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, Partnerships and Collaboration:
Carbon Storage and Oil and Natural Gas Technologies Review Meeting

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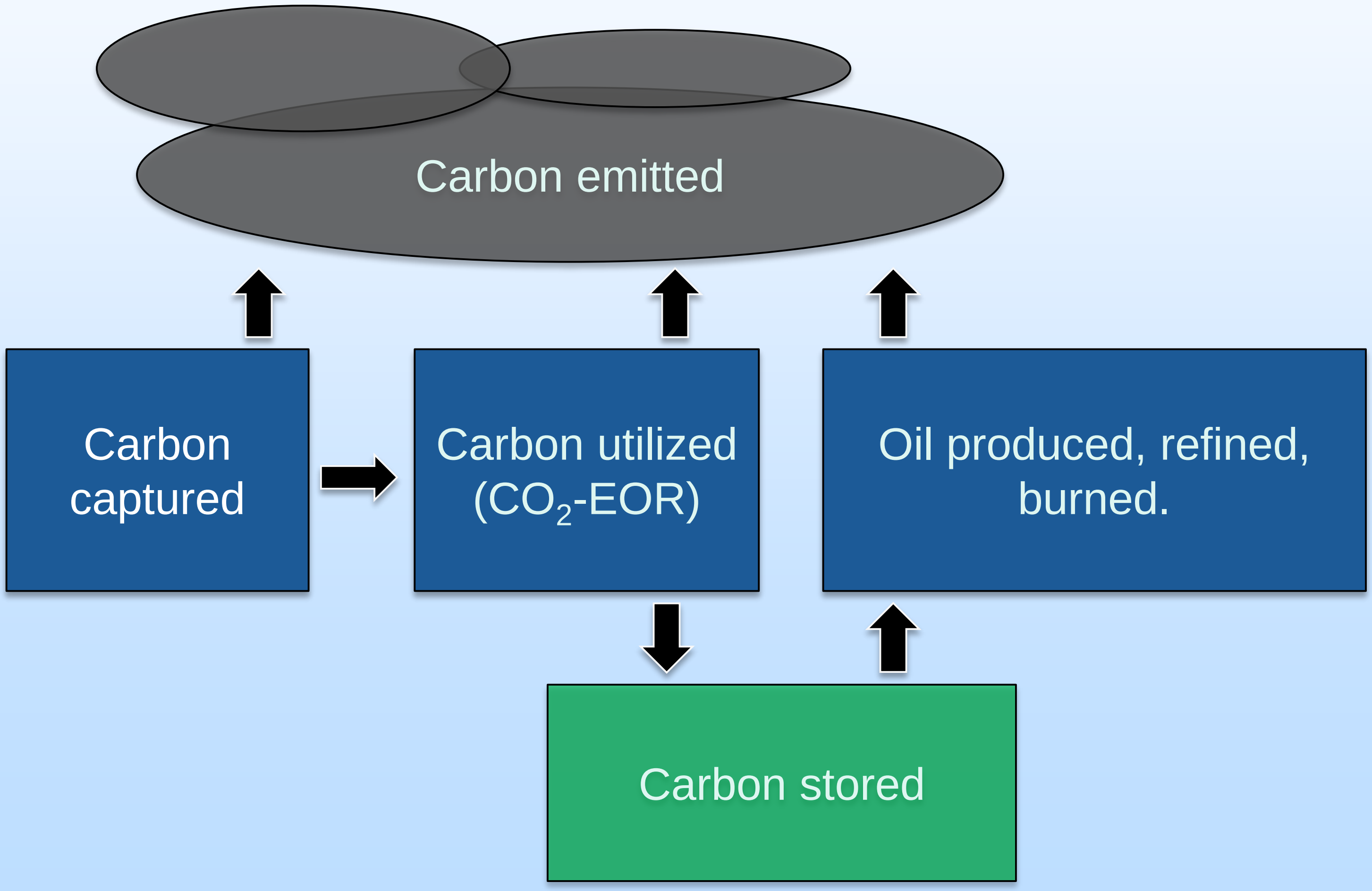
Presentation Outline

- Project Overview: Goals and Objectives
- Technical Status
- Accomplishments to Date
- Lessons Learned
- Synergy Opportunities
- Project 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?

