Carbon Life Cycle Analysis of CO_2-EOR for Net Carbon Negative Oil (NCNO) Classification

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Mastering the Subsurface through Technology Innovation and Collaboration

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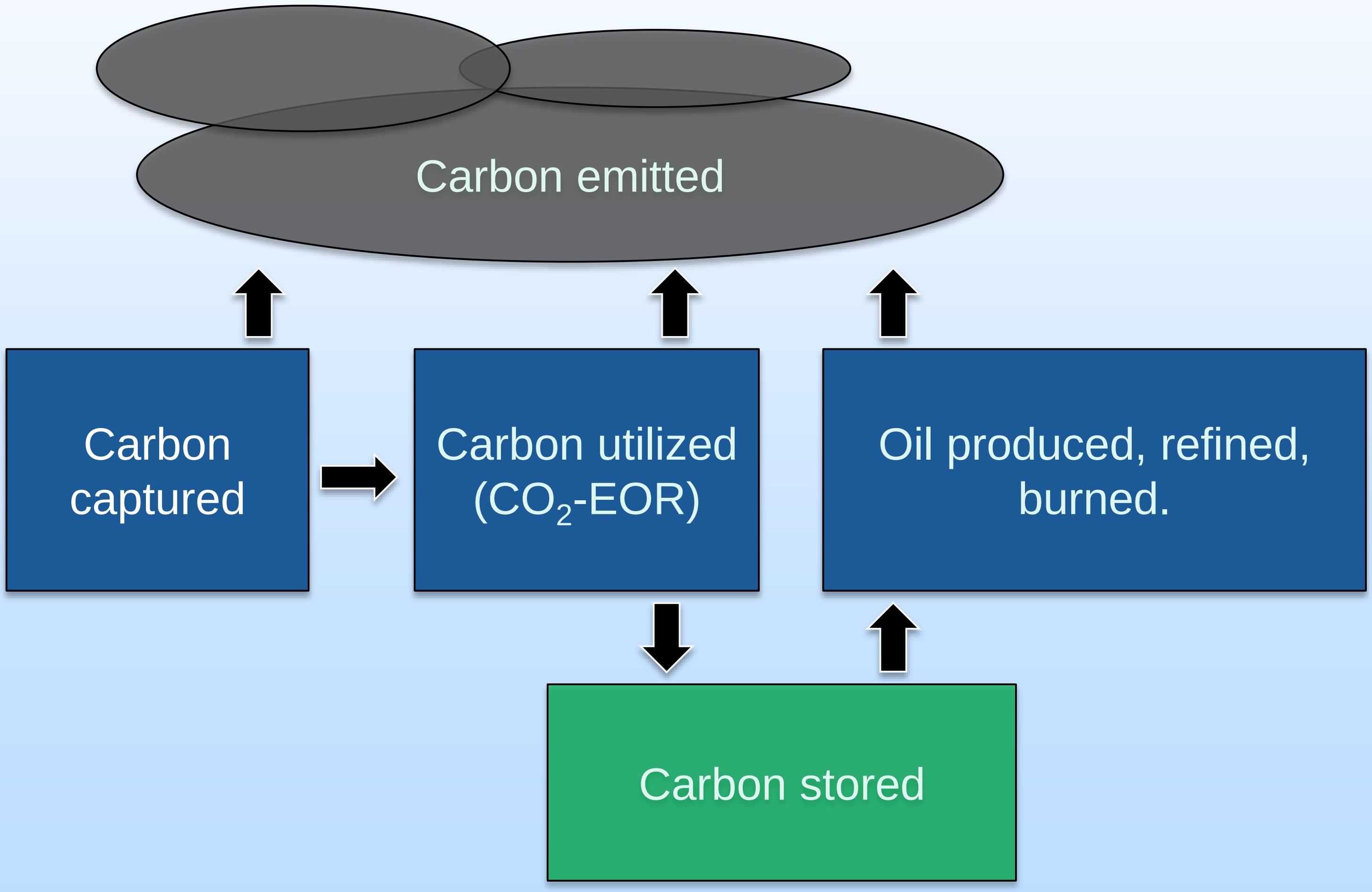
Presentation Outline

- Project overview
  - Goals and objectives
  - Methodology
- Accomplishments to date
- Expected Outcomes
- Summary

Problem Statement

- Is CO_2-EOR a valid option for greenhouse gas emission reduction? Are geologically stored carbon volumes larger that direct/indirect emissions resulting from CO_2-EOR operations?

