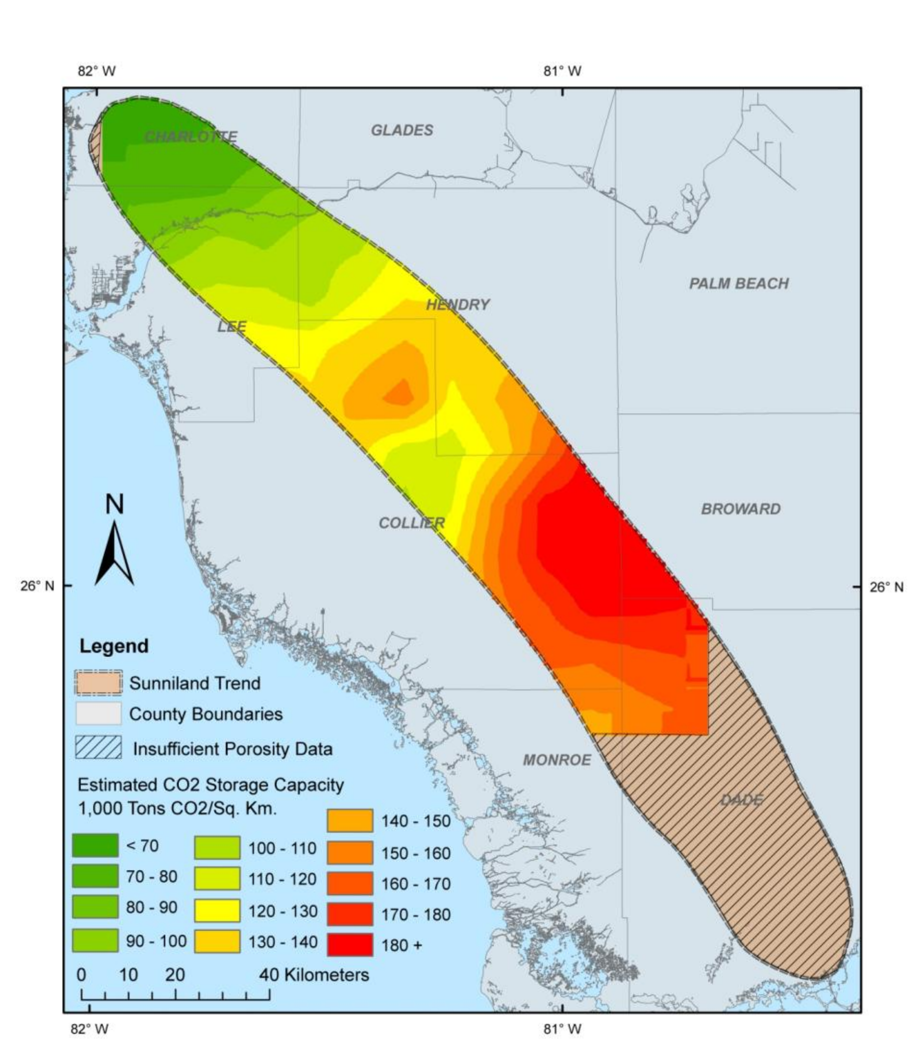
Source: Intergovernmental Panel on Climate Change (IPCC)

In Florida?



- Sunniland Trend
- Oil and gas fields
- Viable, but probably relatively low storage capacity

In Florida?