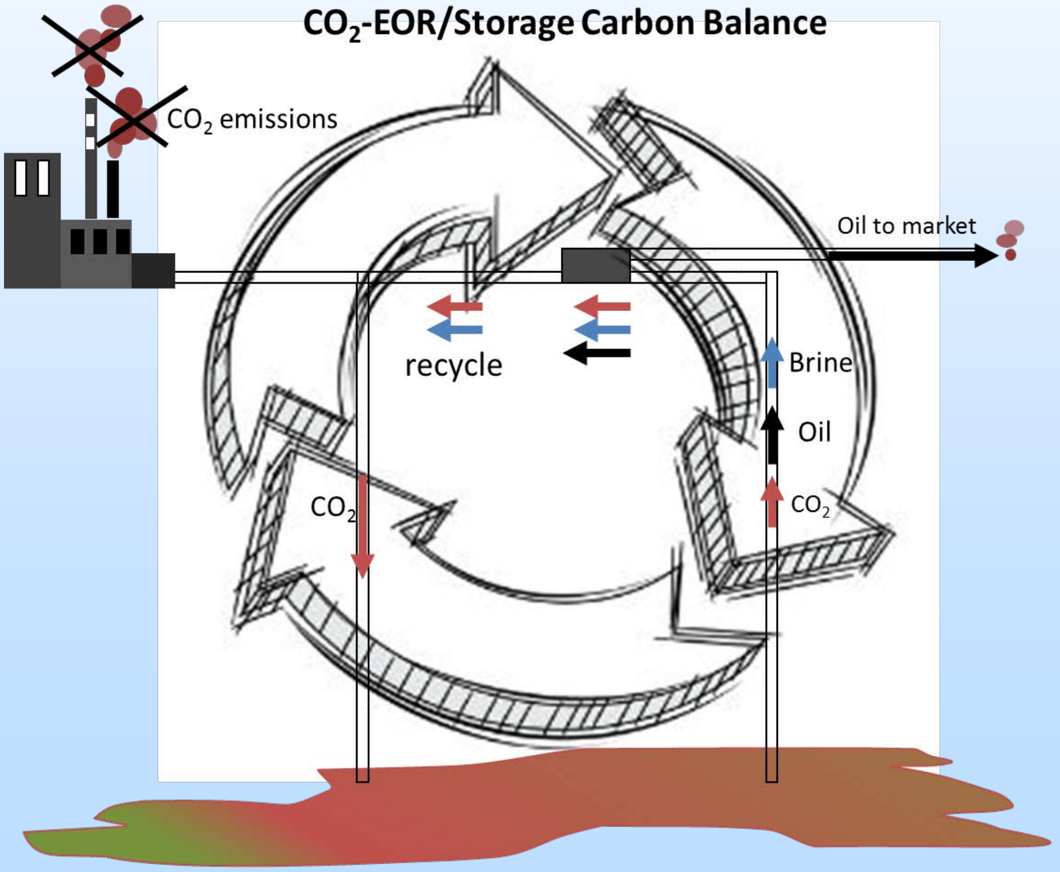


Project Overview:
Goals and Objectives

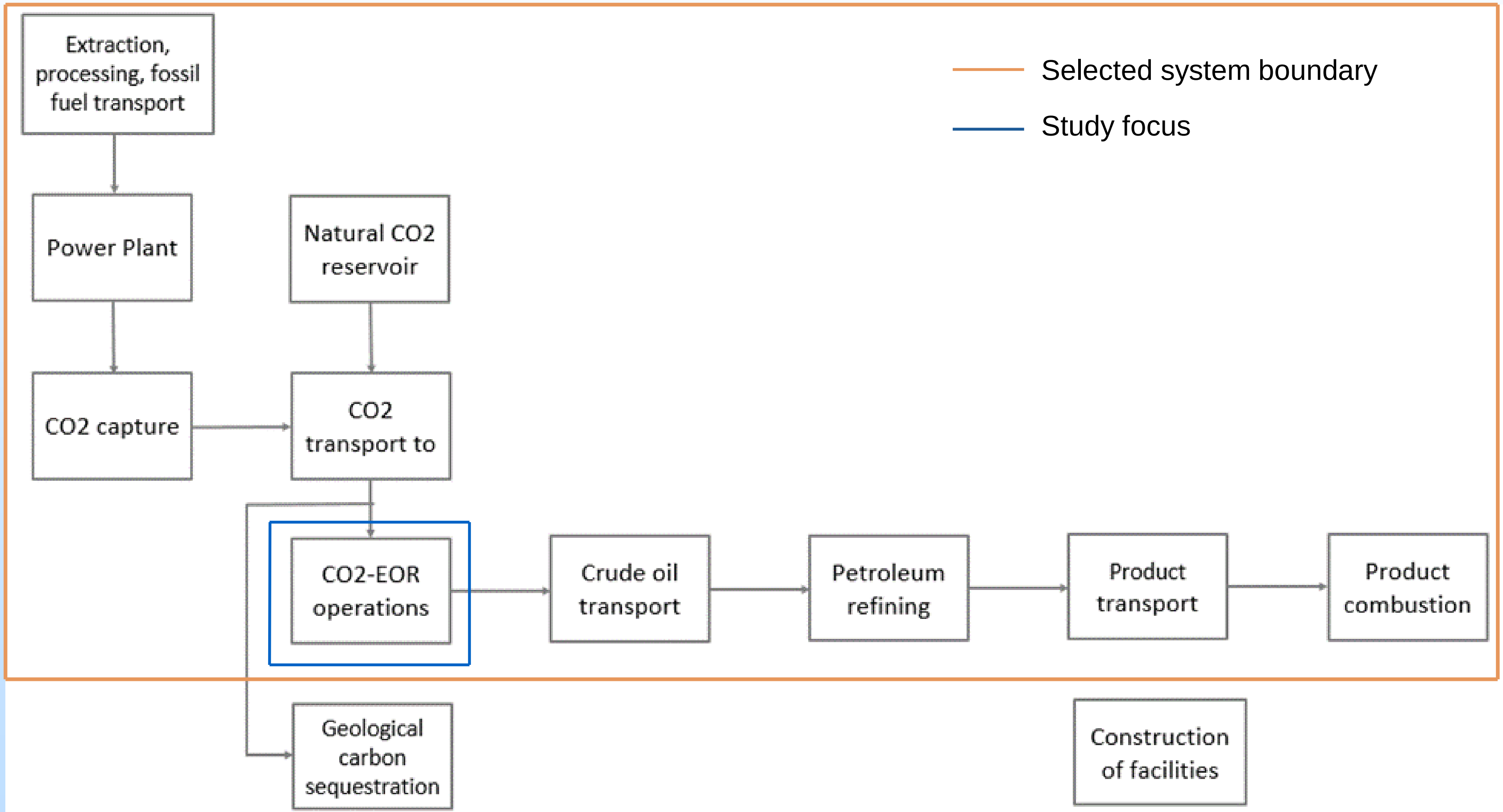
Goal: To develop a clear, universal, repeatable methodology for making the determination of whether a CO_2-EOR operation can be classified as Net carbon Negative Oil (NCNO)

Objectives:

