CO_2-EOR: Approaching an NCNO classification

(Cranfield case)

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Presented by:
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Sponsors meeting
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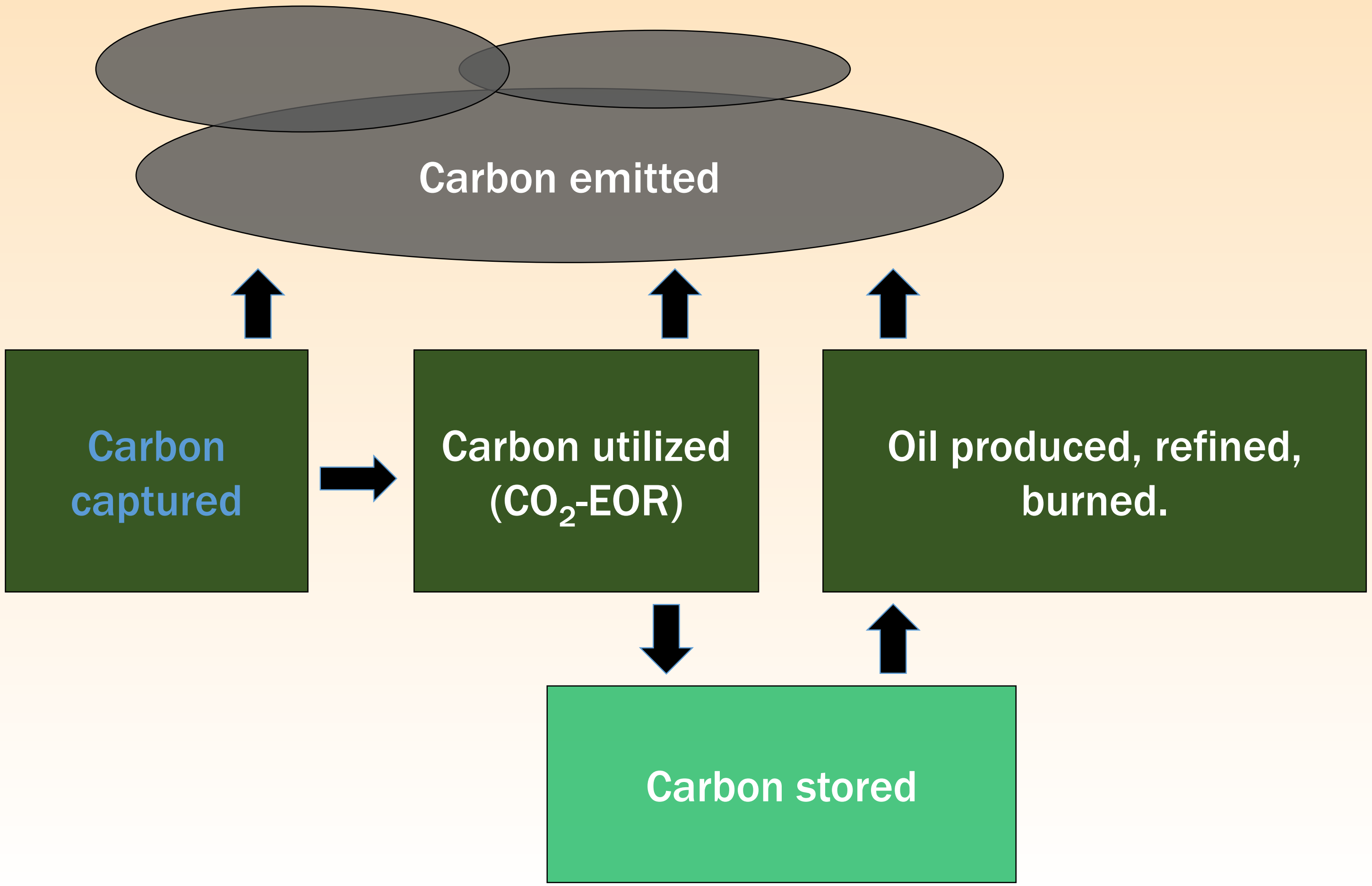
Problem Statement



1. Is CO_2-EOR a valid option for greenhouse gas emission reduction?
2. How do different injection strategies affect EOR's Carbon Balance?
3. What is the impact of different gas separation processes on EOR emissions?
4. What is the impact of the downstream emissions on the Carbon Balance?

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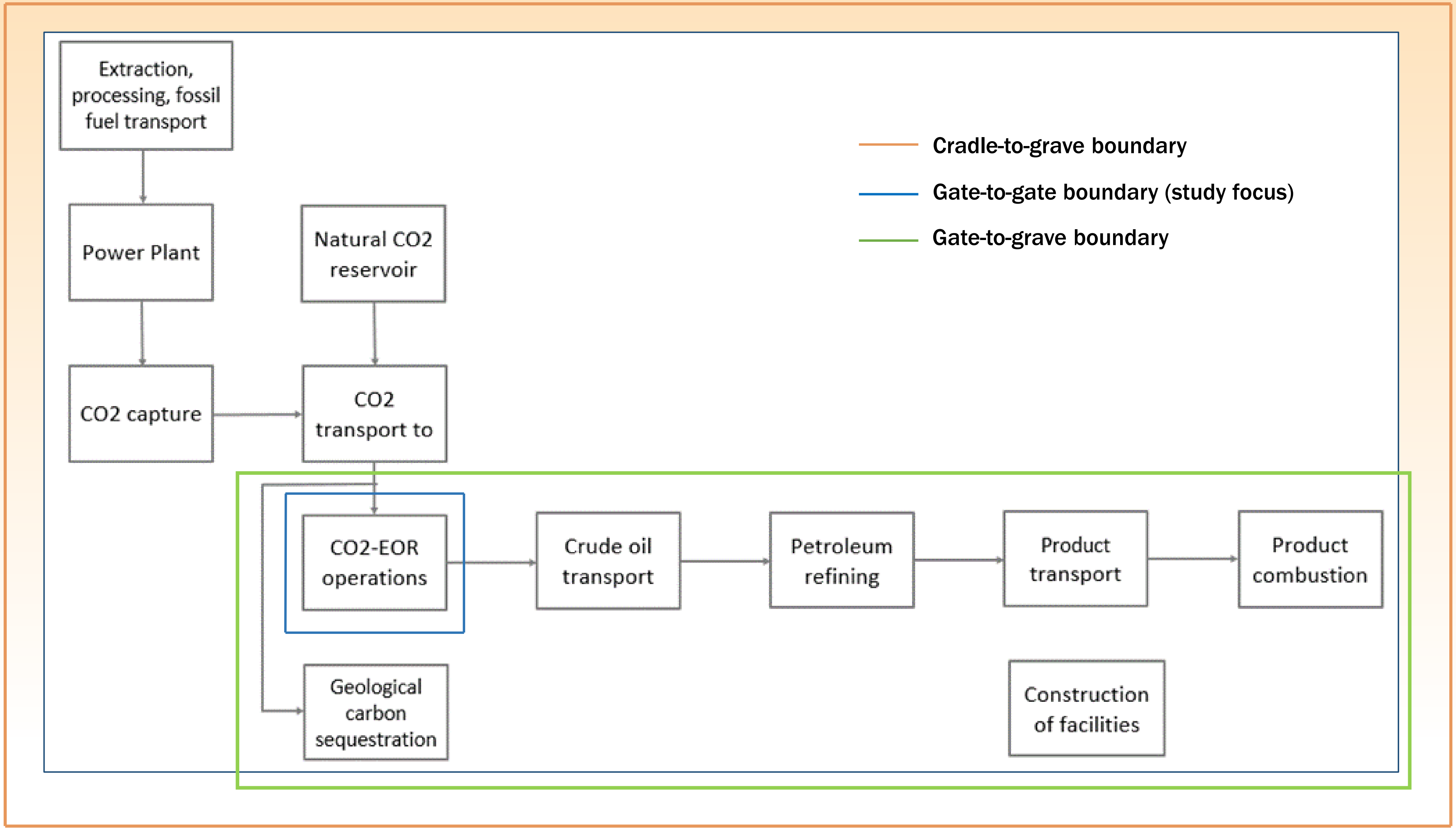
Selection of system boundaries for NCNO classification



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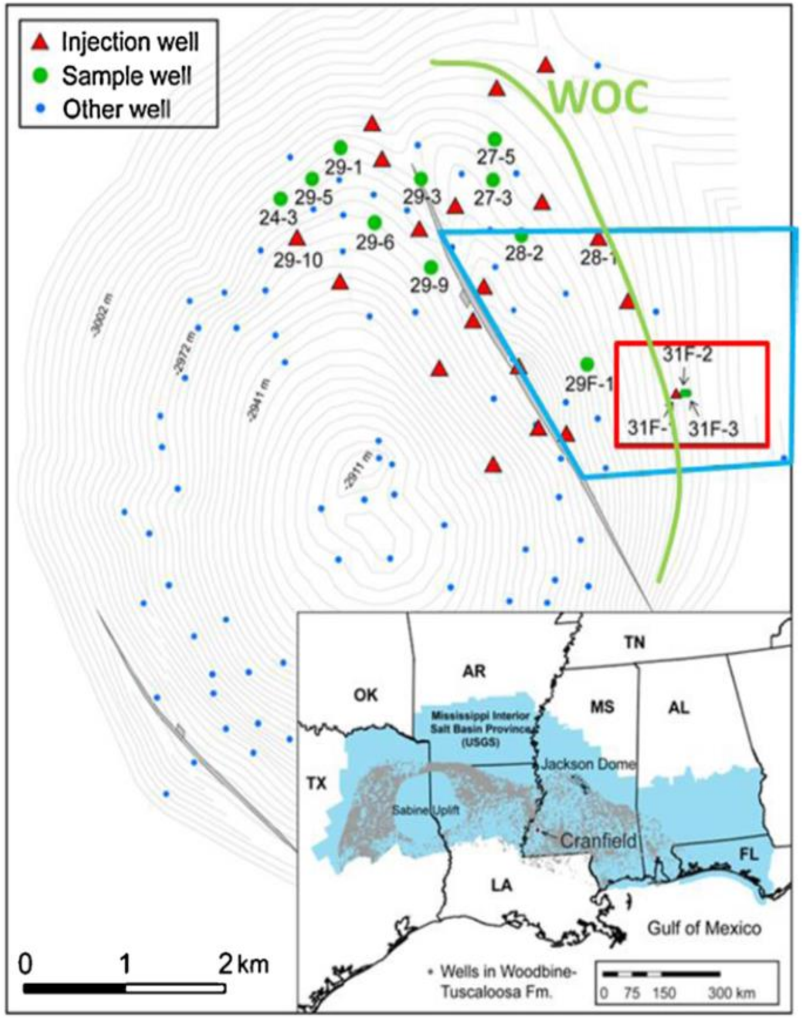
CO_2-EOR GHG accounting:



