Potential for Geologic Carbon Sequestration in Deep Saline Aquifers in Florida

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

Project Team

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Outline

- Introduction to Carbon Capture and Storage (CCS)
- Carbon capture
- Geologic repositories for CO2 in Florida
- Estimating effects of CO2 storage in Florida
  - Physical effects
  - Chemical effects
- Take-home messages

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Why CCS?

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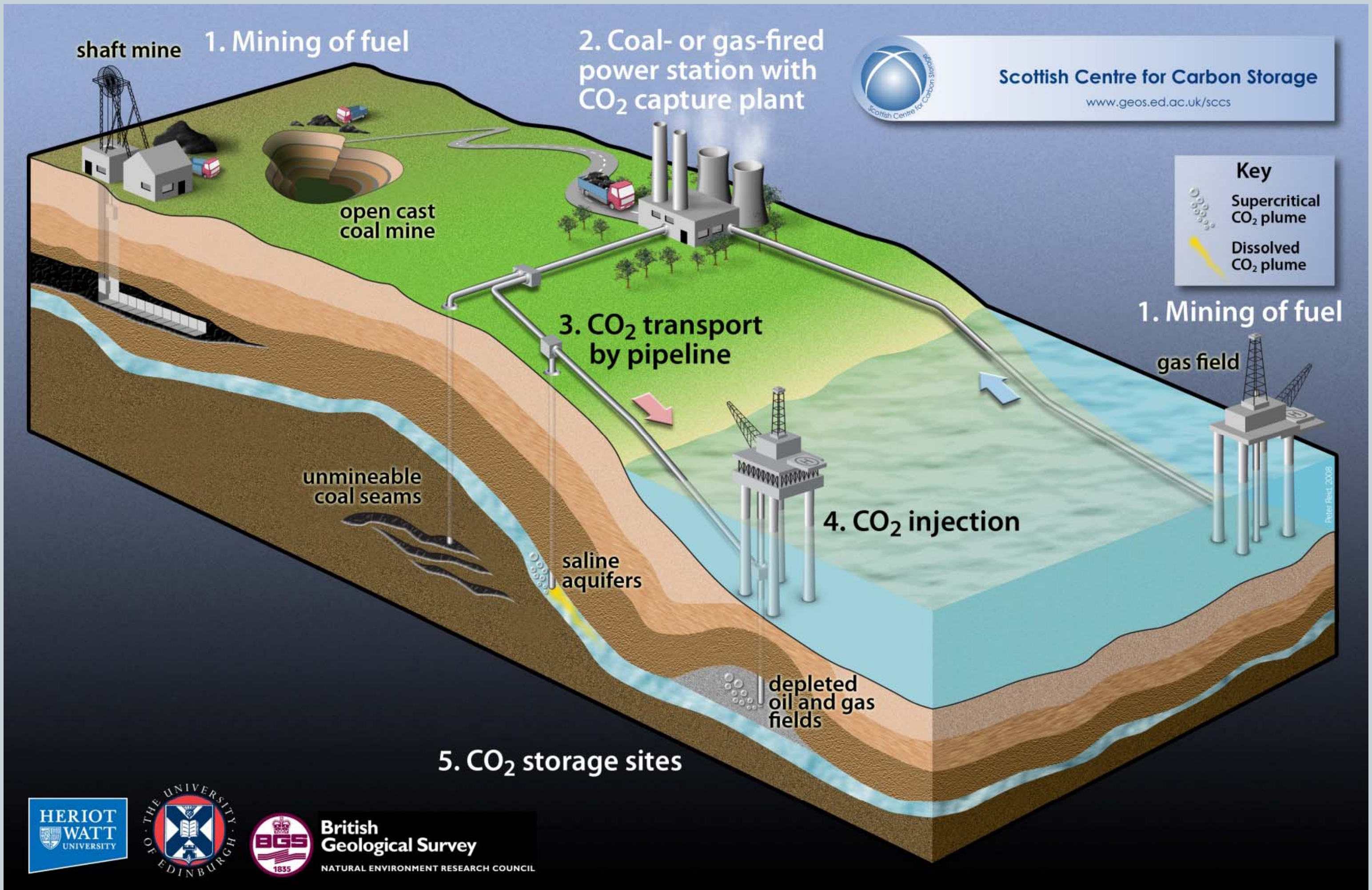
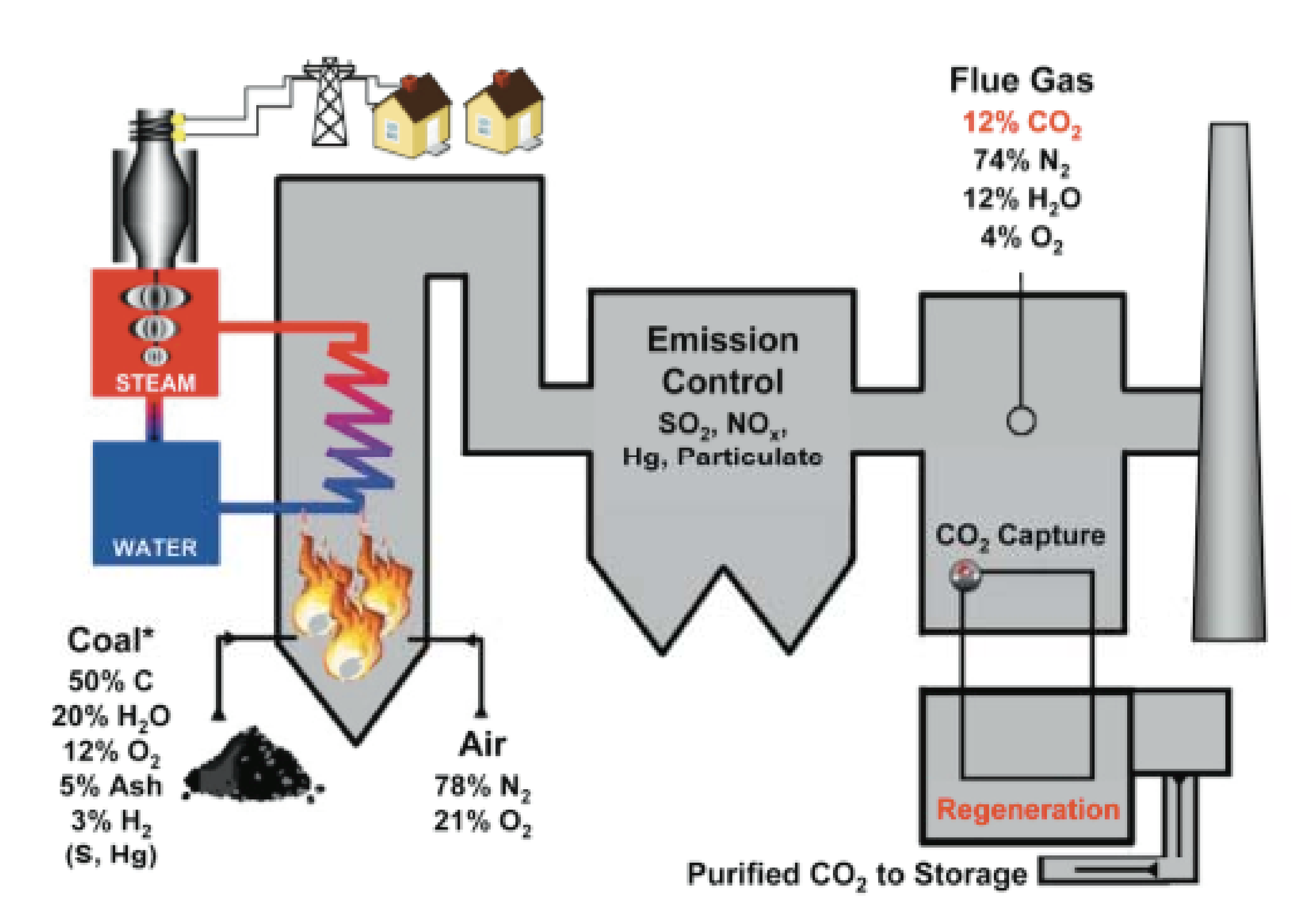
- Reduces CO2 emissions from large stationary sources
  - Especially fossil-fuel-fired power plants
  - Also petrochemical plants, refineries, cement production
- Mitigates effects of energy production on climate
  - Allows us to continue using fossil fuels until new technologies are ready for full-scale 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