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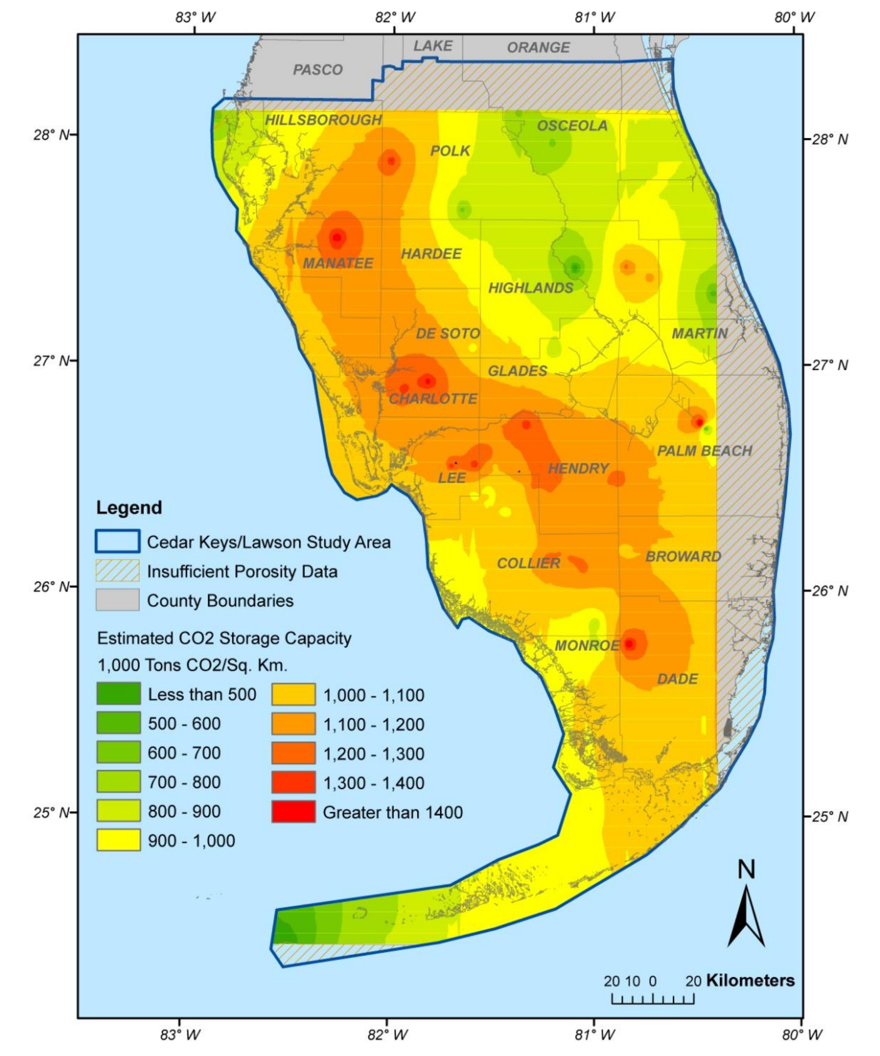
In Florida?

- 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

In Florida?



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Results from 2009-2010

THIRD GOAL:

ESTIMATE/PREDICT EFFECTS OF CO_2 STORAGE IN CANDIDATE REPOSITORIES

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Proposed CO2 Injection

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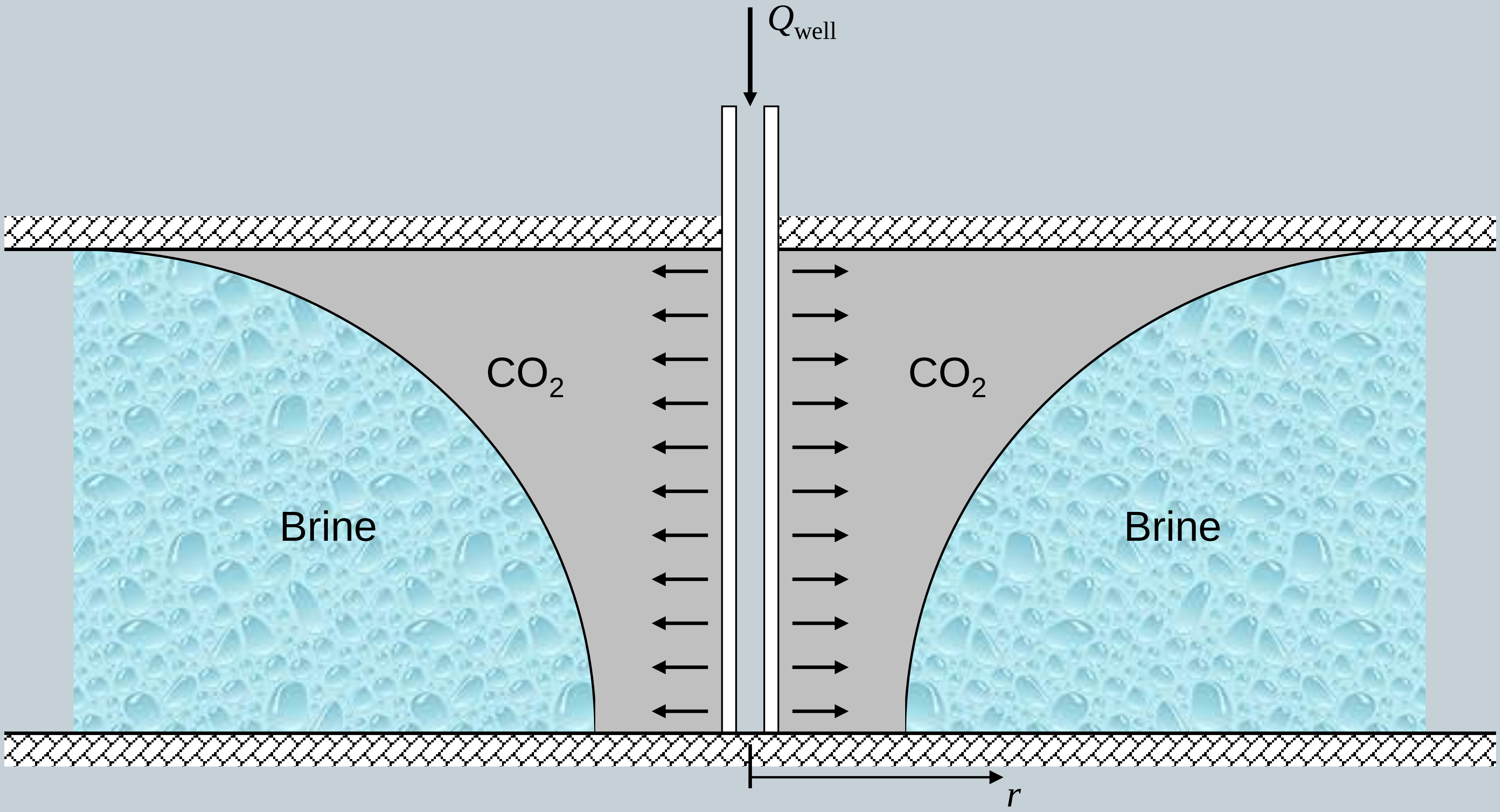
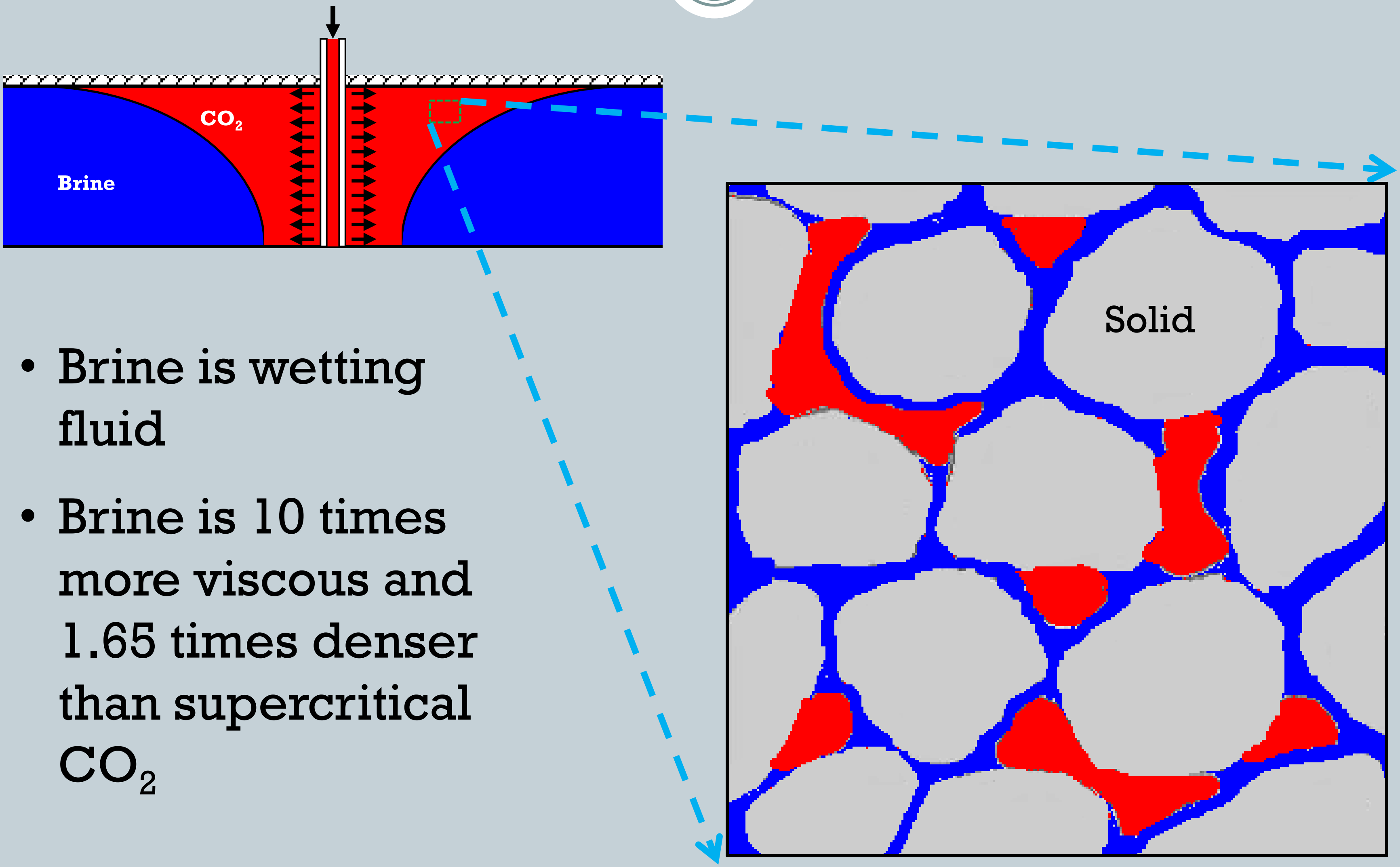