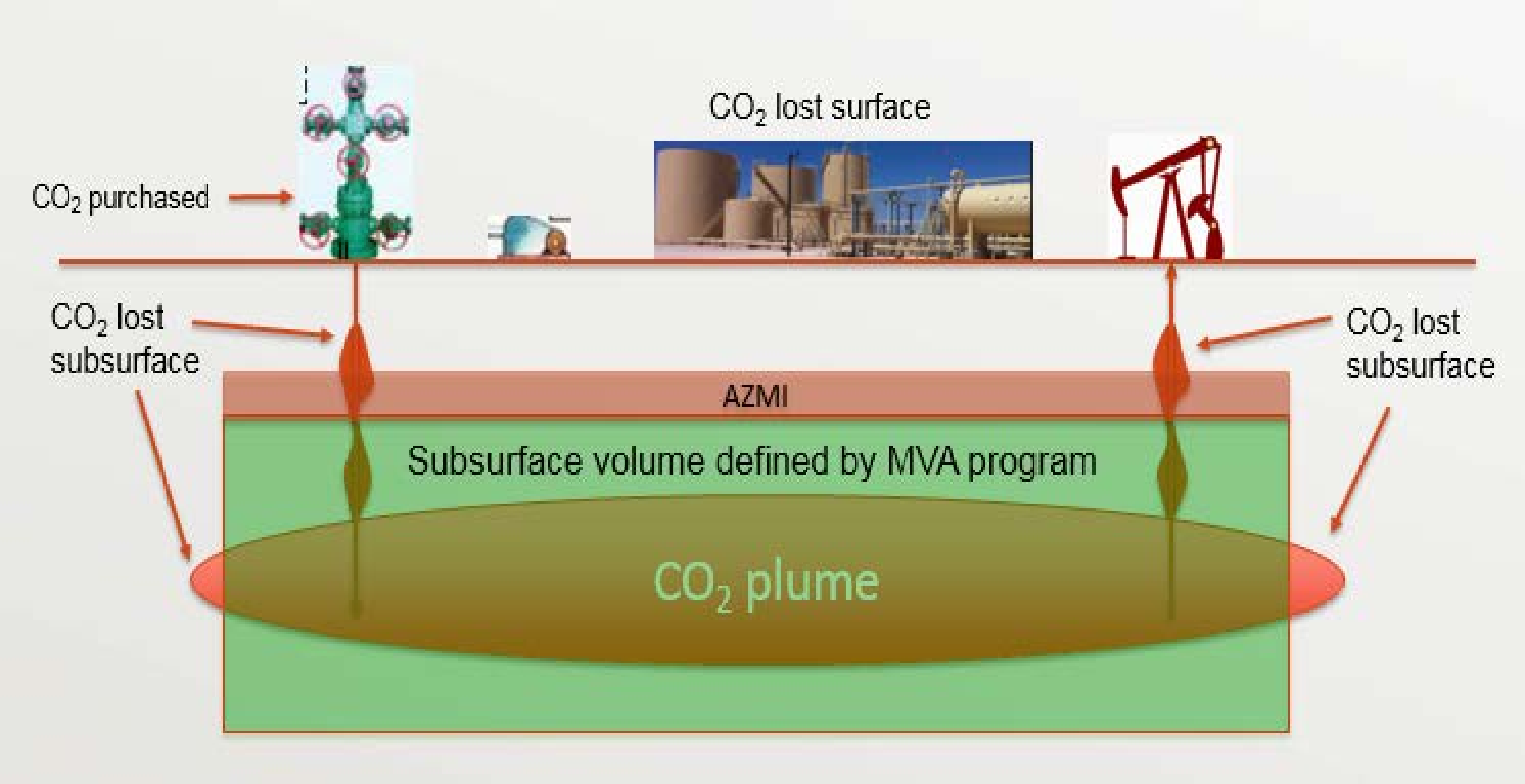
- Identify and frame critical carbon balance components for the accurate mass accounting of a CO_2-EOR operation.
- Develop strategies that are conducive to achieving a NCNO classification.
- Develop a comprehensive, yet commercially applicable, monitoring, verification, and accounting (MVA) methodology.



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



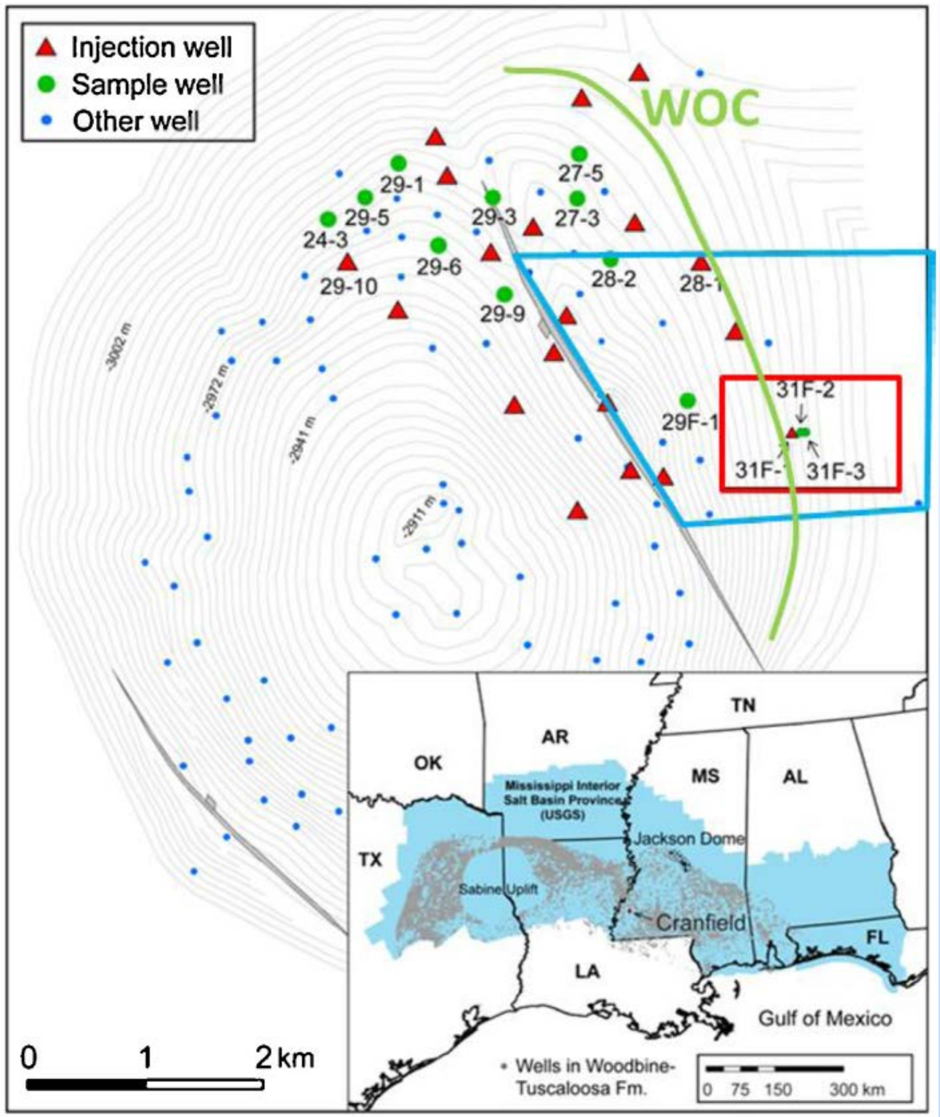
Technical Status: Carbon Mass Accounting Methodology at the EOR Site