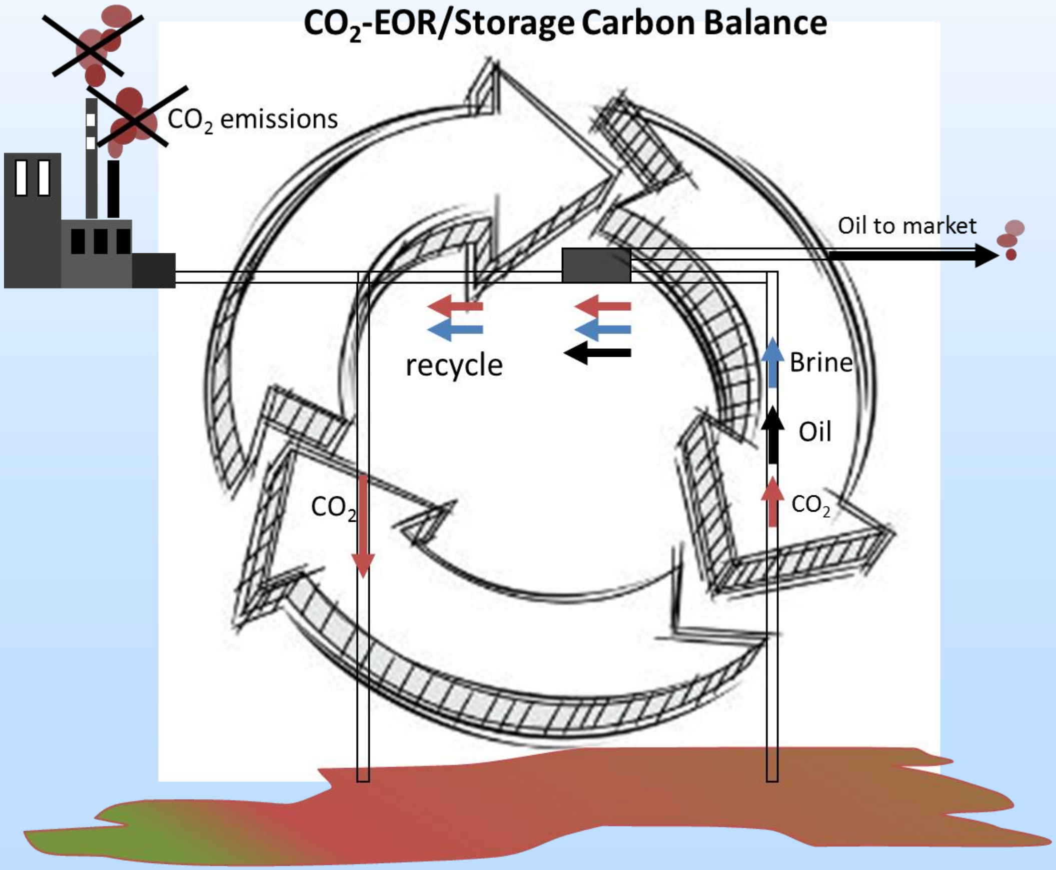


Project Overview: Goals and Objectives

Goal: To develop a clear, universal, repeatable methodology for making the determination of whether a CO_2-EOR operation can be classified as Net carbon Negative Oil (NCNO)

Objectives:

- Identify and frame critical carbon balance components for the accurate mass accounting of a CO_2-EOR operation.
- Develop strategies that are conducive to achieving a NCNO classification.
- Develop a comprehensive, yet commercially applicable, monitoring, verification, and accounting (MVA) methodology.



Related Literature

Environ. Sci. Technol. 2009, 43, 8027–8032

Life Cycle Inventory of CO_2 in an Enhanced Oil Recovery System

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Energy & Fuels 2001, 15, 303–308

Reducing Carbon Dioxide Emissions with Enhanced Oil Recovery Projects: A Life Cycle Assessment Approach

Anne-Christine Aycaguer, Miriam Lev-On, and Arthur M. Winer

Environmental Science & Technology — Article — pubs.acs.org/est

Evaluating the Climate Benefits of CO_2-Enhanced Oil Recovery Using Life Cycle Analysis

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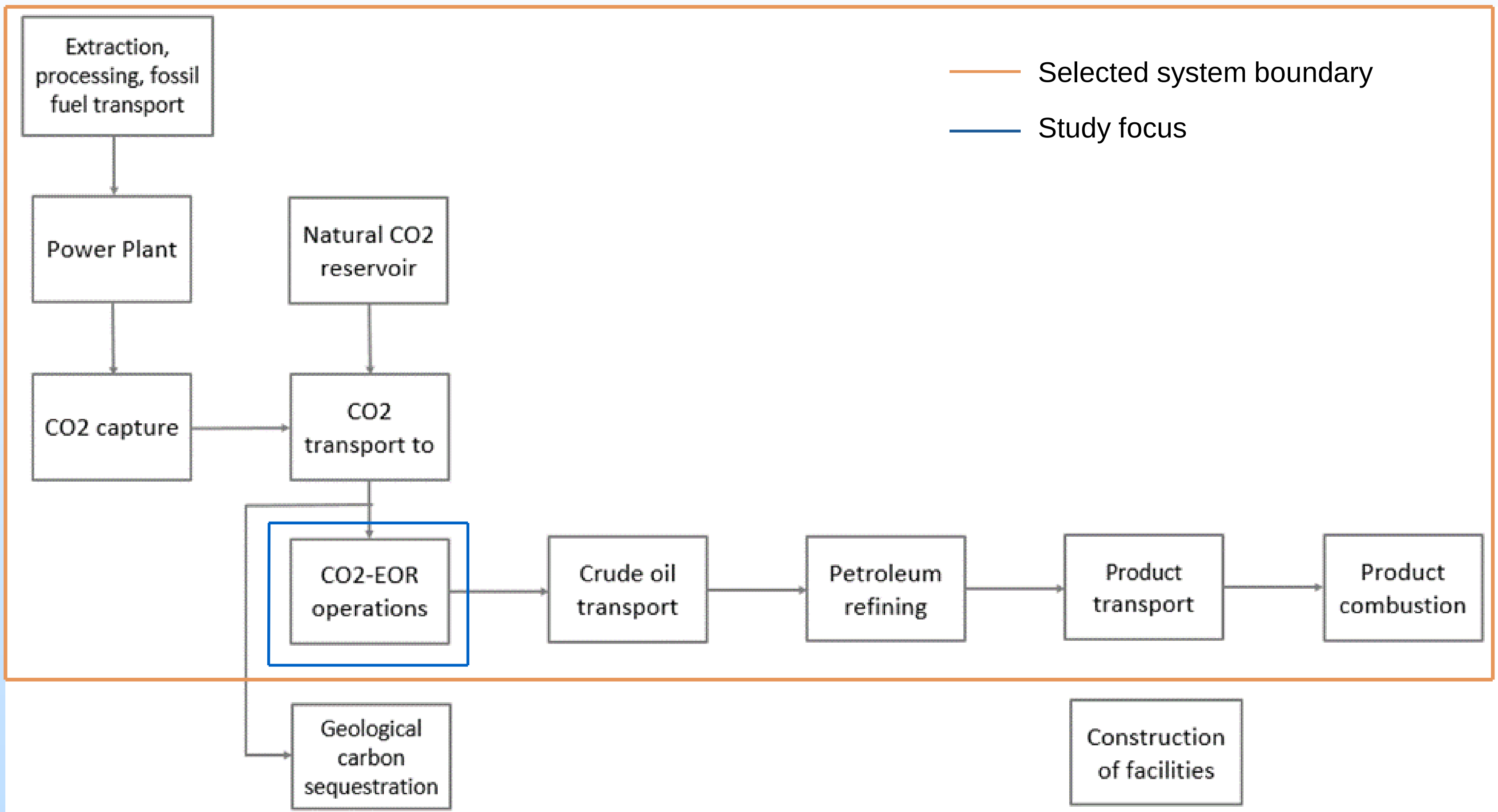
Supporting Information

