Matching Environmental and Economic Performance of CCUS systems: an approach to a decision-making methodology for sustainable development

Focus in CCUS Power Plant for CO2-EOR

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Content:

– Brief overview
– System Characterization
  • CCUS in Electric Power generation
  • CO2-EOR
  • Business Models
– Decision Making (methodological Approach)
  • Common practices
  • Integrated Framework
– Methodological proposal
– Conclusions
Main Objectives:

- Identify and frame critical aspects of the CCUS Electric Power for CO2- EOR.
- A quick review of the integrated assessment methodology for decision-making in complex systems
- Develop a first approach to a broad decision-making framework for CCUS Electric Power for CO2- EOR systems
Brief overview

- Climate Change is real, it is occurring NOW!
- Anthropogenic prominent role.
- Paris Agreement
- The Goal was set (UNFCCC & IPCC): -2°C
BROWN TO GREEN: THE G20 TRANSITION TO A LOW-CARBON ECONOMY | 2017 by Climate Transparency

CLIMATE POLICY PERFORMANCE

COMPATIBILITY OF CLIMATE TARGETS WITH A 2°C SCENARIO

Source: CAT, 2017
Brief overview

• Means Energy de-carbonization:
  – Transportation electrification
  – Phase-out large number of coal-fired Power Plants by 2030
  – Significantly share growth of renewables (+70%)
  – Carbon Capture, Utilization and Sequestration (CCUS)
  – Side demand energy efficiency.

• Simultaneous implementation of these technologies
• CCUS should be a priority [IPCC, 2013]
• All the Global Climate Change models necessarily include CCUS
Brief overview

What is CCUS?

From: CCS, IPCC, 2005
System Characterization
Electric Power Sector

• Strategical High Value Sector
• High Capital Intensive
• Integrated and interconnected system
• Major changes in markets pressure the system to its operable limits
• Planning is becoming increasingly complex
Figure from: DOE - Quadrennial Energy Review
System Characterization

CCUS in Electric Power Sector

- CCUS is a key factor in least-cost transitions to a low-carbon electricity system in 2050
- The scale of Power Plants force thinking their integration to a CCUS system
- Capture technology is expensive and energy intense
- Energy penalties reduce competitiveness
- Low energy prices, low demand growth, more renewals share and others limits investments on CO2 capture
- Power Sector CO2 supply require long term demand
System Characterization

CO2-EOR

- Promissory CCUS technology
- Mature process. Tertiary Recovery
- Additional 4-15% of OIP (Mezler, 2012)

CO2 – Enhanced Oil Recovery

Improves Balance of Trade
$3.5 trillion over 60 years

Promotes Energy Security
30-40% reduction in imported oil*

Increases Domestic Activity
$10 trillion over 30 years*

Creates Jobs
2.5 million jobs over 30 years*

- CO2-EOR potential requires expanded access to CO2 sources
- Historically Oil Optimization
- Next Generation Technologies improves oil production and CO2 storage capacity
Business Models

- CO2-EOR: activity dominated by independents
- Predominant CO2 source: Gas Processers and Fertilizer plants
- Operators look for Upstream integration building pipelines
- Two large independent companies control half of total CO2-EOR production and expanding
- Petranova, CCUS Coal firered Power Plant. New player build a downstream integration model.
MAIN DIFFICULTIES INTEGRATING THIS CCUS SYSTEM 1/2

- Alignment of the industries sectors that integrate the CCUS system (economic performance)
- Strategic sectors have high regulatory intervention that has to be harmonized
- Product optimization and emission intensity
- CO2 emissions: externality vs commodity
MAIN DIFFICULTIES INTEGRATING THIS CCUS SYSTEM 2/2

- Assignment of the environmental responsibilities (the environmental performance - LCA)
- Different methodological approaches to emissions accounting and allocation processes.
- DOE-NETL recommends system expansion with displacement (Skone et al., 2016)
  - which product or process of the systems (up, middle, or downstream),
  - under which criteria (cost or emission efficiency, marginal or average), and
  - All or part of it?
Decision Making (methodological Approach)

- **Common practices**
  - two different methods are commonly known, not integrated for environmental and economic evaluation (LCA and LCC)
  - Different purpose different method and scope
  - From LCA-LCC to ELCC

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Decision Making (methodological Approach)

- Integrated Framework
  - The CCUS system for EOR integrates productive sectors of significant national relevance in terms of economy, security and environment
  - System optimization and appropriate cost-benefit assessment necessarily goes through an overview both cross-sector and public-private trade-off
  - Integrated Analysis for: Feed Stock, PowerPlant, CO2-EOR site, Refinery and Product combustion
Decision Making (methodological Approach)

