LIFE CYCLE ANALYSIS FOR PRIMARY AND SECONDARY ENHANCED OIL RECOVERY AT THE BELL CREEK FIELD COMPLETED

Plains CO_2 Reduction (PCOR) Partnership Phase III
Task 9 – Milestone M57

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EERC DISCLAIMER

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ACRONYMS AND ABBREVIATIONS

bbl	barrel
CH_4	methane
CO_2	carbon dioxide
DOE	U.S. Department of Energy
EERC	Energy & Environmental Research Center
EOR	enhanced oil recovery
GREET	Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation [model]
kg	kilogram
LCA	life cycle analysis
Mcf/bbl	thousand cubic feet per barrel
Mscf/bbl	thousand standard cubic feet per barrel
NGL	natural gas liquid
OOIP	original oil in place
PCOR	Plains CO_2 Reduction [Partnership]
WAG	water alternating gas

Plains CO_2 Reduction (PCOR) Partnership
Energy & Environmental Research Center (EERC)

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INTRODUCTION

The Energy & Environmental Research Center (EERC) is working with The CETER Group, Inc., through the Plains CO_2 Reduction (PCOR) Partnership Program to determine, using life cycle analysis (LCA) methodology, if oil produced by enhanced oil recovery (EOR) using anthropogenic CO_2 has a smaller CO_2 footprint than conventionally produced oil. An LCA is used to evaluate the environmental impacts associated with each stage of a product's life, from raw material procurement and processing to distribution, use, and disposal or recycling. This type of assessment results in a broad view of environmental issues through the compilation of an inventory of relevant material and energy inputs and releases to the environment, evaluation of potential impacts, and interpretation of the results.

Using information provided by Denbury Resources as well as in-house PCOR Partnership data, two LCAs are being performed: the first of oil produced during primary and secondary recovery (i.e., conventional oil production) and the second for oil produced during EOR activities at the Bell Creek Field in southeastern Montana. The Argonne National Laboratory Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model, known as the GREET model, is being used for both LCAs. Published literature has shown that other LCA methodologies result in cost and/or emission results that are not the same as those obtained using the GREET model. Therefore, a different methodology is being used to repeat the LCAs for the two oil production scenarios to assess any variances in the models' results. The resulting CO_2 footprints will then be compared to highlight any differences between the two scenarios (i.e., conventional oil production vs. EOR). The information will be invaluable to the U.S. Department of Energy (DOE) and Denbury Resources because it offers an objective determination of the CO_2 emission differences between oil produced during EOR and non-EOR activities.

This research project has been performed with two milestones. The first, development of an LCA for conventional (i.e., primary and secondary) oil production, was designated M56 and was completed on March 31, 2016. The second milestone, development of an LCA for the Bell Creek Field in southeastern Montana, is discussed in this report.

GREET MODEL CHALLENGES

Mathematical model development for process simulation consists of three steps: configuration, tuning, and maintenance. Configuration involves selecting and linking process equipment and steps, often accepting default parameters that are incorporated into the process simulator. Tuning involves modifying parameters within and between each process step to more accurately reflect observed performance. Maintenance involves modifying equipment and steps, as well as parameters, to more accurately reflect observed performance or to track changes in the process being modeled. The GREET modeling activities within this reporting period consisted of troubleshooting configuration issues with the LCA model and acquiring more representative parameters (e.g., specific equipment emissions) to tune the process model. Results from the model will be inserted into an Excel spreadsheet that will manipulate those values to provide final emission numbers. The spreadsheet provides capability that is not yet available in the GREET model.

BELL CREEK PROJECT-SPECIFIC DATA COLLECTION

Specific information for the Lost Cabin and Shute Creek gas-processing plants and the Bell Creek Field operation is being collected and incorporated into the LCA framework that was developed in GREET and a spreadsheet model for M56. The integration of Bell Creek-specific information will produce an estimate of the actual CO_2 emission advantages associated with EOR using anthropogenic CO_2 at the Bell Creek Field.

The information and data that have been sought are detailed below.

Lost Cabin/Shute Creek Gas Processing

- Natural gas composition, % by mass (most importantly CO_2 and CH_4 as this input feeds directly into venting and flaring calculations)
- kg CO_2 vented per kg natural gas that is sweetened
- Percent volume CO_2 in the nonhydrocarbon gas stream

Oilfield Operations

- Original oil in place, OOIP (bbl)
- Oil recovery factor (%)
- Net CO_2 utilization (Mcf/bbl over a period of about 30 years)
- Phase-specific data rather than whole-field data
- Incremental oil recovery factor (cumulative %OOIP over a period of roughly 30 years)
- CO_2 recycle rate (cumulative Mscf/bbl over a period of about 30 years)
- Fugitive losses of purchased CO_2 at the surface (% of purchased CO_2)
- Daily CO_2 production rate (recycled)
- Daily CO_2 injection rate (total volumes = recycled + purchased makeup CO_2)
- Oil production rate
- Hydrocarbon gas production rate (produced with the oil and CO_2)
- Approximate hydrocarbon gas composition (methane, ethane, propane, butane, pentane, etc.)
- Brine production rate (produced with the oil and CO_2)
- Water alternating gas (WAG) ratio or brine injection rate (injection into the reservoir, not for waste disposal)

- Brine waste disposal rate
- Land area of the Bell Creek Field (by phase) and number of wells, including well depths
- Water wells used for disposal, if any, with well depths
- Sizes and power ratings of all on-site pumps and compressors and their approximate daily use. These include artificial lift for the wellheads and any compressors that are associated with well operations. Also included are pumps for brine injection or disposal.
- Vent and flare rates, with the proportion of vented gas that is flared
- Natural gas and electrical needs associated with oil, gas, and water separation (or if two-phase, then gas/liquid separation)
- Details about on-site crude oil and brine storage (volumes, venting or flaring from tanks, etc.)
- Details about the gas-processing facility that takes the CO_2/hydrocarbon gas mixture and separates it into natural gas liquids (NGLs), CH_4, and recycled CO_2. Important aspects include natural gas and electrical power needs, as well as any on-site diesel fuel-run equipment.

Oil Refining

- Where is the Bell Creek oil going?
- How is it transported there (e.g., pipeline)? How far must it be transported?
- Information has been found for many of these topics, but some critical data are still missing. These include:
  - Sizes and power ratings of all on-site pumps and compressors and their approximate daily use, including artificial lift for the wellheads, any compressors that are associated with well operations, and pumps for brine injection/disposal.
  - Vent and flare rates, with the proportion of vented gas that is flared
  - Natural gas and electrical needs associated with oil, gas, and water separation (or if two-phase, then gas/liquid separation)
  - Details about on-site crude oil and brine storage (volumes, venting or flaring from tanks, and proportions if both, etc.)
  - Pipeline distances, i.e., where does Bell Creek crude oil go?

Once these data have been collected, they will be input into the spreadsheet and GREET models. When Milestone M57 has been completed, a revised milestone report will be submitted. The data collection delay should have no effect on the timing of the project completion unless the critical data cannot be obtained before the end of August 2016.