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LCA
Life Cycle Analysis
environmental | economic | social



Is net carbon negative crude achievable with CO_2 enhanced oil recovery?

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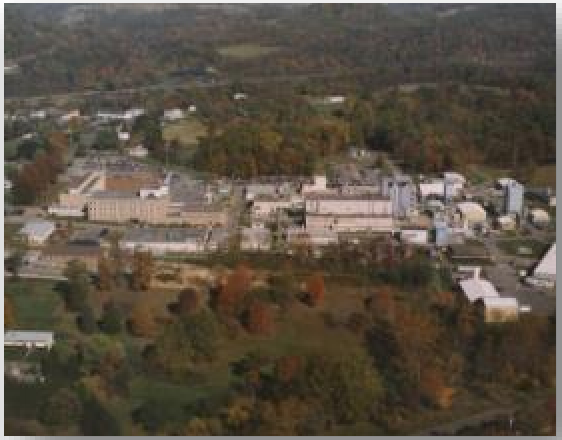
Carbon Capture, Utilization & Storage Conference
June 16, 2016.

National Energy Technology Laboratory

MISSION
Advancing energy options to fuel our economy, strengthen our security, and improve our environment

Oregon

Pennsylvania

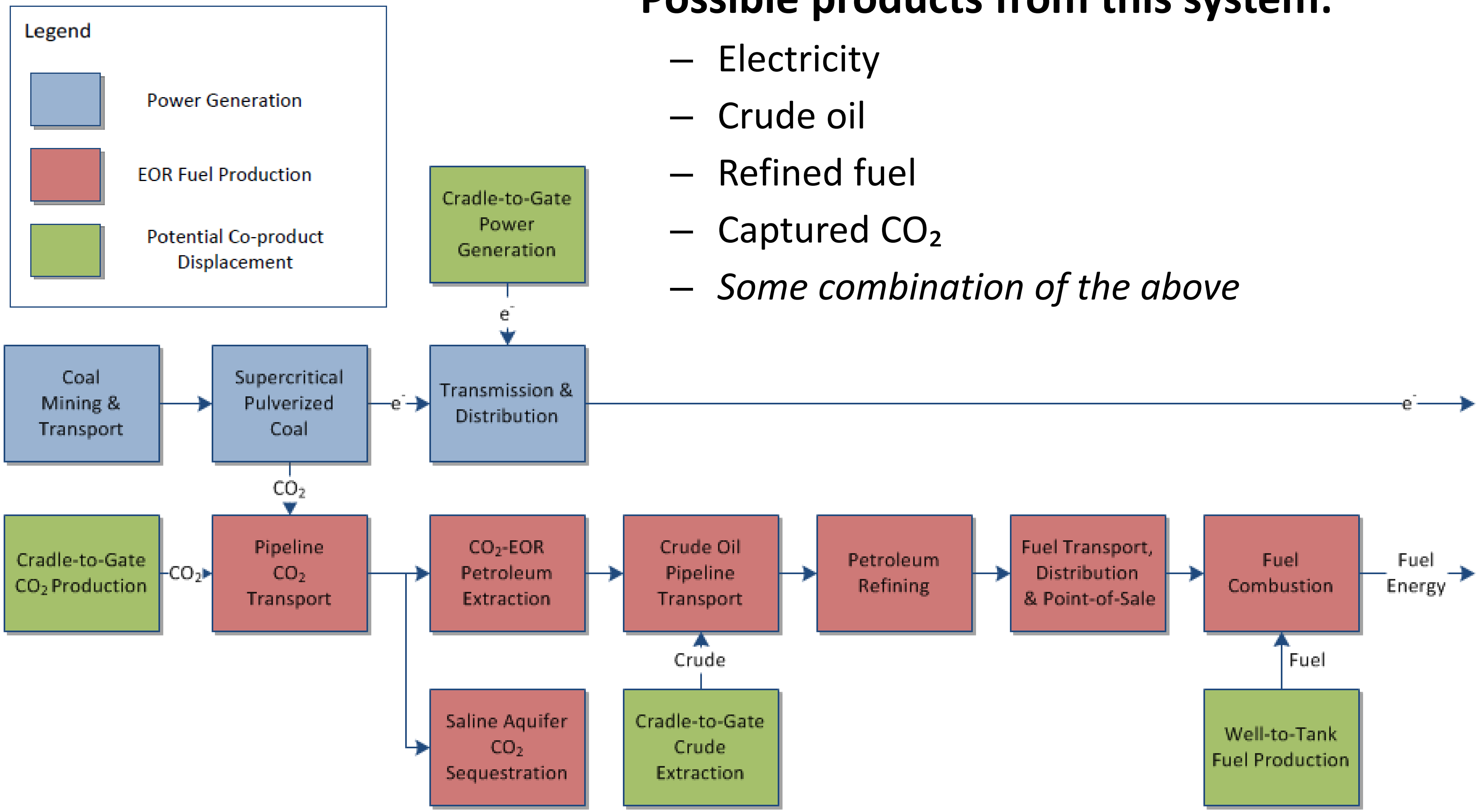


West Virginia

Life Cycle Analysis (LCA)

LCA is a comprehensive form of analysis that evaluates the <u>environmental</u>, <u>economic</u>, and <u>social</u> attributes of energy systems ranging from the extraction of raw materials from the ground to the use of the energy carrier to perform work (commonly referred to as the "life cycle" of a product).

CO_2 Capture, Utilization, and Storage (CCUS) creates a very complex life cycle system to model



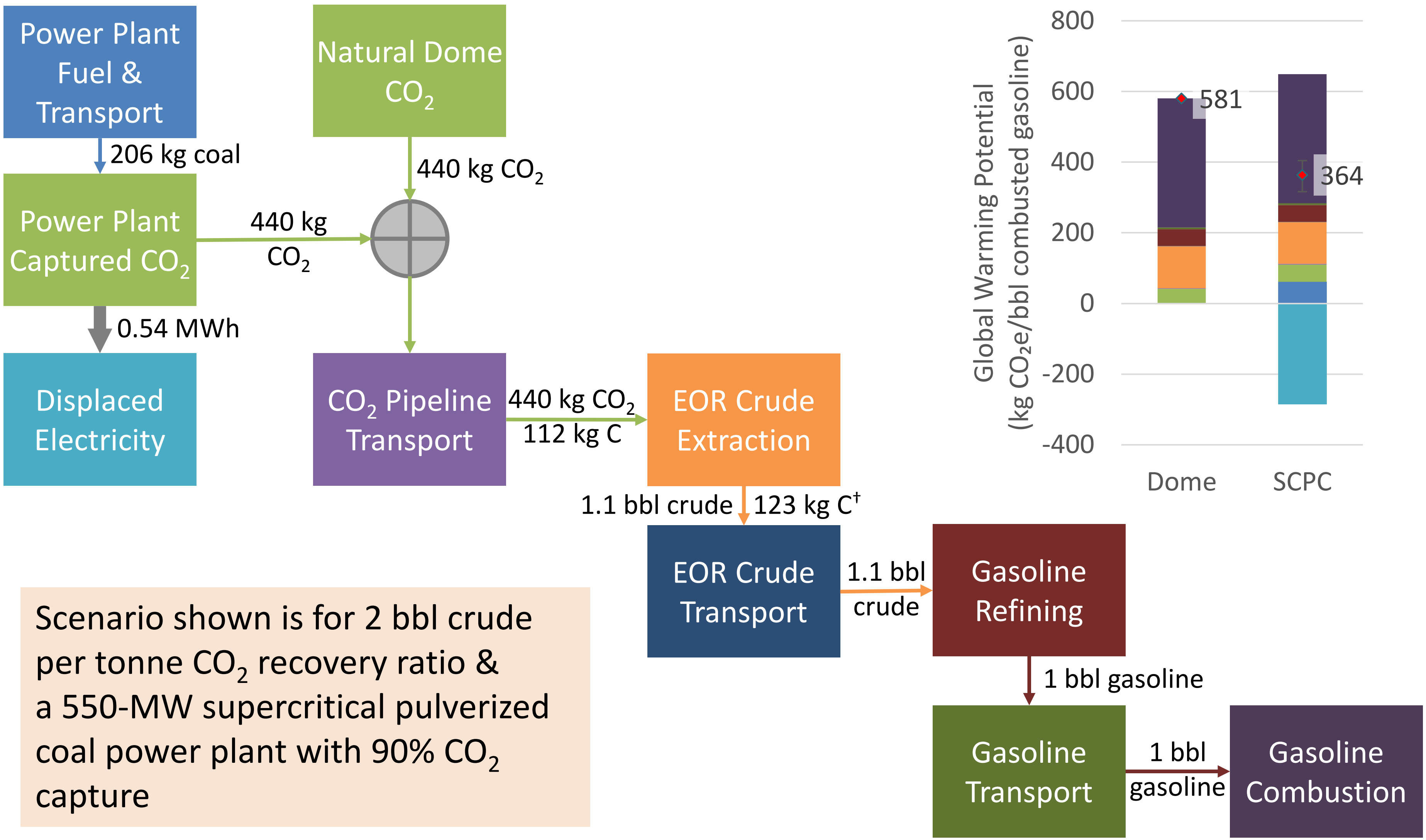
Possible products from this system:

- Electricity
- Crude oil
- Refined fuel
- Captured CO_2
- *Some combination of the above*

LCA of complex systems requires co-product management to apportion burdens

- **The objective of LCA is to assign ownership of environmental burdens to a single function**
- **When more than one product exits the system boundary of an LCA, it is necessary to redefine the system boundaries or apply an assignment that splits life cycle burdens between products**
- **NETL has studied the system (captured fossil power coupled with CO_2-EOR extensively and recommends system expansion with displacement**
  - System expansion alters system boundaries to include all co-products
  - With displacement, the system receives a credit for the GHGs emitted via the conventional product route for co-products
  - This analysis expands the boundaries of the system to include displacement of one of the co-products, leaving us with the desired product (power or fuel)

Life Cycle of Gasoline from CO_2-EOR-Crude



Scenario shown is for 2 bbl crude per tonne CO_2 recovery ratio & a 550-MW supercritical pulverized coal power plant with 90% CO_2 capture

† Lyons, W.C., and Plisga, G.J. (2011). Standard Handbook of Petroleum and Natural Gas Engineering . Gulf Professional Publishing. – Crude content of oil is 84-87 wt%.