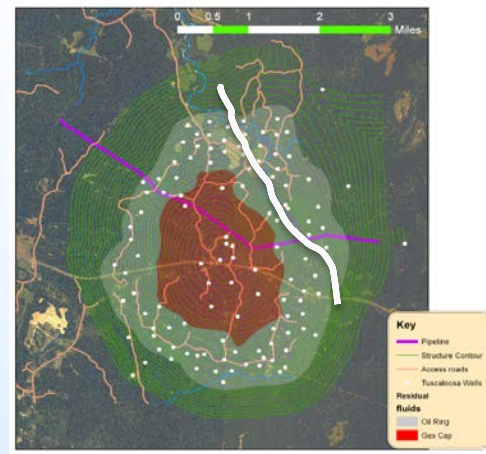


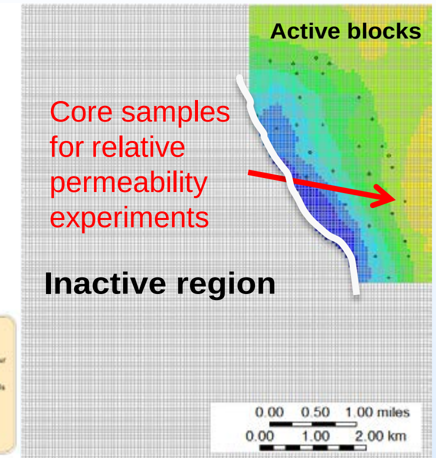
$$M_{stored} = M_{purchased} - M_{lost\,subsurface} - M_{lost\,surface}$$

$$M_{stored} = M_{total\,injected} - M_{recycle} - M_{lost\,subsurface} - M_{lost\,surface}$$

Technical Status: Cranfield Static Model





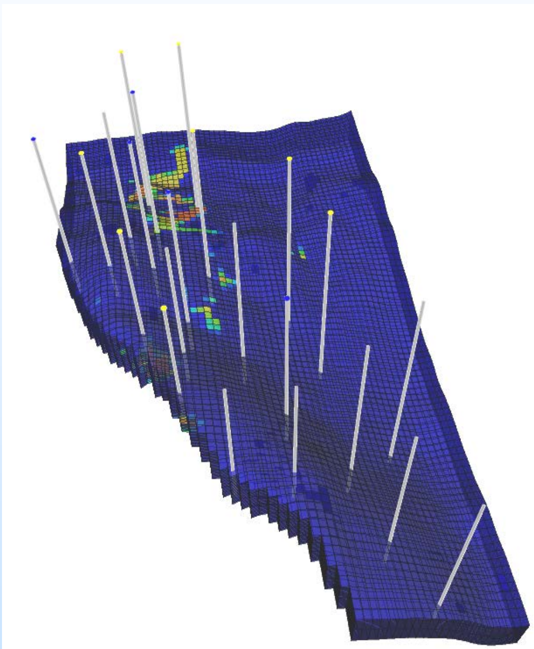


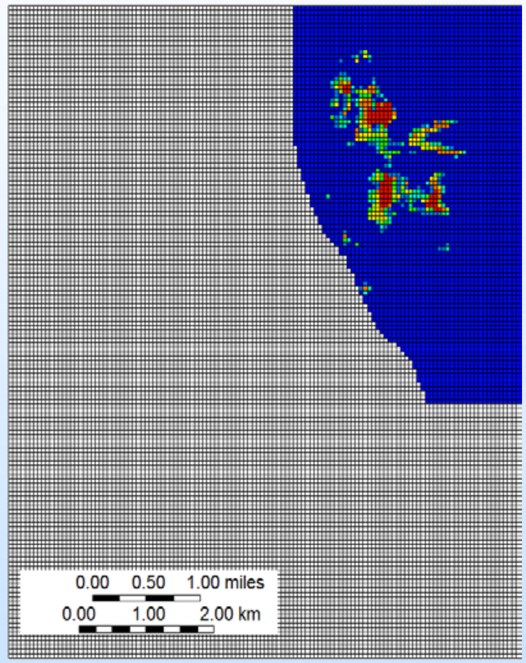
Cranfield overview:

- 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.