Carbon Capture

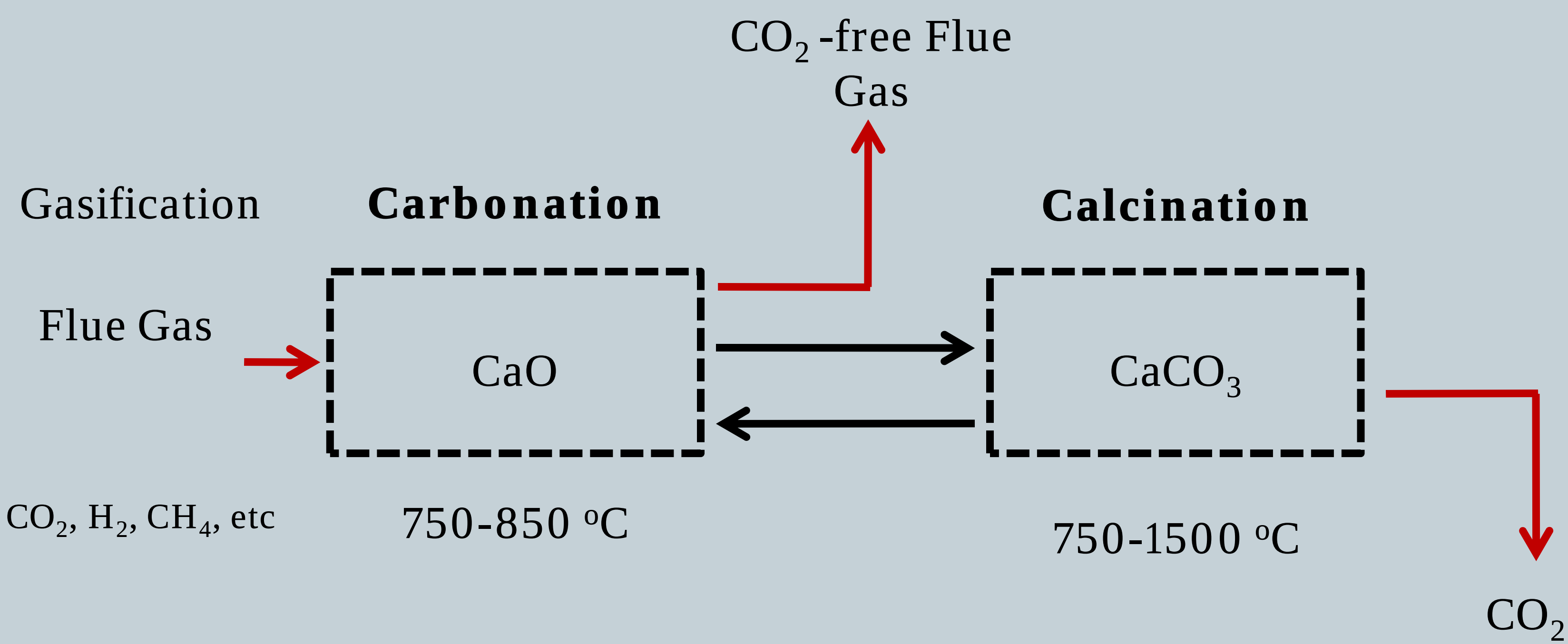


- "Post-combustion" CO2 capture
- Source: U.S. Department of Energy
- Technologies needed to separate CO2 from flue gas