ABSTRACT: This study uses life cycle analysis (LCA) to evaluate the greenhouse gas (GHG) performance of carbon dioxide (CO_2) enhanced oil recovery (EOR) systems. A detailed gate-to-gate LCA model of EOR was developed and incorporated into a cradle-to-grave boundary with a functional unit of 1 MJ of combusted gasoline. The cradle-to-grave model includes two sources of CO_2: natural domes and anthropogenic (fossil power equipped with carbon capture). A critical parameter is the crude recovery ratio, which describes how much crude is recovered for a fixed amount of purchased CO_2. When CO_2 is sourced from a natural dome, increasing the crude recovery ratio decreases emissions, the opposite is true for anthropogenic CO_2. When the CO_2 is sourced from a power plant, the electricity coproduct is assumed to displace existing power. With anthropogenic CO_2, increasing the crude recovery ratio reduces the amount of CO_2 required, thereby reducing the amount of power displaced and the corresponding credit. Only the anthropogenic EOR cases result in emissions lower than conventionally produced crude. This is not specific to EOR, rather the fact that carbon-intensive electricity is being displaced with captured electricity, and the fuel produced from that system receives a credit for this displacement.

Selection of system boundaries for NCNO classification: Cradle-to-Grave



Methodology: Select Field Setting

- (Cranfield, Mississippi)
  - It provides the optimal mass accounting data set as it was required by its comprehensive SECARB MVA program
  - It is a desirable direct injection (no WAG), which is favorable for achieving NCNO
  - Pattern geometry and operations repeated systematically around field development
  - Provides a simpler environment than many CO_2-EOR floods

Methodology: Numerical Simulation

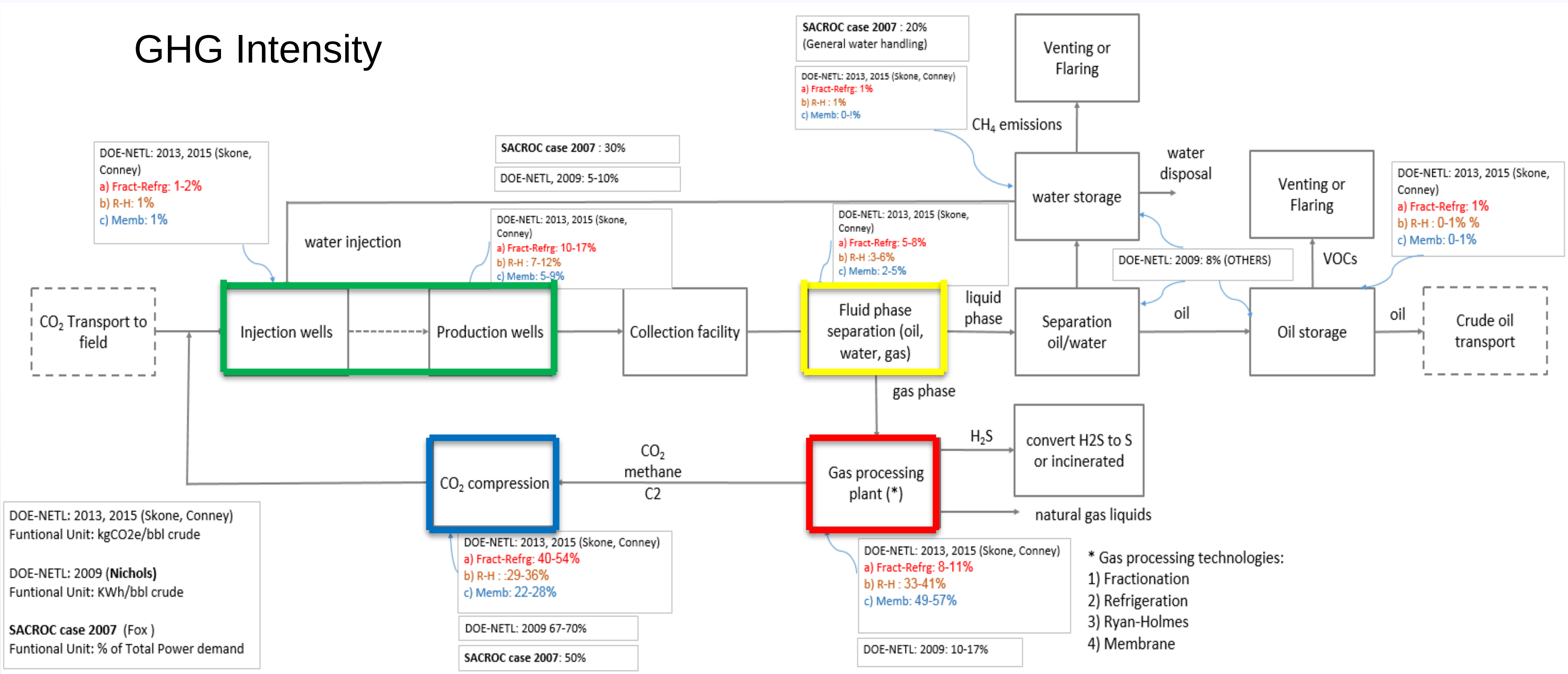
- Utilize Cranfield pattern calibrated models to:
  - Run numerical simulations for different novel and standard CO_2 injection scenarios (WAG, direct CO2 injection)
  - Evaluate how the variability of CO_2 utilization ratios for the different injection scenarios affects the identified system components.
  - Understand the carbon balance evolution from start of injection to completion.