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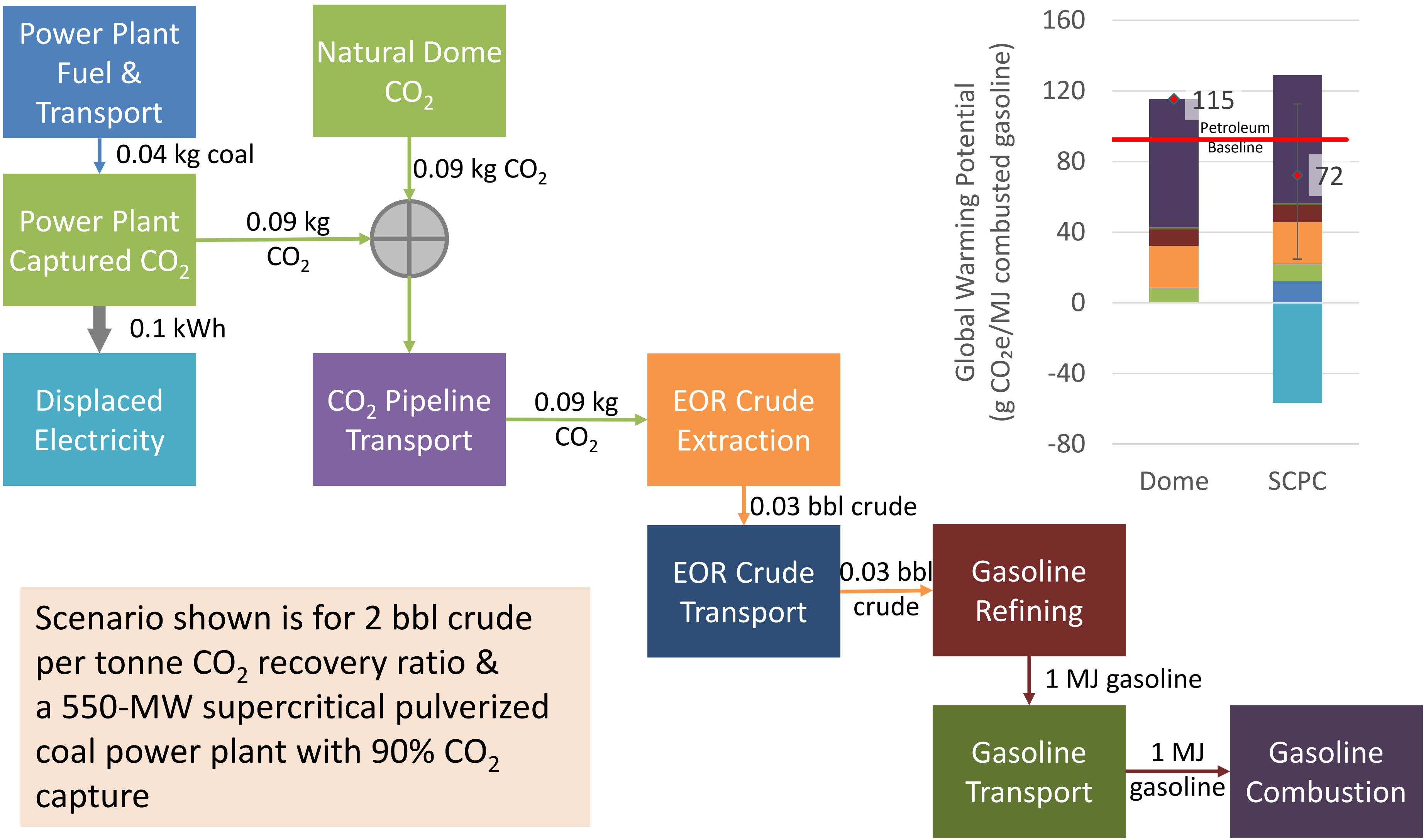

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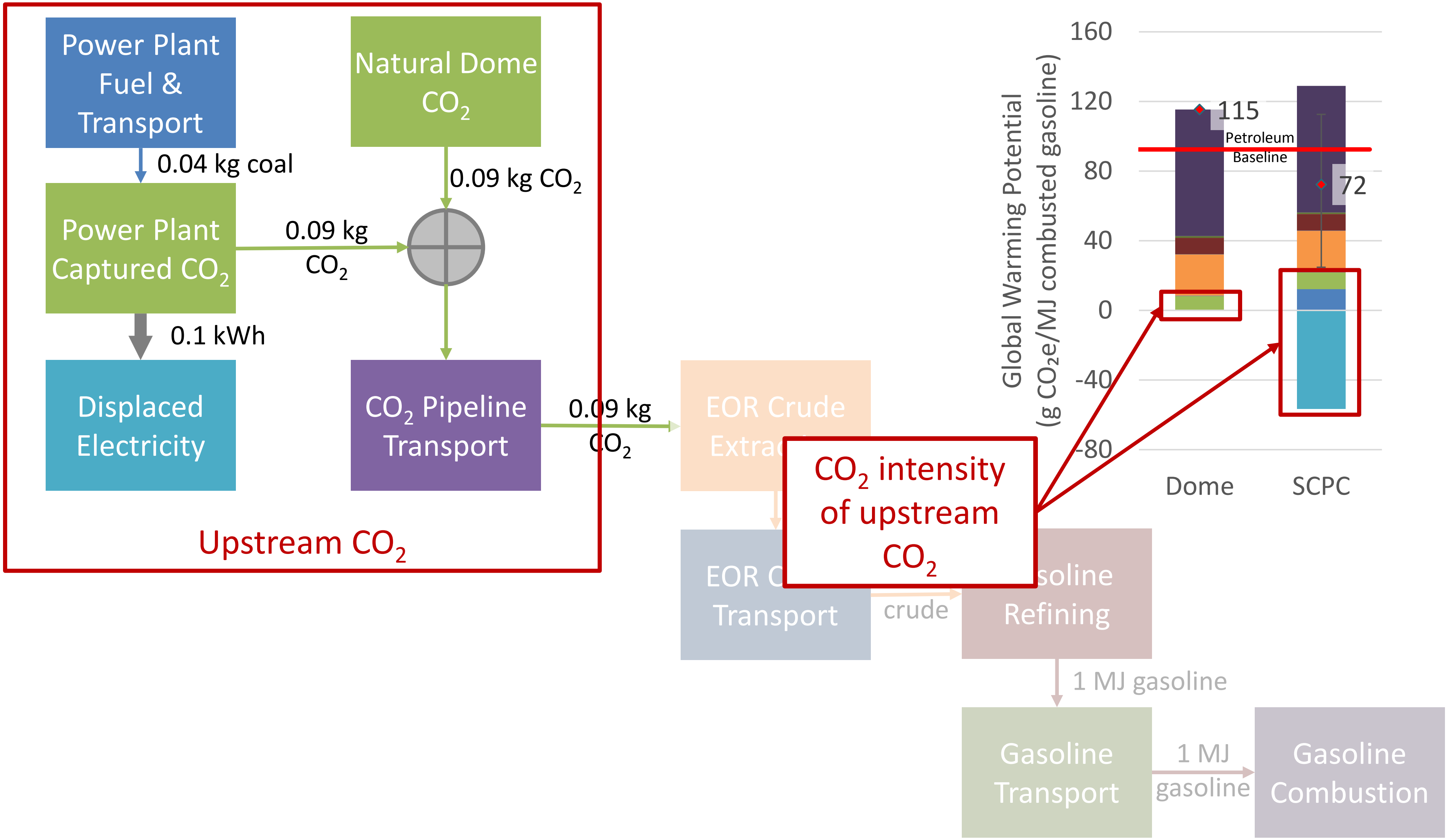
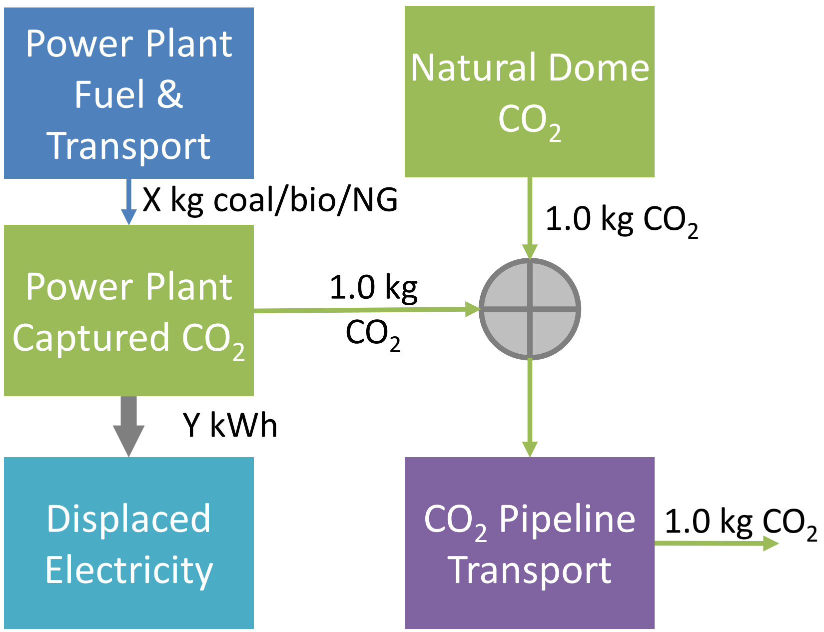
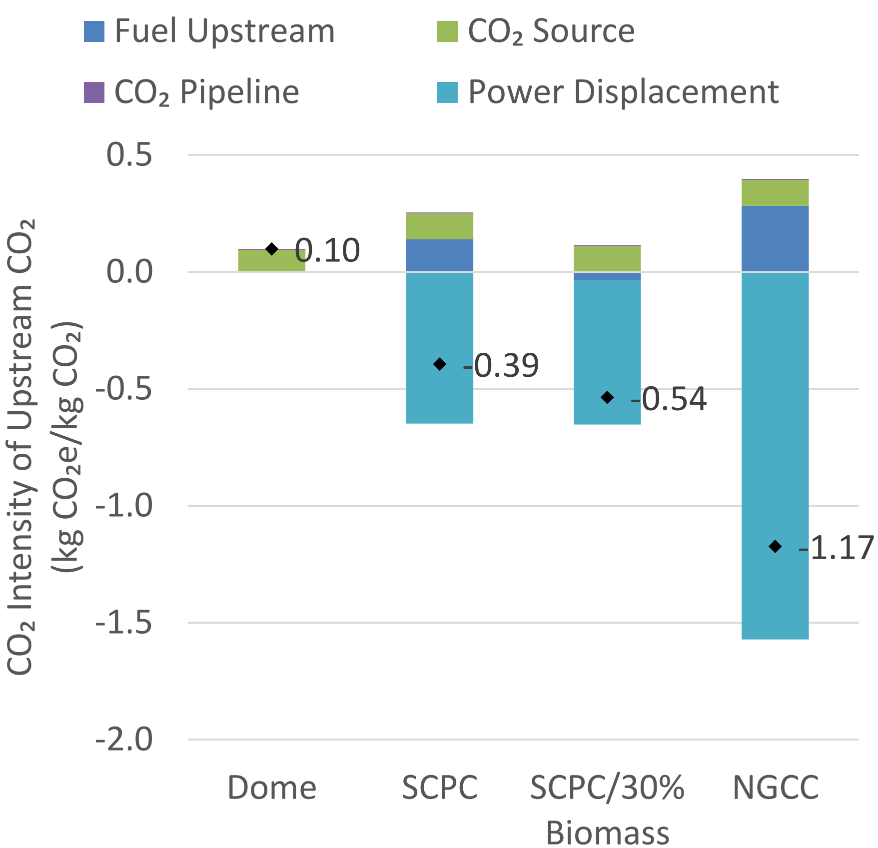


