Discussion on life-cycle assessments (LCA)

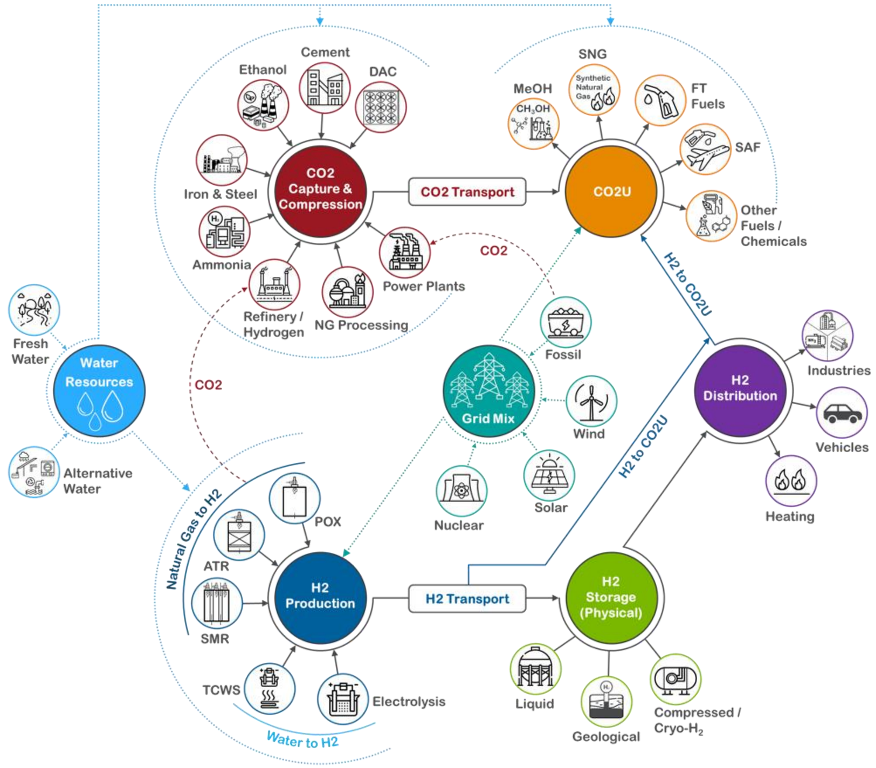
- What kind of methodologies for LCA and WTW are used?
- What are typical and expected net GHG effects of e-fuel production and utilization?
- What is the result of other sustainability evaluations related to air pollutant emissions and water consumption?

September 22, 2022 – Task 64

Life-cycle Analysis of Electro-fuels Using GREET

Uisung Lee and Michael Wang
Energy Systems Analyst
Systems Assessment Center
Argonne National Laboratory

Argonne has built comprehensive system assessment capability



CCUS Topics	Current Research
CO_2 Capture & Compression	Process Modeling, TEA and LCA of CC technologies
CO_2 Transport	CO_2 pipeline transportation cost
CO_2 Utilization	Process modeling, TEA and LCA of CO2U
H_2 Production	H_2 production technologies and market analysis TEA and LCA
H_2 Transport	TEA and LCA of H_2 liquefaction, compression, delivery and fueling infrastructure
H_2 Storage	TEA and LCA of H_2 storage
Electricity Supply	TEA and LCA of electric power supply by technology and region
Water Resources	Regional water availability, footprint, and stress of CO_2U technology deployment

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GREET is the gold standard life cycle analysis (LCA)

Greenhouse gases, Regulated Emissions, and Energy use in Technologies

- Tracks life cycle performance of energy and products
- Developed since 1995 with annual updates and expansions
- Long-term support from U.S. Department of Energy
- Expanded from transportation-focus to include a wide range of technologies

GREET

LIFE-CYCLE ANALYSIS MODEL

greet.es.anl.gov

Federal, state, and international agencies use GREET

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IEA-AMF
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Advanced Motor Fuels

