Examining the Climate-Energy Nexus for CO₂-Enhanced Oil Recovery

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• Introduction
  • Climate-Energy Nexus
  • Motivation
  • CO₂-EOR Supply Chain

• Research Objectives
  • Scope, Goal, and Sustainability Metrics

• Results
  • Scenario Analysis
  • Tradeoffs in the Climate-Energy Nexus

• Summary
Introduction
Climate-Energy Nexus

• Climate-Energy Nexus
  • Intersection of climate and energy objectives

• Climate-Energy issues are multifaceted and highly interconnected
  • Single metric analysis fails to capture tradeoffs in the Climate-Energy Nexus

Human Health Impacts
Loss of Natural Capital

Air and Water Pollution
Global Climate Change

Energy Security
Economic Growth
Quality of Life

Human & Ecological Impacts
Climate Effects
Introduction

Motivation

• **Benefits of CO$_2$-EOR**
  • Tertiary oil production from existing oil-fields
  •Injecting captured CO$_2$ from power plants allows for concurrent abatement of anthropogenic CO$_2$

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1Cooney et al. Environmental Science and Technology 2015
Source: https://energy.gov/fe/science-innovation/oil-gas-research/enhanced-oil-recovery
Introduction

CO₂-EOR Supply Chain

Natural Gas Extraction → Natural Gas Transport

Coal Extraction → Coal Transport

Biomass Cultivation & Harvesting → Biomass Transport

Power Plant

Natural Dome

CO₂ Pipeline Transport

EOR Crude Extraction → EOR Crude Transport

Petroleum Refining

Hydrocarbon Transport → Product Combustion

Legend

- Feedstock
- Feedstock Transport
- CO₂ Source
- CO₂ Pipeline
- EOR Crude Extraction
- EOR Crude Transport
- Petroleum Refining
- Hydrocarbon Transport
- Product Combustion

Flow

Feedstock

Fuel

Technology
Research Objectives
Scope, Goal, and Sustainability Metrics

• Scope & Goal
  • Scope and Goal: Comparative LCA of hydrocarbon fuels produced via CO$_2$-EOR
  • Boundary: Cradle-to-Grave
  • Functional Unit: 1 MJ of Hydrocarbon Fuel
    • Gasoline
    • Diesel
    • Aviation Fuel

• Sustainability Metrics
  • Life Cycle Greenhouse Gas (GHG) Emissions
  • Primary Energy Consumption
Life Cycle GHG Analysis

Life Cycle GHG Emissions by Supply Chain Stage

- Life Cycle GHG Emissions (gCO₂e / MJ-Diesel)

- Error bars represent the 10th and 90th percentiles obtained via varying EOR crude recovery ratio


*Error bars represent the 10th and 90th percentiles obtained via varying EOR crude recovery ratio*
Life Cycle Energy Analysis
Primary Energy Use by Supply Chain Stage

*Error bars represent the 10th and 90th percentiles obtained via varying EOR crude recovery ratio

Life Cycle Energy Analysis

Box and Whisker Plots: Net Primary Energy Use

Net Primary Energy Use (MJ Primary Energy / MJ-Diesel)

-0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8

Natural Dome IGCC SCPC
IL #6 PRB IL #6, 50% SG IL #6 PRB IL #6, 50% SRWC IL #6 PRB IL #6, 50% SG PRB, 50% SG
IL #6, 50% SG PRB, 50% SRWC PRB, 50% SG PRB, 50% SG
IL #6, 50% SRWC IL #6, 50% SG PRB, 50% SRWC PRB, 50% SG
IL #6, 50% SRWC IL #6, 50% SG PRB, 50% SRWC PRB, 50% SG
Natural Gas

90th Percentile
75th Percentile
50th Percentile
25th Percentile
10th Percentile
• **Sustainability Implications**
  - Increasing biomass feed rate
    - Lowers life cycle GHG emissions
    - Lowers Energy Return on Investment
  - Near carbon-neutral fuel is obtainable if cofiring rate exceeds 75%
    - Under these conditions, system is not energetically viable
    - Similar environmental profile to hydrocarbon biofuels\(^1\)

\(^1\)Zaimis et al. *Energy and Environmental Science* 2017
Climate-Energy Nexus
Tomado Plots: USCPC, Co-firing PRB & 50% SG

Displacement Credit (Electricity)
Crude Recovery Ratio
Biomass Feed Fraction
CO₂ Capture (%)
Coal Mine Methane
EOR Formation Leakage (%)

Energy Return on Investment
(MJ Diesel / MJ Primary Energy)

Life Cycle GHG Emissions
(gCO₂e / MJ-Diesel)

USCPC: Ultra-SuperCritical Pulverized Coal; PRB: Powder River Basin; SG: Switchgrass
Summary

Main Findings

• Climate-Energy Nexus
  • Implicit tradeoff between life cycle energy use and GHG abatement across CO₂-EOR scenarios
  • Results are sensitive to the electricity displacement credit and environmental profile of captured CO₂
    • Coupling of Power Generation Supply Chain with EOR
    • Implications for grid de-carbonization

• Tradeoffs
  • Increasing the crude recovery ratio results in lower primary energy use but higher life cycle GHG emissions
  • Co-firing biomass reduces life cycle GHG emissions but increases primary energy use
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