Technical Status: Numerical Simulation

Compositional model simulates CO_2 injection





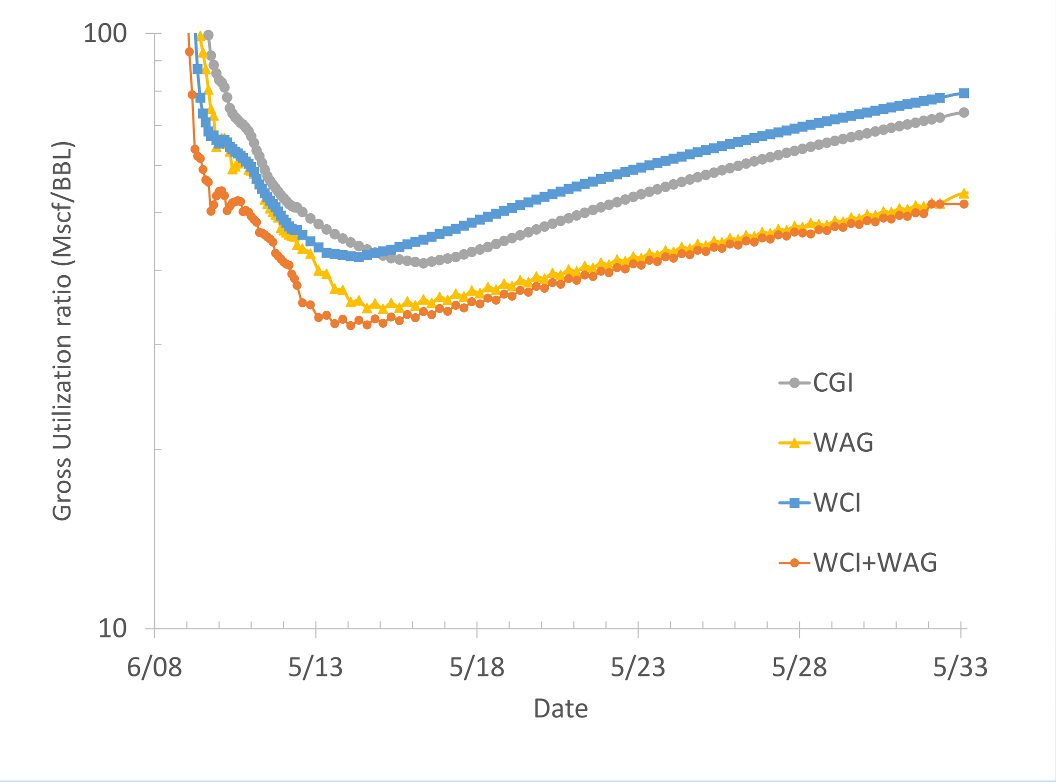
- CMG-GEM compositional package
- Solubility modeled with Henry's law
- Oil and gas PVT tuned
- History matching of historic production data (1944-1964)
- Oil, water, gas production data is available
- Shut-in period (1964-2008)

- **Compositional simulation**
- **Total number of block = 82,500**
- **25 yrs injection +75 yrs of post injection**

CO_2 Injection Scenarios

- Continuous CO_2 injection (CCI)
- Water Alternating GAS (WAG)
- Water Curtain Injection (WCI)
- WAG+WCI

Gross Utilization Ratios



CO_2 Injection Scenarios

- Continuous CO_2 injection (CCI)
- Water Alternating GAS (WAG)
- Water Curtain Injection (WCI)
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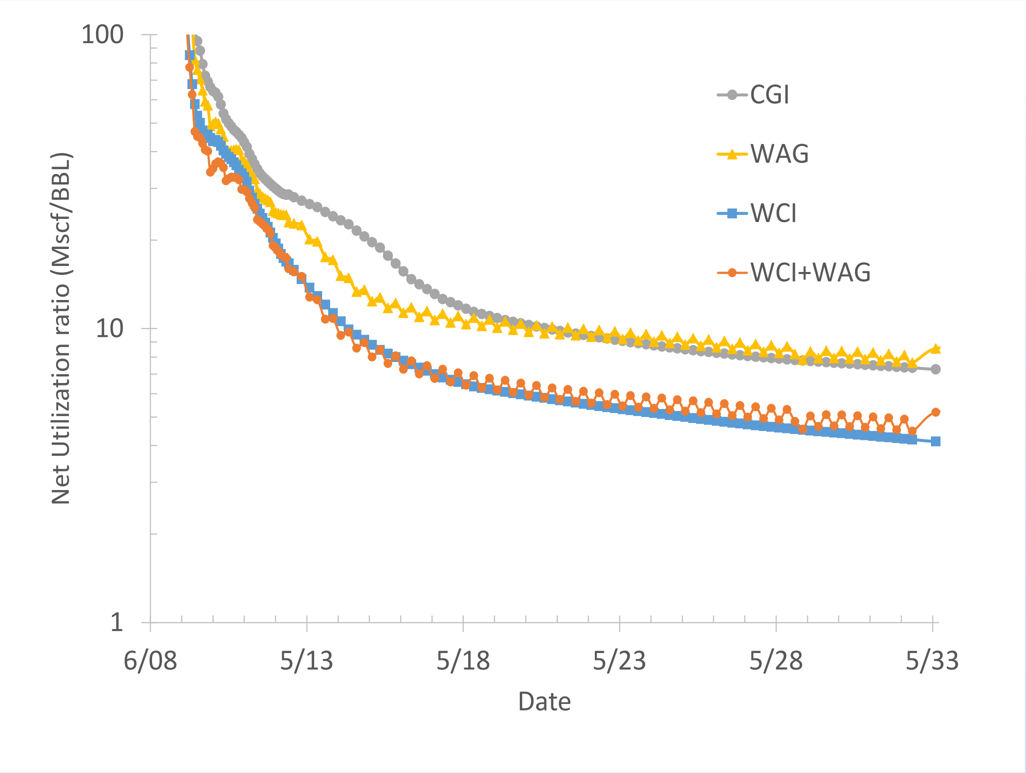
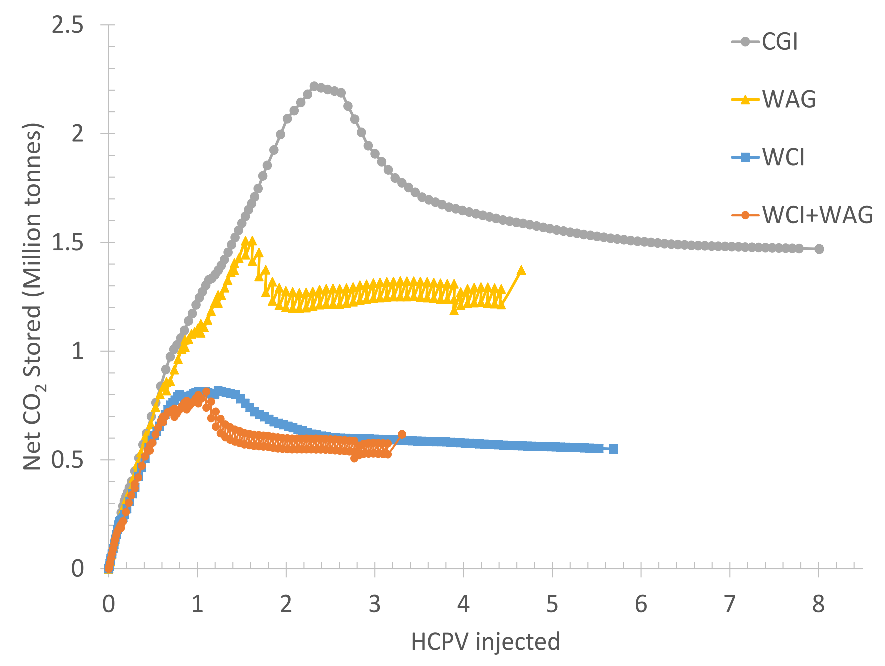
Net Utilization Ratios

