Replacing All Crude Oil with Cellulosic Hydrocarbon Biofuels

Gasoline, Diesel, Jet Fuel and Chemical Feed Stocks

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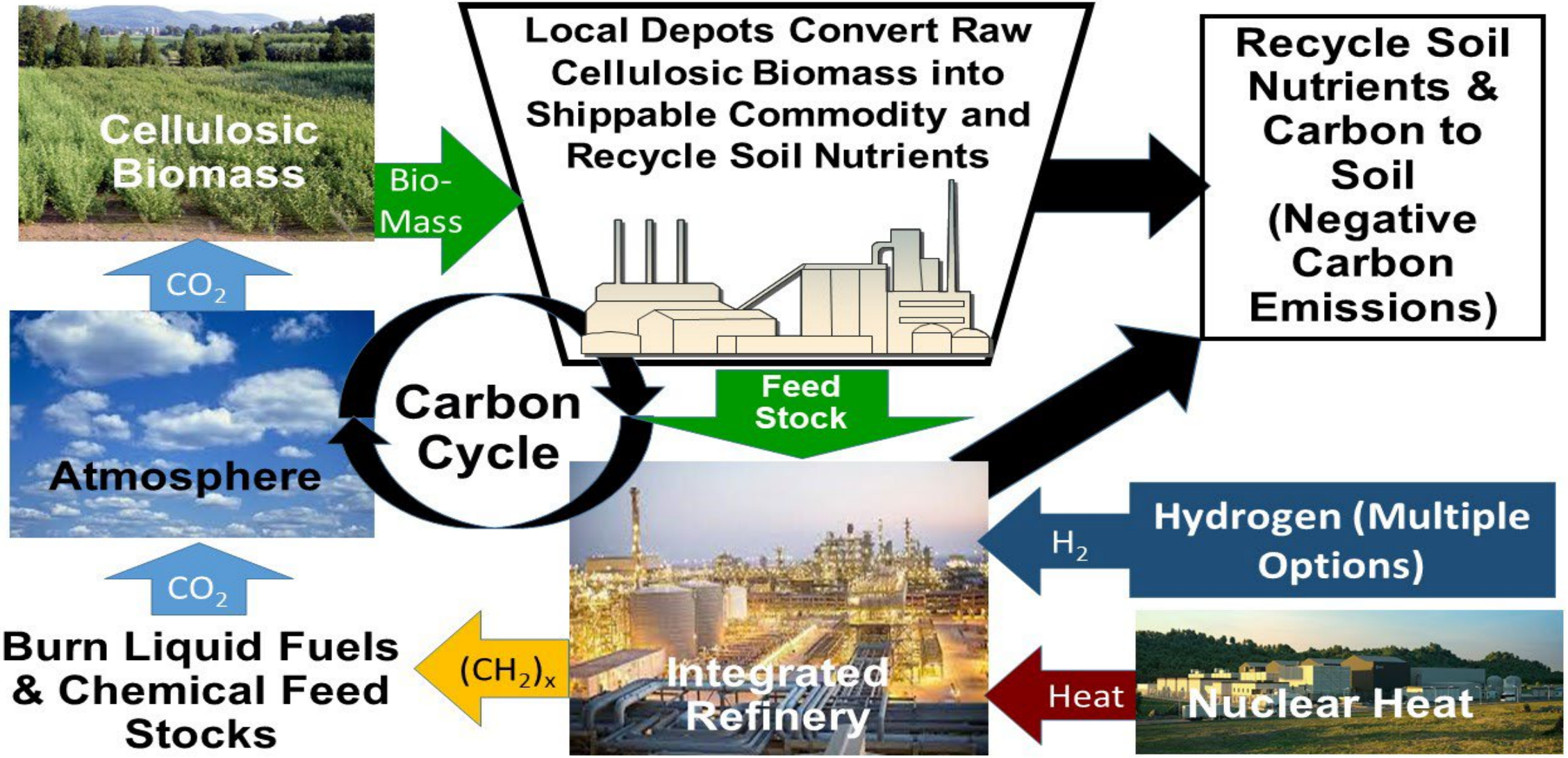