CO_2 Intensity of Upstream CO_2



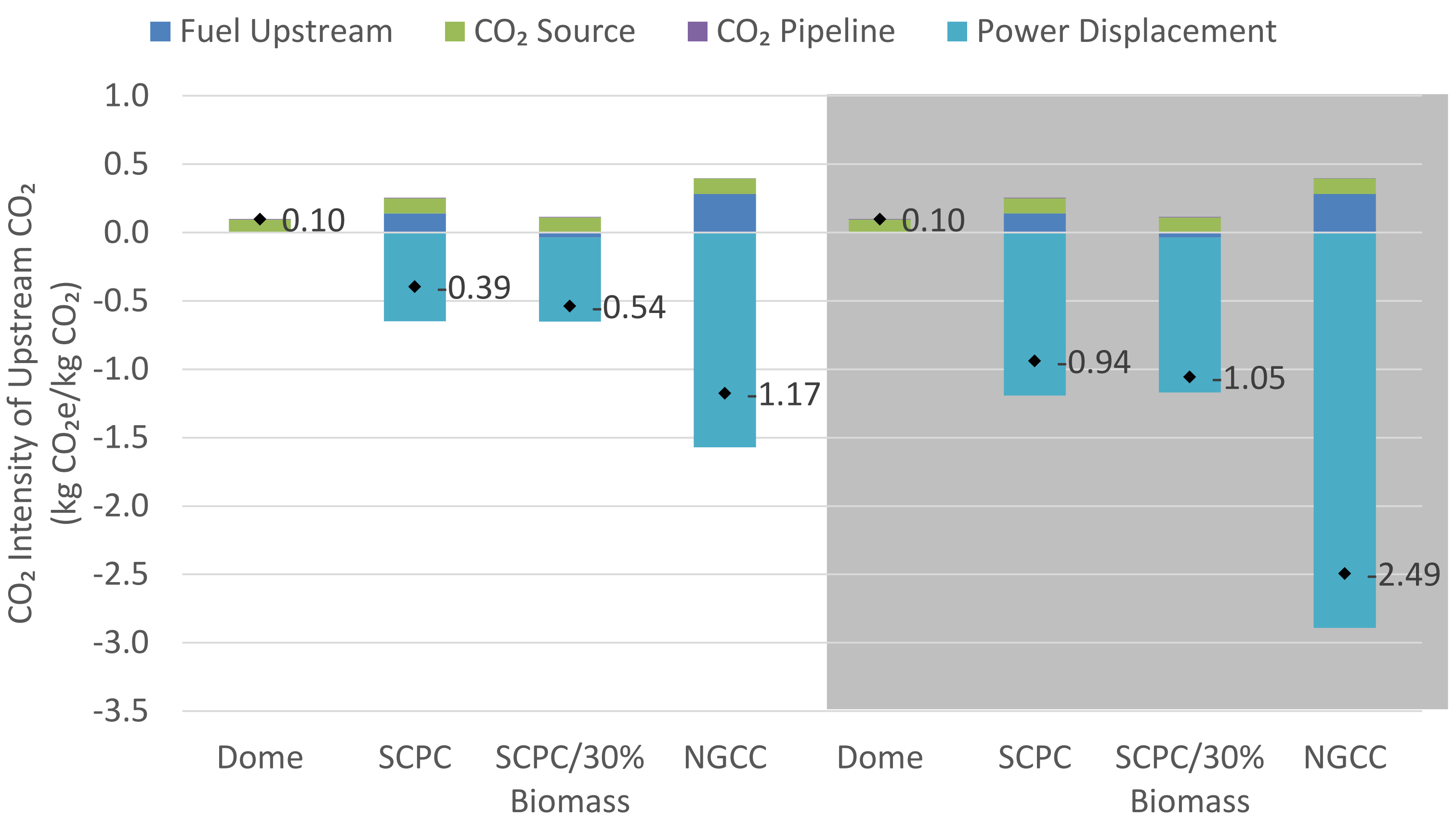
- **Emissions downstream of EOR are static**
- **EOR is indifferent to CO_2 source**
- **CO_2 source choice determines achievable life cycle targets**
- **Options for sourcing CO_2 (modeled)**
  - Natural Dome
  - Supercritical Pulverized Coal (SCPC)
  - Natural Gas Combined Cycle (NGCC)
  - SCPC co-fired biomass and coal
- **Displacement of existing power**
  - 2014 Grid Mix

CO_2 Intensity of Upstream CO_2
Comparison of All Sources



- **Fossil CO_2 is preferred to natural dome**
  - Credit for displacement of existing power
- **Adding biomass reduces upstream fuel component**
  - 30% switchgrass results in net negative upstream fuel GHG emissions
- **NGCC is a less efficient CO_2 generator**
  - For a fixed amount of CO_2, NGCC yields more power and thus receives a larger credit
  - Ratio NGCC:SCPC is 2.4:1

