A Systematic Assessment of CO_2 Enhanced Oil Recovery and Co-Sequestration Potential in Ohio's Depleted Oilfields

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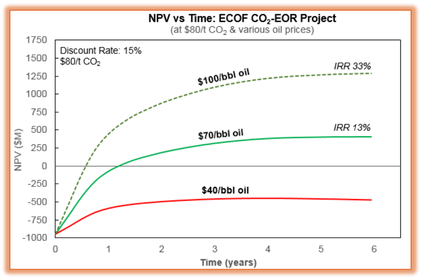
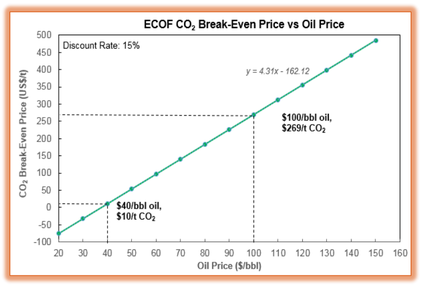
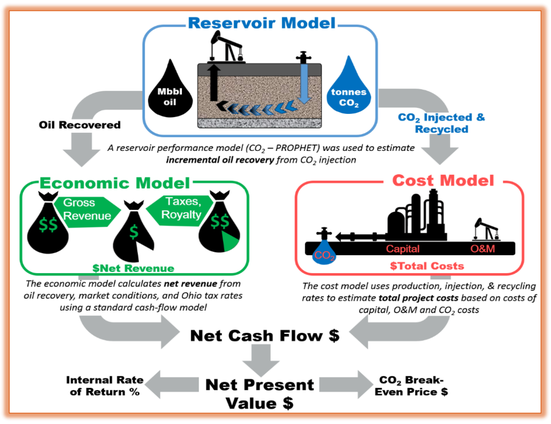
ABSTRACT

The goal of this study is to develop process understanding and evaluate technical and economic feasibility of CO_2 utilization for enhanced oil recovery (EOR) and geologic storage in Ohio. Our focus is on depleted oilfields in the Clinton Sandstone (Eastern Ohio) and the Knox Dolomite Group (North-Central Ohio). These fields are promising candidates for CO_2-assisted EOR because of poor primary recovery efficiency that leaves behind approximately 80-90% of the original oil in place. A systematic assessment of EOR and co-sequestration potential for CO_2 in these depleted oilfields has not been undertaken to date – which is the objective of this research project.



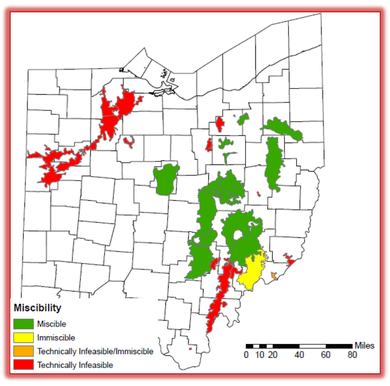


Schematic of the cost-benefit analysis framework (right), NPV curves for a CO_2-EOR operation in the ECOF (left top), and a plot of the CO_2 break-even price calculated as a function of the price of oil for a potential CO_2-EOR project in the ECOF (left bottom)

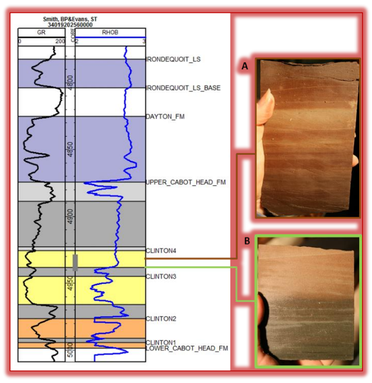


[1] Reservoir Characterization

- Collected data on location and production history for major Ohio oilfields
- Evaluated geologic characteristics from well logs in selected fields



Ohio's 30 depleted oilfields and their miscibility/feasibility classifications

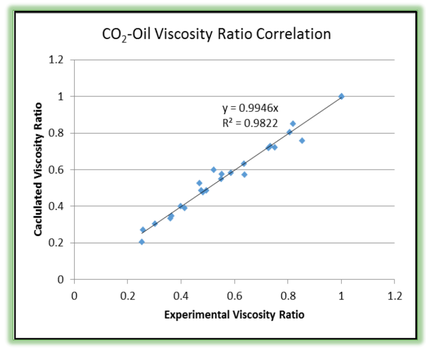


Gamma ray-density log for the Smith and Evans well (API #34019202560) and sample photos of cored interval

[2] Fluid Property Characterization

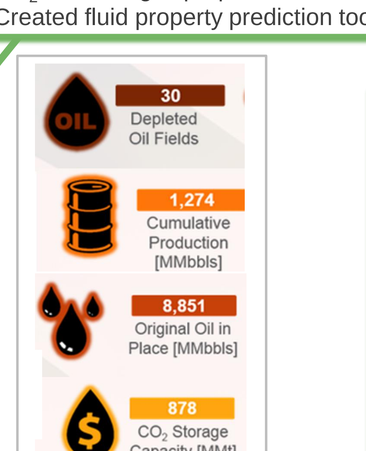
- Evaluated empirical correlations for CO_2-oil-brine-gas properties
- Created fluid property prediction toolbox