Methodology: Develop MVA Plan

- Use predictive flow and pressure elevation results to develop a generic but comprehensive MVA plan that is based on:
  - existing regulatory monitoring requirements
  - existing best practices
  - a number of proposed and suggested processes that are currently being considered for possible future regulatory or credit trading conditions

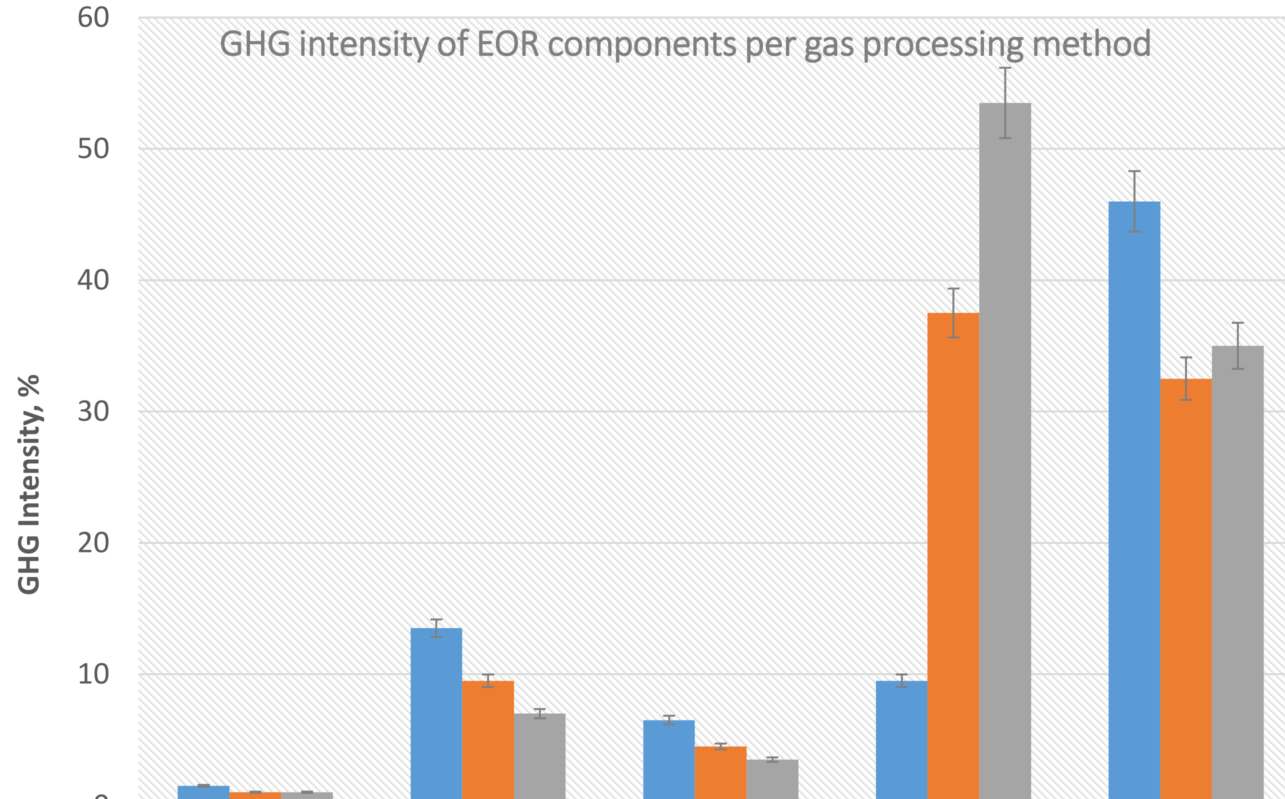
Accomplishments to Date

Identification of critical CO_2 emission components within the EOR site



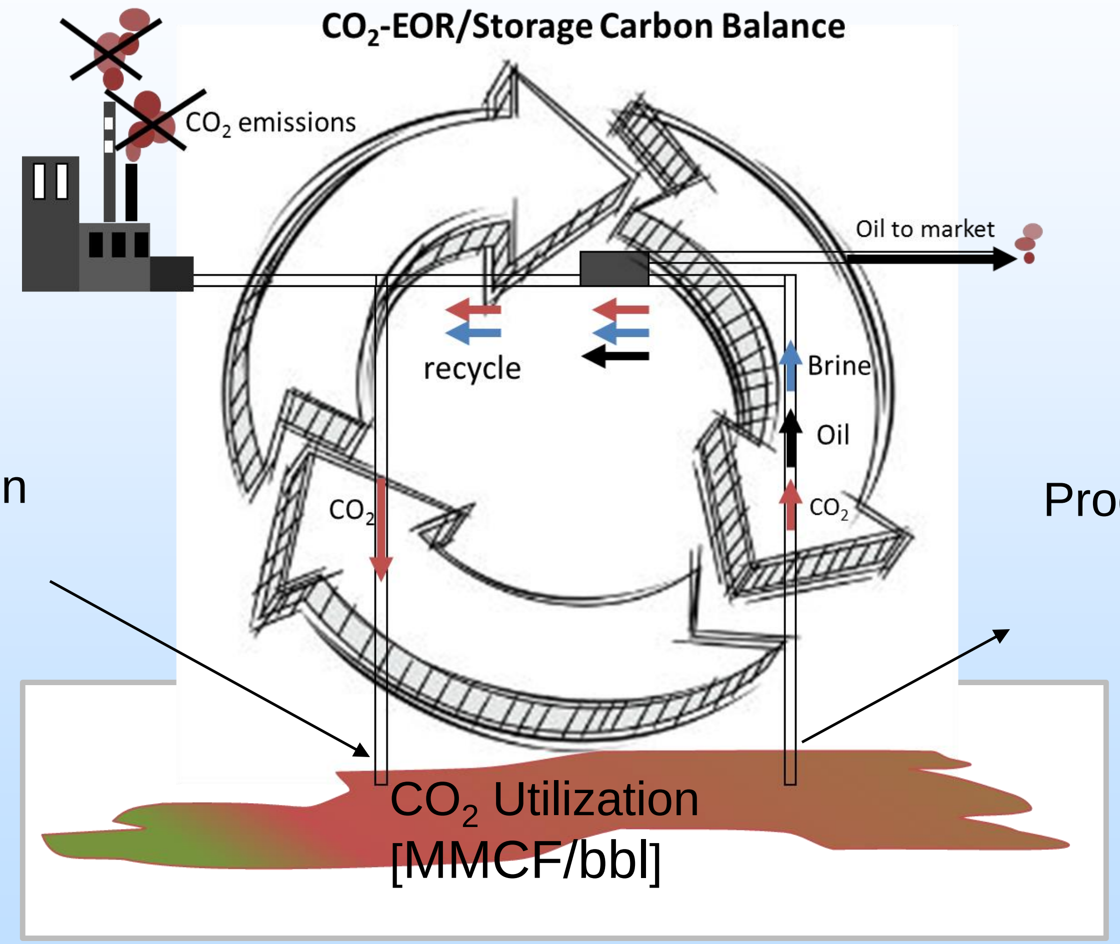
Injection/production wells | Production separation | CO_2 separation | CO_2 compression