California Environmental Protection Agency
Air Resources Board

State of Oregon
Department of Environmental Quality
DEQ

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

NHTSA
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

ICAO • OACI • ИКАО

FEDERAL AVIATION ADMINISTRATION

USDRIVE
DRIVING RESEARCH AND INNOVATION FOR VEHICLE EFFICIENCY AND ENERGY SUSTAINABILITY

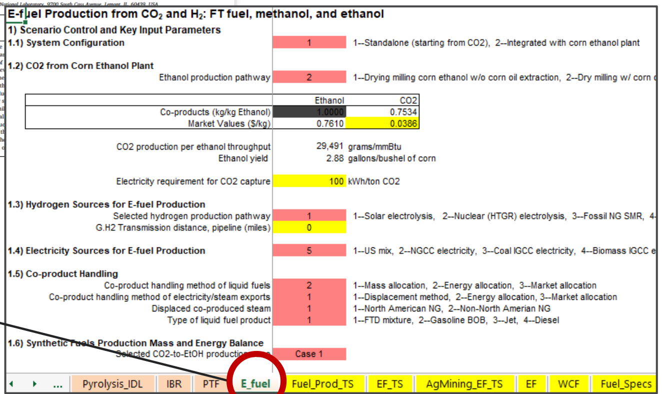
MARAD
Maritime Administration

USDA

Environment and Climate Change Canada

E-fuel module is available in GREET

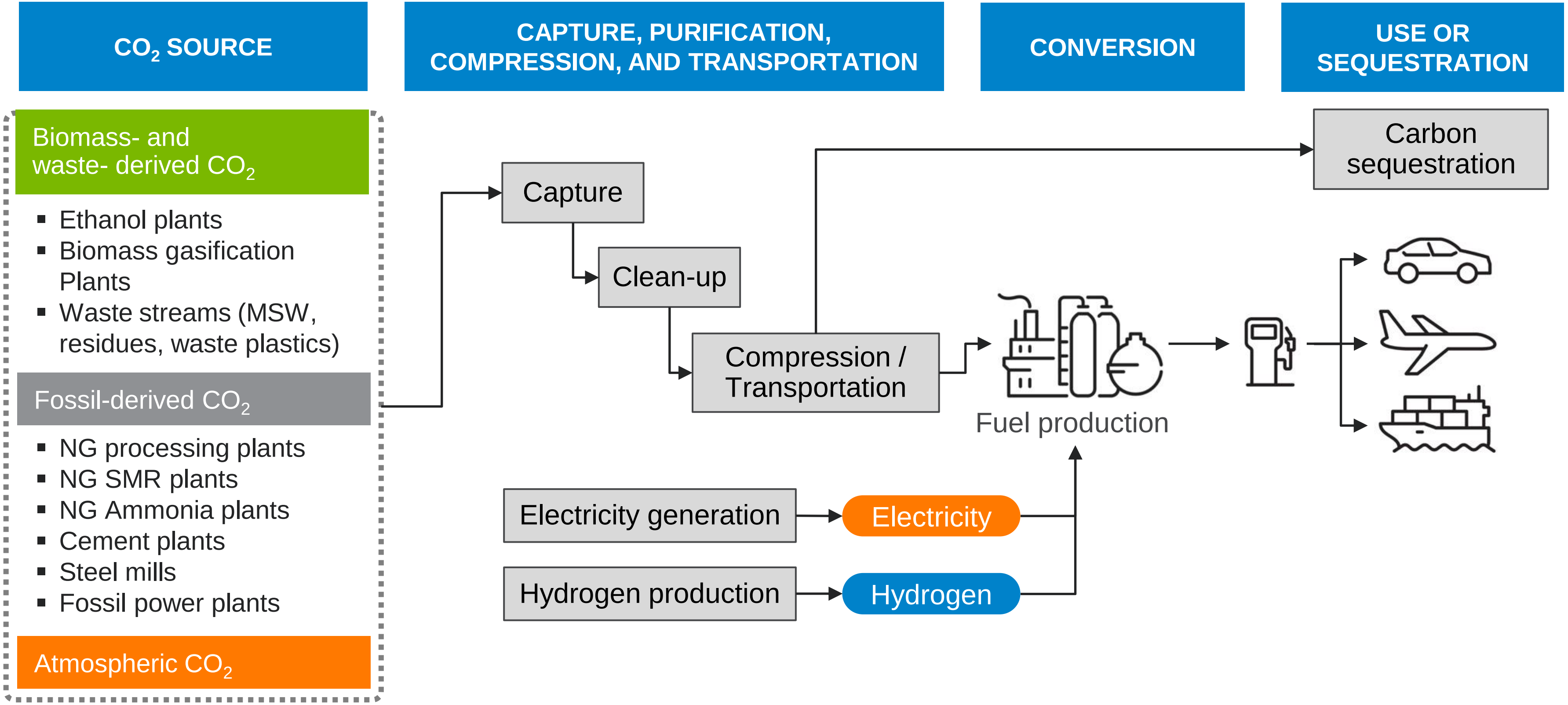
Advanced Motor Fuels
IEA-AMF
Technology Collaboration Programme on Advanced Motor Fuels