CO_2-Oil viscosity ratio correlation calculation versus experimental values



[3] Geologic Modeling and Storage Capacity Estimation

- Assessed available geologic data and rock properties
- Estimated CO_2 storage capacity in depleted oilfields
- Built geologic models for reservoir simulation



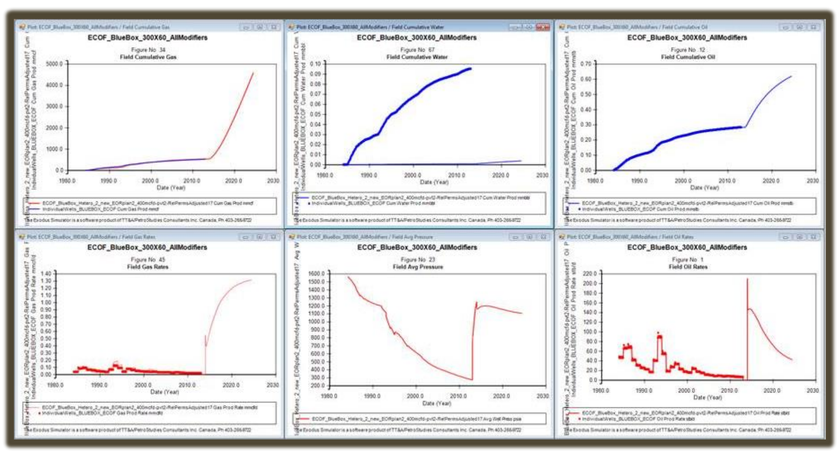
Inputs:		
Shadding Indicates Needed Input		
Input Bubble Point Property		
Select Known Bubble Point Property :	Pressure	
Pressure, pB	2017.0	psia
Additional Reservoir Properties		
Oil gravity, γ_{API}	43.6	API
Gas gravity, γ_g	0.76	-
Reservoir Temperature, T	106	°F
Single Point Pressure of Interest		
Evaluation at right		
Pressure, p	1250	psia
Pressure Range of Interest		
See next sheets for tables and plots		
Maximum Pressure	2894	psia
Min Pressure	15	psia
Brine-Gas Calculations		
Calculate Brine-Gas Properties?	Yes	
If Yes, Salinity =	1.2	Weight % Solids
CO_2 Calculations		
Calculate Pure CO_2, CO_2-Oil and CO_2-Brine Properties?	Yes	
*Pure CO2 properties only available for 100psia ≤ p ≤ 3600psia and 0°F ≤ T ≤ 350°F		
*CO2-Oil and CO_2-Brine Calculations assume dead oil		
If Yes, Avg. Oil Molecular Weight (MW) =	220	lb/lbmol
If Yes, Salinity =	1.5	Weight % Solids

Outputs at Single Point of Pressure:			
At:	Pressure, p	1250	psia
	Bubble Point Pressure, p_b	2017	psia
	Solution Gas Oil Ratio at Bubble Pt, R_{sob}	774	SCF/BBL
Oil-Gas	Formation Volume Factor, B_o	1.21	RB/STB
	Solution Gas Oil Ratio, R_{so}	439.2	SCF/BBL
	Viscosity, μ_o	0.466	cP
	Compressibility, c_o	3.41E-04	1/psi
	Density, ρ_o	45.3	lbm/ft3
Gas	Formation Volume Factor, B_g	0.0103	ft3/SCF
	deviation factor, Z	0.802	-
	Viscosity, μ_g	0.014	cP
	Compressibility, c_g	9.57E-04	1/psi
	Density, ρ_g	5.64	lbm/ft3
Brine-Gas	Formation Volume Factor, B_w	1.0097	RB/STB
	Solution Gas Water Ratio, R_{sw}	15.31	SCF/BBL
	Viscosity, μ_w	0.64	cP
	Compressibility, c_w	5.04E-05	1/psi
	Density, ρ_w	62.29	lbm/ft3
Pure CO_2	Formation Volume Factor, B_{CO2}	0.01	ft3/SCF
	Viscosity, μ_{CO2}	0.03	cp
	Density, ρ_{CO2}	21.88	lbm/ft3
	Compressibility Factor, Z_{CO2}	0.43	-
CO_2 - Oil	CO_2-Oil Solubility, Sol	0.60	mole fraction
	Solution CO2 Oil Ratio, R_{so-CO2}	723.8	SCF/STB
	CO_2-Oil Swelling, SF	1.29	-
	CO_2-Oil Viscosity Ratio, μ_{oCO2}/μ_{ob}	0.24	-
CO_2 -Brine	Solution CO_2-Water Ratio, R_{sw-CO2}	142.3	SCF/STB

Display of Toolbox Inputs and Outputs at a single point pressure of interest entered by the user.