GHG Intensity per EOR Component



	Injetion Wells	Production Wells	Fluid Phase Separation	Gas Processing	CO2 Compression
Fract - Refrg	1.5	13.5	6.5	9.5	46
Ryan Holmes	1	9.5	4.5	37.5	32.5
Membrane	1	7	3.5	53.5	35

Study focus: CO_2 utilization ratios



CO_2 injection [MMCF]

Produced oil [bbl]

CO_2 Utilization [MMCF/bbl]

Field Study

- (Cranfield, Mississippi)
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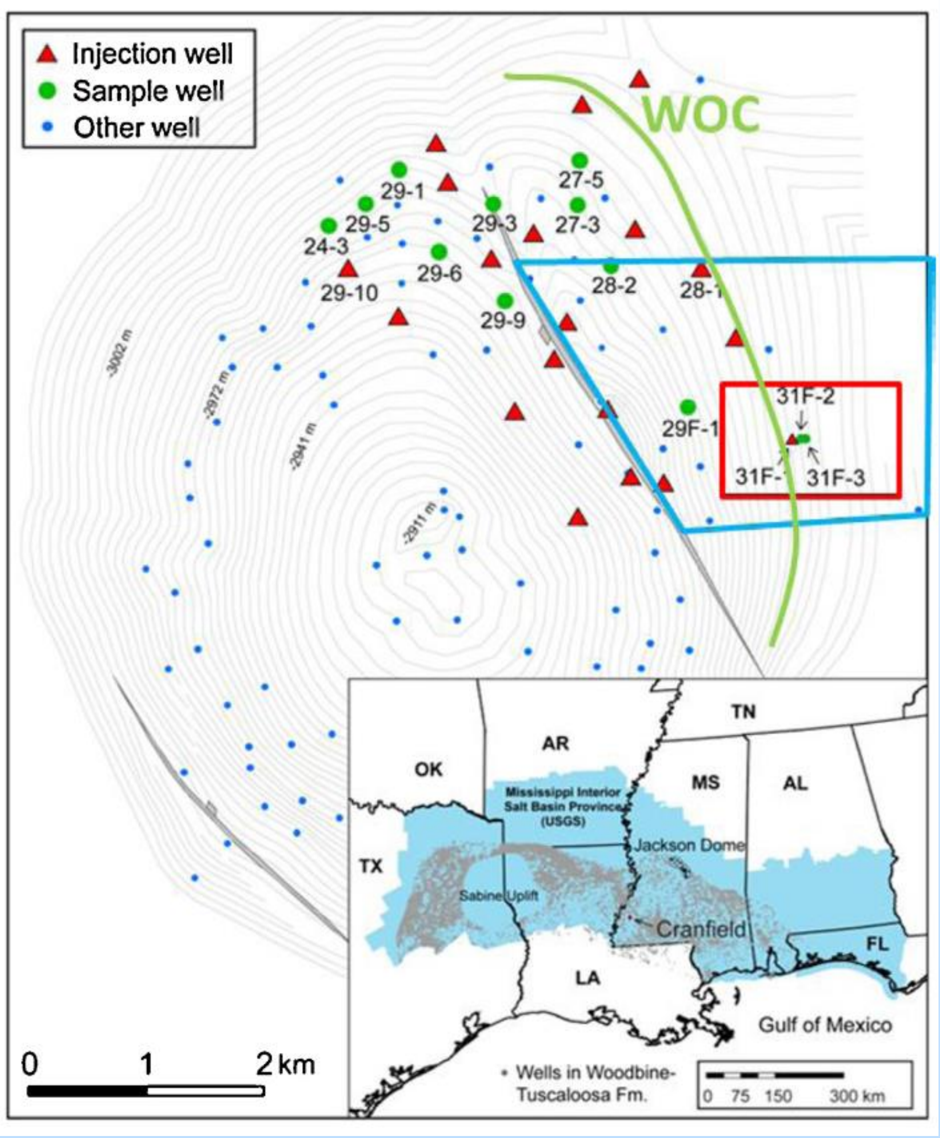
Field Setting



Hosseini et al., 2013

Cranfield overview:

- Clastic Mississippi field
- Apex of 4-way closed anticline
- Main pay is ~10,000 ft deep
- Pi = 4,600 psi, Ti = 150°F
- Original gas cap
- Productive during 1940s and 50s
- CO_2 injection started in 2007
- Available mass accounting data as required by SECARB's monitoring program.