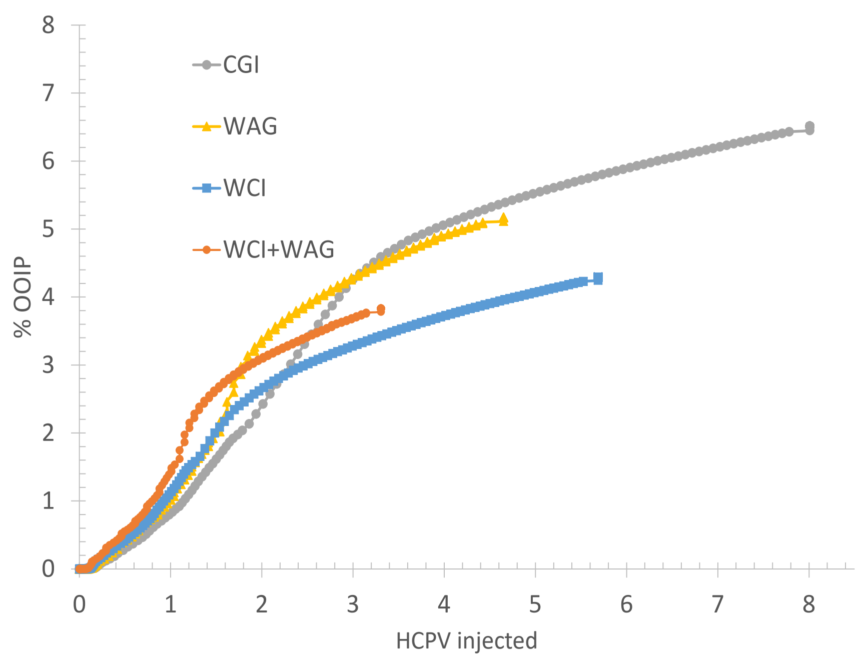


CO_2 Injection Scenarios

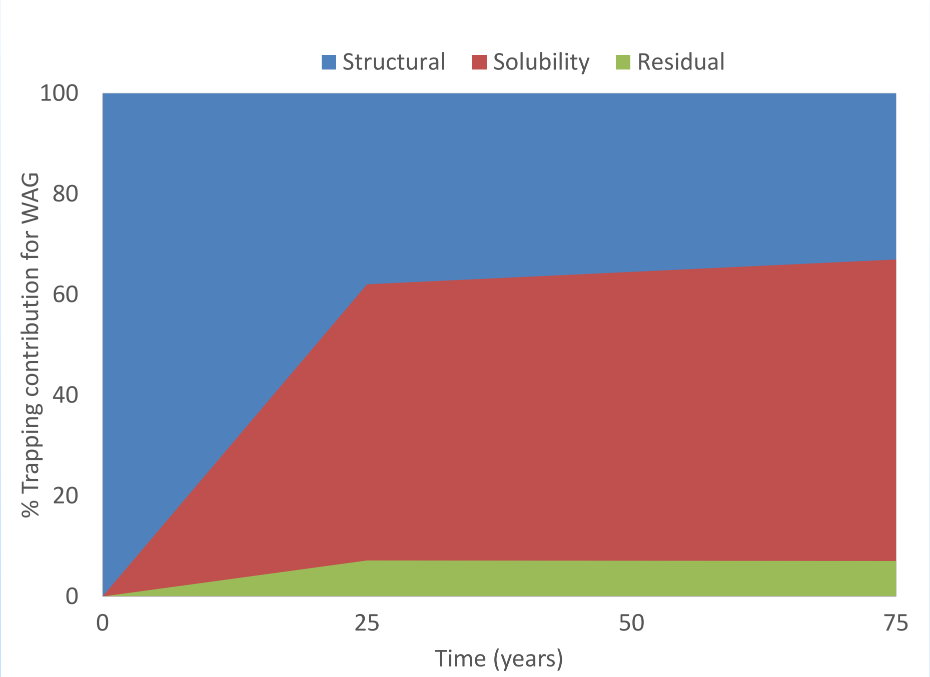
Net CO_2 Stored



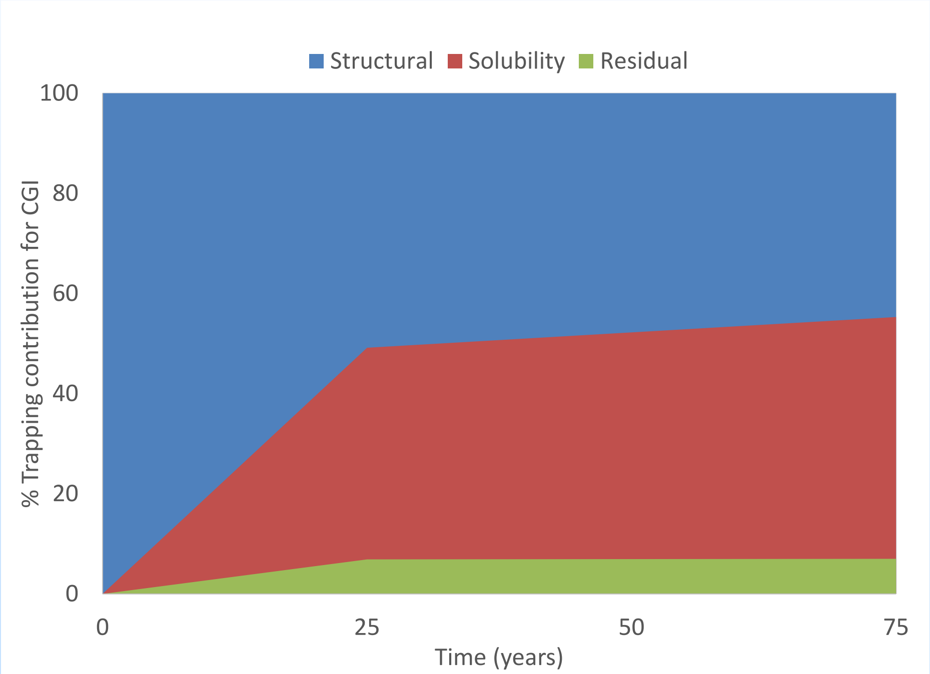
Oil Recovery Factor



Trapping Mechanisms: WAG- CGI evolution

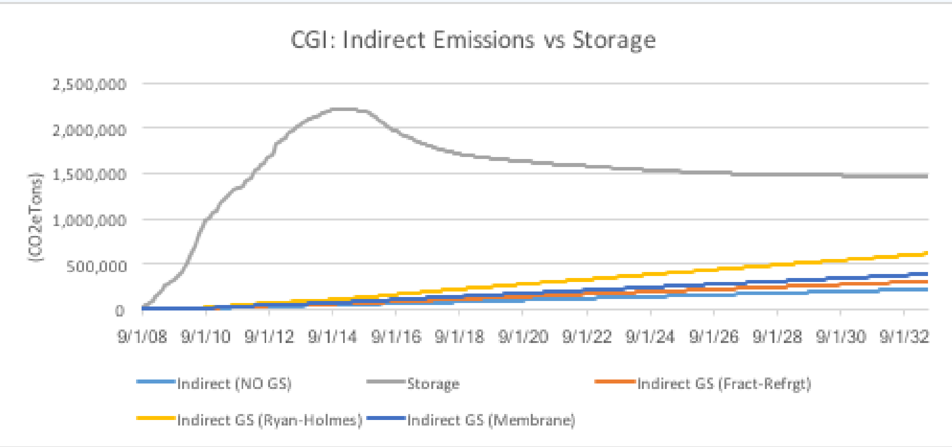


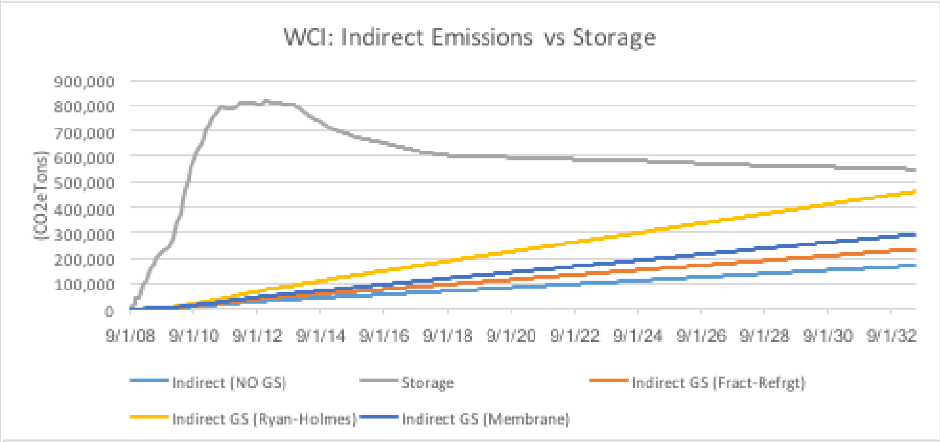
CGI

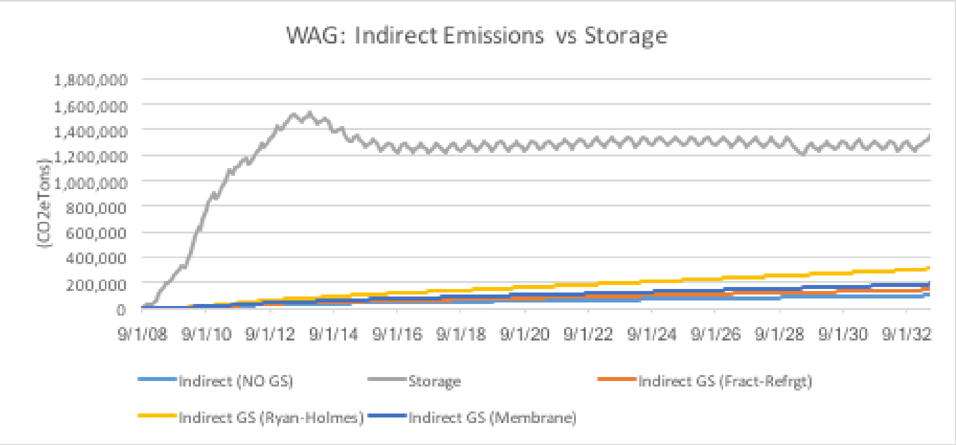


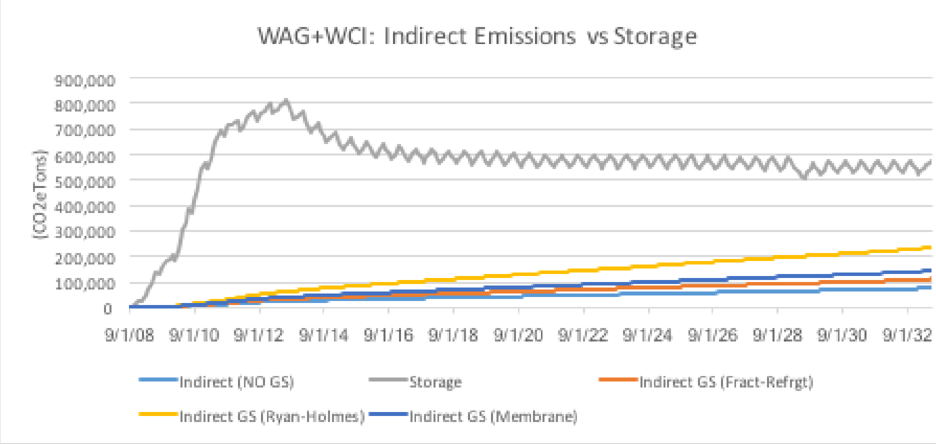
WAG

Carbon Balance Evolution: Gate to Gate









Accomplishments to Date

- 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 classified Cranfield mass accounting data
  - ✓ Developed an EOR site carbon mass accounting procedure
  - ✓ 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
  - ✓ Started scenario analysis
  - ✓ Linked results from numerical simulations with energy consumption model