Gate to Gate (EOR Site) boundary:

Indirect Emissions: ← Power source from SRMV Grid (468 KgCO2e/MWh)

- Artificial Lift (Gas Lifting)
- Gas Injection Compression
- Pumping for injection and fluid handling
- Gas Separation Process

Direct Emission:

- Bulk Separation (VOC)
- Fugitive CO_2 released to air

Gate to Grave boundary:

EOR Site + Downstream: ← EIA average of carbon content and heat content of crude oil going into U.S. refineries

+ Refinery
+ Product combustion

Cranfield CO_2-EOR operations scenarios:

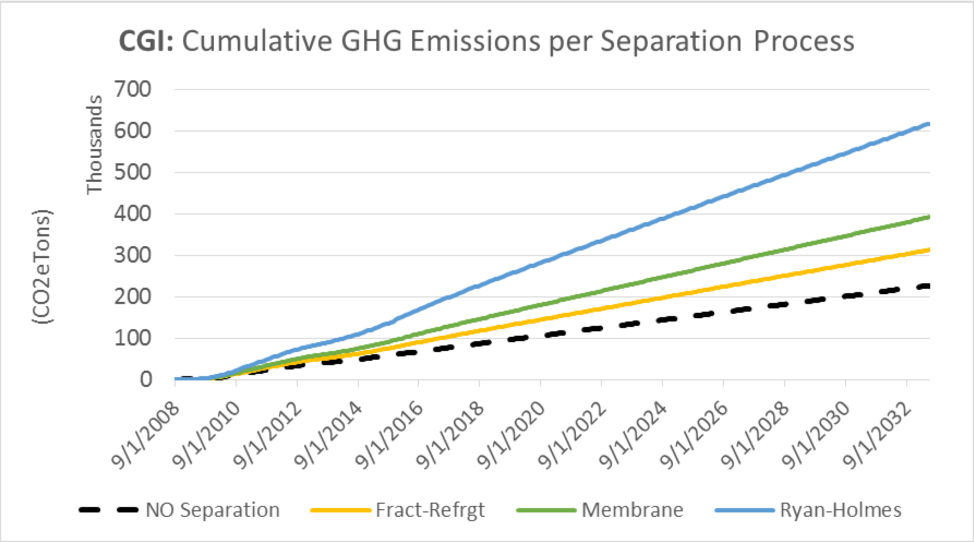
Injection Scenarios:

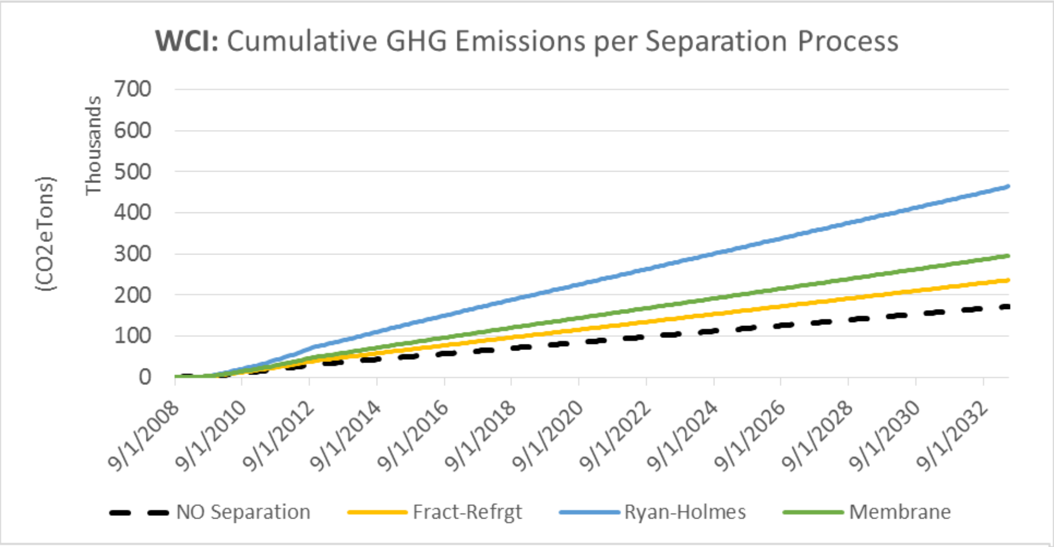
- Continuous CO_2 injection (CCI)
- Water Alternating GAS (WAG)
- Water Curtain Injection (WCI)
- WAG+WCI

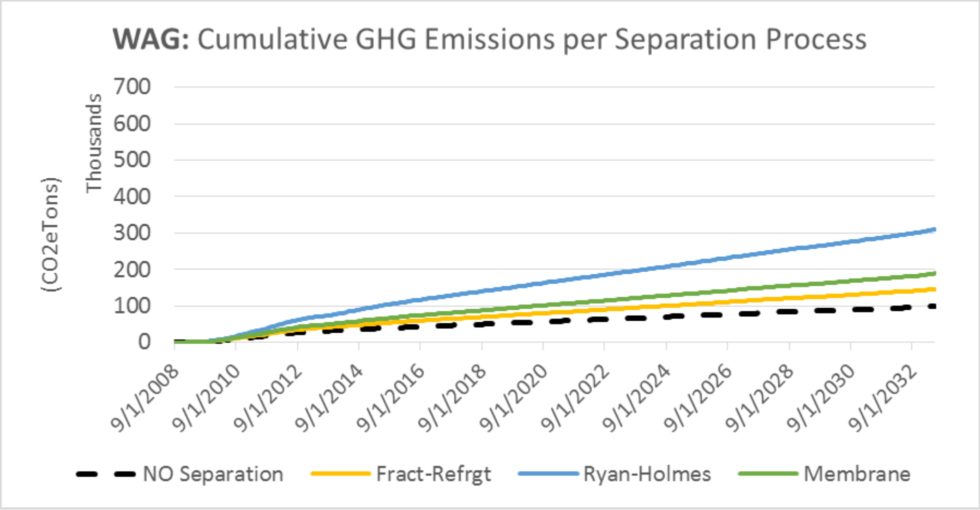
Gas separation Methods:

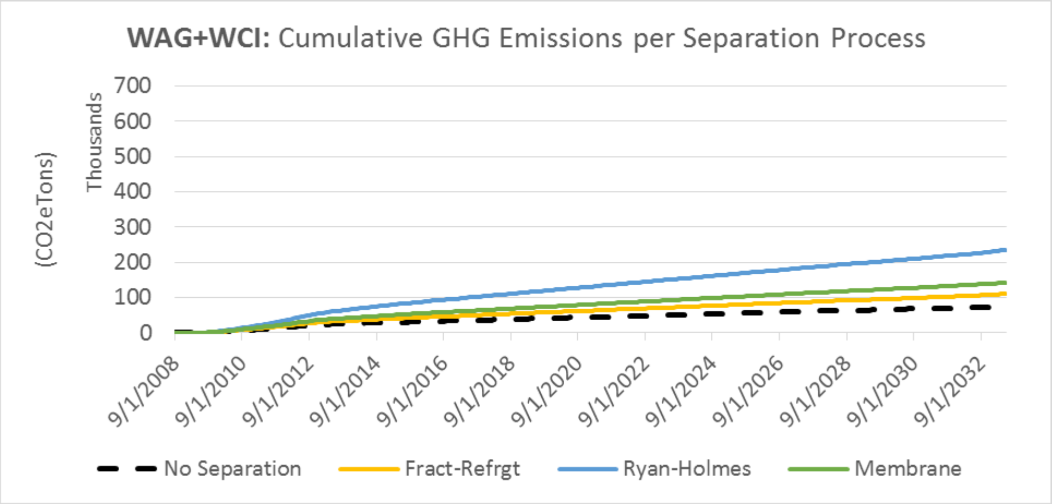
- No Separation Process
- Ryan-Holmes
- Membrane
- Fractionation-Refrigeration

Emissions Evolution : EOR Site (Gate to Gate)