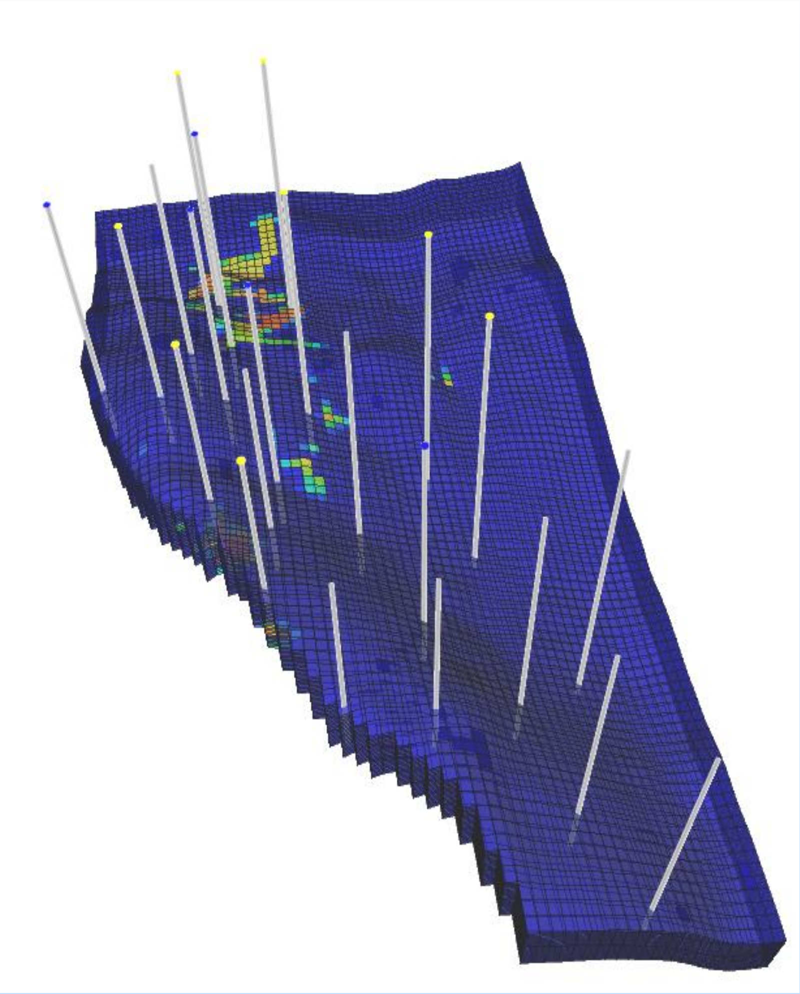
Methodology: Numerical Simulation

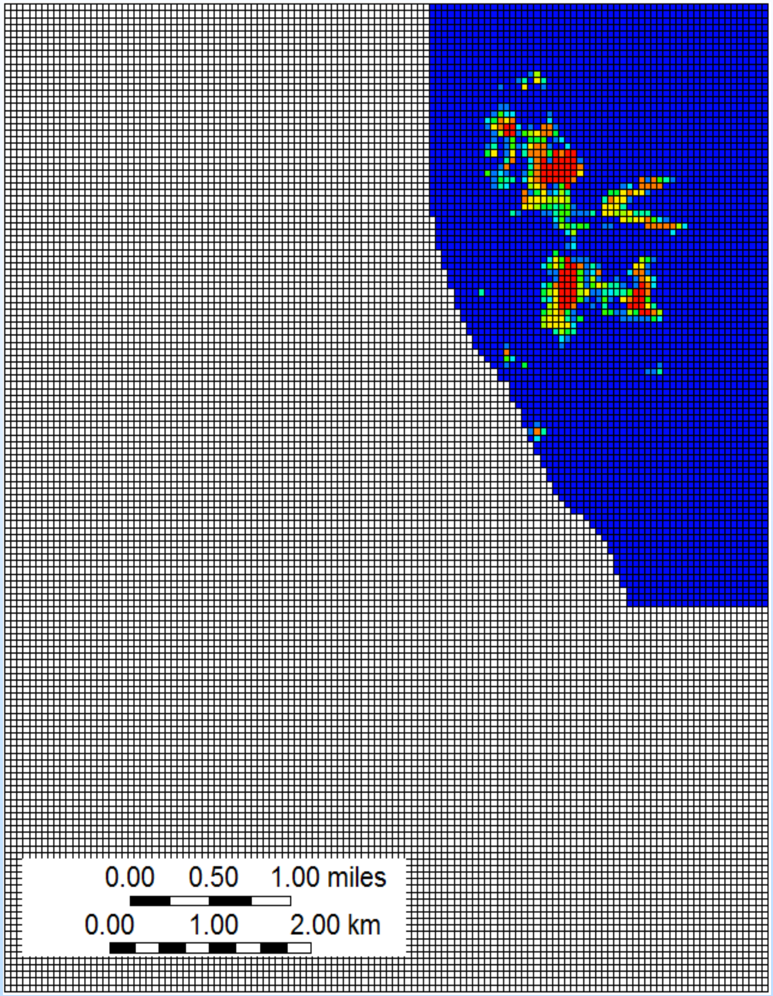
- Utilize Cranfield pattern calibrated models to:
  - Run numerical simulations for different novel and standard CO_2 injection scenarios (WAG, direct CO_2 injection)
  - Evaluate how the variability of CO_2 utilization ratios for the different injection scenarios affects the GHG intensity of the system components (New contribution)
  - Understand the carbon balance evolution from start of injection to completion (New contribution)

- Current activities:
  - ✓ Updated existing Cranfield models: added physics
  - ✓ Relative permeability laboratory experiments
  - ✓ History matching for historic Cranfield production (1944-1972)