CO_2 Intensity of Upstream CO_2
Grid Displacement Impacts

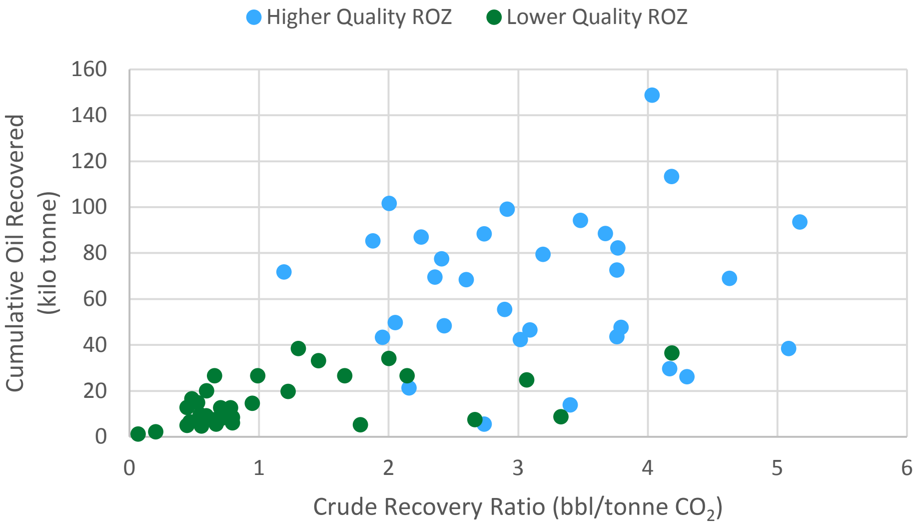


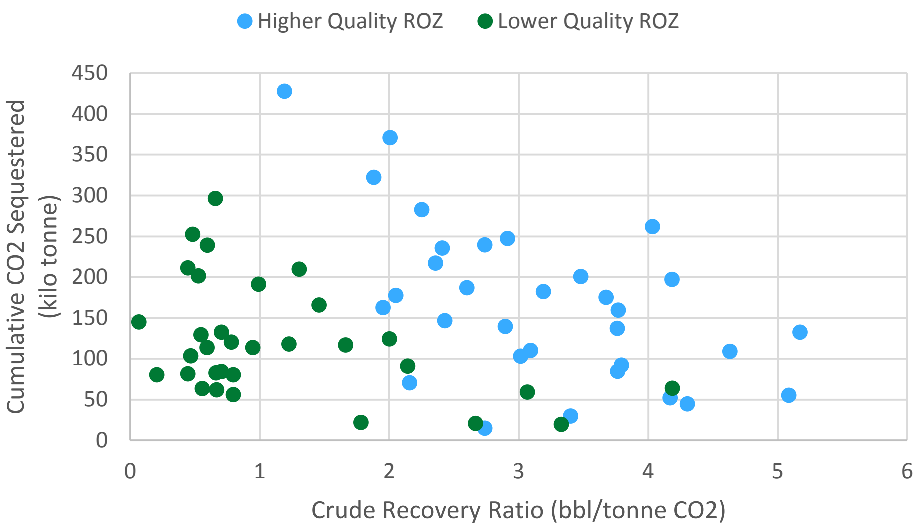
2014 Grid Mix
(566 g CO_2e/kWh)

Fleet Coal
(1,041 g CO_2e/kWh)

CO_2-EOR Performance Data

Crude Recovery Ratio (barrels of crude oil per tonne of CO_2 sequestered)



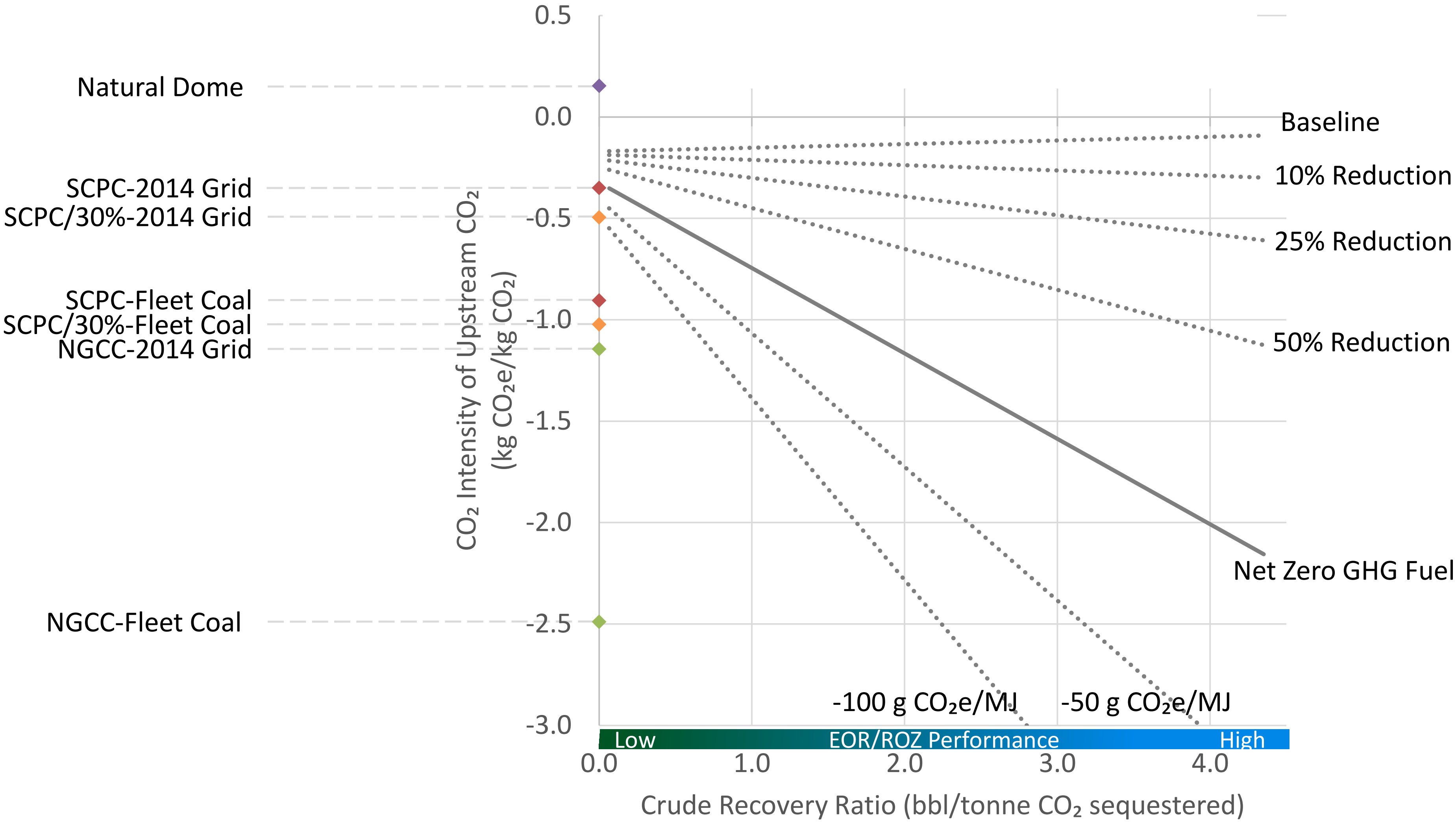


Residual Oil Zone (ROZ) Data Summary:

- Four counties in the Permian Basin of West Texas
- Each county divided into partitions (32 each for low and high quality)
- Crude Recovery Ranges (bbl/tonne CO_2 sequestered):
  - HQ: 1.2 – 5.2 (production wtd. mean 3.2)
  - LQ: 0.07 – 4.2 (production wtd. mean 1.5)

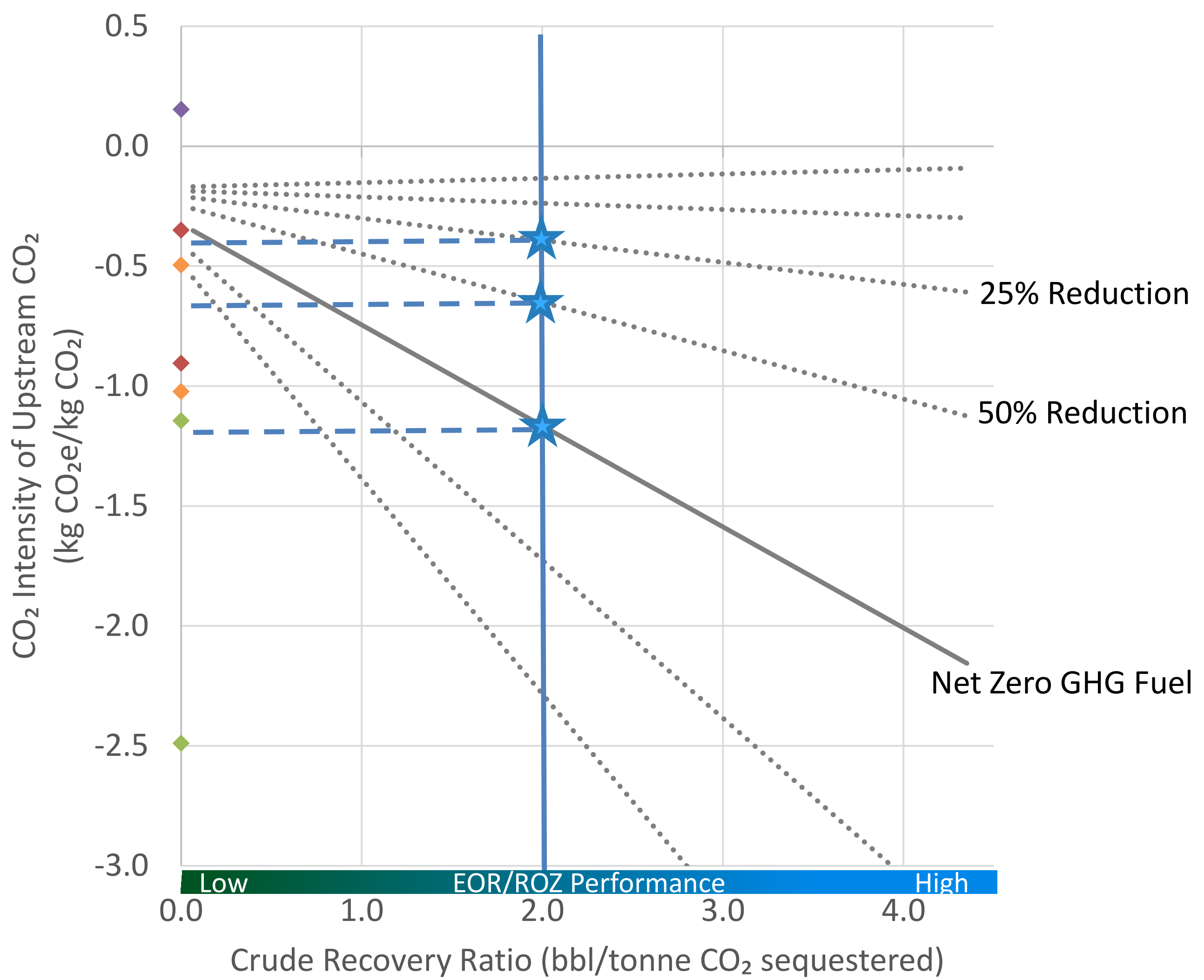
Reference: NETL, 2016; Defining an Overlooked Domestic Oil Resource: A Four-County Appraisal of the San Andres Residual Oil Zone (ROZ) “Fairway” of the Permian Basin, DOE/NETL-2015/1730, U.S. Department of Energy, National Energy Technology Laboratory, Pittsburgh, PA; report prepared by Advance Resources, Inc. *(Draft Report Publication Pending)*