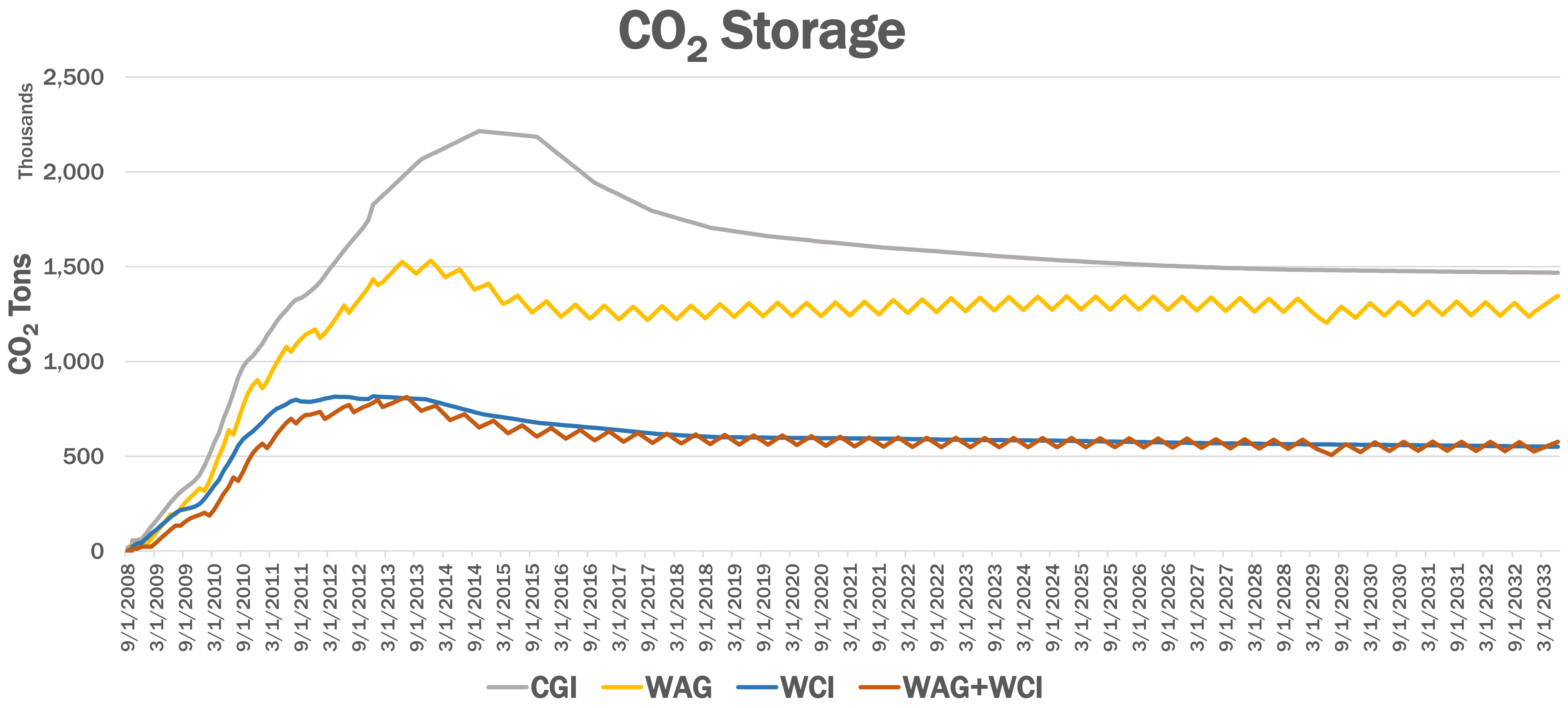




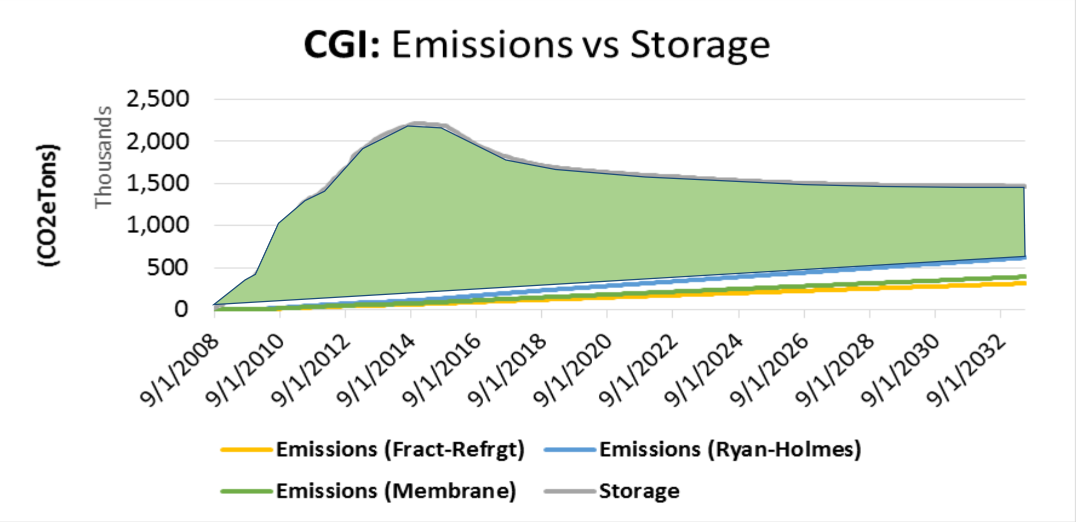


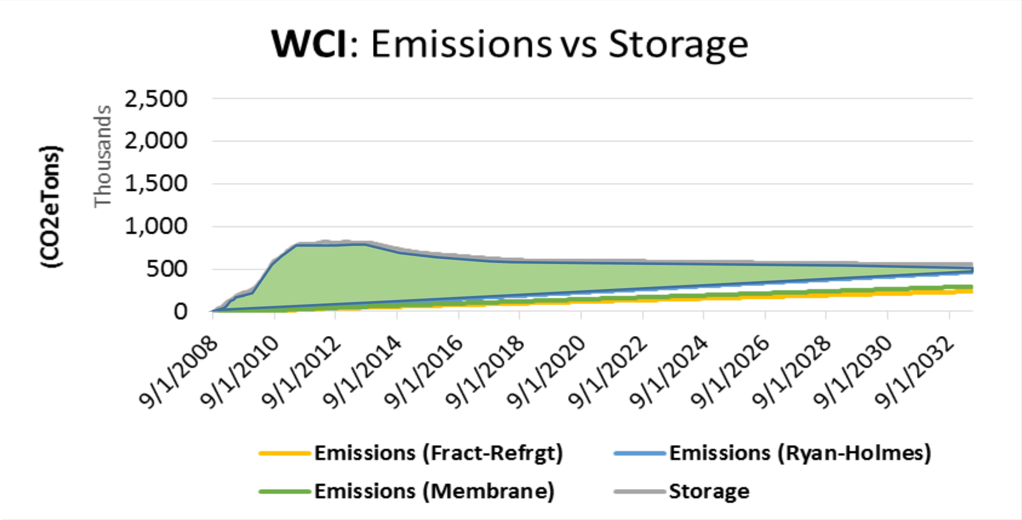


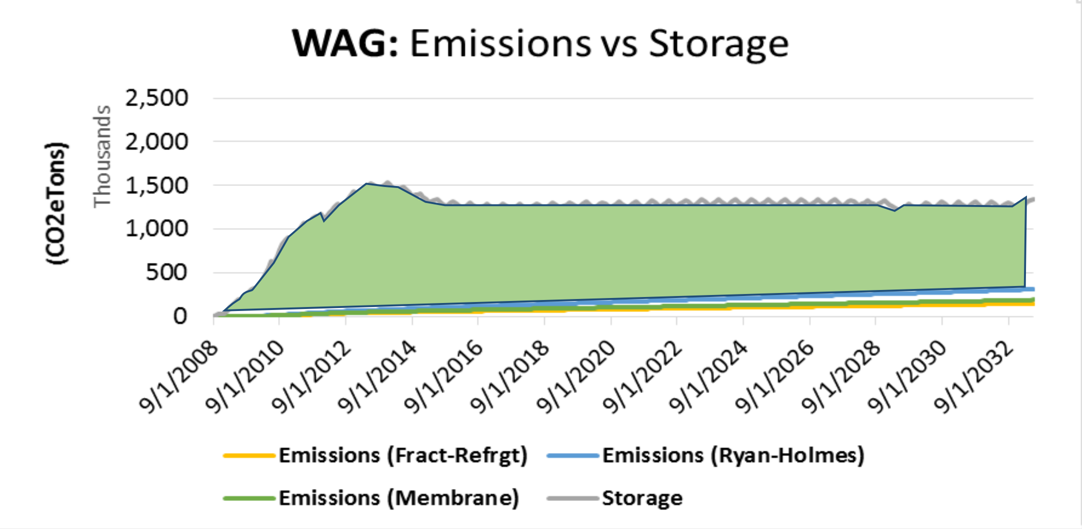
Storage Evolution: EOR Site (Gate to Gate)

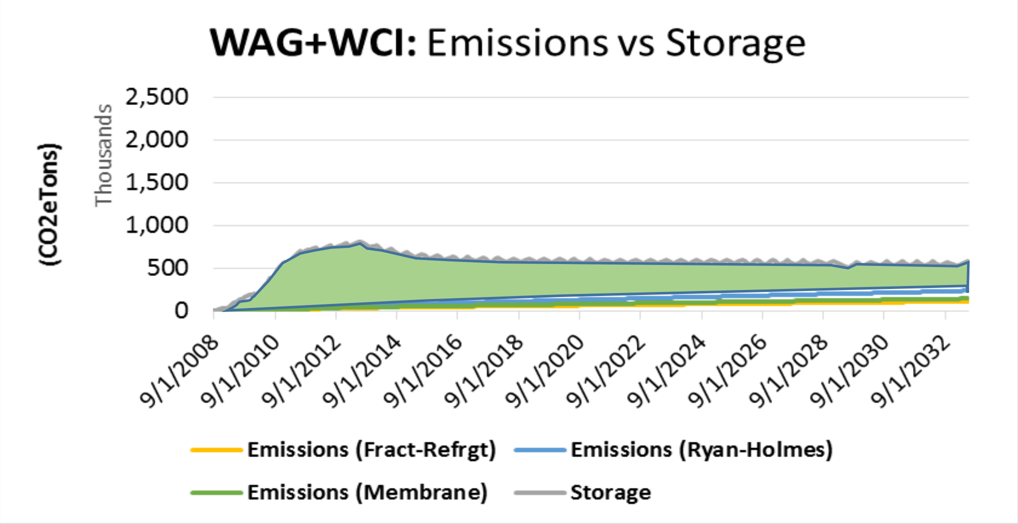


Carbon Balance Evolution: EOR Site (Gate to Gate)



