The Future of SAF: Feedstocks, Conversion, and Innovation Beyond 2030

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Goals

• Overview and context

• Background on eFuels and EERE CO₂ utilization portfolio

• Initial technoeconomic and life-cycle analysis of e-fuels
The persistent need for carbon

A more sustainable economy is not a \textit{low-carbon economy} as much as it will be a \textit{renewable carbon-based economy}. 
How much biomass is out there?

• The Billion Ton Report sought to answer the big question: “Do we have enough biomass to make a meaningful impact in our petroleum consumption?”

• The Report concludes that the US has the potential to produce at least 1B tons of biomass (agricultural, forestry, waste, and algal materials) on an annual basis without adversely affecting the environment.

• This is enough to displace approximately 30% of 2005 U.S. petroleum consumption.
How much renewable carbon will we need?

- 36B gallons of SAF = 600M tons of biomass
- ~9B gallons of marine fuel (EIA 2019) = 150M tons of biomass
- ~5B gal of diesel (~10% of today’s use) = 80M tons of biomass
- 100M tons of chemicals (~50% of today's market) = 400M tons of biomass
- ~ 500M tons of carbon removal via BECCS or BiCRS = 500M tons of biomass (assumes roughly half of CDR uses biomass)

- TOTAL = 1.8B tons of biomass
What is an e-fuel?

• Interchangeably called synthetic fuels, power-to-liquids, power-to-gas or electrofuels

• At its core, e-fuels are made by converting electricity into chemical bonds
  • This generally refers to CO₂ conversion to liquid or gaseous carbon fuels
  • There are many routes to make e-fuels, each with pros and cons and different TRL

• E-fuels provide an option for “electrifying” sectors where a battery or hydrogen cannot.

• E-fuels can have a very low carbon intensity IF they are made with renewable electricity
CO2-to-Fuels approach in EERE

Conventional biofuels

E-fuels

Engineered Carbon Reduction

Reduced Intermediate Conversion & Upgrading

Biomass Deconstruction, Conversion & Upgrading
Assessing the viability of E-fuels

- Near term opportunities in indirect CO₂ conversion (i.e., making H₂ and reacting it with CO₂)
- Direct electrochemical are lower TRL but offer more efficient electron use
- Biotic routes have significantly higher specificity for C-C formation but lower rates
- Abiotic routes generally have higher rates of conversion
Select CO$_2$ utilization work in EERE

National lab projects to explore the key areas:

**BETO/HFTO: Power-to-gas for energy storage**

**Intermediate upgrading**

FY18 *Rewiring Carbon Utilization* FOA topic area: $4.5M to 3 projects which coupled carbon reduction to biological upgrading

FY20 *Scalable CO$_2$ Electrocatalysis* FOA topic area: $7.5M to companies to push the limits of electrocatalysis
Comparing two pathways to make a fuel

Corn ethanol + CCS

Vs.

$CO_2$ conversion to ethanol (e-fuel)
LCA of E-fuels

- CCS drops corn ethanol carbon intensity to ~75% GHG reduction
- Using grid mix electricity produces a fuel that is over 4X the carbon intensity of gasoline
- Grid mix needs to be ~80% renewables before you reach fossil parity on carbon intensity
• CCS adds 15¢/gal (equal to 45Q value of $50/ton CO2)

• At 7¢/kwh, cost is over 3x higher for e-fuels (2018 grid)

• At 2¢/kwh, cost is much lower (renewable grid)
Net-Zero Carbon Fuels vs “e-fuels”

Net-Zero Carbon Fuels: Renewable fuels made from some carbon feedstock that have a net life-cycle of zero

E-fuels: Synthetic fuels made from combining CO₂ and electricity/hydrogen

E-fuels CAN be net-zero carbon, but they are not inherently so and are not necessarily the easiest way to achieve low carbon intensity fuels
Questions
Although not carbon-neutral, the Ethanol with fermentation CCS case decreases the carbon intensity of ethanol by 29 gCO₂/MJ. Gasoline baseline: 92 gCO₂/MJ
Corn ethanol today: 56 g CO₂/MJ; 40% GHG reduction. (USDA average)
Corn EtOH w/CCS: 15 – 27 gCO₂/MJ; ~70-85% GHG reduction*

Minimum Ethanol Selling Price: $1.77/gal
Minimum Ethanol Selling Price w/CCS: $1.92/gal
This additional $0.15 per gallon price ends up being about $52/ton CO₂
(for reference, 45Q tax credit = $50/ton)

*Depending on initial ethanol plant carbon intensity
Initial findings: Fuels via CO2 Electrocatalysis ("E-fuels")

Price of electricity is the key factor in TEA