New version with updates in the E-fuel module will be released in October 2022

GREET E-fuel Module

Our CCUS Life cycle analysis includes all the supply chains



Recently published paper on LCA framework of e-fuels

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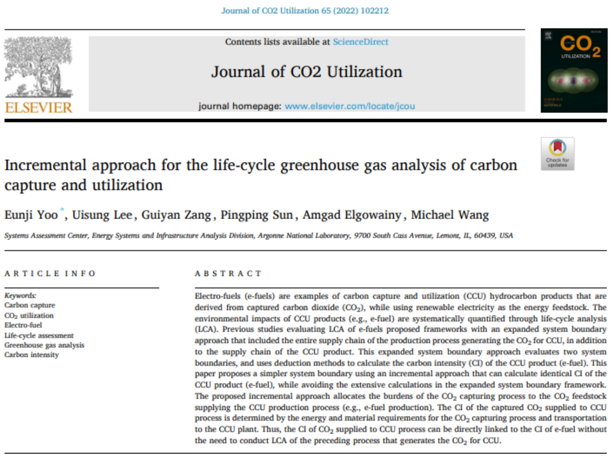
- Reviewed various LCA approaches available
- Suggested an incremental approach starting from CO_2 capture, which presents consistent results compared to existing substitution approach
- Considers carbon emissions from e-fuel production/combustion to be carbon neutral


Journal of CO2 Utilization 65 (2022) 102212
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Journal of CO2 Utilization
journal homepage: www.elsevier.com/locate/jcou
ELSEVIER

Incremental approach for the life-cycle greenhouse gas analysis of carbon capture and utilization

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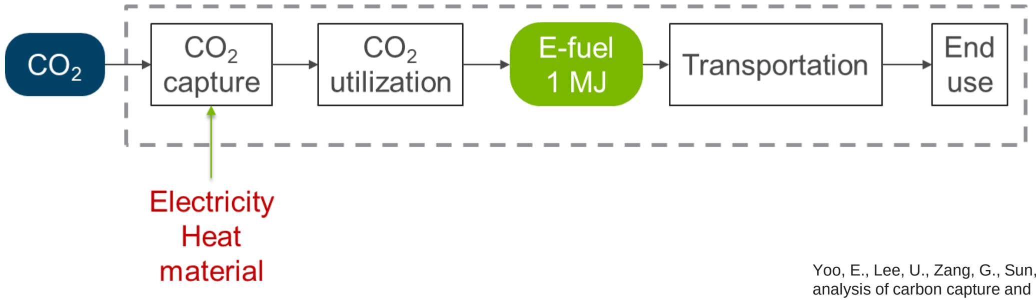
ABSTRACT

Electro-fuels (e-fuels) are examples of carbon capture and utilization (CCU) hydrocarbon products that are derived from captured carbon dioxide (CO_2), while using renewable electricity as the energy feedstock. The environmental impacts of CCU products (e.g., e-fuel) are systematically quantified through life-cycle analysis (LCA). Previous studies evaluating LCA of e-fuels proposed frameworks with an expanded system boundary approach that included the entire supply chain of the production process generating the CO_2 for CCU, in addition to the supply chain of the CCU product. This expanded system boundary approach evaluates two system boundaries, and uses deduction methods to calculate the carbon intensity (CI) of the CCU product (e-fuel). This paper proposes a simpler system boundary using an incremental approach that can calculate identical CI of the CCU product (e-fuel), while avoiding the extensive calculations in the expanded system boundary framework. The proposed incremental approach allocates the burdens of the CO_2 capturing process to the CO_2 feedstock supplying the CCU production process (e.g., e-fuel production). The CI of the captured CO_2 supplied to CCU process is determined by the energy and material requirements for the CO_2 capturing process and transportation to the CCU plant. Thus, the CI of CO_2 supplied to CCU process can be directly linked to the CI of e-fuel without the need to conduct LCA of the preceding process that generates the CO_2 for CCU.

(e) Incremental Approach



Yoo, E., Lee, U., Zang, G., Sun, P., Elgowainy, A., & Wang, M. (2022). Incremental approach for the life-cycle greenhouse gas analysis of carbon capture and utilization. Journal of CO2 Utilization, 65, 102212. https://doi.org/10.1016/j.jcou.2022.102212