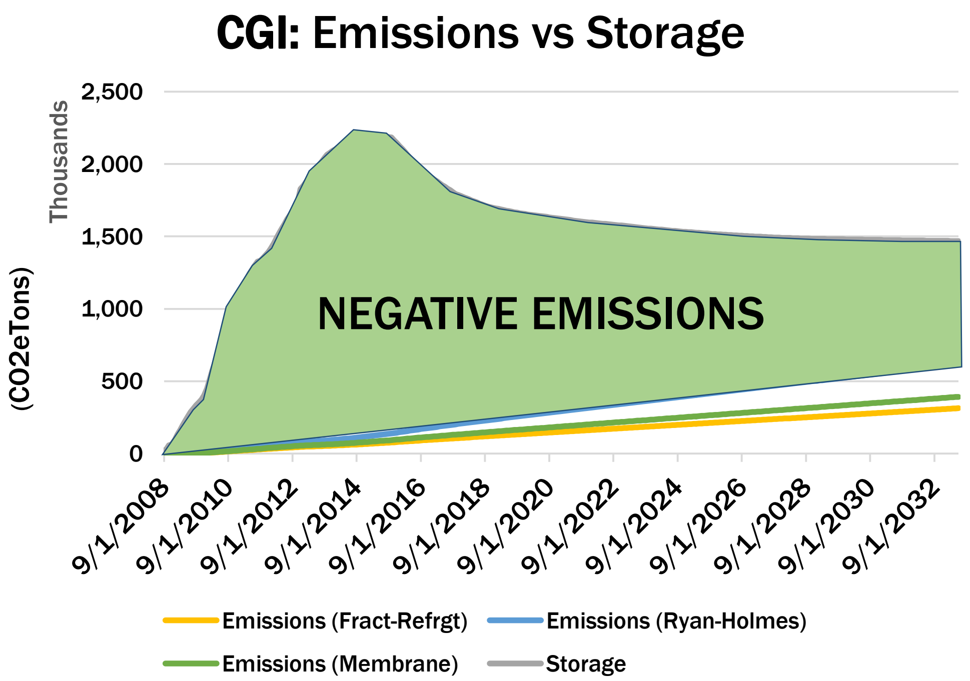




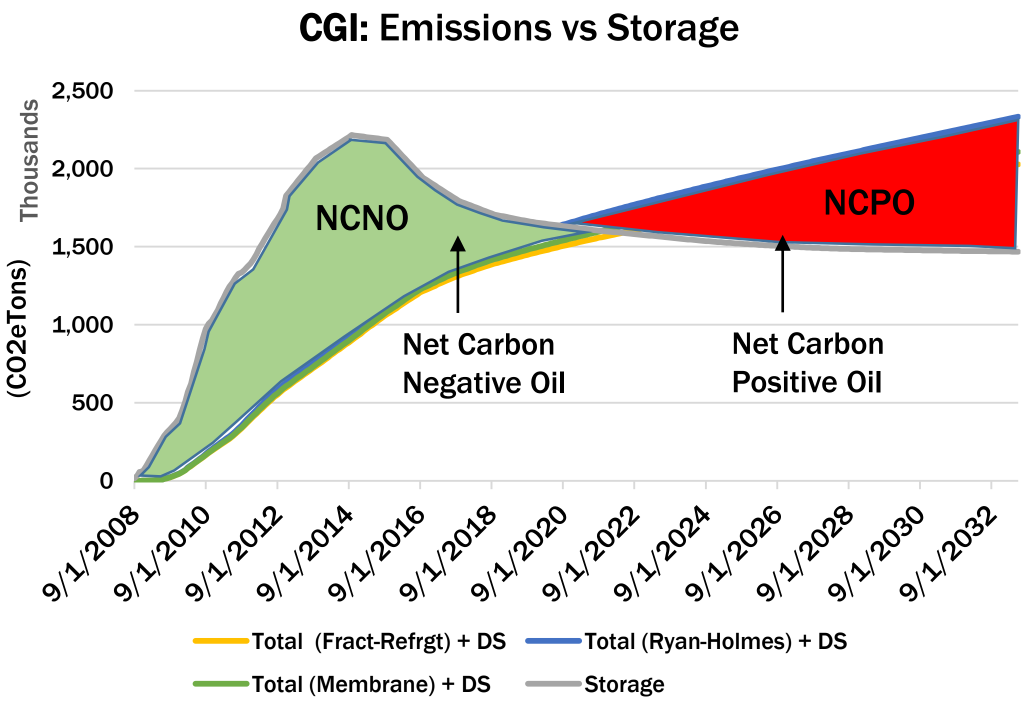


Impact of Downstream Emissions (Gate to Grave)
(CGI Scenario)

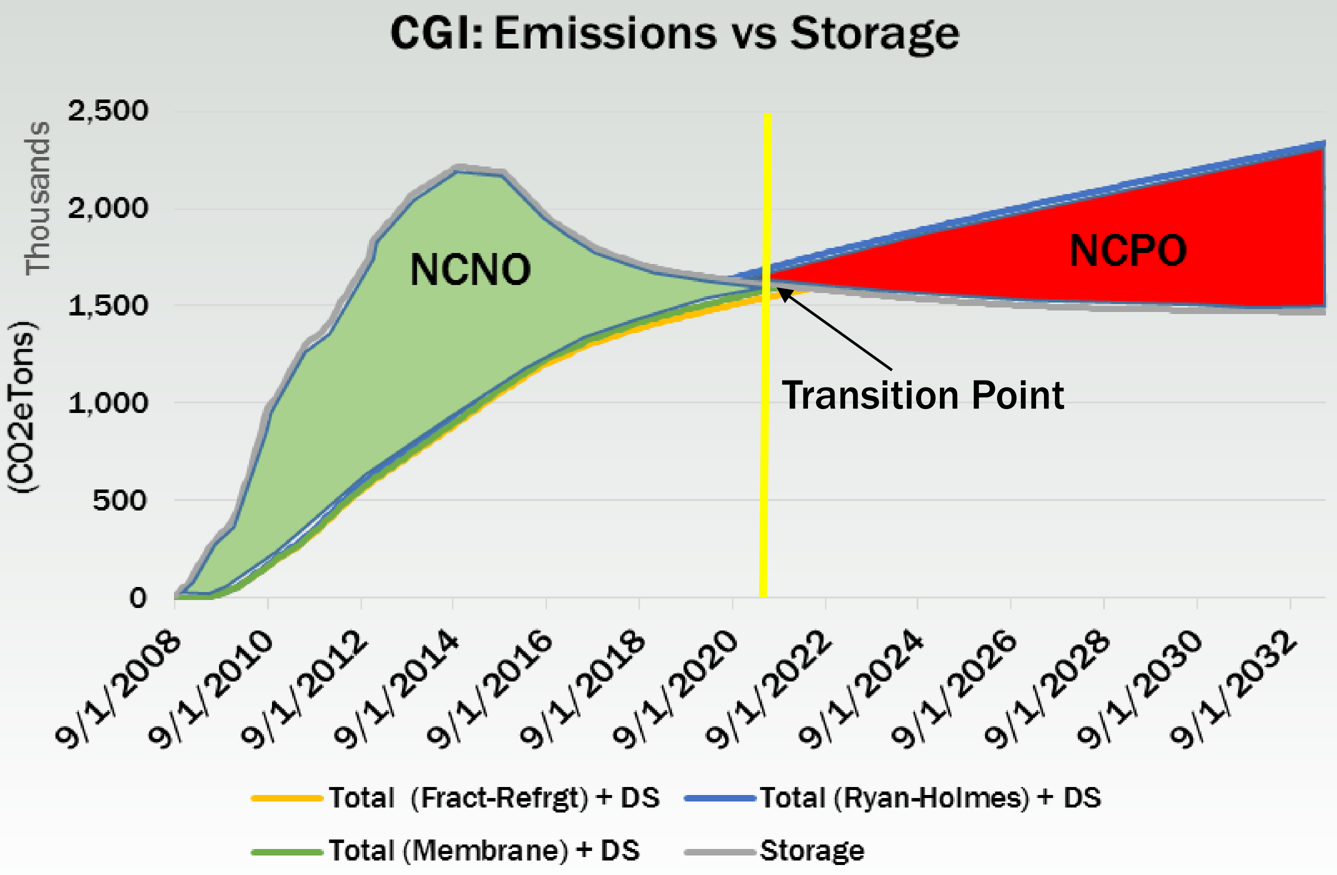
Gate to Gate



Gate to Grave



Carbon Balance Evolution: Gate to Grave (CGI Scenario)



Statistics at Transition Point:

Storage: 1.6 MMtons CO_2e

Production: 3.1 MM bbls

% of Ultimate Prod. : 81%

NCNO Period: 52% (13 yrs)

Emission Rate: 0.51 (Tons/Bbl)

Net Injection Rate: 5.25 (Tons/Bbl)

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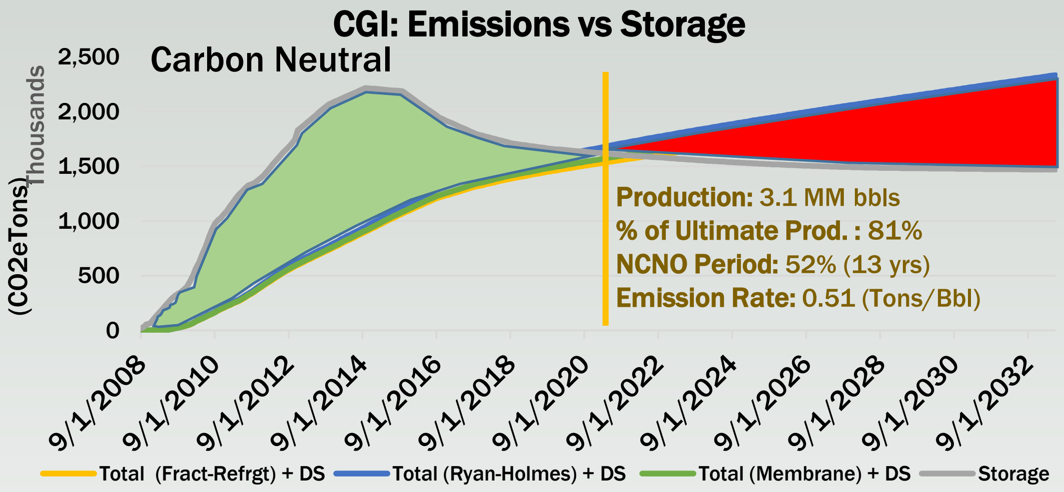
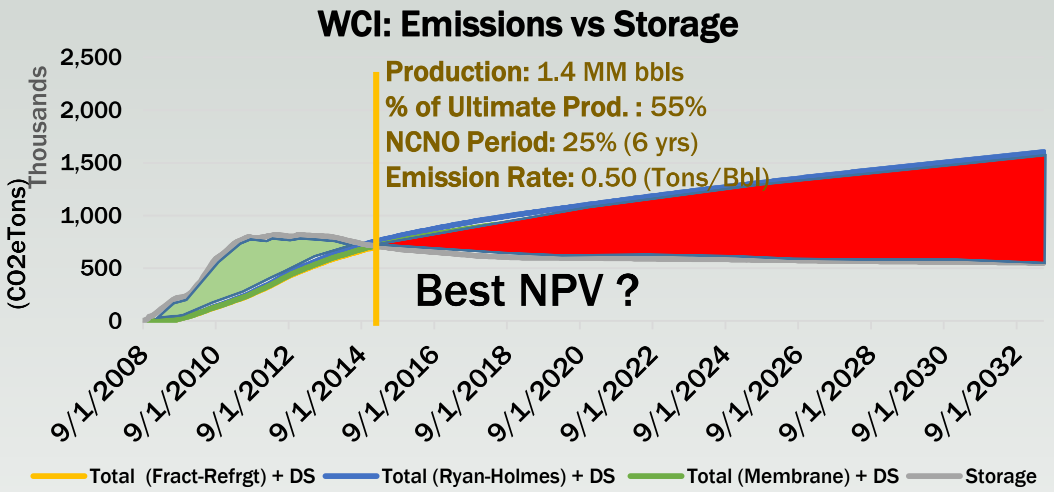
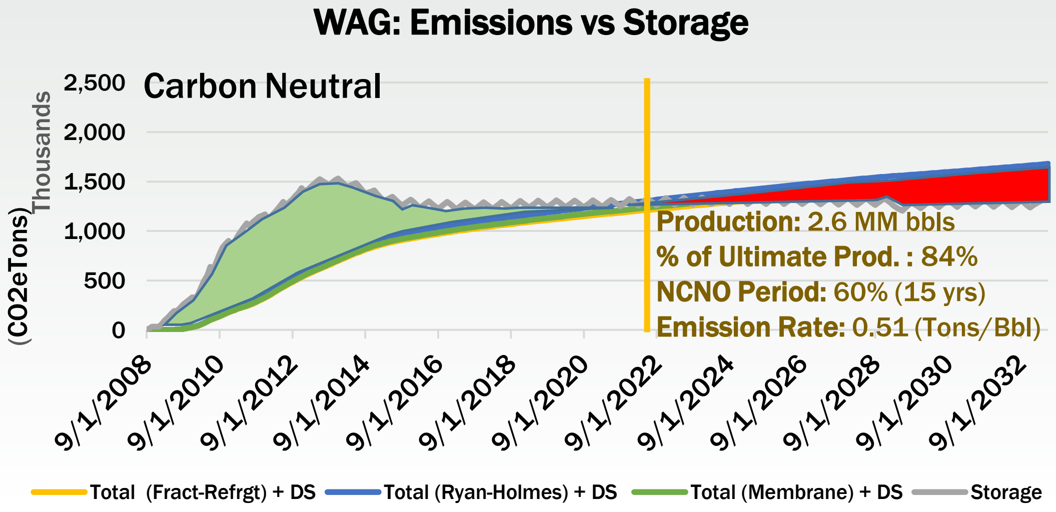
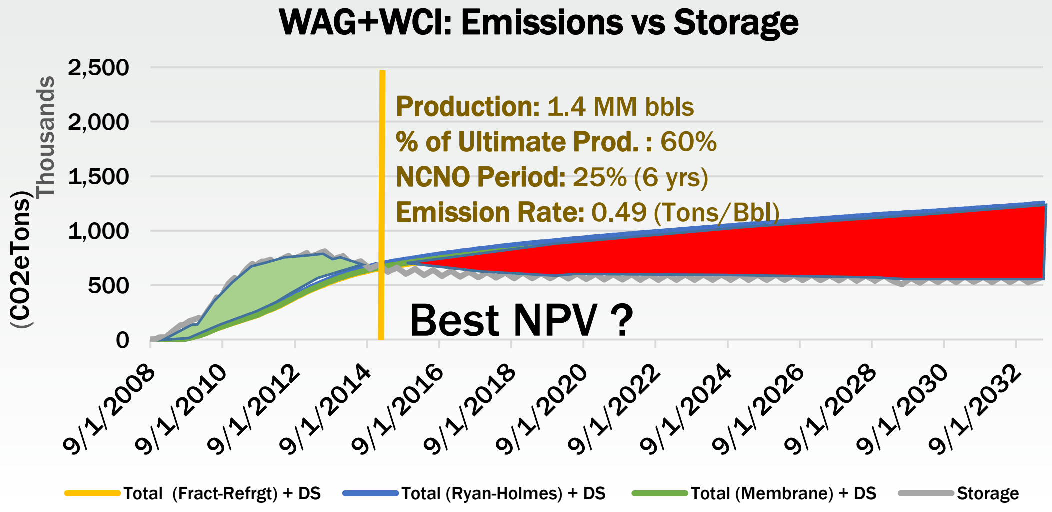
Carbon Balance Evolution: Gate to Grave