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

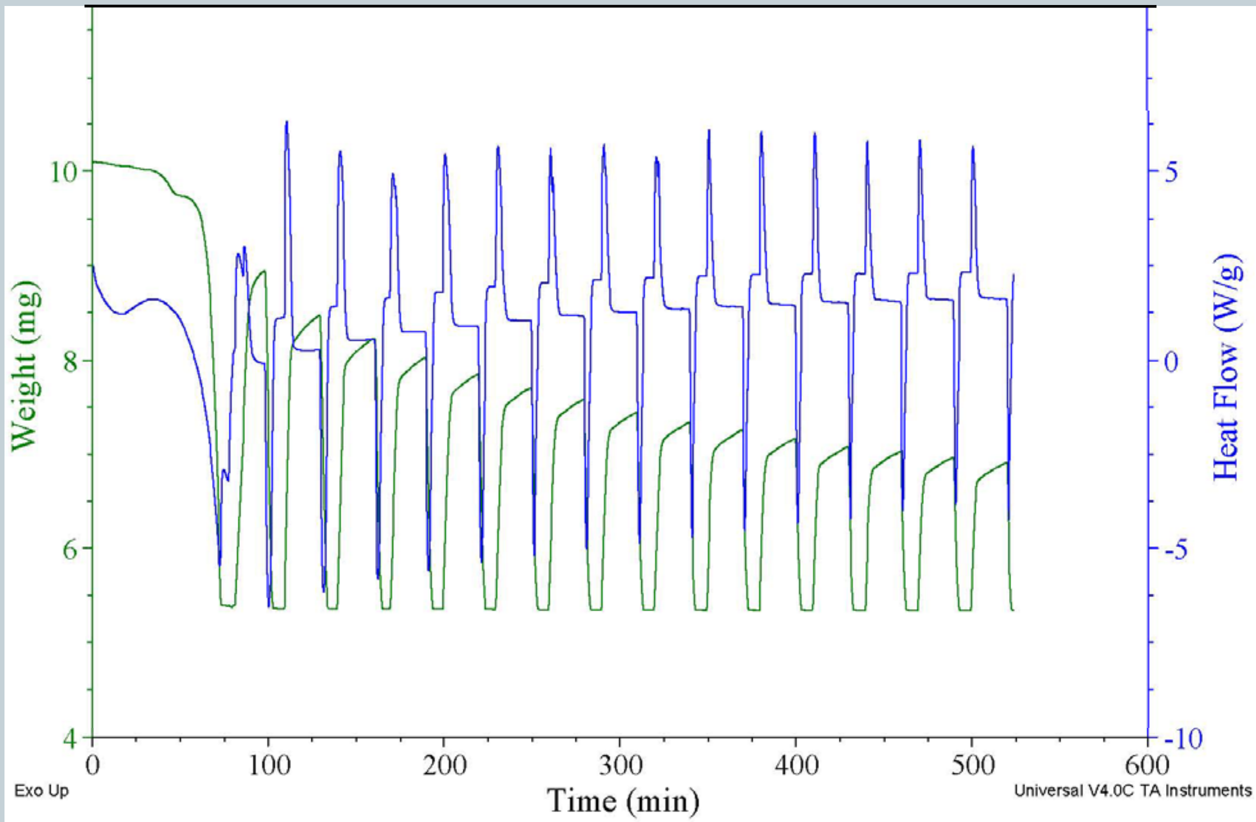
Carbon Capture



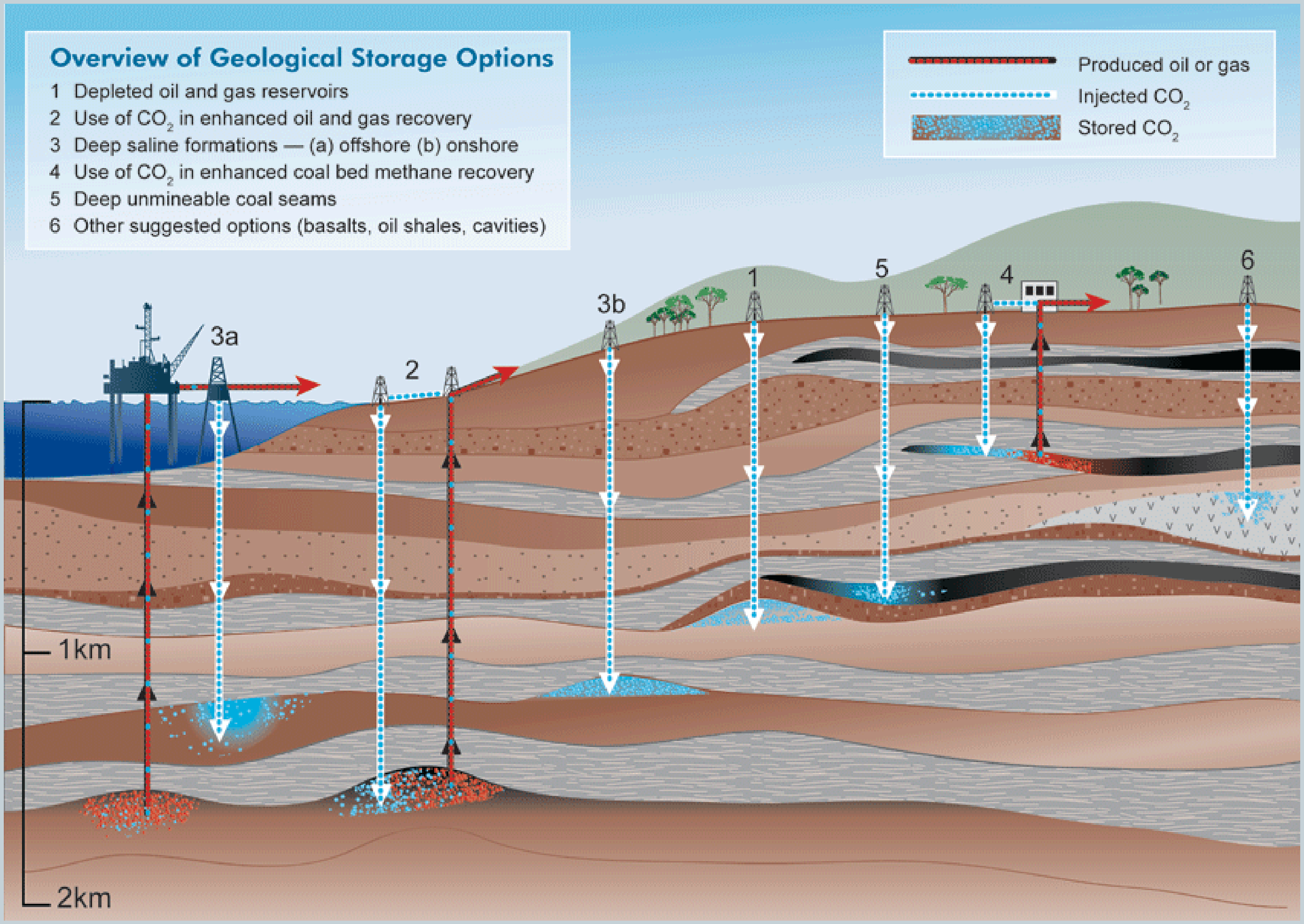
- Sorbent: material composite, film of calcium oxide (CaO) impregnated on the fibers of a ceramic fabric
- Also investigating CaO/MgO ←→ MgCa(CO3)2