Methodology: Numerical Simulation

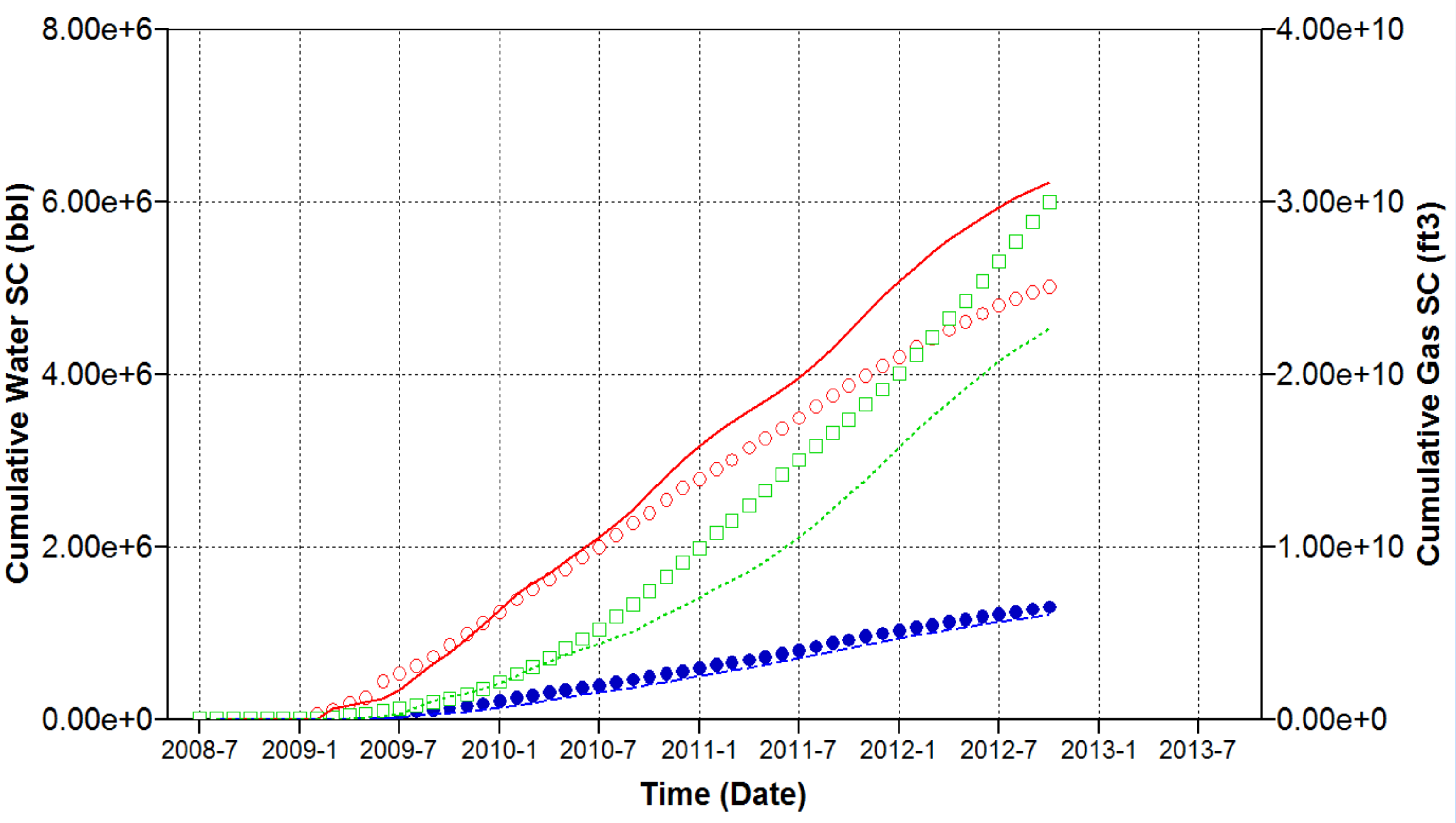
Compositional model simulates CO_2 injection





Methodology: Numerical Simulation

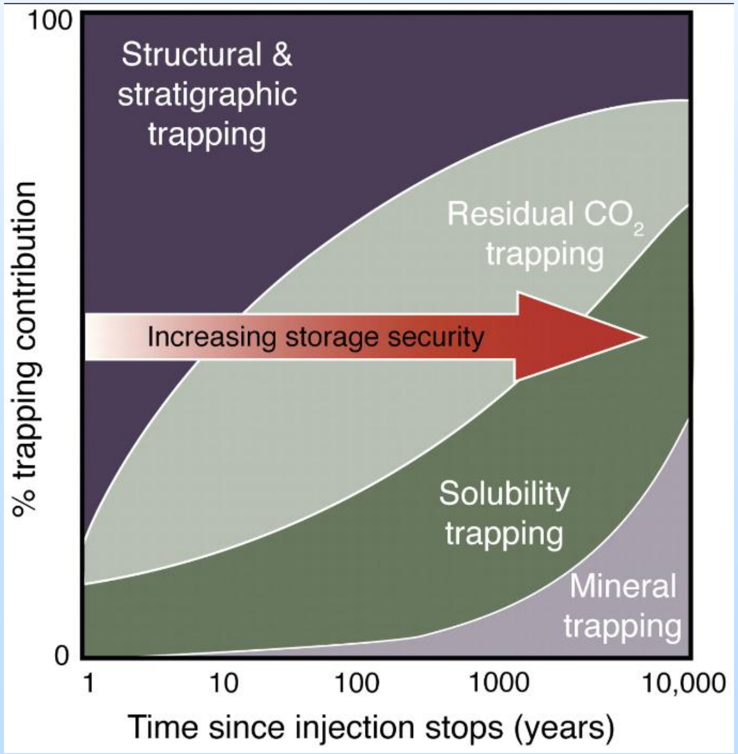
Preliminary History Matching of Primary Production



Trapping Mechanisms

- Additional funds allowed us to add valuable work to the modeling tasks by studying the trapping mechanisms that contribute to the geological permanence of the stored CO_2

1. Residual/capillary trapping
2. CO_2 dissolution into brine
3. CO_2 dissolution into oil
4. Mineral trapping

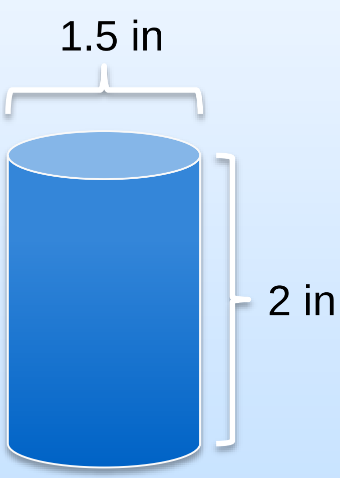


Benson, 2003

New CO_2-brine Relative Permeability

12 Cranfield core plugs were sent to a commercial laboratory

Relative permeability experiments will be run in in 2 composite samples consisting of 6 aligned core plugs



Weatherford LABORATORIES

SUMMARY OF ROUTINE CORE ANALYSES RESULTS

Vacuum Dried at 140°F Net Confining Stress: 3400 psi

Bureau of Economic Geology
Undisclosed Project

USA
File: HH-79894
Date: 2-5-16

Sample Number	Sample Type	Sample Depth, feet	Permeability, millidarcys		NCS Porosity, percent	Grain Density, gm/cc
			to Air	Klinkenberg		
22	Horizontal	10462.66	312.	288.	27.7	2.68
23	Horizontal	10462.83	483.	452.	28.3	2.69
24	Horizontal	10463.00	278.	256.	27.8	2.69
26	Horizontal	10463.45	107.	95.2	25.9	2.69
29	Horizontal	10464.04	207.	189.	28.3	2.69
30	Horizontal	10464.20	286.	264.	28.9	2.69
31	Horizontal	10464.45	237.	217.	28.2	2.69
3	Vertical	10461.80 - 10462.30	6.79	5.61	28.3	2.69
1A	Vertical	10463.60 - 10464.10	10.3	8.05	28.7	2.69
1B	Vertical	10463.60 - 10464.10	11.2	9.17	28.9	2.70
2A	Vertical	10465.30 - 10465.80	3.71	2.97	28.2	2.70
2B	Vertical	10465.30 - 10465.80	9.40	7.39	28.2	2.69
		Average values:	160.	150.	28.1	2.69

Expected Outcomes

- A comprehensive carbon balance analysis of a CO_2-EOR operation with an accurate mass accounting methodology for determining whether the operation can be classified as NCNO.
- A recommendation of CO_2 surface operation and injection strategies that are conducive to achieving a NCNO classification.
- A universal MVA methodology encompassing the entire CO_2-EOR operation and inclusive of pre CO_2 injection, injection, and stabilization periods.