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Conclusions:

1. The assessment of the Carbon Balance of CO_2-EOR needs to be dynamic, as it evolves in time. All projects transition from Net Carbon Negative to Net Carbon Positive in a Gate to Grave system.

2. CO_2 storage is greatest in absolute volume terms for the CGI scenario, followed by WAG, and then by WCI and WAG+WCI scenarios. CGI injects a larger gross volume of CO_2, so a larger volume is left behind.

3. 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.

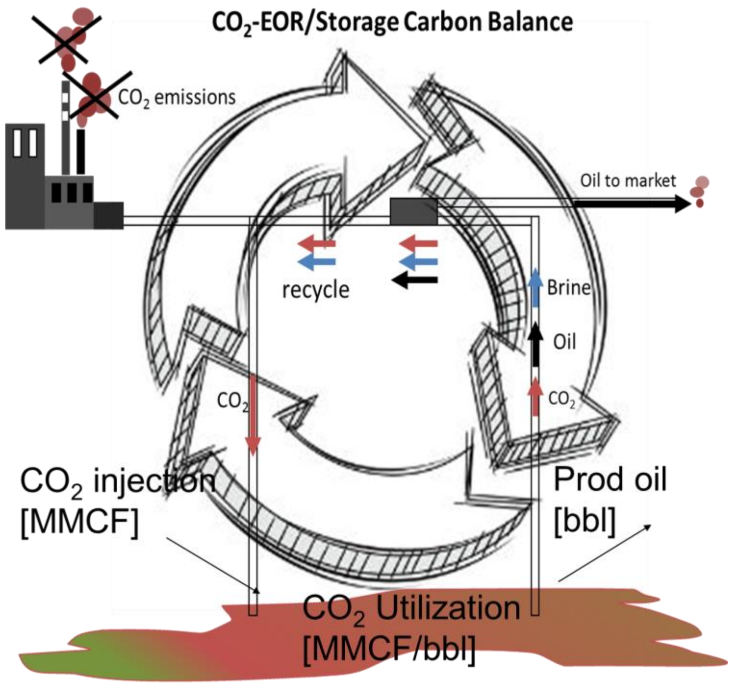
4. WCI and WAG+WCI scenarios have more efficient Oil recovery rate in short term before the transition from Net Carbon Negative to Net Carbon Positive in a Gate to Grave system.

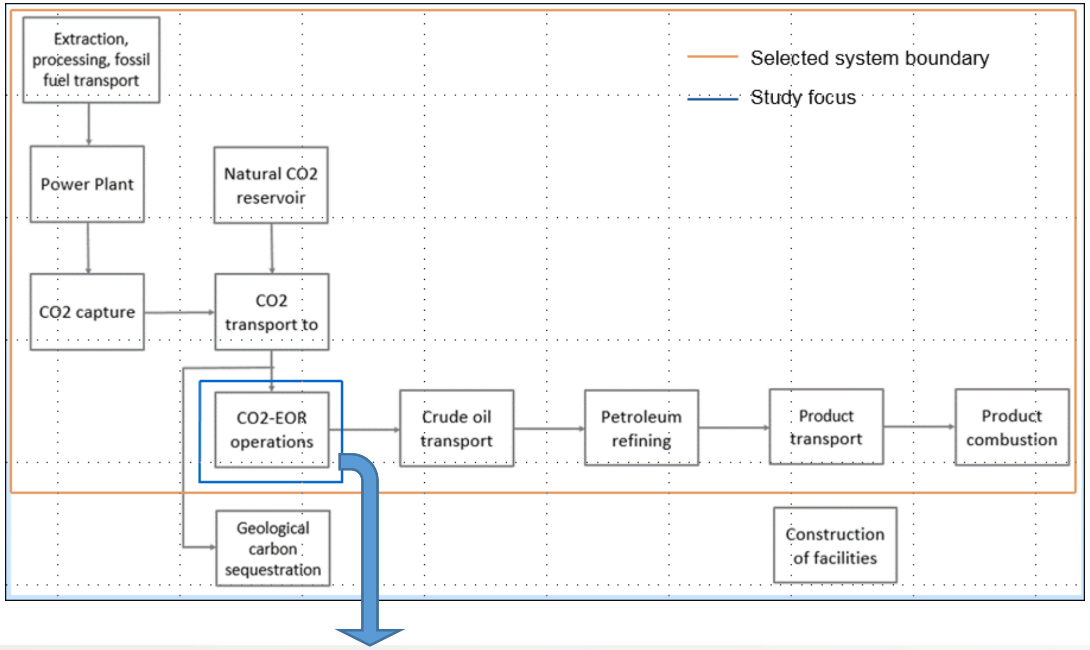
5. WAG offers the best compromise between oil production and CO_2 storage, and it has a better potential to be optimized for flood performance in the field especially when analyzed on hydrocarbon pore volume (HCPV) injected.

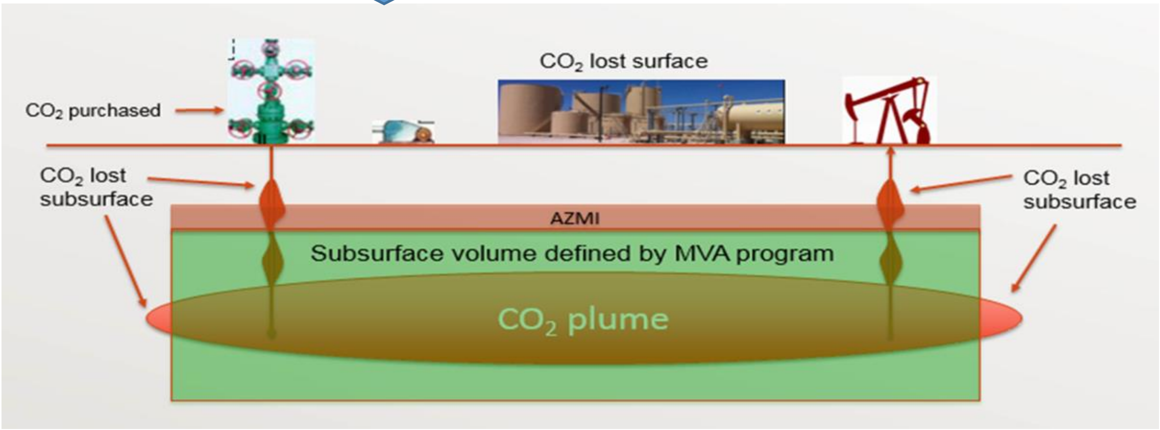
6. Our numerical simulations, based on Cranfield CO_2-EOR project data, demonstrate that flood efficiency variations are significant and mostly depend on the operator's selected field development strategy. These variations greatly affect the carbon balance of a project.