Carbon Capture

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

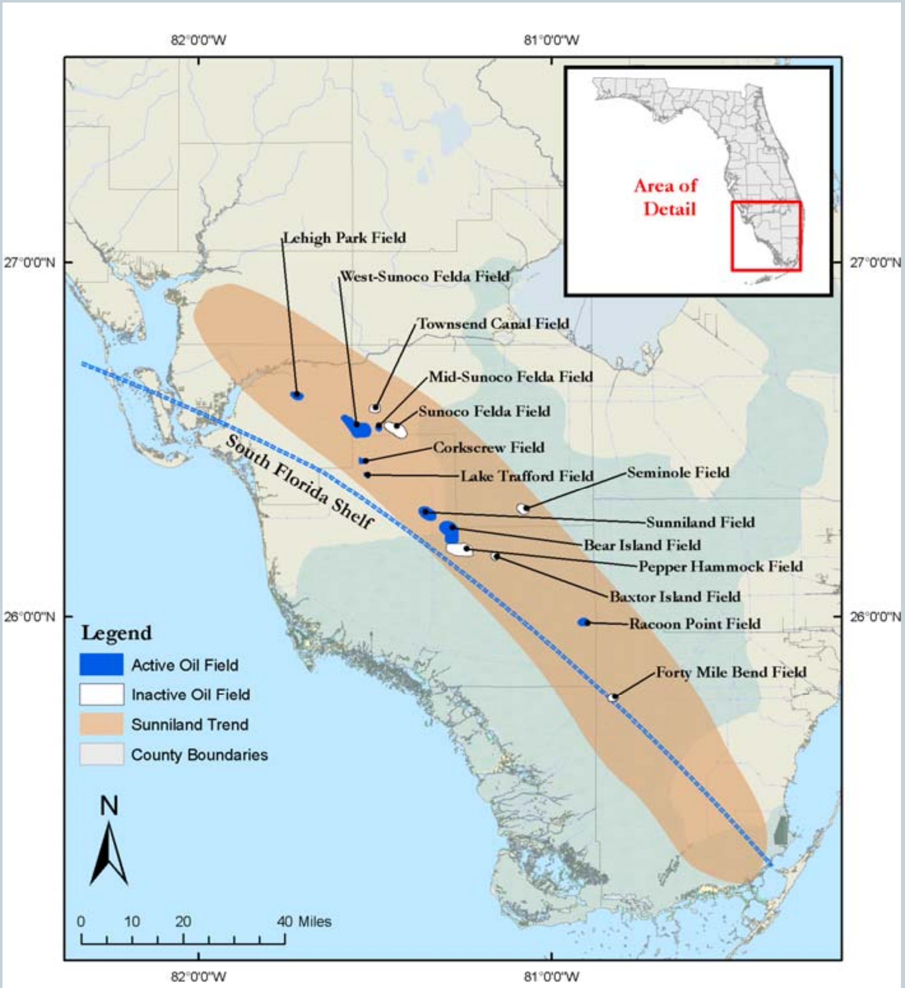


Geologic Sequestration



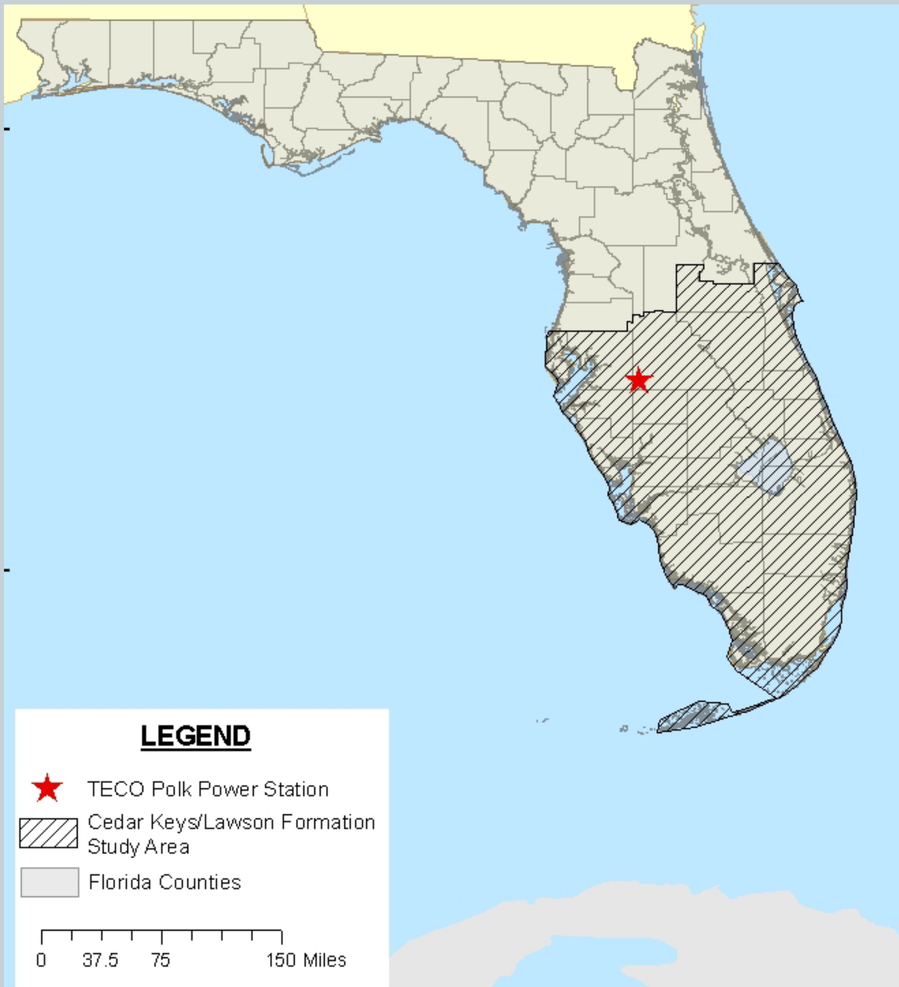
Source: Intergovernmental Panel on Climate Change (IPCC)

In Florida?



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

In Florida?