CO_2 capture from various sources and CO_2 transportation

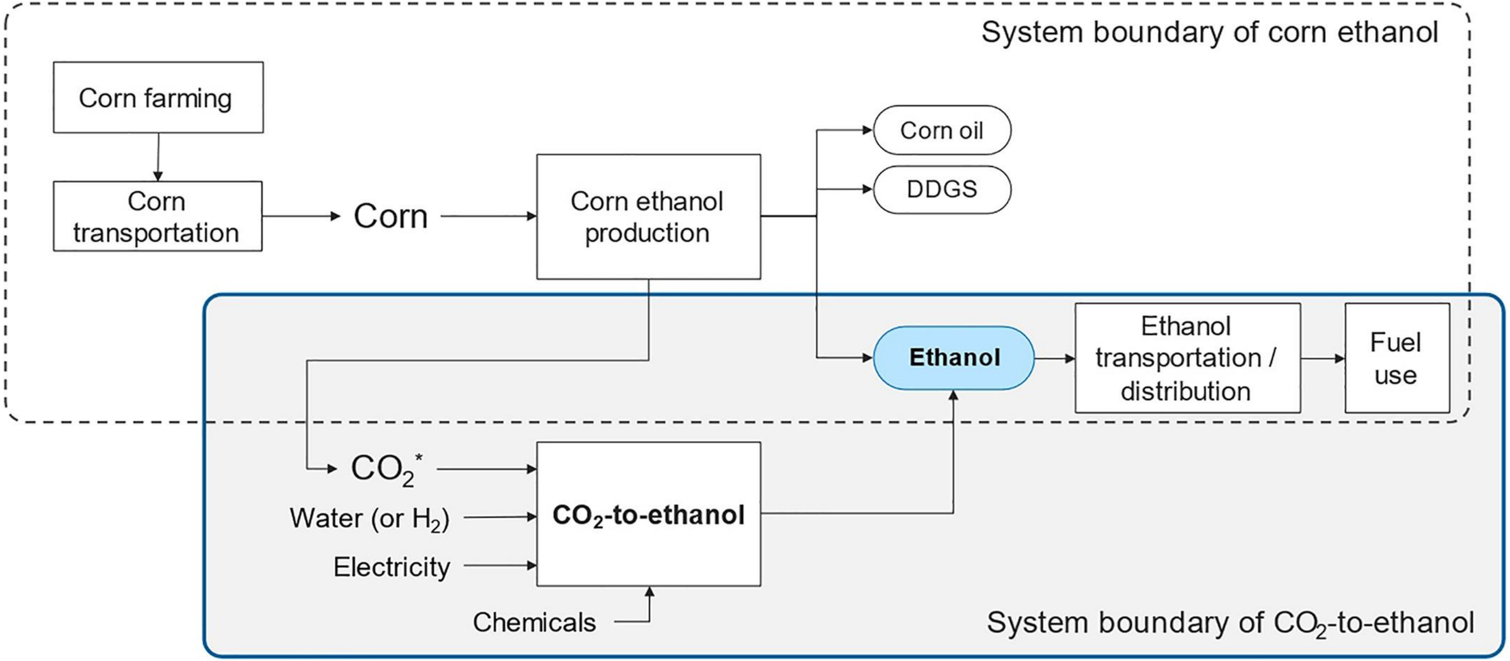
[MJ/MT-CO_2]	Ethanol	Ammonia	NG process	Hydrogen	Cement	Iron/steel	NGCC power	Coal fired power	DAC⁋
Electricity for CO_2 capture	0	0	0	131	149	150	806	955	1,436
Natural gas for CO_2 capture	0	0	0	4,218	4,208	4,227	0	0	6,750
Electricity for CO_2 compression at the source	420	318	352	420	420	420	357	357	420
Electricity for CO_2 pipeline transportation*	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	0.0

⁋ Low-temperature solid sorbent DAC is considered (high-temperature liquid solvent and cryogenic options are available)
* Transportation distance: 200 miles except for DAC (0 mile)

- Energy for CO_2 capture vary mainly due to CO_2 concentration.
- Electricity for onsite compression is calculated based on inlet/outlet pressure, compression ratio, the number of stages, and efficiency.
- Additional electricity for the booster pumps spacing 100 miles.