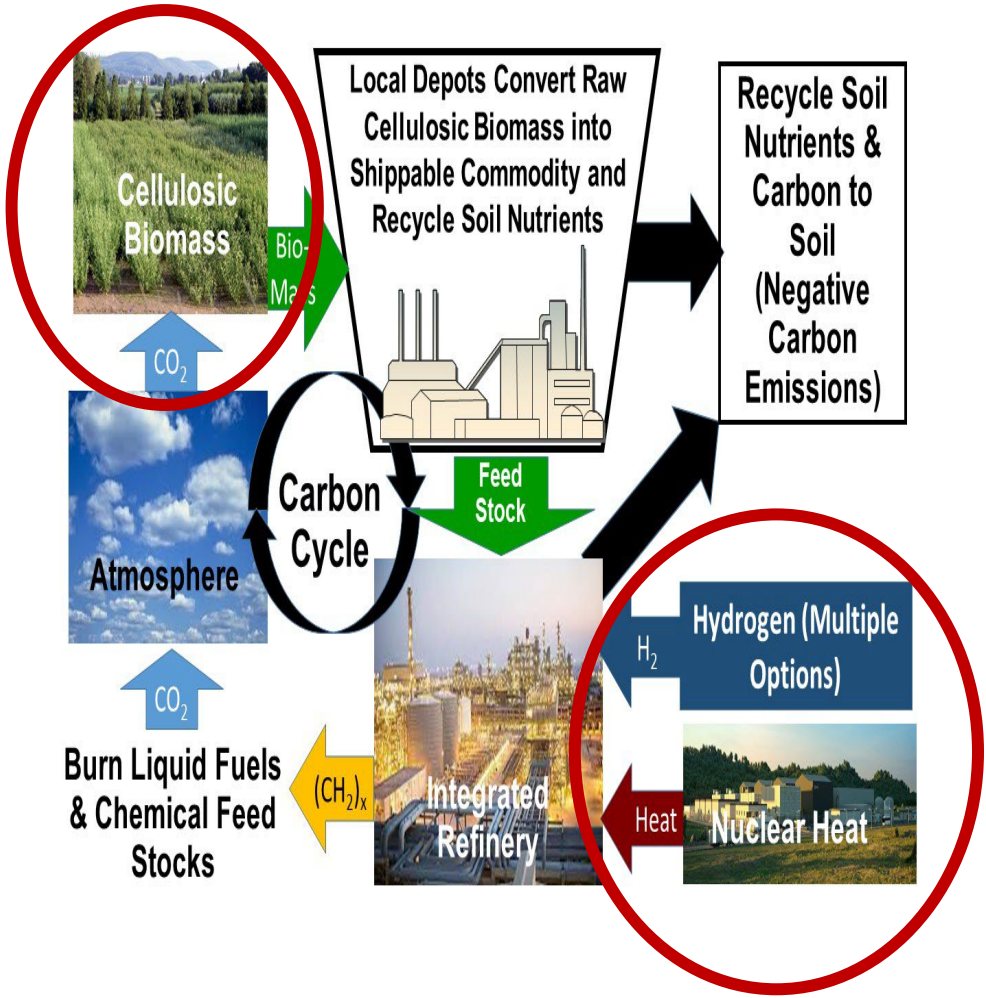
Replacing All Crude Oil
Negative Carbon Emissions
Massive Hydrogen and Heat Inputs
Modify Existing Refineries
Same products to Customer