- Future Plans:
  - Develop an MVA plan

Lessons Learned

- CO_2 storage is greatest in absolute volume terms for the CGI scenario, with 1.5 million tons (Mt) CO_2 stored. In decreasing order, this is followed by 1.3 Mt CO_2 stored for WAG, and 0.6 Mt for both WCI and WAG+WCI scenarios. CGI injects a larger gross volume of CO_2, so a larger volume is left behind.
- CO_2 net utilization ratio, defined as the amount of CO_2 injected to produce 1 unit of oil, is lowest for hybrid WAG+WCI scenario, followed by WCI, WAG and CGI in increasing order.
- Oil production is greatest in absolute volume for the CGI scenario, with 4 million barrels (MMbbl) of incremental oil produced, versus 3 MMbbl for WAG, 2.5 MMbbl for WCI and 2 MMbbl for the hybrid WAG+WCI scenario.
- Our numerical simulations, based on Cranfield CO_2-EOR project data, demonstrate that flood efficiency variations are significant and mostly depend on the operator‘s selected field development strategy. These variations greatly affect the carbon balance of a project.

Synergy Opportunities

– Our NCNO methodology can be applied to the development of any hydrocarbon resource (conventional or unconventional) for Carbon Balance assessments.

Appendix

– These slides will not be discussed during the presentation, but are mandatory.

Benefit to the Program

Program goals being addressed.

(4) Develop Best Practice Manuals for monitoring, verification, accounting (MVA), and assessment; site screening, selection, and initial characterization; public outreach; well management activities; and risk analysis and simulation.

In support of:

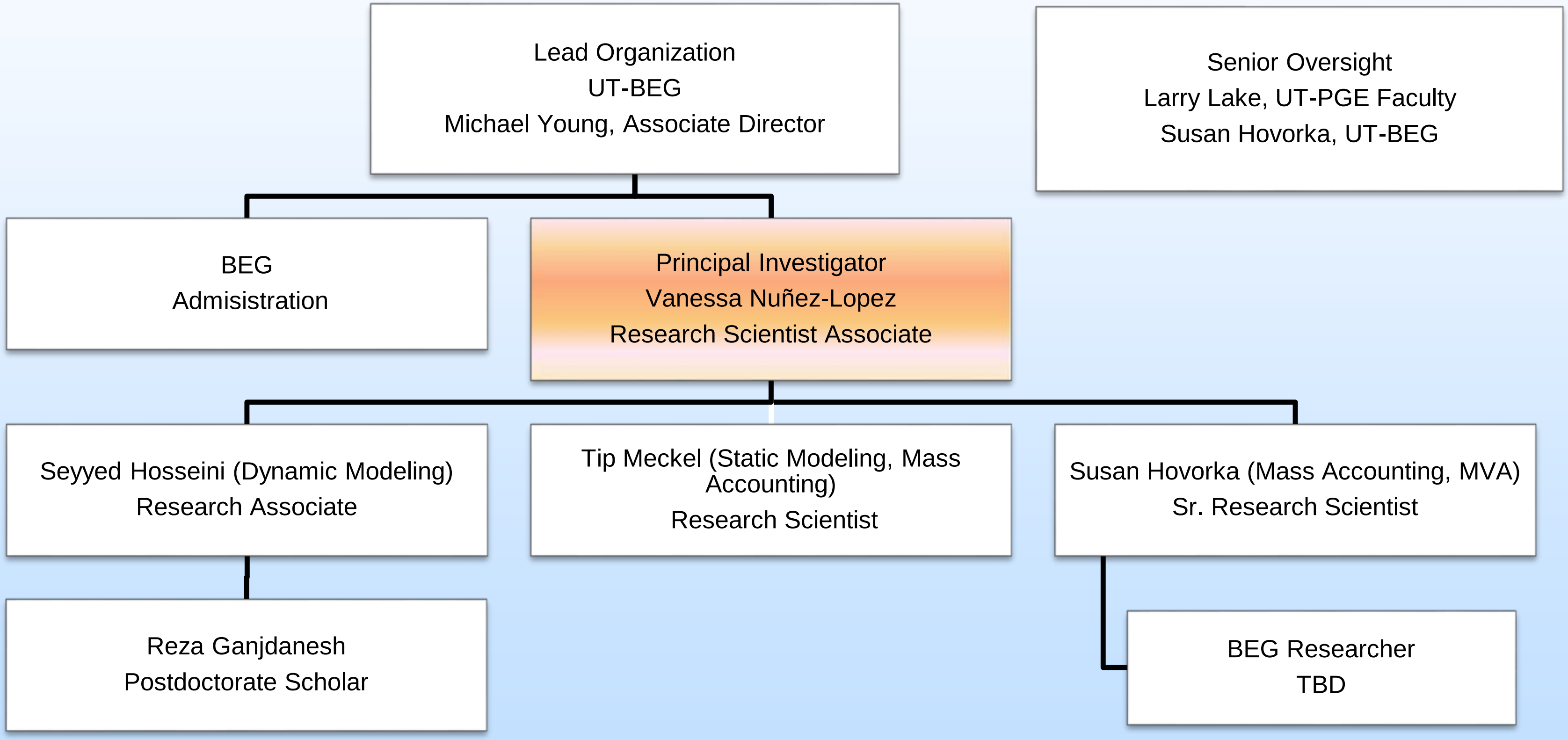
(1) Develop and validate technologies to ensure 99 percent storage permanence.

Project benefits statement.

The project will conduct research under Quantifying the Carbon Balance of CO_2-EOR Operations and Identifying “Net Carbon Negative Oil”, via development of a reliable, clear, repeatable and universal CO2-EOR mass accounting methodology. The overall impact of this study will be the economic influence that a project classified as Net Carbon Negative Oil (NCNO*) would have on a CO2-EOR operation, if future laws and regulations provide value to the emissions and/or storage of CO_2.

*NCNO is defined in the FOA as oil whose carbon emission to the atmosphere, when burned or otherwise used, is less than the amount of carbon permanently stored in the reservoir in order to produce the oil

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													