Achievable targets are based on the intersection of CO_2 source technology and crude recovery



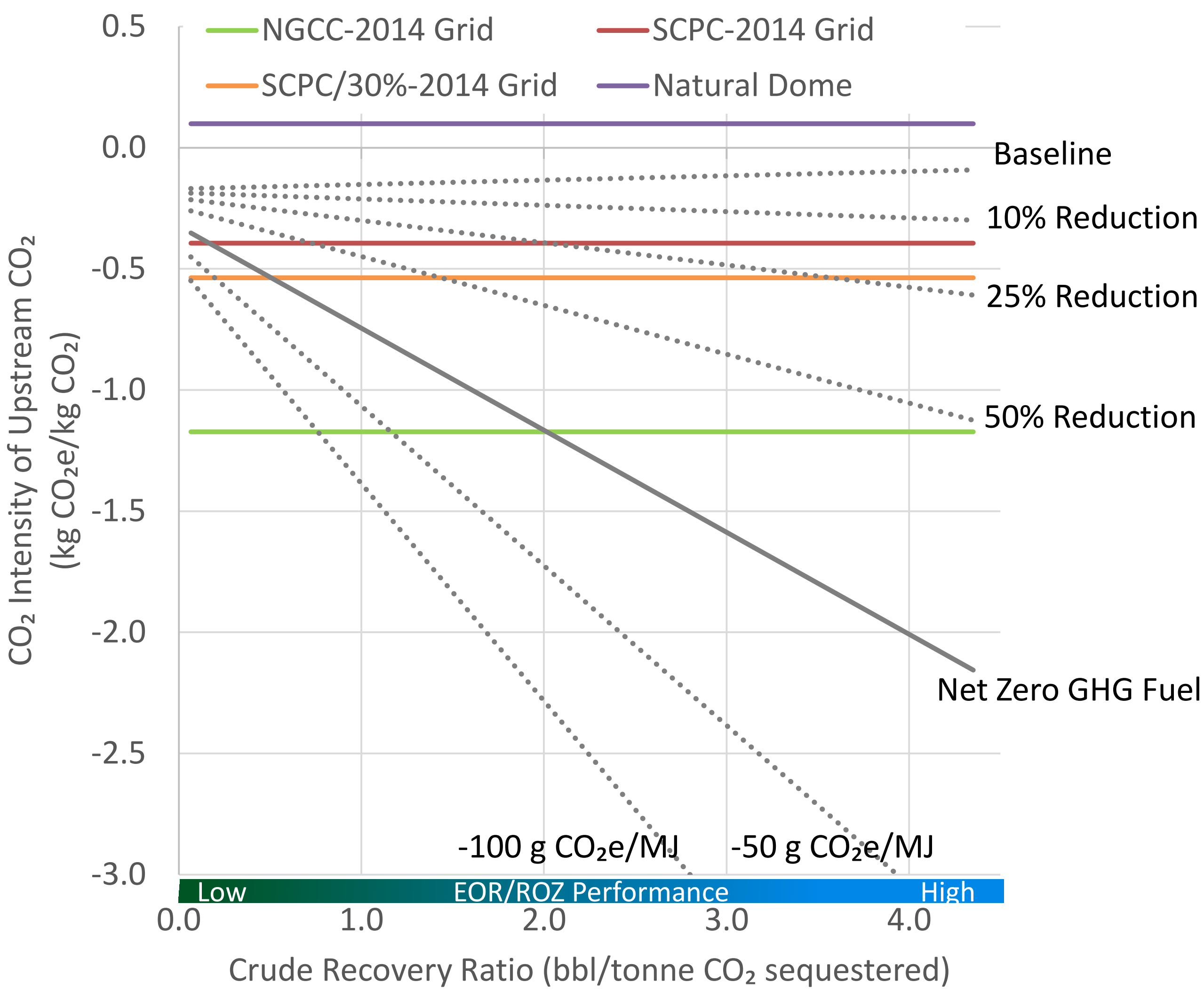
Fixed Crude Recovery Ratio – 2.0 bbl/tonne EOR Operator Perspective

- **For a fixed crude recovery ratio, determine CO_2 intensity of upstream CO_2 required to meet a specific reduction target**
  - Net Zero: -1.2 kg/kg
  - 50% Reduction: -0.6 kg/kg
  - 25% Reduction: -0.4 kg/kg



Achievable targets are based on the intersection of CO_2 source technology and crude recovery

- **The CO_2 intensity of a given source (e.g. NGCC or SCPC) is not a function of the crude recovery ratio**
- **More aggressive target can be achieved as the CO_2 intensity becomes more negative or the crude recovery ratio is reduced**