Cellulosic Hydrocarbon Biofuels With Massive External Heat and Hydrogen Inputs Can Replace All Crude Oil



Tradeoff Between Cellulosic Feedstock Requirements and External Heat and Hydrogen Inputs

- Traditional biofuels uses biomass carbon as (1) carbon source for the product, (2) remove oxygen from biomass as carbon dioxide, (3) energy for conversion process and (4) feedstock to make hydrogen
- Tradeoff between biomass requirements and external heat and hydrogen inputs—no feed stock constraint if external hydrogen and heat in production process
- Low-cost hydrogen from natural gas with sequestration of the carbon dioxide byproduct
- Heat from nuclear reactors

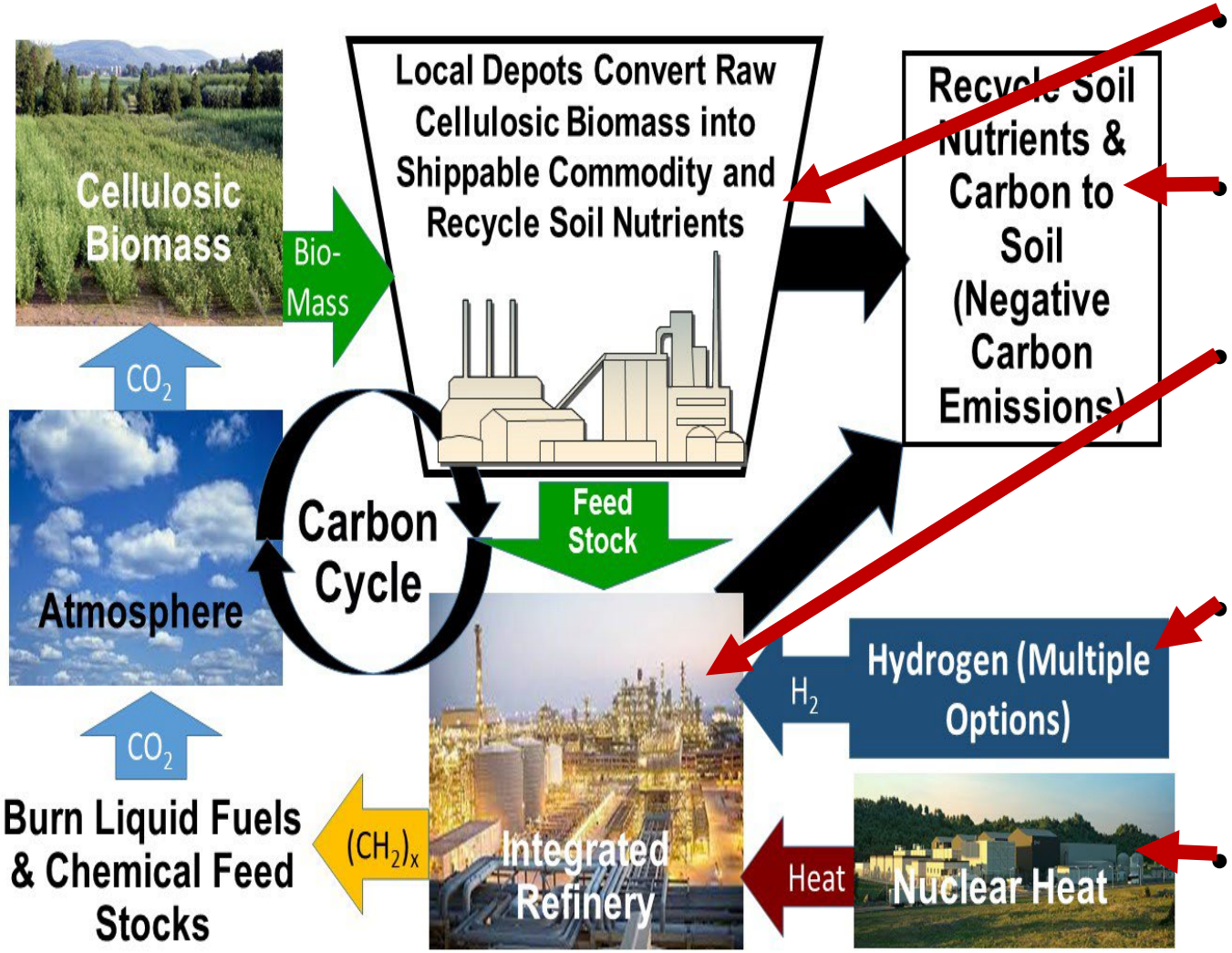


Feed Stock Supply and Economics Is Driving System to Cellulosic Hydrocarbon Biofuels

Carbon Source	Hydrogen Input	Primary Cost	Constraints
Starch (Corn), Sugar and Plant Oils (Soybeans, etc.)	Small	Biomass	Limited Available Feedstock (Food Sources)
Cellulosic Biomass (Corn stover, grass, trees, kelp, etc.)	2 Hydrogen Atoms per Carbon Atom	Hydrogen	Cost of Hydrogen (Cheaper bio feed stock)
Carbon dioxide (Electric Fuels)	6 Hydrogen Atoms per Carbon Atom	Hydrogen	Cost Hydrogen and Carbon Dioxide

Cost: <100/Barrel Crude Oil Equivalent from Cellulosic Biofuels

We are Moving Toward Cellulosic Hydrocarbon Biofuels



- Depots built for other products and biofuels
- Government incentives for carbon sequestration
- First integrated crude oil refinery announces plans to convert to bio-refinery
- Exxon announces first billion cubic foot per day hydrogen plant using natural gas with CCS
- Dow announces nuclear reactors to provide heat to chemical plants

Decarbonize All Liquid Fuels with Drop-In Replacements

Results based on workshops and analysis

1. C. Forsberg and B. Dale. Fuelling the World with Biomass, The Chemical Engineer, 3 November 2023. https://www.thechemicalengineer.com/features/fuelling-the-world-with-biomass/
2. C. W. Forsberg, "What is the Long-Term Demand for Liquid Hydrocarbon Fuels and Feedstocks?" Applied Energy, 341, 121104 (1 July 2023). https://doi.org/10.1016/j.apenergy.2023.121104
3. C. W. Forsberg and C., B. Dale, Can a Nuclear-Assisted Biofuels System Enable Liquid Biofuels as the Economic Low-carbon Replacement for All Liquid Fossil Fuels and Hydrocarbon Feedstocks and Enable Negative Carbon Emissions?, https://doi.org/10.2172/2281710 April 2022

Industry moving in this direction

Dow Chemical has ordered 4 reactors to provide heat to their Seadrift chemical plant in Texas. .

Affordable hydrogen at scale.

•Exxon-Mobil recently announced plans for the first billion cubie foot per day natural gas to hydrogen plant with sequestration of more than 98% of the carbon dioxide byproduct. Cost under $2/kg.
•Topsoe (flowsheets): Blue Ammonia Fueling the Future Today, https://engage.topsoe.com/l/997541/2023-12-21/211vc/997541/1703167792ngjp1DT2/0390.pdf

Integrated oil/biofuels refinery.
Neste Corporation, Neste's crude oil refinery in Finland to be gradually transformed into a renewables and circular solutions refining hub, 20 December 2023 https://www.neste.com/releases-and-news/sustainability/nestes-crude-oil-refinery-finland-be-gradually-transformed-renewables-and-circular-solutions
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