- Cedar Keys / Lawson Formation
- Deep saline aquifer
- Approximately 3000-5000 ft (1000-1500 m) below ground surface – deep enough for CO_2 to be supercritical
- Not considered a potential “underground source of drinking water” (USDW) – too salty

Lawson Formation

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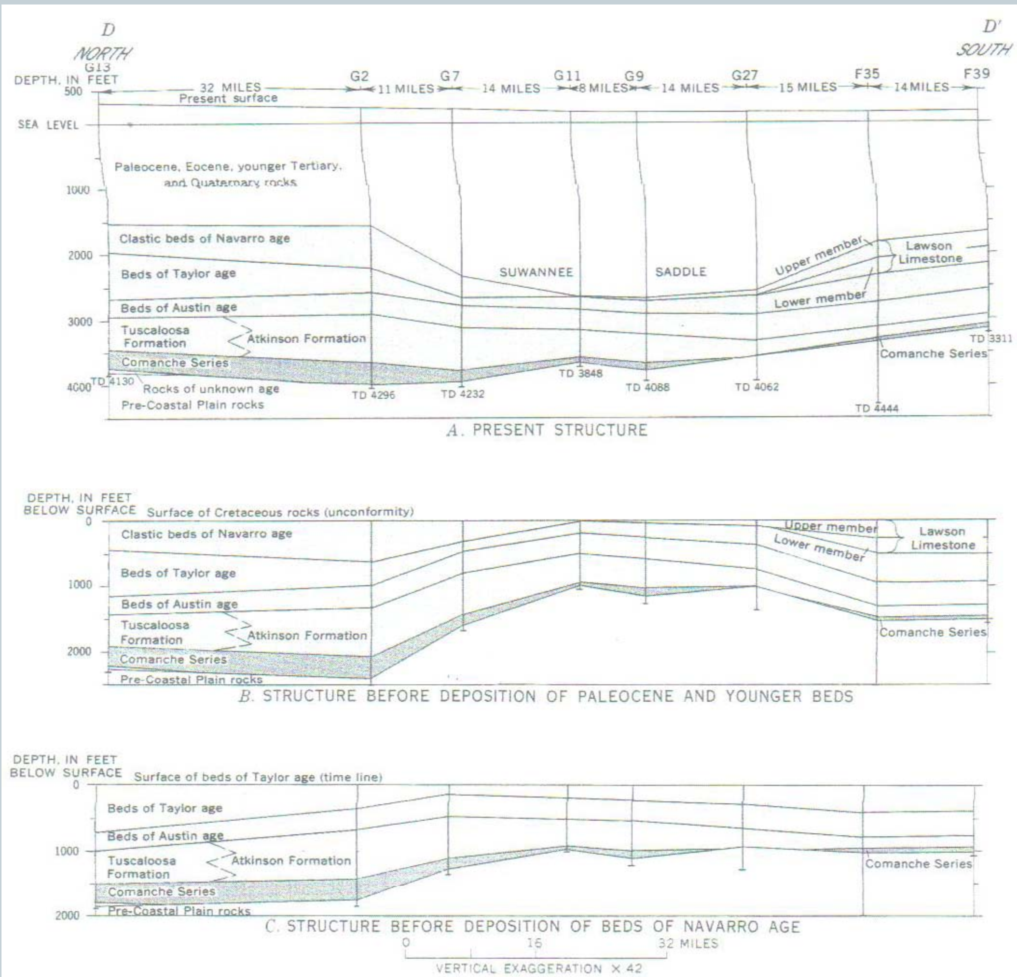
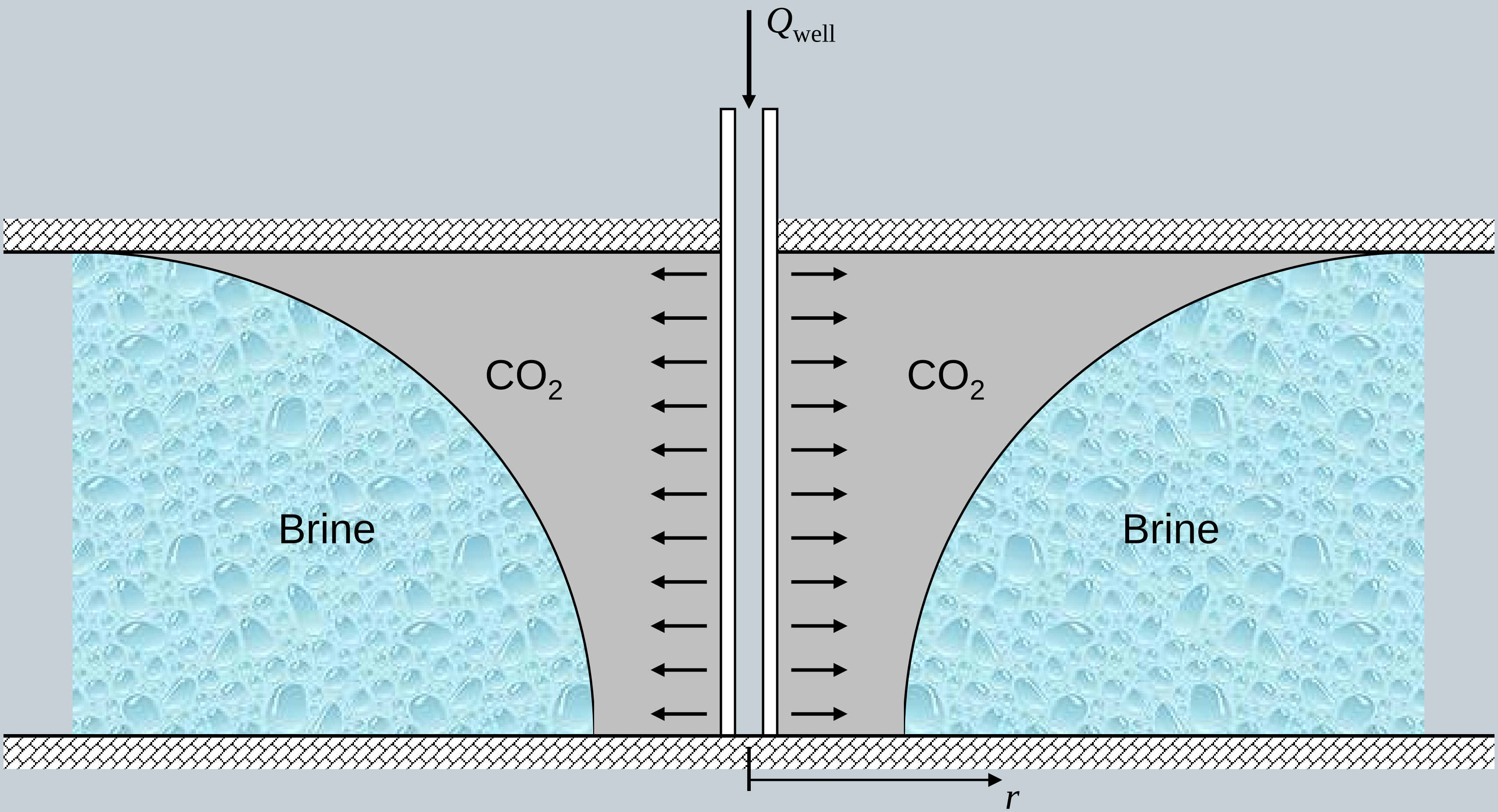


