Reducing lifecycle biofuel emissions with CCS

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Why care about CCS in biofuel applications?

We must not only **reduce emissions rapidly** to reach the Paris target, but also **drive net emissions below zero** in the second half of the century (Sanderson et al., 2016)

1. On a lifecycle basis, greenhouse gas emissions from biofuels can be lower than petroleum fuels, but are generally **greater than zero** (Cherubini & Strømman, 2011)

2. Emissions intensity-based trading systems, e.g., the California Low Carbon Fuel Standard (LCFS), are driving reductions in fuel emissions intensity and **create a value proposition for CCS**

3. Use of CCS in biofuels can contribute to **learning and cost reduction** in capture, and **development of transport and storage infrastructure** for all potential applications
Lifecycle emissions intensity of fuels in the LCFS varies widely

Data: ARB, 2016
Where can CCS be applied in biofuel production?

Agriculture
- Fertilizers
- Pesticides
- Fuels

Pre-treatment

Feedstock Transport

Fuel Production
- Co-products
- Fuels
- Electricity

Distribution & Blending

Co-products

Vehicle Transport
Case study: retrofitting CCS to corn ethanol plants

- The vast majority of fuel ethanol consumed in the U.S. – nearly 14 billion gallons (53 billion liters) in 2015 – is produced from corn starch.

- Rapid growth in corn ethanol production was driven largely by the U.S. Renewable Fuel Standard, introduced in 2005 (“RFS1”), and expanded and refined in 2007 (“RFS2”).

- 90% of US ethanol production comes from the dry milling process; the remainder comes from multi-product biorefineries that use the wet milling process (Chum et al., 2013; RFA, 2016).

- A representative dry mill ethanol plant produces about **60 million gallons** (227 million liters) of ethanol per year, and 340 million lb (156 kt) dry distillers grain solids (DDGS) and smaller amounts of corn oil as byproducts (Mueller & Kwik, 2013).
Historic and projected US biofuel consumption

EIA Reported Consumption

- Biodiesel
- Cellulosic Biofuel (Ethanol)
- Other Advanced Biofuel
- Conventional Biofuel (Ethanol)

EPA or EISA Mandate

- EIA Reported
- EPA Regulation
- EISA 2007 Mandate

Billion Gallons

Case study: the dry mill process and CO\textsubscript{2} capture options

Utility Steam

Grain Drying

Fermentation

McAloon et al, 2000
Case study: three scenarios with differing levels of capture

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Description</th>
<th>Production Emissions (gCO₂/MJ)</th>
<th>Emissions Change (%)</th>
<th>Capture Energy (MJ/L)</th>
</tr>
</thead>
</table>
| Baseline          | • Dry-mill, gas-fired DDGS dryer  
                   • 2.8 gal ethanol per bushel corn feed (10.3 L/bu)  
                   • 26,200 Btu/gal (7.3 MJ/L LHV)  
                   • 0.63 kWh/gal (0.6 MJ/L LHV) | 30.3                          | -                    | -                     |
| Fermentation Capture | • Baseline plus capture of fermentation CO₂ | 33.6 (-35.5)                  | +11                  | 0.36                  |
| Full Capture      | • Capture of emissions from fermentation and steam | 17.3 (-35.5)                  | -43                  | 0.52                  |

Fermentation emissions are, by convention, considered to be offset by biomass growth; capture is assumed to result in an offsetting credit.
Case study: lifecycle impact of CO$_2$ CCS on ethanol carbon intensity
## Monetizing the emissions reduction benefit

### Federal Policy: RFS2
- The EPA establishes percentage standards for four nested categories of renewable fuels annually.
- Suppliers of transport fuels meet their corresponding Renewable Volume Obligation by retiring Renewable Identification Numbers (RINs).
- RINs are generated by renewable fuel producers based on fuel production.

*Value of RINs is highly variable, not related directly to emissions intensity, and “conventional biofuel” generates the least valuable RINs.*

### California Policy: LCFS
- Goal: reduce lifecycle carbon intensity (CI) of transportation fuels used in California 10% by 2020.
- Target CI declines through 2020: *fuels sold above the target CI generate deficits, below the target generate credits.*
- Crude oil producers and refiners can generate credits by reducing emissions intensity via CCS.

*Value of LCFS credits is a function of the fuel pathway CI and, while prices are variable, they are relatively high and increasing.*
Case study: breakeven costs for capture of fermentation CO$_2$

- Project life of **10 years**
- 15% discount rate
- CAPEX and non-energy OPEX per Illinois Basin Decatur Project
- $40$/MWh electricity cost (MISO)
- $10$/t transport and storage cost

<table>
<thead>
<tr>
<th>Item</th>
<th>Value</th>
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<tbody>
<tr>
<td>Total Capital Cost</td>
<td>$12,893,000</td>
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<tr>
<td>Fixed and Variable Cost</td>
<td>2,833,000/y</td>
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<tr>
<td>Incremental Cost</td>
<td>$0.09/gal</td>
</tr>
<tr>
<td>Avoidance Cost (LC Basis)</td>
<td>$35/t</td>
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</table>

Graph showing GHG emissions (gCO$_2$ eq MJ) for baseline and with fermentation CCS.
August 2016 LCFS price was $75/tCO₂
Where to from here?

1. A California Air Resources Board (ARB) “approved” CCS quantification method is critical - this is in development, and targeted for release in 2017

2. ARB clarification of whether credits can be awarded for capture and storage of biogenic CO$_2$ during ethanol production

3. Process-based LCAs to assess the potential impact of CCS on both alternative (including biofuel) and crude production pathways with different technology options

4. Suitability of current capture processes to alternative fuel pathways should be examined to determine what innovations will be valuable
Thank-you!

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References (1)