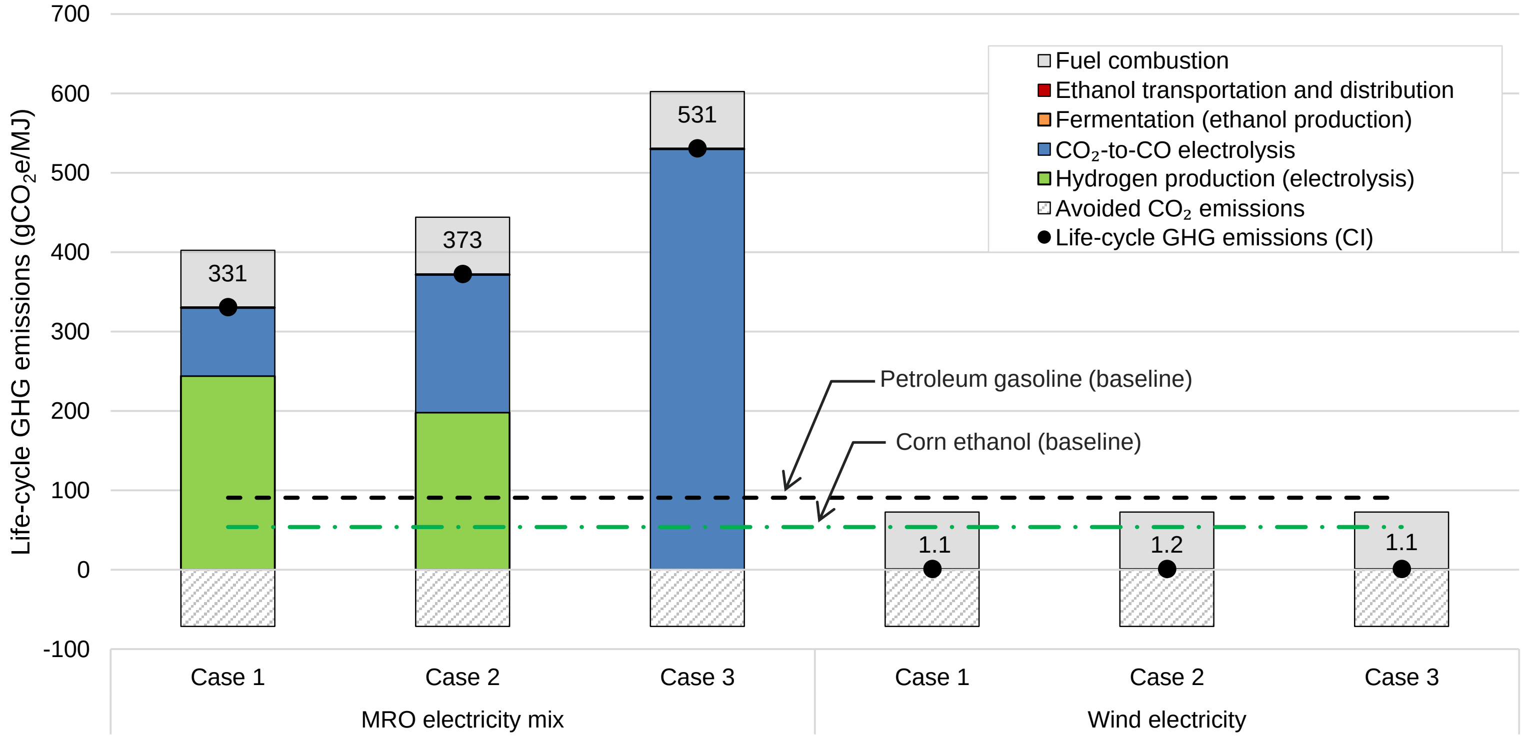
Zang, G., Sun, P., Yoo, E., Elgowainy, A., Bafana, A., Lee, U., ... & Supekar, S. (2021). Synthetic Methanol/Fischer–Tropsch Fuel Production Capacity, Cost, and Carbon Intensity Utilizing CO2 from Industrial and Power Plants in the United States. Environmental Science & Technology, 55(11), 7595-7604.

System boundary of a case producing CO_2-derived ethanol



Lee, U., R Hawkins, T., Yoo, E., Wang, M., Huang, Z., & Tao, L. (2021). Using waste CO2 from corn ethanol biorefineries for additional ethanol production: life-cycle analysis. Biofuels, Bioproducts and Biorefining, 15(2), 468-480.

Without renewable electricity and H_2, e-fuels have high carbon intensities



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Renewable electricity and H_2 are key for low-carbon e-fuels

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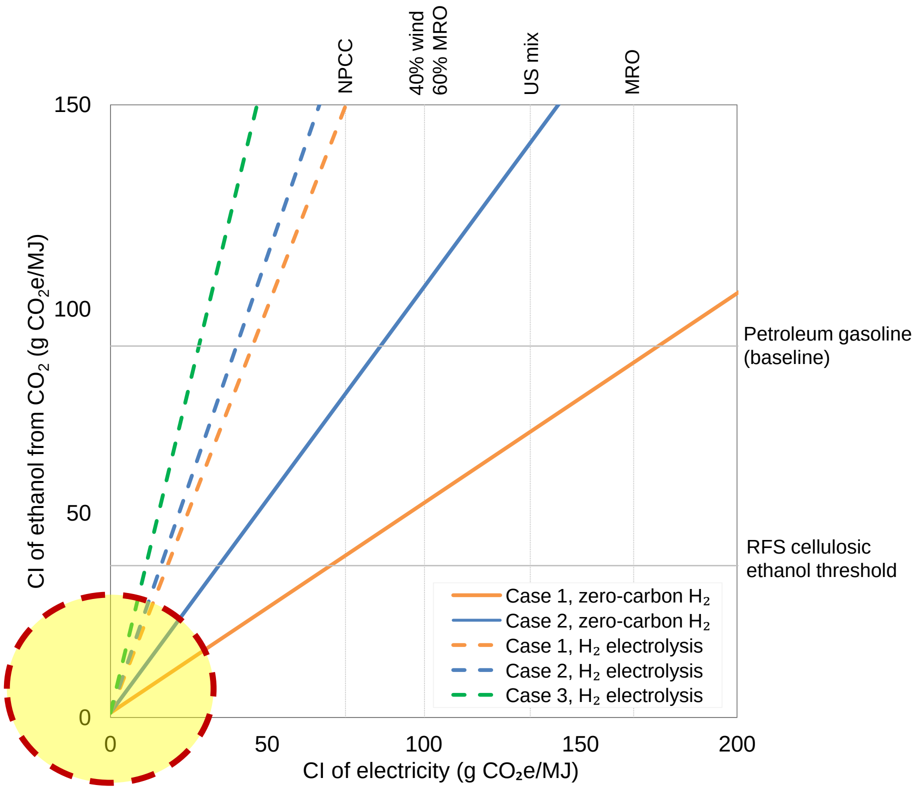