- Diagrammatic cross-sections through wells from southern Georgia to Columbia County, Florida (Applin and Applin, 1967)
- Predominantly porous dolomite, smaller amounts of calcite and gypsum
- Appears to have sufficient porosity, permeability, chemistry to store CO2
- Appears to have adequate seals so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

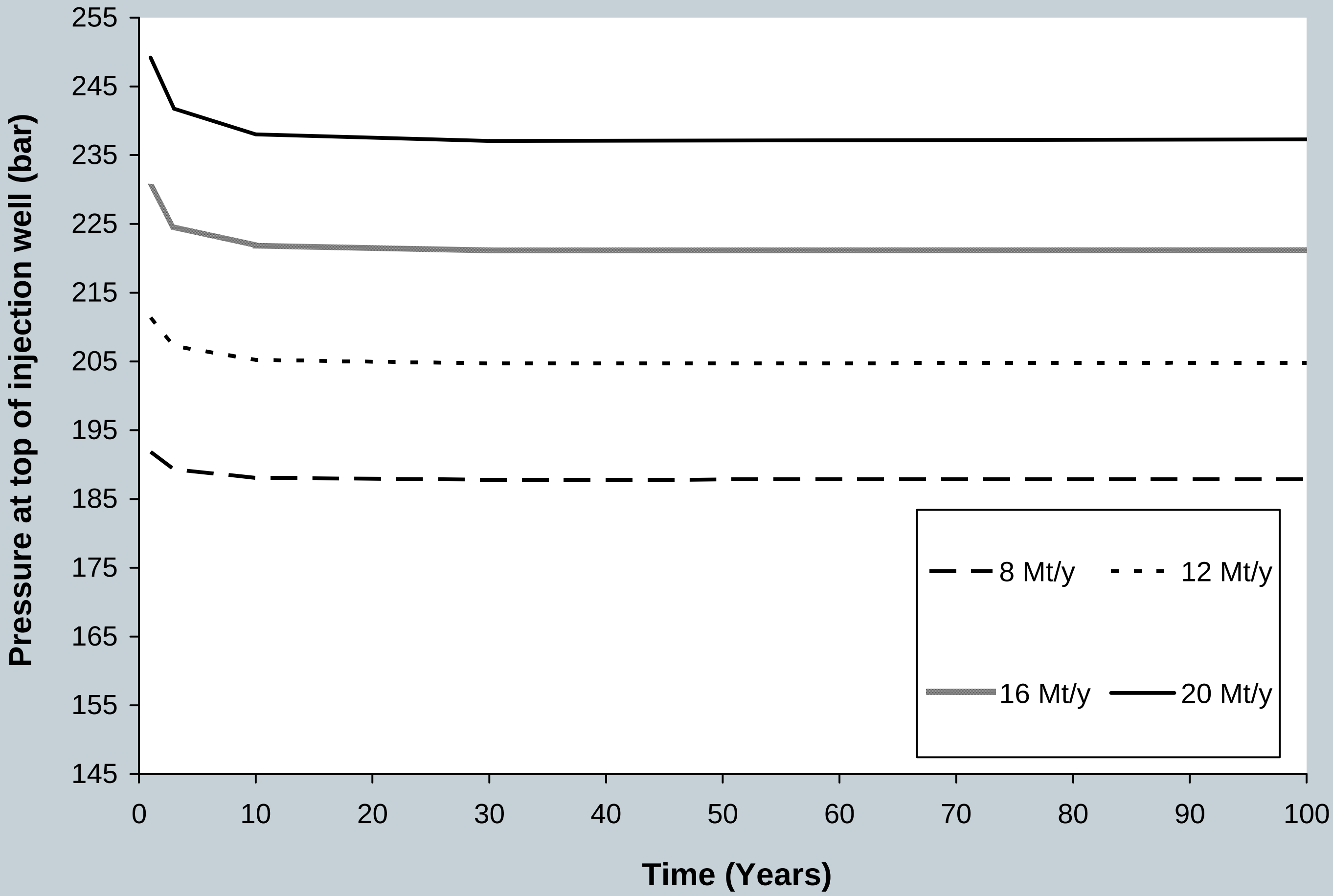
Proposed CO2 Injection



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?
  - Over-pressurizing will crack the seals, allowing CO_2 to leak out
- How far will the CO_2 plume travel from its injection well in, say, 50 or 100 years?
  - Interesting legal question about who owns the porosity below a piece of property…is it the owner of the (surface) property?