[4] Reservoir Modeling and Simulation

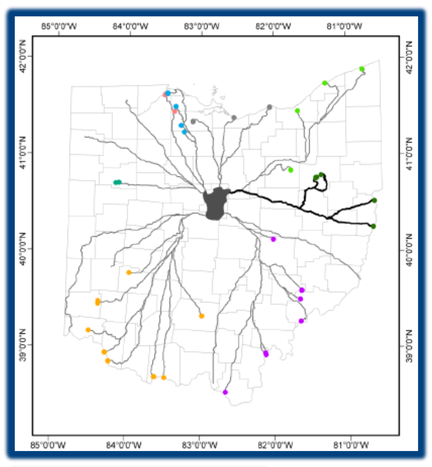
- Assessed simulation tools for CO_2 storage and CCUS
- Executed simulations for CO_2-Brine-Oil interaction within modeled oilfields



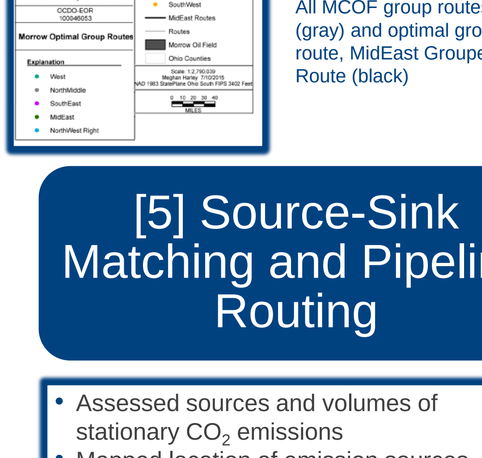
ECOF CO_2 Modeling Simulation Dashboard

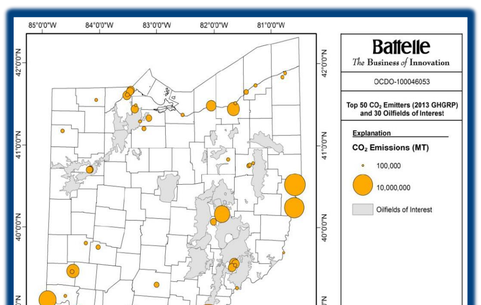
[5] Source-Sink Matching and Pipeline Routing

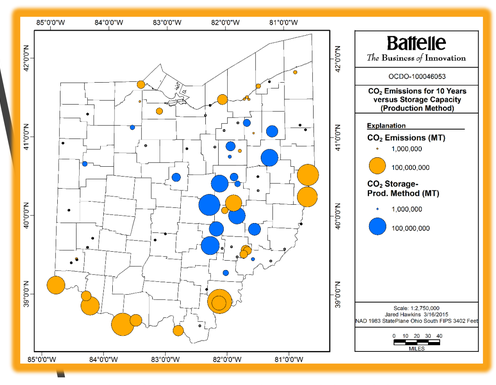
- Assessed sources and volumes of stationary CO_2 emissions
- Mapped location of emission sources vis-a-vis depleted oilfields sinks
- Developed a pipeline routing methodology



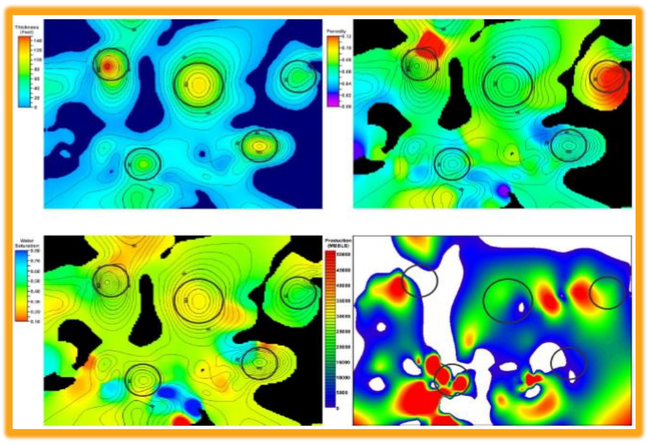
All MCOF group routes (gray) and optimal group route, MidEast Grouped Route (black)



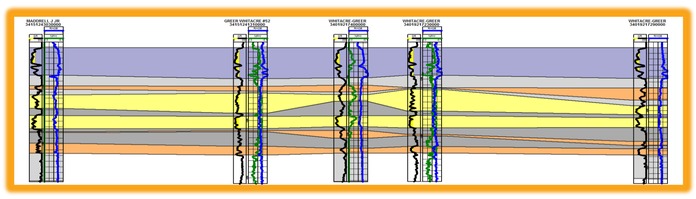




Map showing relative volume of the of the CO_2 emissions for the 45 Ohio power plants reporting in the 2013 GHGRP along with the storage capacities of the 30 fields of interest



Isopach (A), average porosity (B), average water saturation (C), and cumulative production (D) maps for Copper Ridge Dolomite Reservoir using the moving average method.



A cross section through multiple wells of ECOF zones and layers. Yellow/orange zones represent sands and gray zones represent maximum flood surfaces.

CCUS in Ohio's Depleted Oilfields