- **System Assessment**
  - Risk and Uncertainty Technology
  - Planning and Projection
    - Technology Readiness Levels
    - Technology Roadmapping
    - Expert Elicitation
    - Experience Curve Analysis
  
- Analysis Tools and Metrics
  - Life-Cycle Assessment Overview
    - Greenhouse Gas Emissions
    - Other Emissions
    - Water Use
    - Land Use
  - Materials and Criticality
  - Reliability and Resilience
  - Other Metrics

- **System Assessment (cont..)**
  - Economics metrics
    - Levelized Cost of Energy
    - Life-Cycle Cost -LCC- (e.g. PTLaser, TCAce)
    - Environmental Life-Cycle Cost -ELCC-

- Evaluation Tools
  - Options Space Analysis
  - Wedge Analysis
  - Integrated Assessment Models
  - Science of Human Decision Making
  - Real Options Valuation
General Methodological Proposal

- **System Assessment**
  - Risk and Uncertainty Technology
    - CO2-EOR site selection - Characterization and technology implementation
    - CCUS Power Plant
    - Vehicle efficiency
  - Planning and Projection
    - Technology Readiness Levels
    - Technology Roadmapping
    - Expert Elicitation
    - Experience Curve Analysis

- **System Assessment (cont..)**
  - Analysis Tools and Metrics
    - Life-Cycle Assessment
      - GHG
      - Water Use
      - Land Use
    - Economics metrics
      - Levelized Cost of Energy
      - LCC (e.g. PTLaser, TCAce)
      - ELCC
  - Evaluation Tools
    - Integrated Assessment Models
    - Real Options Valuation

Key aspects of this proposal would be modeling the operation and investments of the Grid (e.g. ERCOT) system by minimizing the cost to meet the emission reduction goals.
Conclusion

• CCUS in Power Plants for CO-EOR is a very complex cross-sector system that require be develop at the minimum economic and environmental cost

• The real value of CCUS can only be determined by an integrated analysis of economic and ecological performance

• The integrated assessment models require greater diffusion and validation that allows standardization and implementation in different levels of analysis. In particular for the making of private decisions

• Methodological proposal must be reviewed and refined in order to improve the decision making in the CCUS system
Questions?
It’s a Complex Problem

LCA for CO$_2$-EOR have many pathways, products and sub-products

Cradle-Grave Boundary

Jaramillo et al., 2013, *Comparative LCI GHG emission in EOR Operations from different sources*
It’s a Complex Problem

LCA for CO$_2$-EOR have many path ways, products and sub products

Gate-Gate Boundary

Jarrel, P.; et. all.(2002), *Practical aspects of CO2 flooding*
My contribution:

Central Objective: Create model to analyze the relation between energy consumption, oil production, CO2 injection, GHG emissions and sequestration oriented to achieve the NCNO classification for CO2-EOR Operations and energy efficiency recommendations.

Specific objective:

- Review the boundaries criteria
- Homogenize the functional units
- Clearly understand the CO2-EOR surface operations/emissions/energy efficiency
- Collaborate with other phases of the project
- Present advances of the model developed
- Help developing strategies that are conducive to achieving a NCNO classification.

Our Efforts

- Reviewed, process, classified and referred in the reports to DOE-NTEL large number of studies (60+)
- Selected the most consistent and commonly referred works
- Conversions and calculations
- Developed some schematics with all significant components for EOR and established the mass and/or energy flow between them
- Sought without much success a detailed real list of surface equipment and its operating conditions
System boundaries of previous studies

- Extraction, processing, fossil fuel transport
- Power Plant CO2 capture
- Natural CO2 reservoir
- CO2 transport to field
- CO2-EOR operations
- Geological carbon sequestration
- Construction of CO2-EOR facilities
- Decommissioning of CO2-EOR facilities
- Crude oil transport
- Petroleum refining
- Product transport
- Product combustion/usage

*Only combustion of gasoline vehicle
*Total combustion of products, medium oil
*Only average car gasoline combustion

Aycaguer et al. 2001, 40 years
Suebsiri et al. 2006, 25 years
Khoo and Tan 2006, 40 years
Jaramillo et al. 2009, 8-21 years
DOE-NETL 2009 years/cases: West Texas-30, California-24 & Mississippi-21
FOX, 1 year (2007)
Hertwich et al. 2008, 30 years
Cooney et al. 2015, 25 years
Summary