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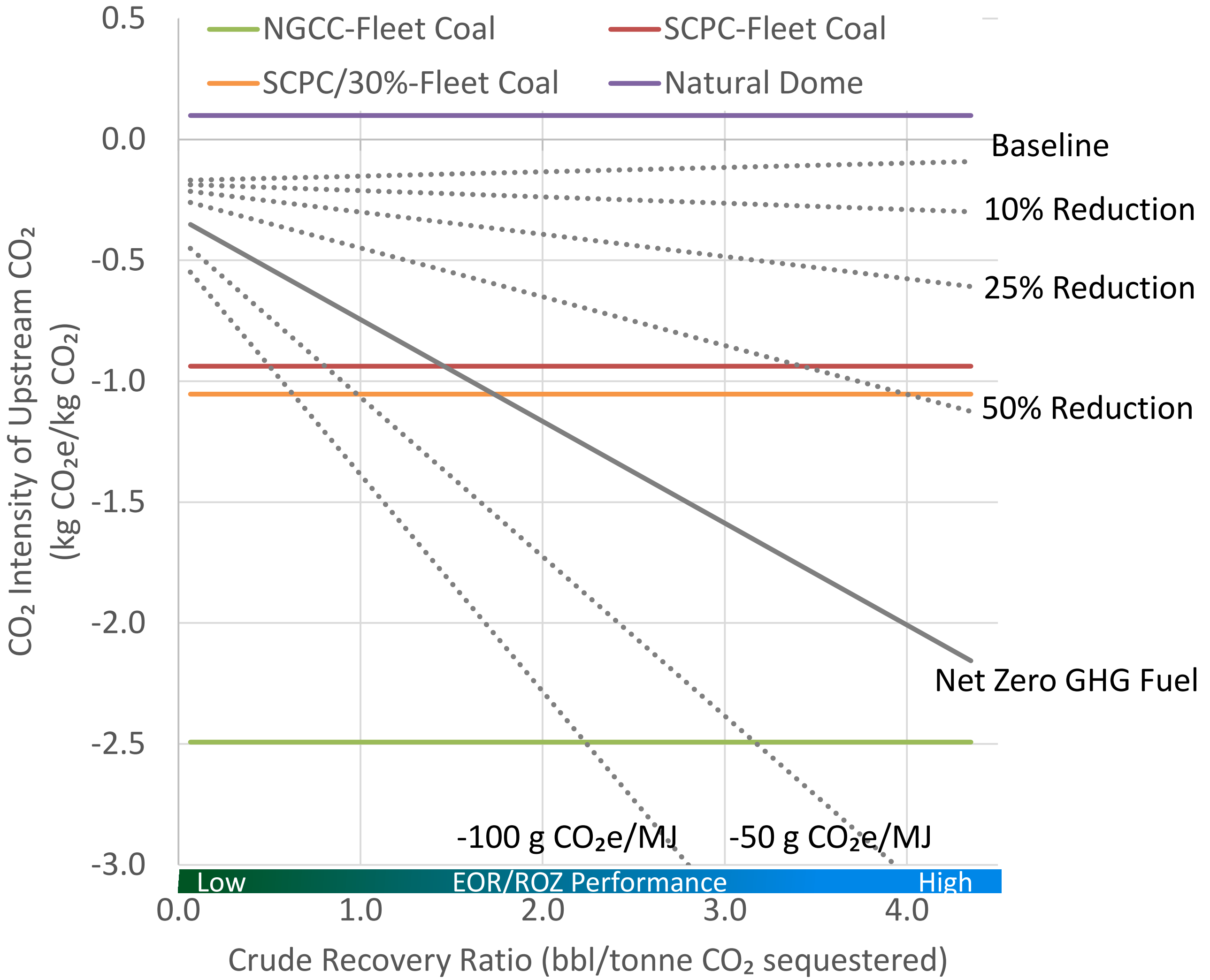
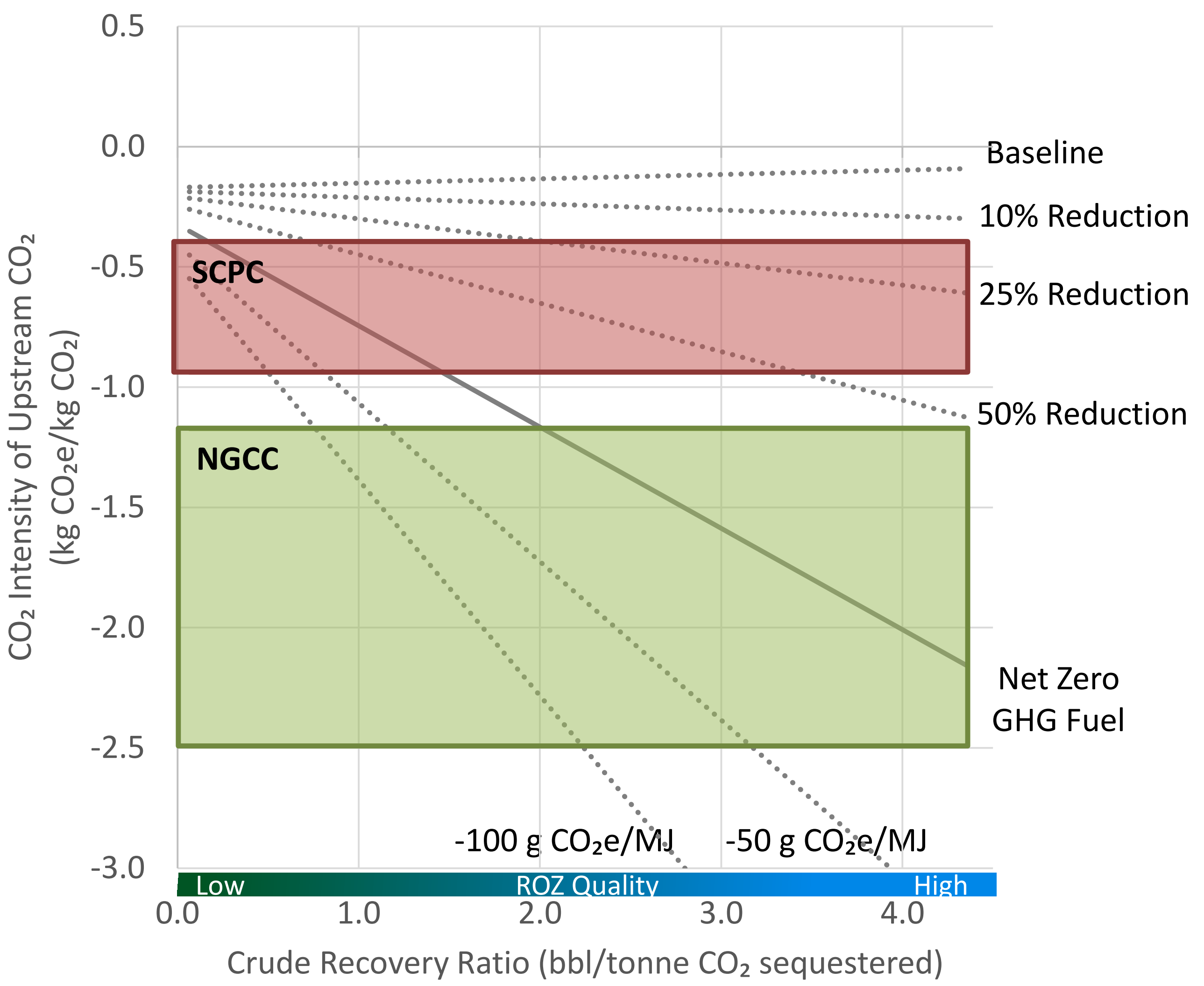
- The CO_2 intensity of a given source (e.g. NGCC or SCPC) is not a function of the crude recovery ratio
- More aggressive target can be achieved as the CO_2 intensity becomes more negative or the crude recovery ratio is reduced
- The type of electricity displaced is key to determining the CO_2 intensity and achievable reductions (fleet coal at 1,041 g CO_2e/kWh)



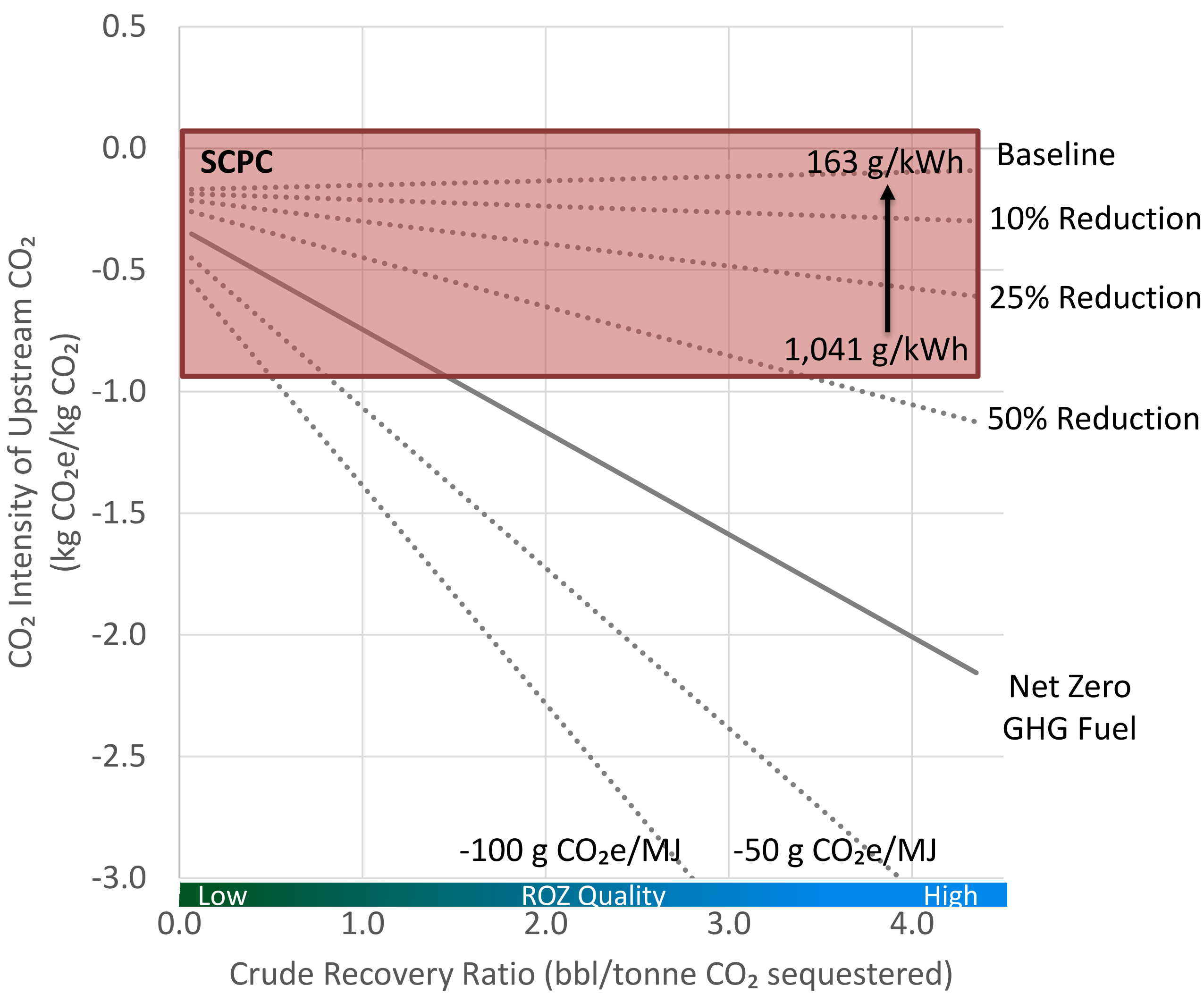
Variability in CO_2 Intensity Due to Displacement Mix

- A given source of CO_2 can span a range of CO_2 intensities according to the assumptions regarding the type of displaced electricity
- This range can inform the types of reduction targets that may be achievable



As the grid decarbonizes, the CO_2 intensity of upstream CO_2 increases

- As capture is implemented, the grid becomes less GHG intensive
- Hypothetical example depicts range from fleet coal (1,041) to a carbon constrained grid (163)
- This analysis can help determine the grid GHG intensity at which it is no longer possible to hit a target
- Under full fossil capture, transportation would likely shift away from conventional technology