Back-up Slides

Selection of system boundaries and mass accounting







Proposed mass accounting

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

Avoids accounting for recycled CO_2

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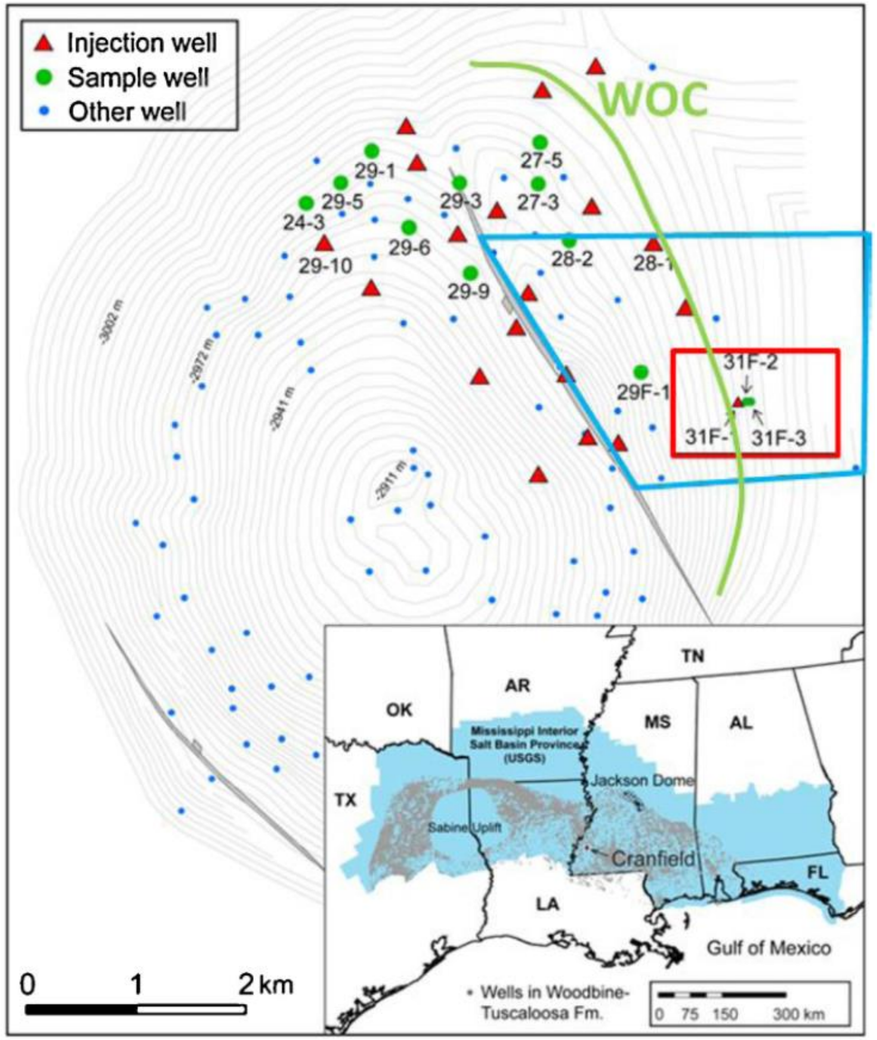
Cranfield CO_2-EOR operations & assumptions:

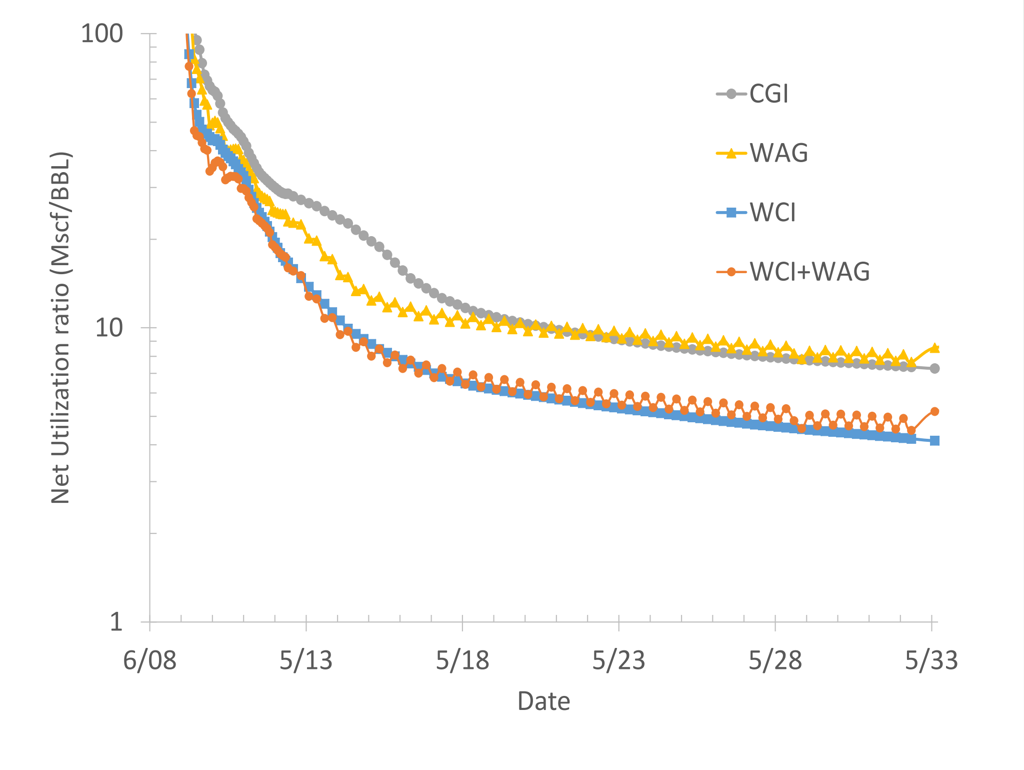


1. North East side field, 10 producing wells, 11 injecting wells
2. 10,000 ft deep, 86% water cut, oil 38 API
3. All produced gas is processed
4. The uninjected produced gas is returned to the pipeline and/or intended for injection into neighboring patherns
5. The uninjected produced water is injected in disposal neighboring wells
6. Produced gas, high pressure on line (700 psi, Avg.)
7. Purchased Gas pressure: 1,800 psi, assumed
8. Injection Gas pressure: 3,000 psi
9. Compressibility: 0.9963; ratio of specific heat: 1.25
10. Reservoir has recovered original pressure
11. Mostly natural lift oil production, 3 months of Gas lift starter
12. Centralized Facility
13. Power source from SRMV Grid (468 KgCO2e/MWh)

CO_2 Injection Scenarios

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

Net Utilization Ratios



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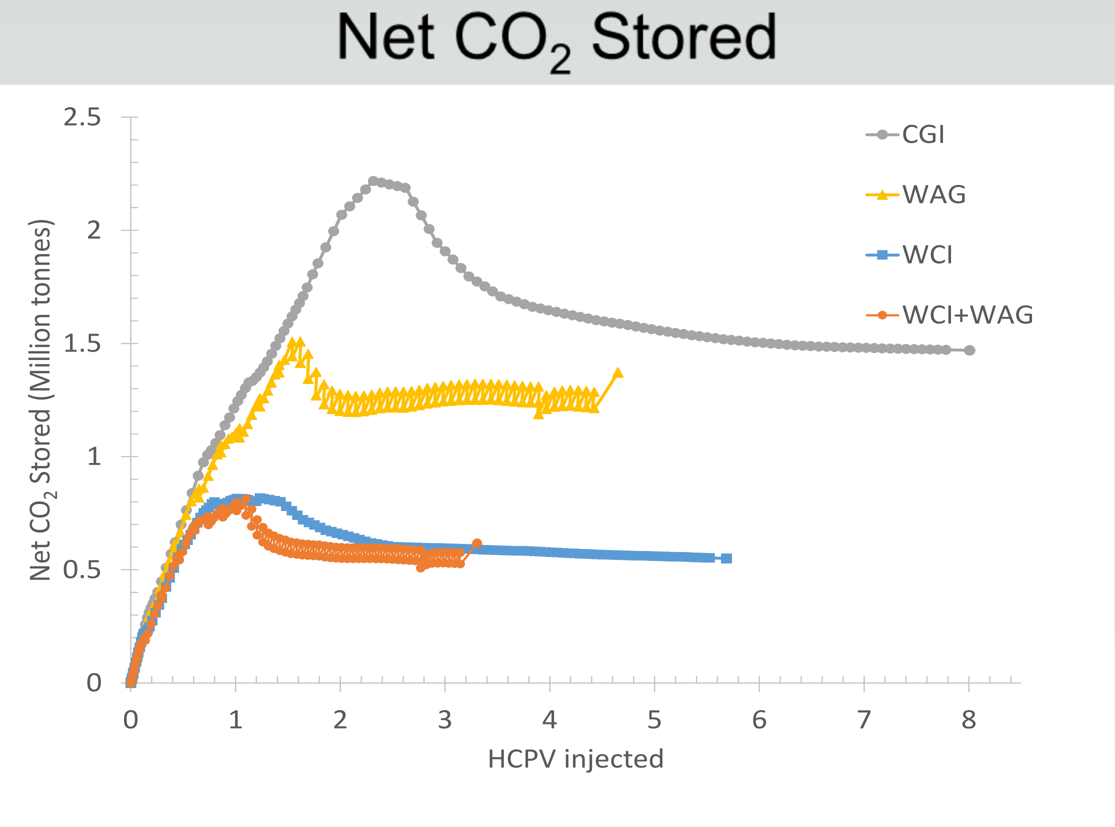
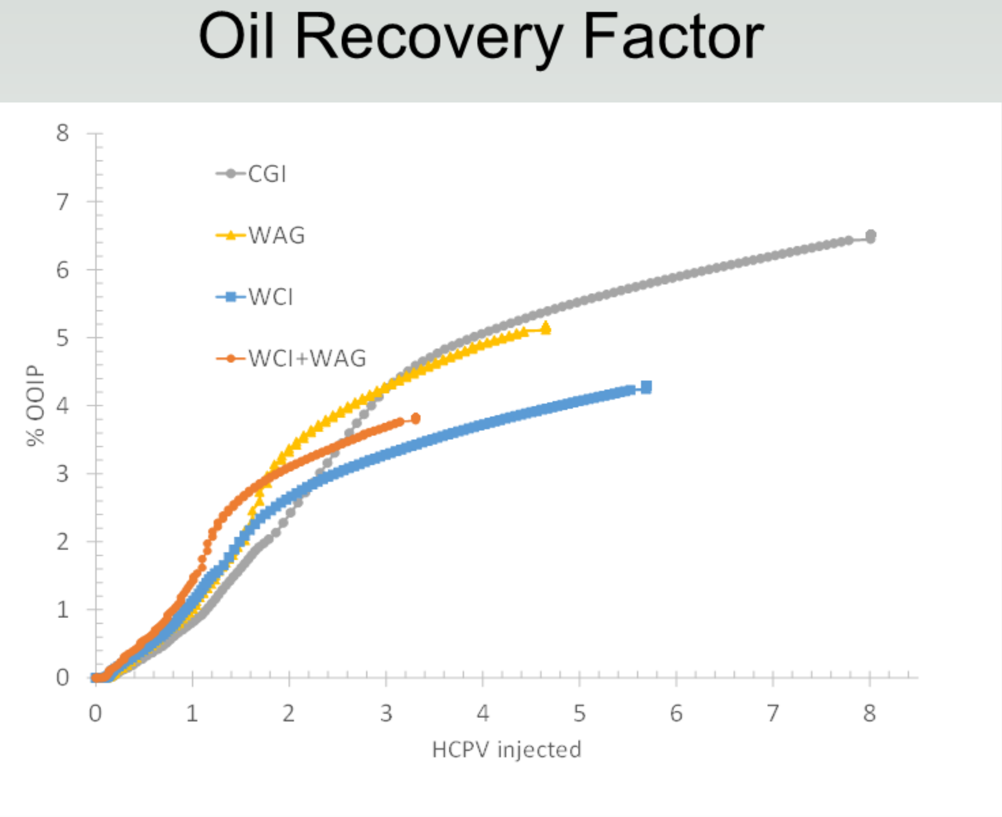
CO2 Injection Scenarios