Questions: Physical

- Will CO_2 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 CO_2 (say, 1 million tons per year) without increasing the pressure too high in the formation?
- How far will the CO_2 plume travel from its injection well in, say, 50 or 100 years?
- How does CO_2 displace the brine?
  - Need to examine phenomena at the pore scale

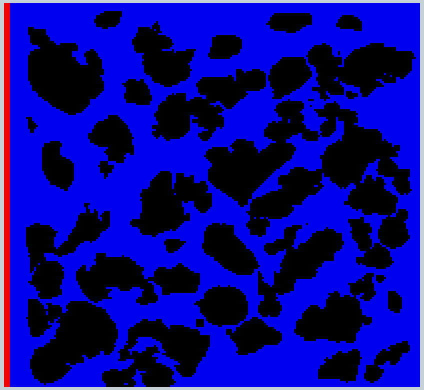
Pore-scale Model



- 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 CO_2



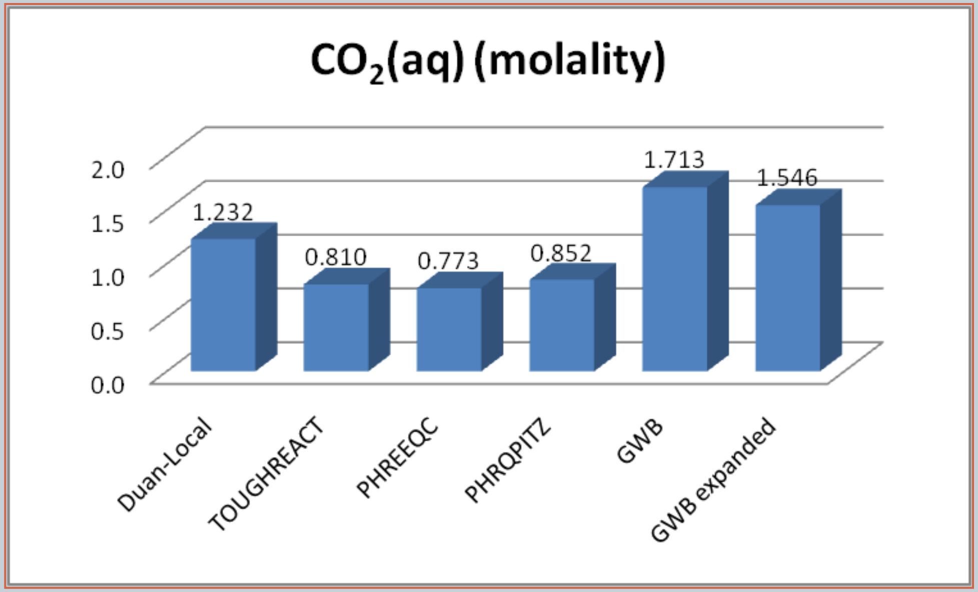
- Will use this model to determine how displacement depends upon pore-scale morphology
- Can couple the physical model to chemical models

Questions: Chemical

- Will CO_2 injection cause the rock matrix to dissolve?
  - CO_2 dissolves into brine, forms carbonic acid
  - Carbonate minerals typically dissolve at low pH
  - Could threaten the integrity of the formation
- Will CO_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 $$

"Off-the-shelf" Chemical Models

- How well do "off-the-shelf" geochemistry programs agree in their predictions of CO_2 solubility in high-pressure, high-salinity environments?



P = 180 bar CO_2
15% salinity
Temp. = 45°C

- We decided to build our own "in-house" chemical model

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 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

Porosity Change

- 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

Take-Home Messages

- 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_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!

…coming soon?

TECO Strives to Cut CO_2 Emission

By: Zacks Equity Research
September 13, 2010

In a quest to lower emission levels, electric utility **TECO Energy Inc.** (**TE** - Analyst Report) said that its subsidiary Tampa Electric company will construct a pilot project, which will remove sulfur and capture and sequester carbon dioxide (CO_2) from the Tampa Electric Polk Power Station's 250-megawatt integrated gasification combined cycle unit.

TECO Energy will partner with RTI International for the development and completion of the pilot project. The design, construction and operation of the pilot plant will be entrusted upon RTI, with an aim to capture a portion of the plant's CO_2 emissions to demonstrate the technology.

The pilot plant, which is designed to capture CO_2 from a 30% side stream of the coal-fired plant's syngas, is expected to complete in 2013. The project is expected to sequester approximately 300,000 tons of CO_2 more than 5,000 feet below the Polk Power Station in a saline formation. The new carbon capture technology is aimed to