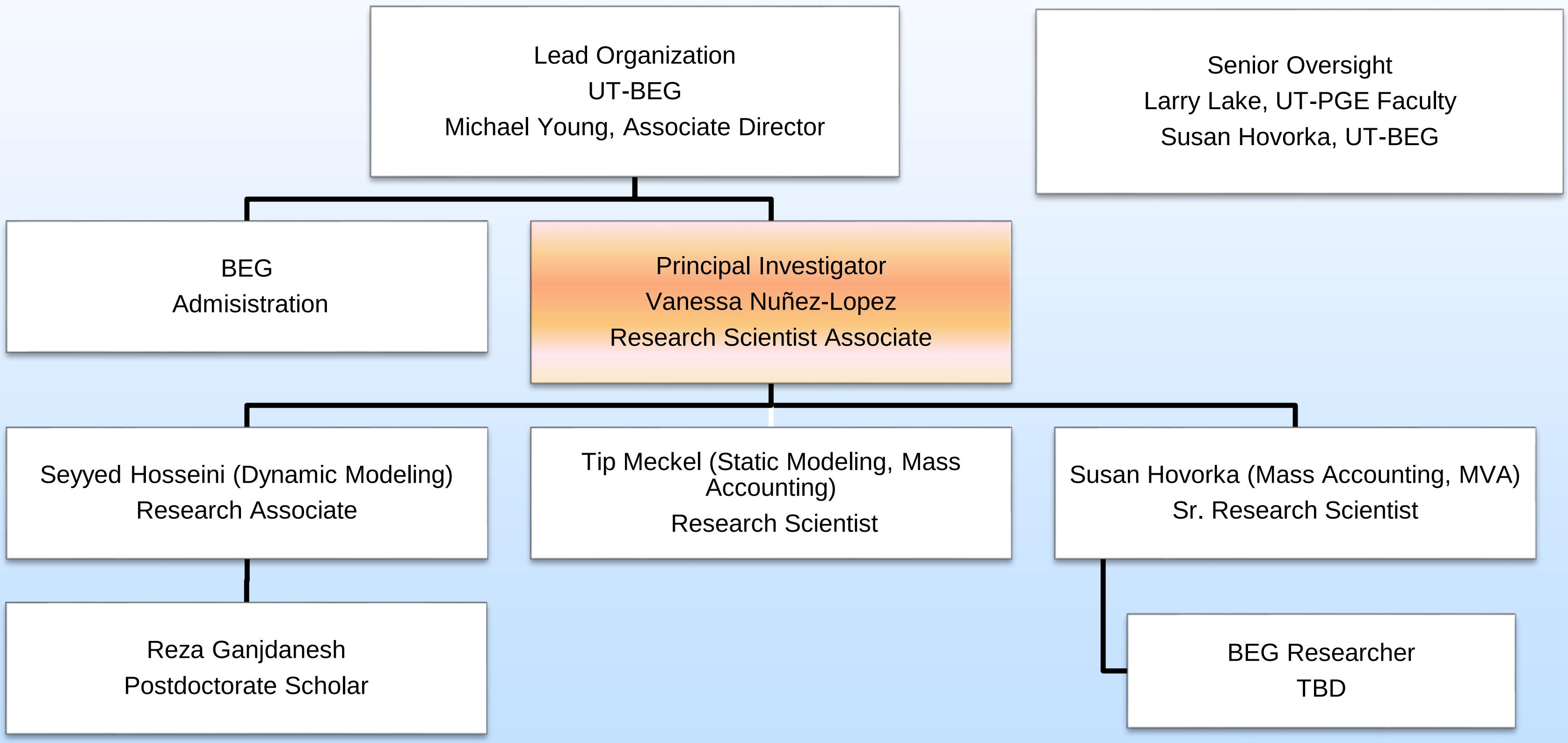
Summary

- Accomplishments:
  - ✓ Selection of system boundaries relevant to NCNO classification: gate-to-grave
  - ✓ Identification of critical CO_2 emission components within the EOR site
  - ✓ Gathered and classifying Cranfield mass accounting data
  - ✓ Built Cranfield static model
  - ✓ Completed historic and EOR history matching
  - ✓ Started numerical simulation tasks
  - ✓ Build a model for energy consumption of the CO_2-EOR operation

- Future Plans:
  - Start scenario analysis
  - Link results from numerical simulations with energy consumption model
  - Develop an MVA plan

Appendix

Organization Chart



Gantt Chart

		BUDGET PERIOD 1				BUDGET PERIOD 2				BUDGET PERIOD 3			
		Year 1:FY 2015				Year 2: FY 2016				Year 3: FY 2017			
		qtr1	qtr2	qtr3	qtr4	qtr1	qtr2	qtr3	qtr4	qtr1	qtr2	qtr3	qtr4
Task	Tasks												
	Carbon Life Cycle Analysis of CO_2-EOR for Net Carbon Negative Oil (NCNO) Classification												
1	Project Management, Planning, and Reporting												
1.1	Revision and Maintenance of Project Management Plan	D 1.1											
1.2	Management and Reporting	Q	Q	Q	Q	Q A	Q	Q	Q	Q A	Q	Q	Q F
2	Project Framework and Data Gathering												
3	Reservoir Mass Accounting Methodology												
			I, 2					D, 3.1					
4	Static and Dynamic Modeling												
4.1	Static Model												
4.2	EOR-storage performance model development										D, 4.2		
5	Monitoring, Verification, and Accounting (MVA) methodology												
													D, 5.0
Q = Quarterly Report; A = Annual Report; F = Final Report													
D = Deliverable													

Bibliography

None yet