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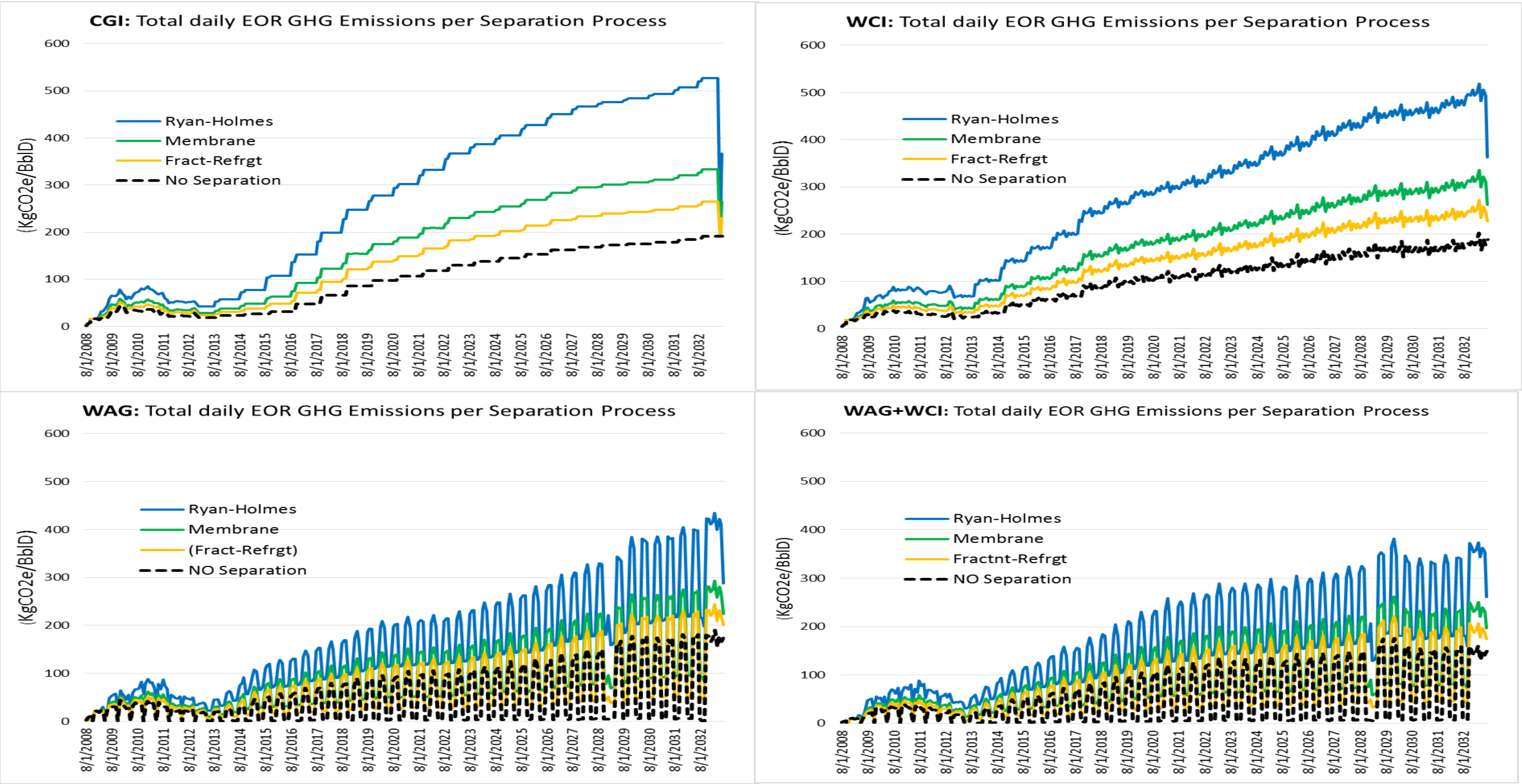
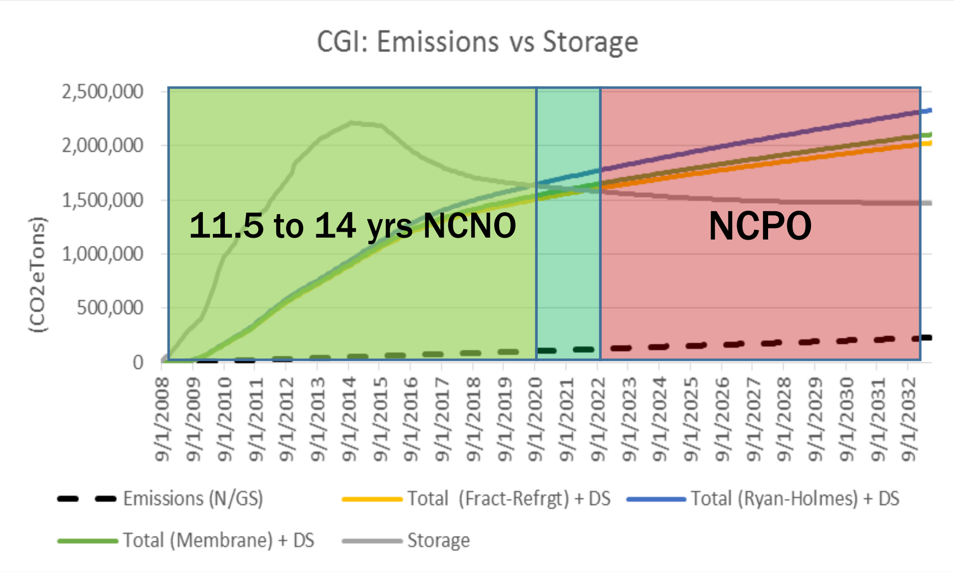
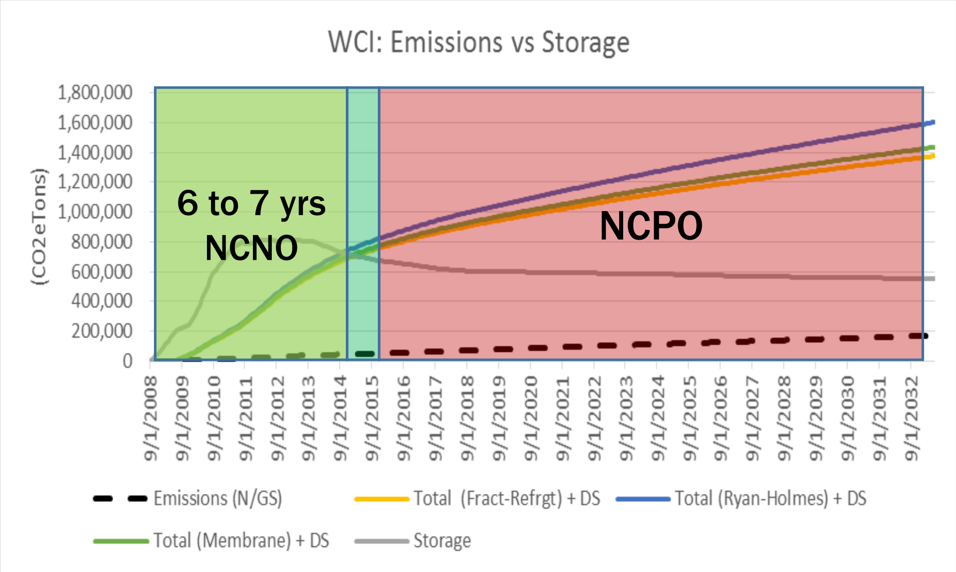
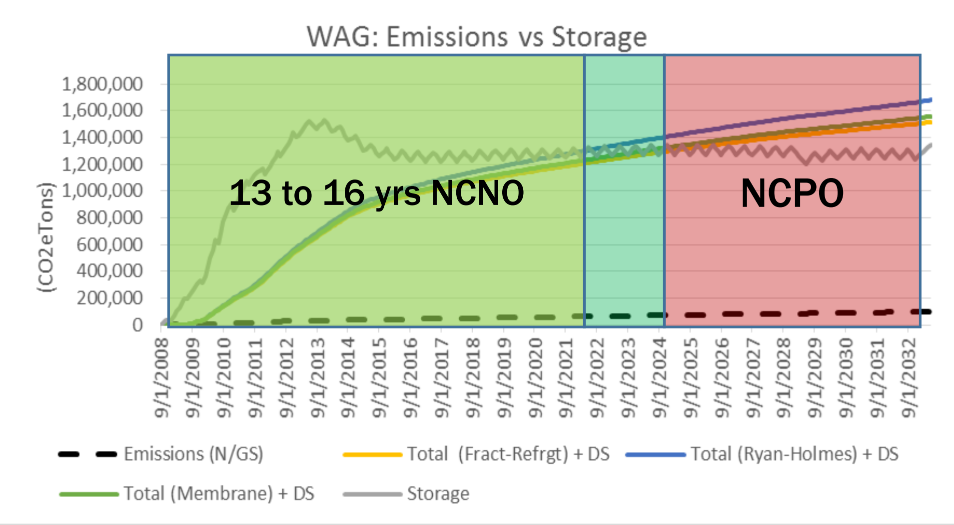
Emissions Evolution: Gate to Gate