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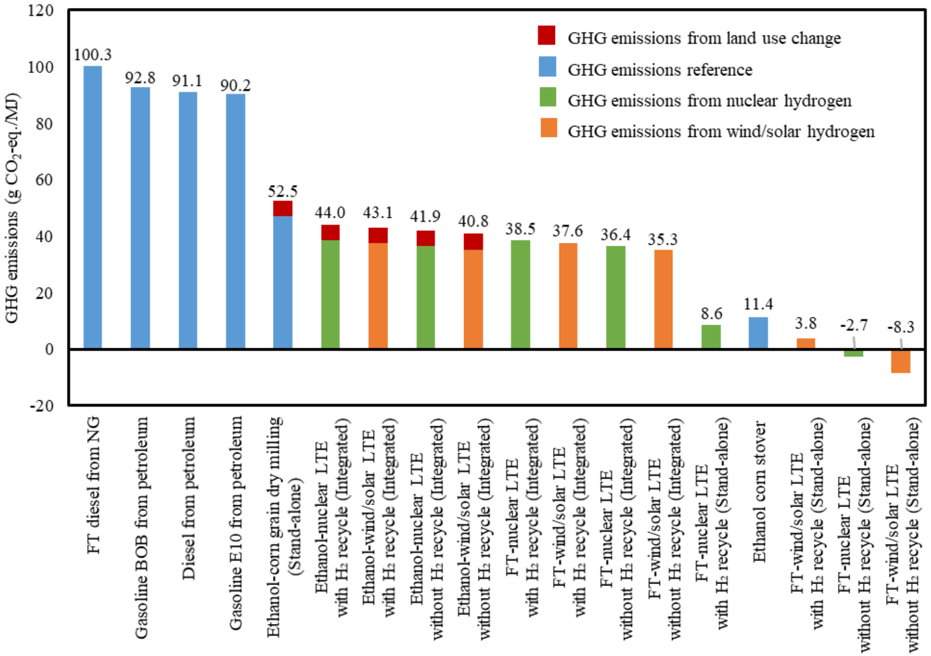
Life-cycle GHG emissions of Fischer-Tropsch fuels