• Goings-on:
  ✓ Selected the system boundaries relevant to NCNO classification
  ✓ Identification of critical CO\textsubscript{2} emission components within the EOR site
  ✓ Homogenize the functional units to determinate the parameter in our study
  ✓ Looking for Cranfield CO\textsubscript{2}-EOR electricity consumption

• Next Tasks:
  In current Study
  – Build a model for energy consumption of the CO\textsubscript{2}-EOR operation
  – Start scenario analysis
  – identify and analyze significant relationships between energy consumption, oil production, CO2 injection, GHG emissions and sequestration
  – Link results from numerical simulations with energy consumption model
  – Help developing the strategies to achieve the NCNO classification for CO2-EOR Operations and energy efficiency recommendations
Conclusions

• Carbon balance of CO$_2$-EOR is sensitive to the system boundary.

• In a gate-to-gate life cycle analysis, the electricity consumption (purchased and generated) is responsible for almost all the emissions associated with the EOR operation, particularly at the CO$_2$ separation and compression processes.

• Each CO$_2$-EOR facility is unique. Different facility dissing and operational strategies, different energy requirements, performance and GHG emissions

• Electricity consumption data is critical to allow appropriate correlation in mass/energy flows. Not have this would lead to assume generalizations with very high uncertainties.

• Carbon balance is sensitive to CO2 flood performance (CO2 utilization rates).

• A universal methodology for NCNO classification will certainly benefit CO$_2$-EOR operations as there might be an economic impact if potential future regulations provide value to the emissions and/or storage of CO$_2$. 
Future Objectives:

- Abstract that summarizes the conceptualization and first results of our model

- Draft conceptualization of a proposal for research:
  The economic Implications of:
  - CO2-EOR Operations with Classification NCNO (with VN)
  - Corrosion Behaviors in CO₂ Injection Wells (with AI)
  - Complement other studies

Other topics of interest:
- CCS Public acceptance (Japan)
- CO₂ Pricing

- Start with contacts in L.A. Oil Companies managers, decision maker, academic and research institutions oriented to promote BEG research, cooperation and interchange interests. (goin-on)
Selection of system boundaries for NCNO classification: Cradle-to-Grave
Strategic Power Plant Investment Planning under Fuel and Carbon Price Uncertainty by Ansgar Geiger 2010
Original Oil in Place: 596 Billion Barrels*
"Stranded" Oil in Place: 400 Billion Barrels*

Future Challenge
400 Billion Barrels

Cumulative Production
175 Billion Barrels

Proved Reserves
21 Billion Barrels

*Excludes deepwater Gulf of Mexico
Source: Advanced Resources Int'l. (2008)
Idem befor (31)
Integrating Life Cycle Cost Analysis and LCA, InLCA: Selected Papers

Gregory A. Norris
Integrating Life Cycle Cost Analysis and LCA, *InLCA: Selected Papers*
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The table above highlights the key differences between Life Cycle Assessment (LCA) and Life Cycle Cost Analysis (LCC) in terms of purpose, activities, flows considered, units for tracking flows, and time treatment and scope.
CO2 Enhanced Oil Recovery
Institute for 21st Century Energy | U.S. Chamber of Commerce

![Graph showing emissions reductions from 2009 to 2050](image)

**Emissions Reductions (GtCO₂)**

- Nuclear: 8% (8%)
- Power generation efficiency and fuel switching: 3% (1%)
- Renewables: 21% (23%)
- End-use fuel switching: 12% (12%)
- CCS: 14% (17%)
- End-use fuel and electricity efficiency: 42% (39%)

**Note:** Per IEA, the numbers in parentheses are shares in 2050. For example, 14% is the share of CCS in cumulative emission reductions through 2050, and 17% is the share of CCS in emissions reductions in 2050, compared with the 6 °C Scenario. (Source: 2013 IEA Global CCS Roadmap).
New unabated coal is not compatible with keeping global warming below 2°C.
New unabated coal is not compatible with keeping global warming below 2°C

Statement by leading climate and energy scientists

![Diagram showing fossil fuel reserves and 2°C budget]

- Coal: 2,191 GtCO₂
- Gas: 690 GtCO₂
- Oil: 982 GtCO₂

2°C budget: 1050 GtCO₂
EOR Delivers Almost as Much Production as Primary or Secondary Recovery

- Tertiary Recovery (CO₂ EOR) ~17%
- Secondary Recovery (waterfloods) ~18%
- Primary Recovery ~20%
- Remaining Oil