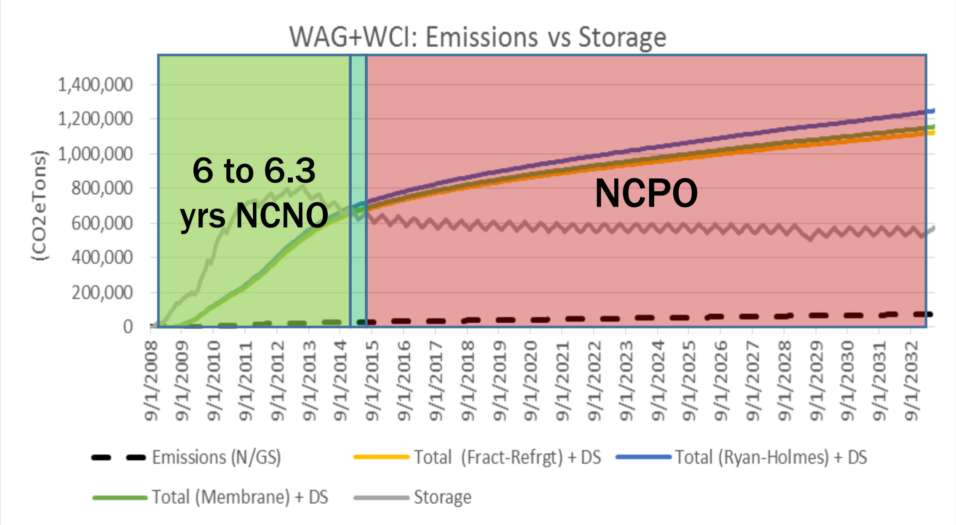


Carbon Balance Evolution: Gate to Grave









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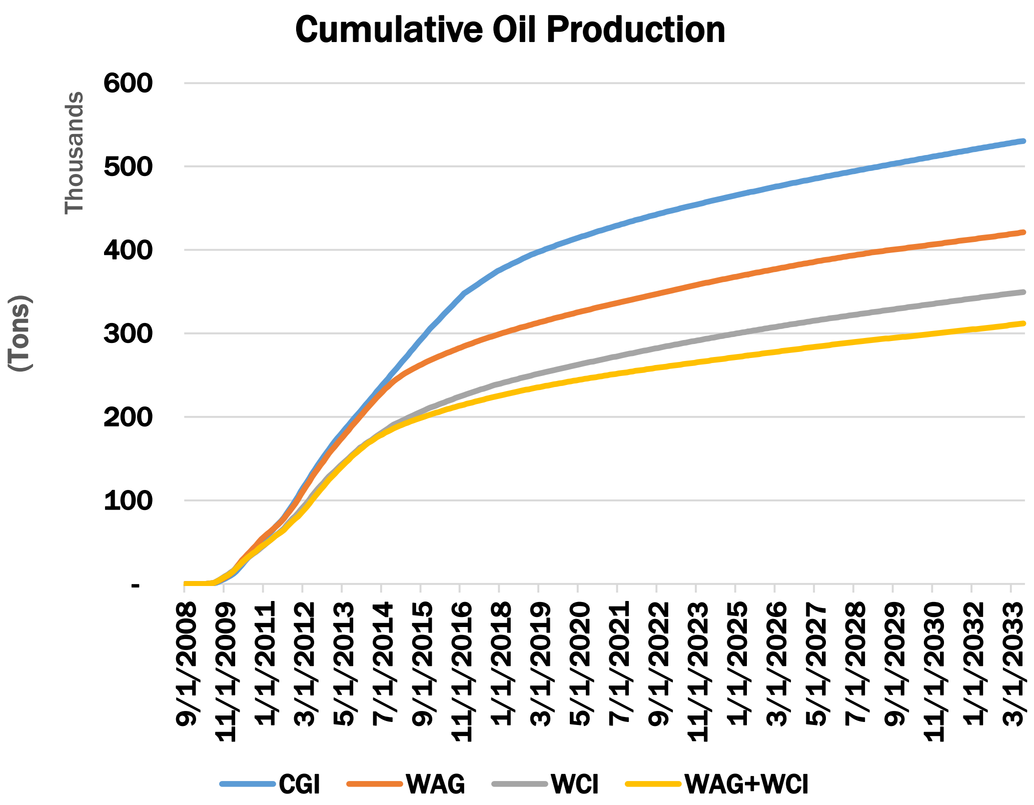
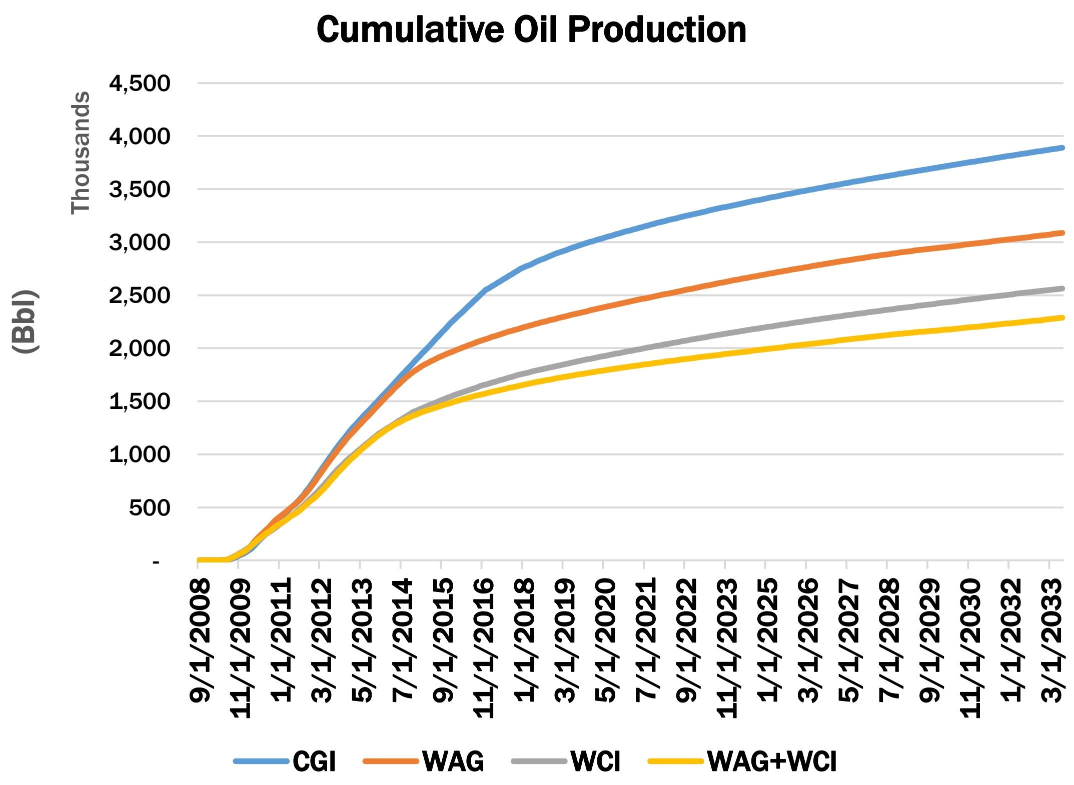
EOR Performance – Gate to Gate

	CGI	WAG	WCI	WAG+WCI
Total Emissions Ind+Dir (w/o gas proc)				
Net Storage (Tons)	1,240,453	1,262,987	377,984	509,057
Net Storage (Tons/Bbl)	0.38	0.41	0.15	0.22
Emissions(*)/Storage (Tons/Tons)	0.15	0.07	0.31	0.13
Total Emissions (w/gas Proc)				
Net Storage (Tons)	1,026,534	1,147,245	217,852	421,906
Net Storage (Tons/Bbl)	0.27	0.37	0.08	0.18
Emissions(*)/Storage (Tons/Tons)	0.30	0.16	0.60	0.28
Production Efficiency (Gross Utilization Factor)				
Tons total CO_2 Inj/Bbl	3.86	2.78	4.10	2.65
Bbl/Tons total CO_2 Inj.	0.26	0.36	0.24	0.38

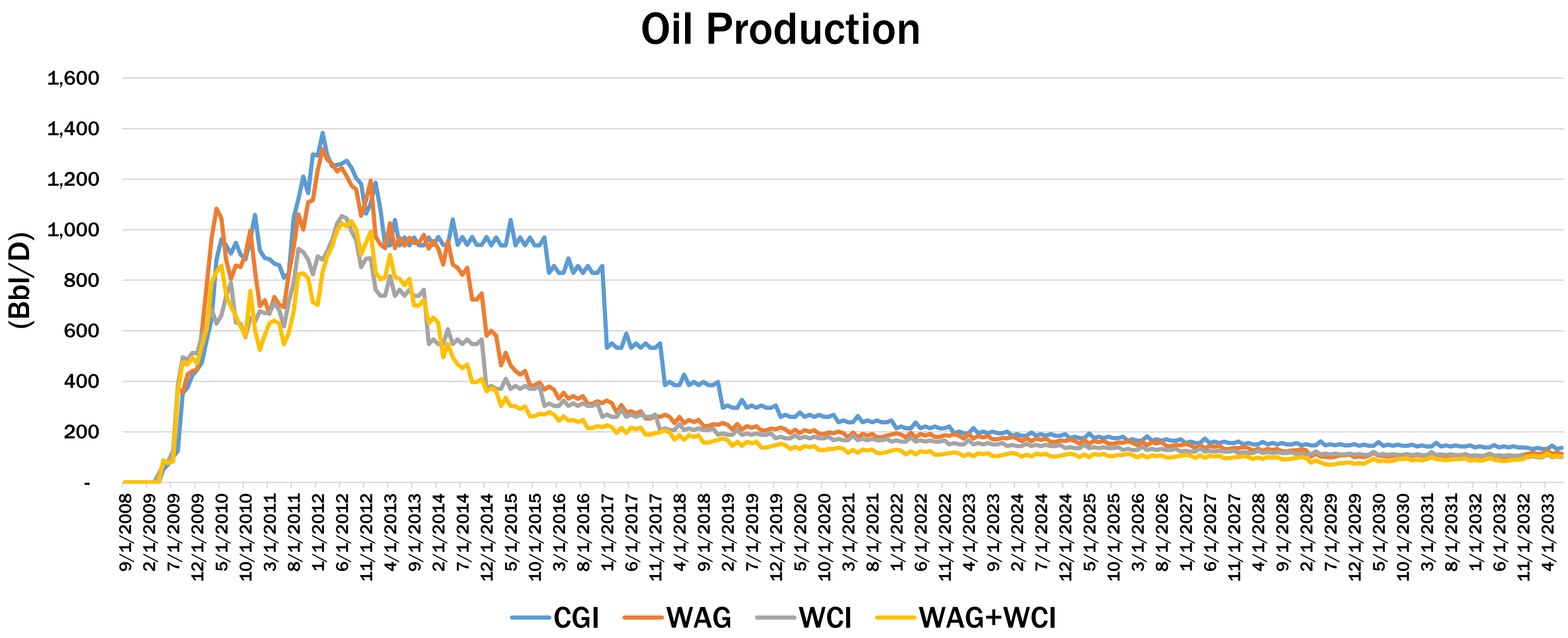
* Emissions (Tons CO_2e)

Cumulative oil production





Oil production rate



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