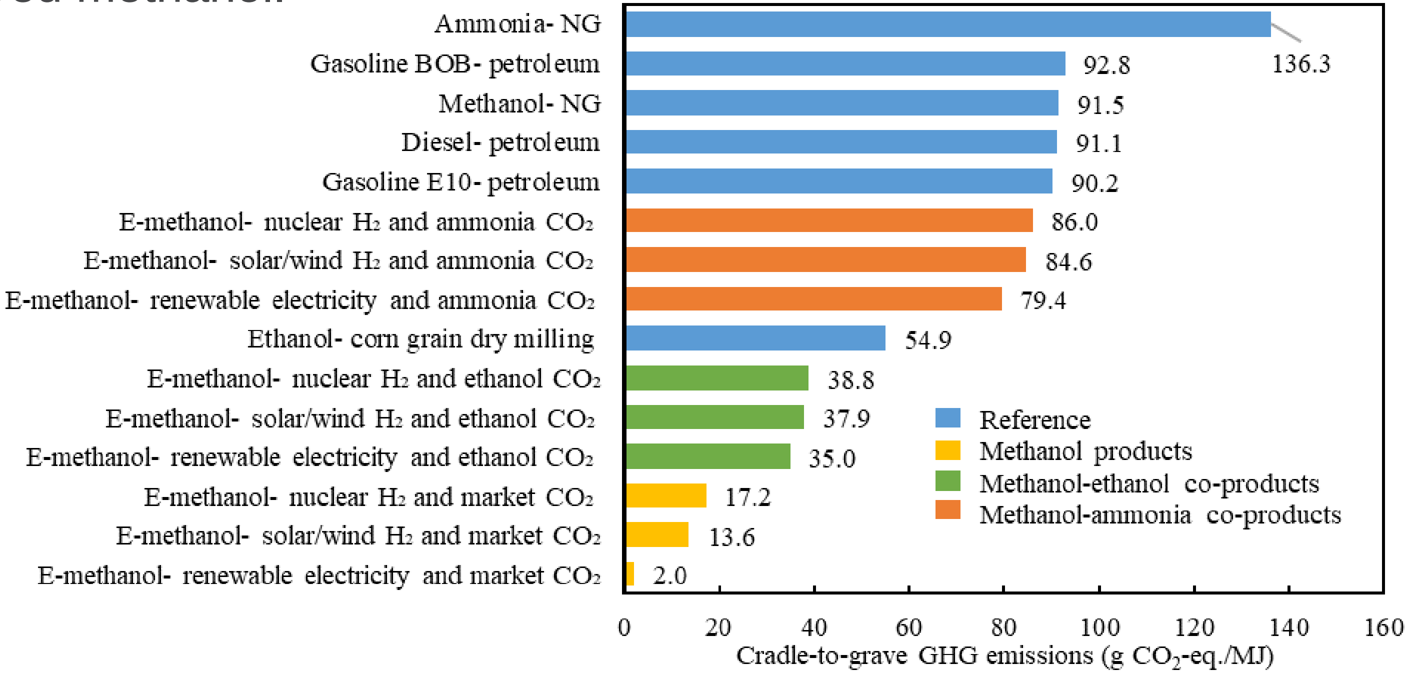
- The e-FT fuels show significant GHG reduction benefit coupled with renewable H_2.



Zang, G., Sun, P., Elgowainy, A., Bafana, A., & Wang, M. (2021). Life Cycle Analysis of Electrofuels: Fischer–Tropsch Fuel Production from Hydrogen and Corn Ethanol Byproduct CO2. *Environmental Science & Technology*, *55*(6), 3888-3897.

Life-cycle GHG emissions of synthetic methanol

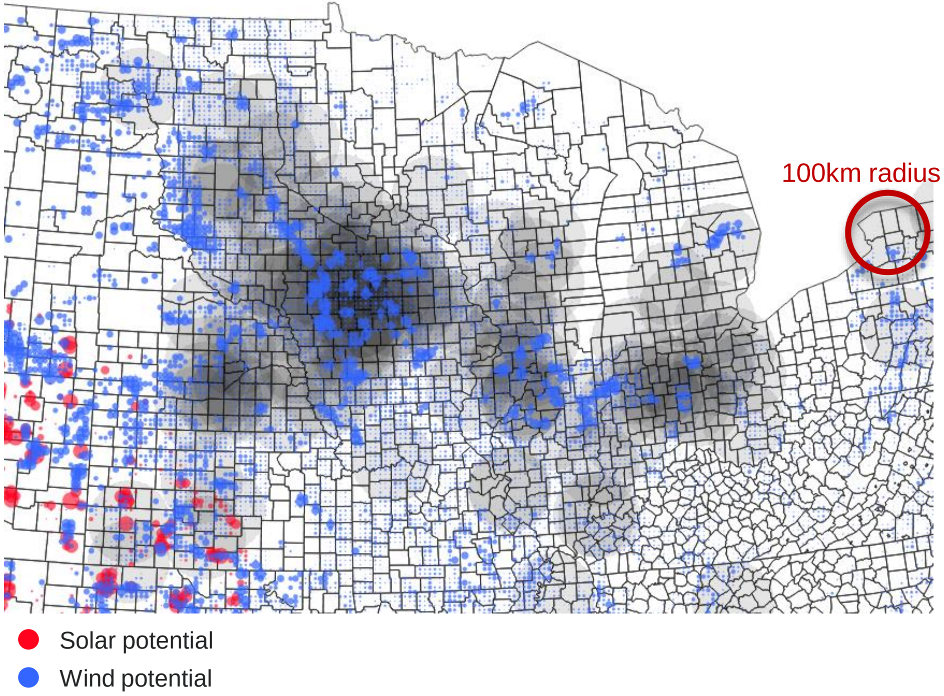
- E-methanol can reduce GHG significantly using renewable H_2 compared to NG-derived methanol.



Zang, G., Sun, P., Elgowainy, A., & Wang, M. (2021). Technoeconomic and life cycle analysis of synthetic methanol production from hydrogen and industrial byproduct CO2. Environmental Science & Technology, 55(8), 5248-5257.