Model Results: Physical



- Simulations based on TOUGH2 model (Lawrence Berkeley National Lab)
- OK to inject up to 8 million tons per year
- Higher injection rates might create too much pressure

Model Results: Physical

Table 1: Estimated extent of CO2 plume as a function of time and injection rate

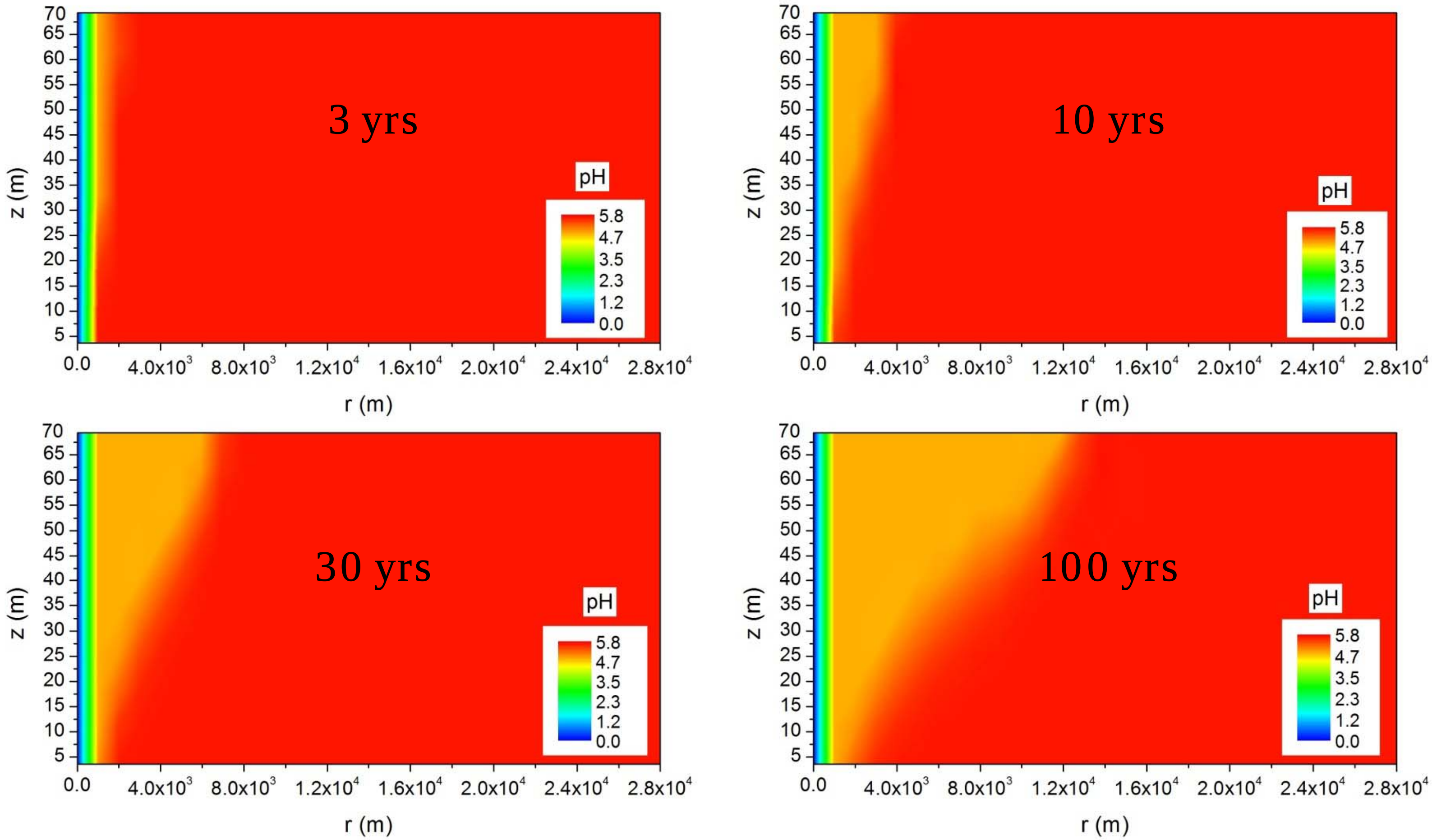
Time (Years)	Flow rate (million tons/year)		
	4	8	12
	r_{max} (km)	r_{max} (km)	r_{max} (km)
1	1.1	1.4	1.7
10	3.7	4.9	5.7
100	12.2	16.2	19.0

- Estimate radial plume extent of about 16 km based on 8 Mt/y for 16 y
- Based on a single vertical injection well
- Other well configurations may be more efficient

Questions: Chemical

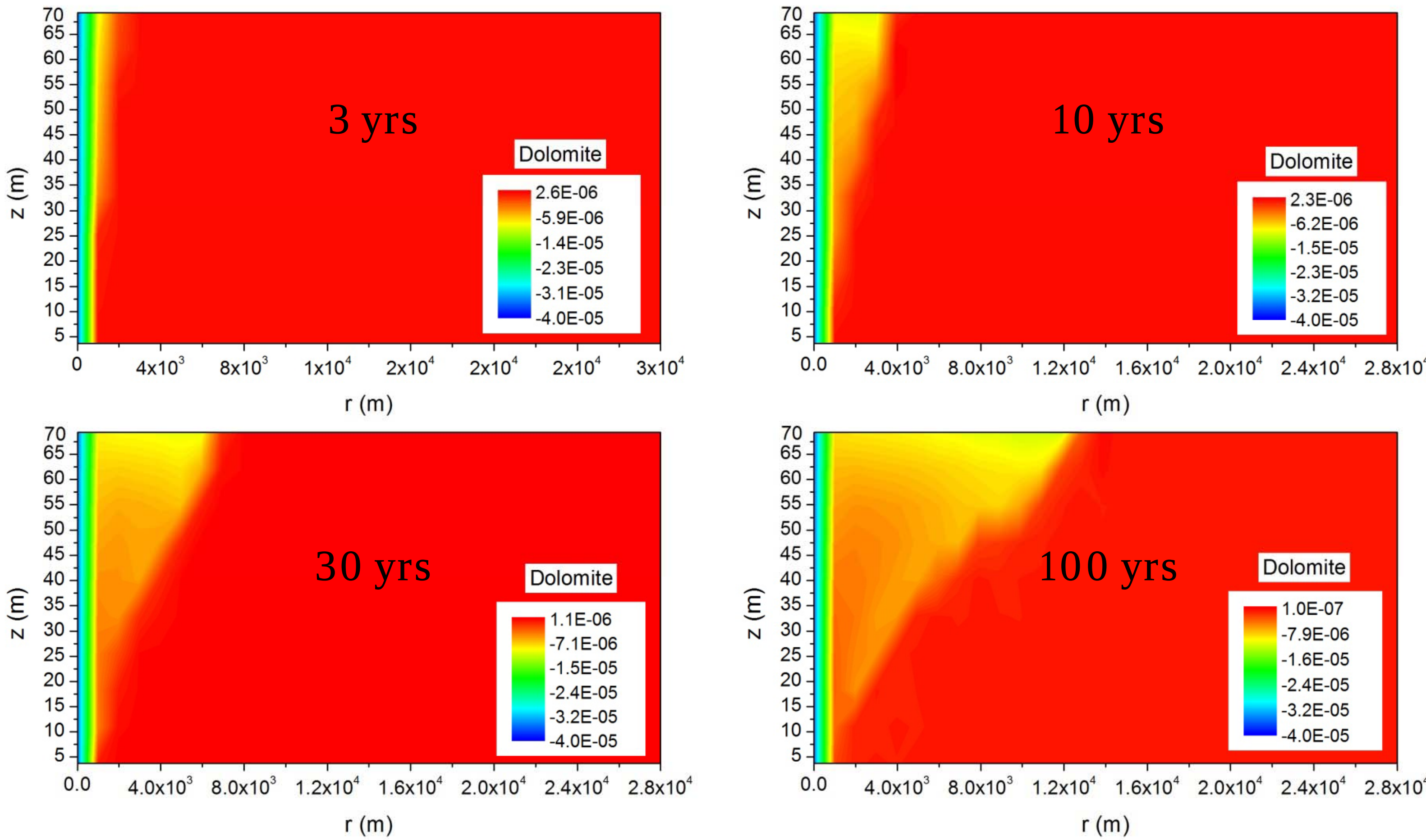
- Will CO_2 injection cause the rock matrix to dissolve?
  - CO_2 dissolves into brine, forms carbonic acid
  - Carbonate minerals typically dissolve at low pH
  - Could threaten the integrity of the formation
- Will CO_2 injection cause new minerals to precipitate?
  - Introduction additional carbonate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