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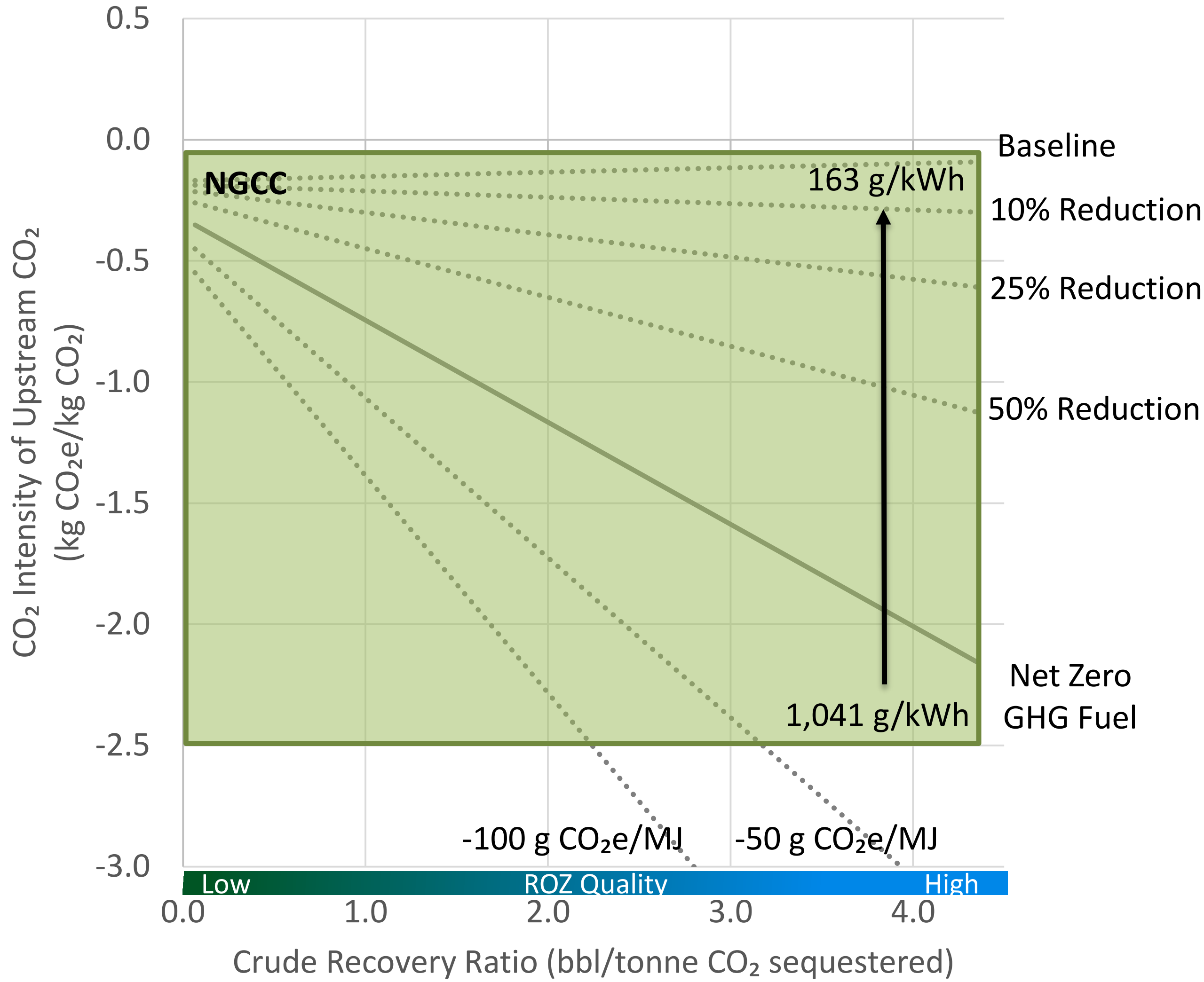

Key Conclusions

- **Life cycle net negative carbon crude oil can be produced from CO_2 EOR pathways**
- **The percentage reduction from the petro baseline depends on the source of CO_2 and the efficiency of the EOR operation**
- **Displacing carbon intensive power by capturing CO_2 at an alternative plant increases the credit**
- **Sources of CO_2 that are inefficient at generating captured CO_2 per unit of power (or other output) result in a larger credit**
- **As the electricity sector becomes less carbon intensive, the life cycle GHG profile for EOR crude will increase**

Contact Information

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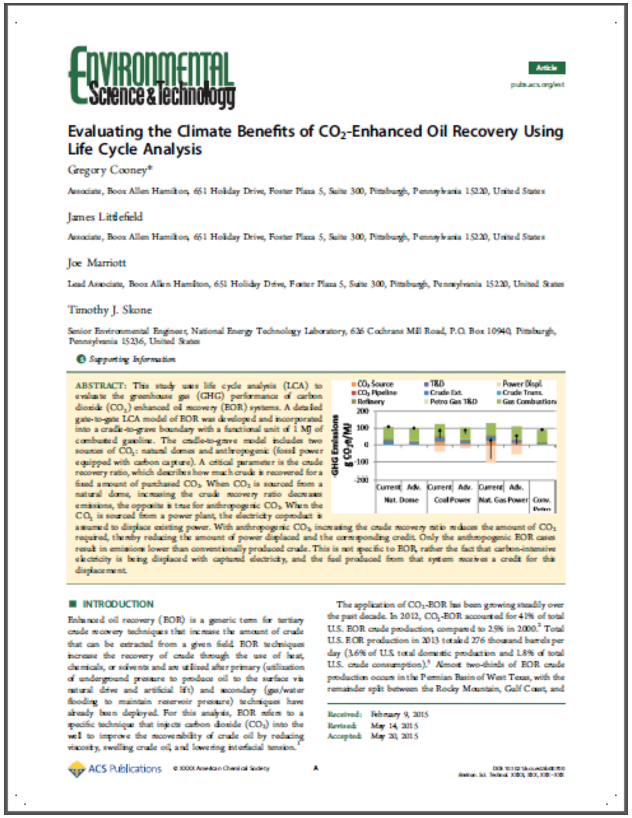
Backup Slides

Evaluating the Climate Benefits of CO_2-Enahanced Oil Recovery Using Life Cycle Analysis

- **Detailed models are necessary to give confidence to broader system applications**
- **CO_2-EOR is a GHG-intensive way of extracting crude compared to conventional extraction methods**
- **Linking EOR with anthropogenic CO_2 yields a benefit due to the displacement of uncaptured electricity**
- **Crude recovery impacts depend on the source of CO_2 (natural vs. fossil)**
- **Inefficient CO_2 generators are best (NGCC vs. SCPC): increasing efficiency will increase the amount of power generated per unit of CO_2 captured and sent to EOR**


Environmental Science & Technology

Article

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Evaluating the Climate Benefits of CO_2-Enhanced Oil Recovery Using Life Cycle Analysis

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Supporting Information

ABSTRACT

INTRODUCTION

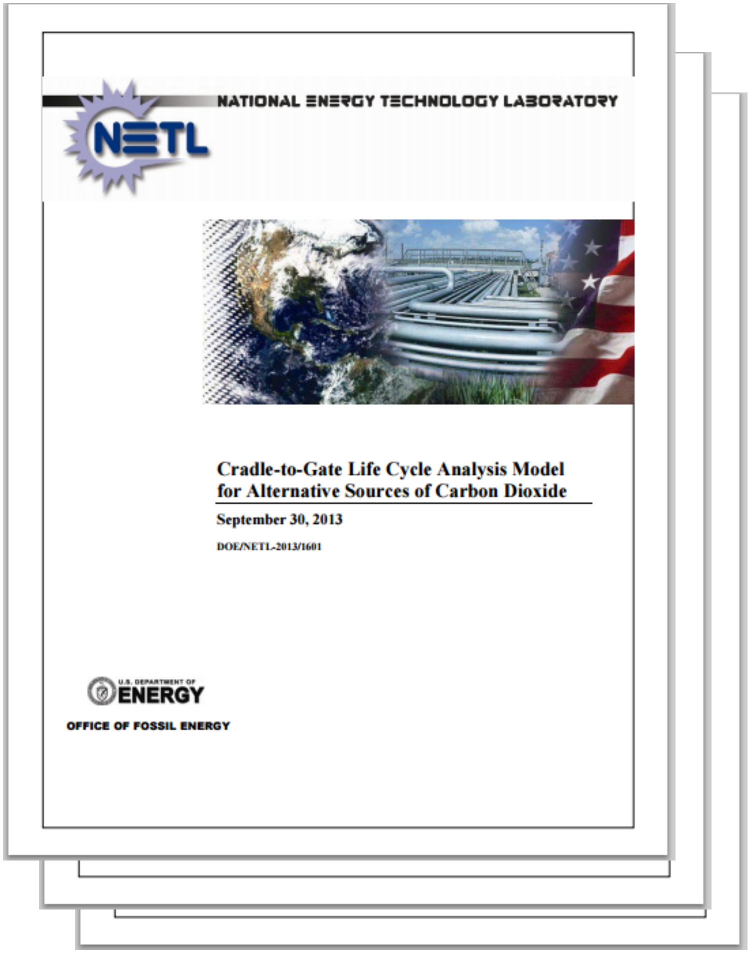
ACS Publications

Cooney, G., Littlefield, J., Marriott, J., & Skone, T. J. (2015). Evaluating the Climate Benefits of CO2-Enhanced Oil Recovery Using Life Cycle Analysis. *Environmental Science & Technology*, 49(12), 7491-7500. doi: 10.1021/acs.est.5b00700

Other NETL CCUS-related publications

- **Gate-to-Gate Life Cycle Inventory and Model of CO_2-Enhanced Oil Recovery *(Sept. 2013)***
  - Full process detail and comparison of four gas processing technologies
- **Gate-to-Grave Life Cycle Analysis Model of Saline Aquifer Sequestration of Carbon Dioxide *(Sept. 2013)***
- **Cradle-to-Gate Life Cycle Analysis Model for Alternative Sources of Carbon Dioxide *(Sept. 2013)***
  - Three potential sources considered: natural dome, ammonia production, natural gas processing
- **All reports accessible via:**

  www.netl.doe.gov/LCA


NATIONAL ENERGY TECHNOLOGY LABORATORY

Cradle-to-Gate Life Cycle Analysis Model for Alternative Sources of Carbon Dioxide