Low-carbon e-fuel production needs renewable electricity

Most CO_2 sources in US have sufficient renewable electricity nearby



- In the Midwest, wind electricity would be mostly used to support CCU (due to solar PV's low capacity factors).
- Even with a regional/temporal mismatch, renewable electricity can be supported for CCU potentially through a power purchase agreement (PPA).

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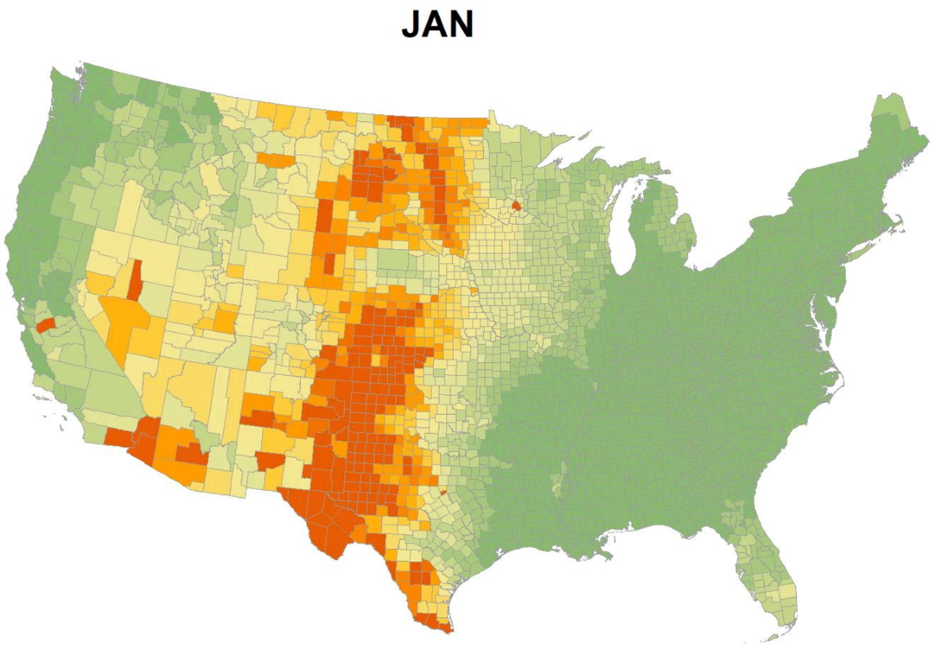
Water consumption for renewable H_2 production is significant



- E-fuel production requires freshwater as a renewable hydrogen source
- Significant regional/seasonal variations exist for water availability/scarcity in the U.S.
- Water scarce areas need to be avoided when locating CCU facilities

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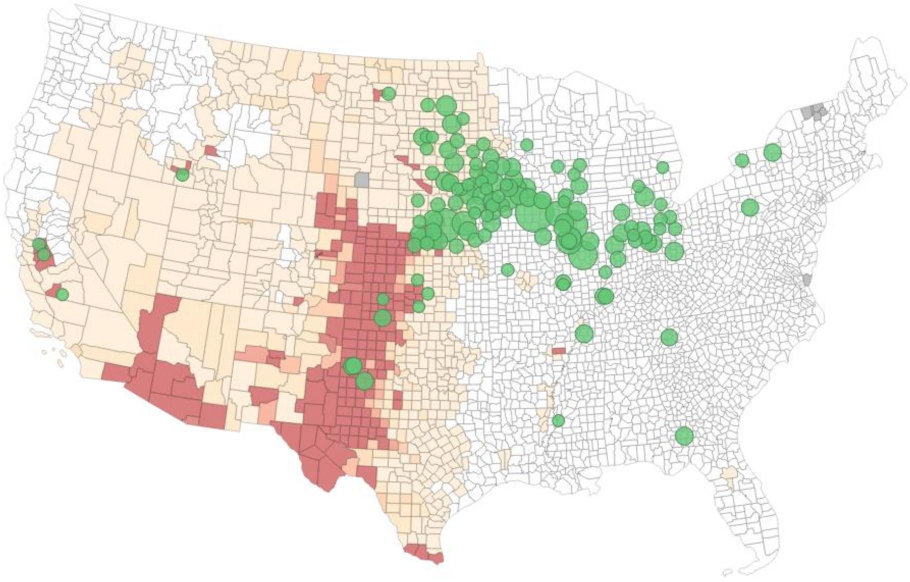
Need to consider seasonal/regional variation of water availability



- Unless renewable H_2 can be economically sourced for CCU, supporting freshwater is important for on-site H_2 production using renewable electricity.
- For 2 BGY CO_2-derived fuel requires 10 BGY water for H_2 production*
- Water stress conditions can be used to limit siting CCU facilities (can use AWARE-US).

* 1 MJ CO_2-derived fuels require 1.6 MJ H2.
25.5 gal water consumption per mmBtu H2 production (GREET)

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