Model Results: Chemical



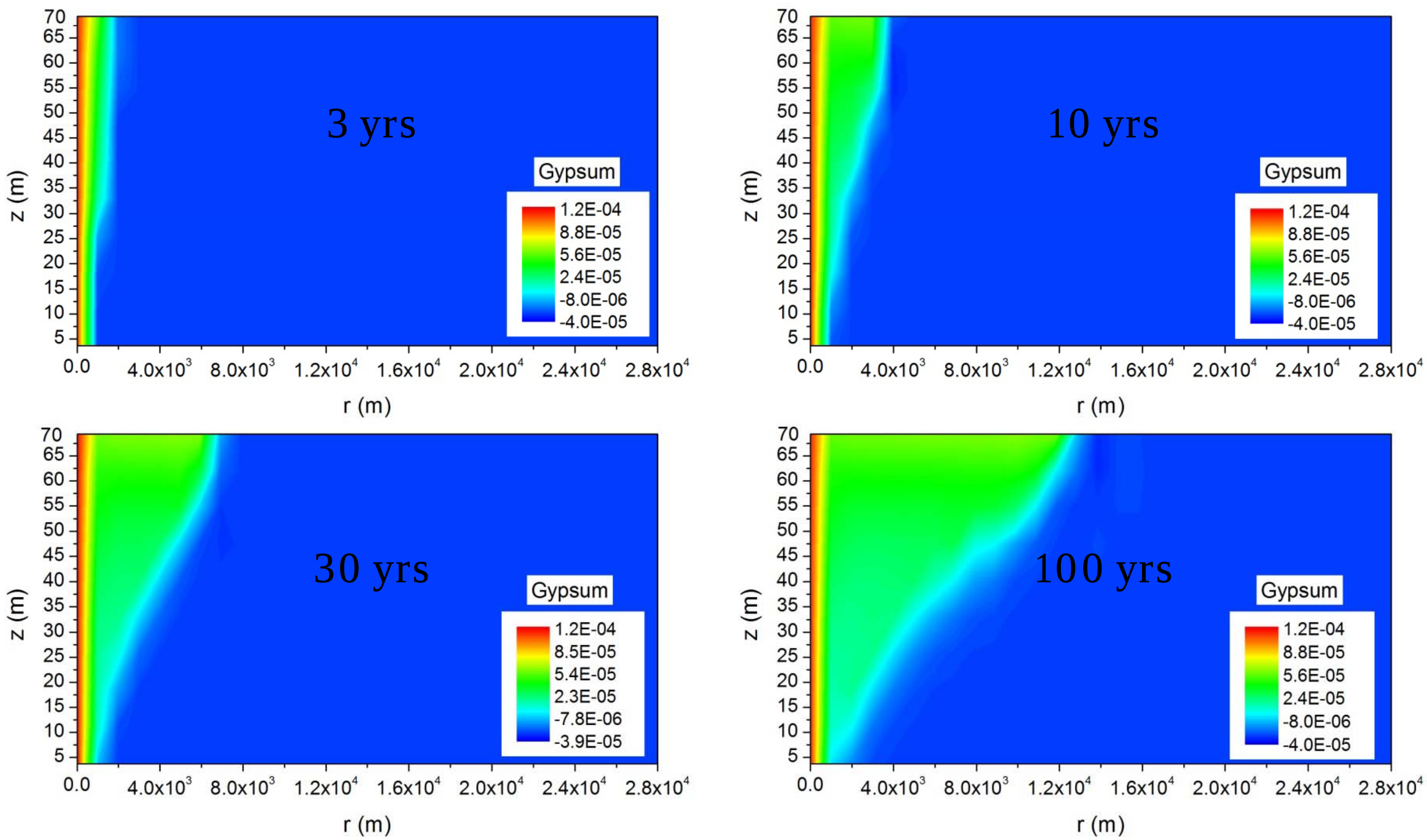
TOUGHREACT simulations, 4 Mt/y injection rate

Model Results: Chemical



TOUGHREACT simulations, 4 Mt/y injection rate

Model Results: Chemical



TOUGHREACT simulations, 4 Mt/y injection rate

Model Results: Chemical

- As CO_2 moves radially outward from the well:
  - CO_2 dissolves into brine
  - pH of brine drops
  - Dolomite ($MgCa(CO_3)_2$) and calcite ($CaCO_3$) dissolve
  - Gypsum ($CaSO_4 \cdot n\, H_2O$) precipitates
- Changes in porosity due to dissolution/precipitation are very small
  - Even after 100 years of injection at flow rates of up to 20 million tons / year
- No apparent "show-stoppers" from chemical modeling

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 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 CO2 flow and geochemistry
- Work with industrial partners
  - Especially with electric power utilities in Florida
- Ultimate goal: pilot-scale CCS demonstration project in Florida