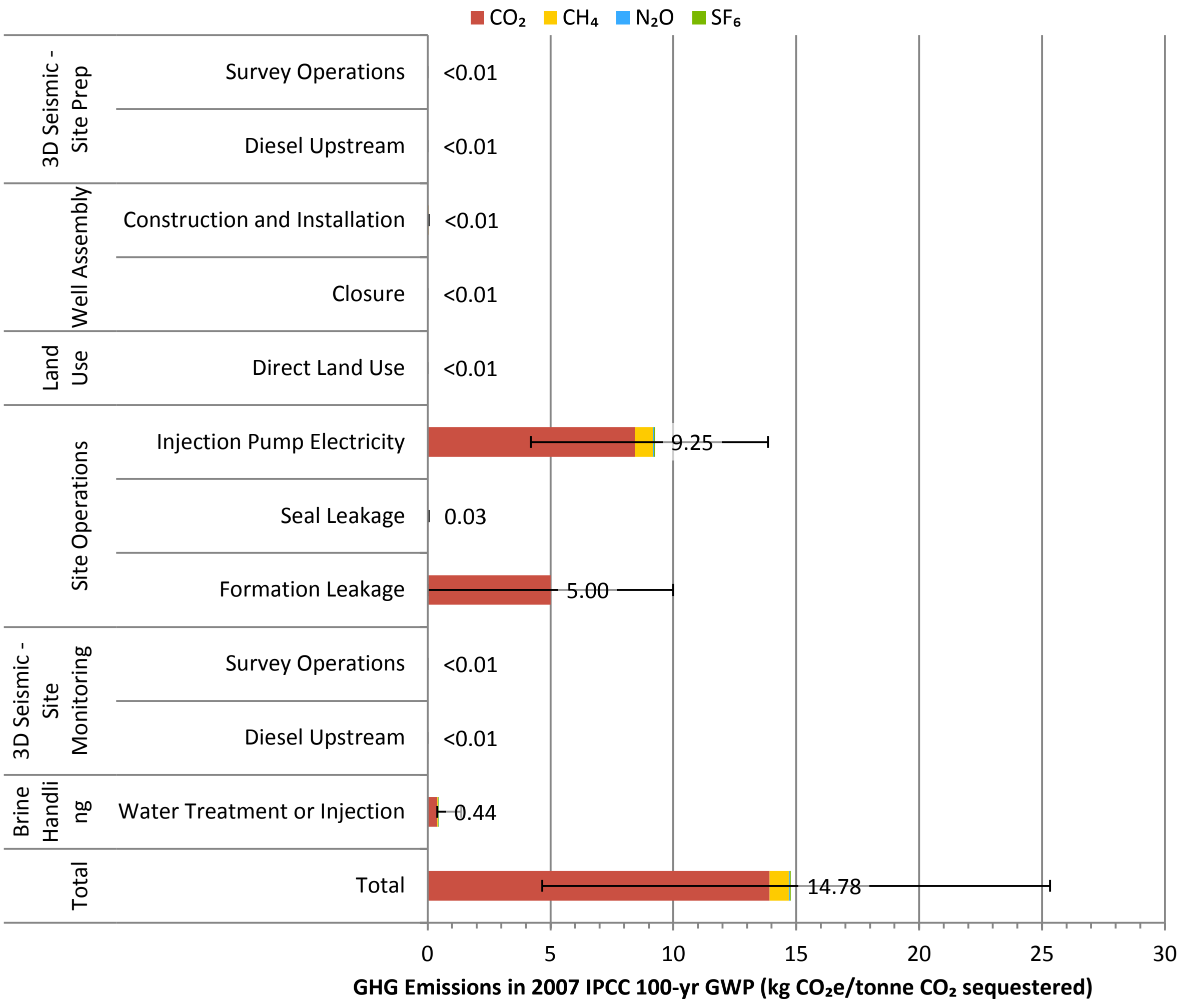
September 30, 2013

DOE/NETL-2013/1601

U.S. DEPARTMENT OF ENERGY

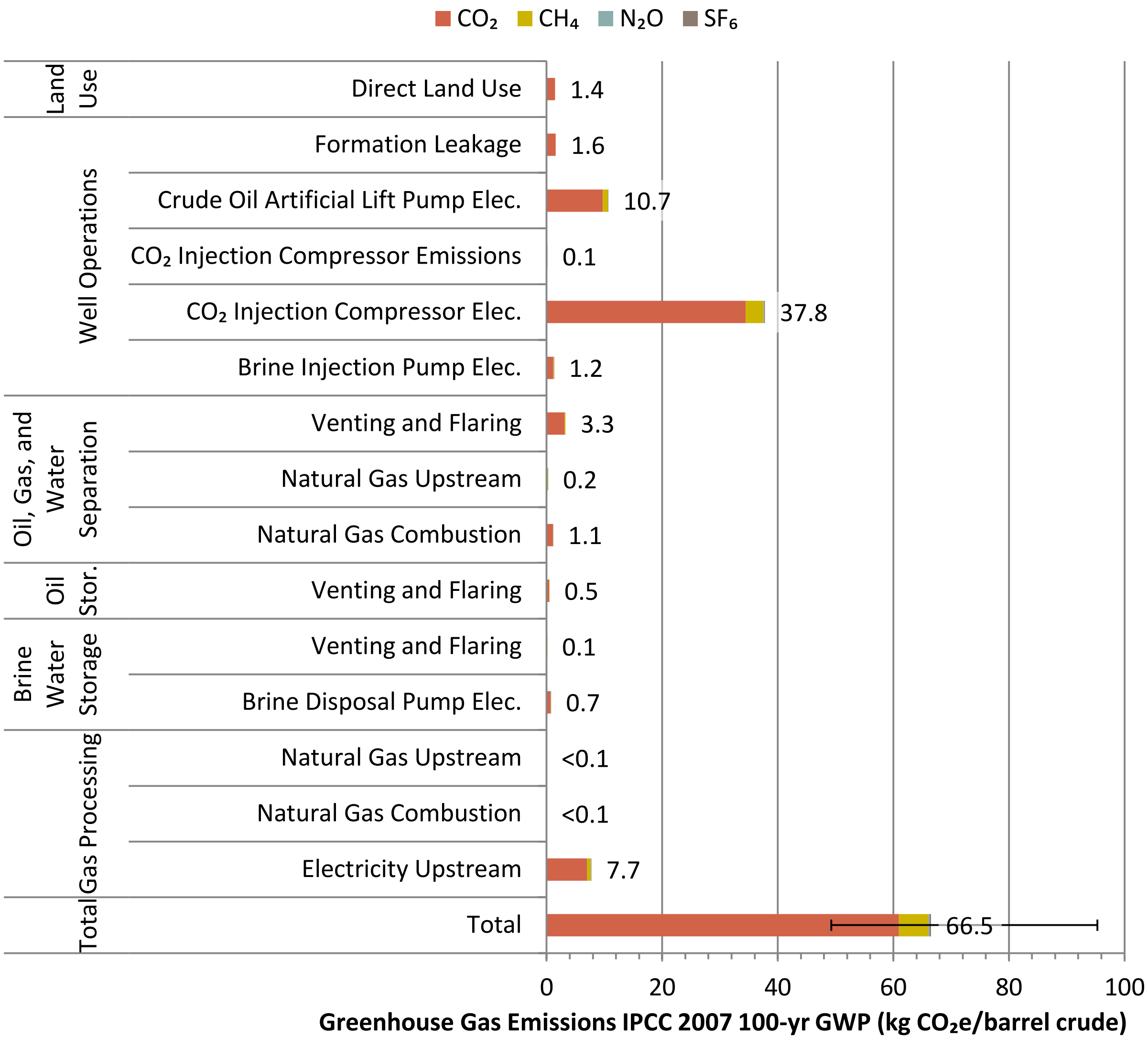
OFFICE OF FOSSIL ENERGY

Saline aquifer sequestration of CO_2 drilldown of gate-to-grave GHG emissions



- Emissions associated with electricity for CO_2 injection pump compose 62.6 percent of gate-to-gate GHG emissions
- Next highest contributor is leakage of sequestered CO_2 from formation (33.8 percent)
- Lower bound of uncertainty bars for formation leakage is zero, representing a scenario with no leakage from formation
- Uncertainty in CO_2 injection pump electricity requirement is based on power demand for pump to achieve required injection pressure (function of geology)
- Added uncertainty for pumping GHG emissions is due to source of electricity to power pump (U.S. grid mix, ERCOT mix, GTSC)

Enhanced oil recovery drilldown of gate-to-gate GHG emissions



- Results are gate-to-gate and thus do not account for the source of CO2
- Mass allocation used to NGL co-product
- Emissions associated with electricity for CO_2 injection compressor, crude oil artificial lift pump, and gas processing compose majority of gate-to-gate GHG emissions
- 98% of purchased CO2 is sequestered
- Other significant contributors include venting and flaring activities during oil, gas, and water separation, as well as natural gas combustion
- Uncertainty in total gate-to-gate GHG emissions is driven by three main factors: crude recovery per tonne of CO_2 sequestered, required formation injection pressure, and makeup of electricity grid