Can a Nuclear Biofuels System Enable Liquid Biofuels as the Economic Low-carbon Replacement for All Liquid Fossil Fuels and Hydrocarbon Feedstocks and Enable Negative Carbon Emissions?

Three Wednesday Webinars (No Registration Fee): 10:00-1:30 Eastern; August 4, 11 and 18

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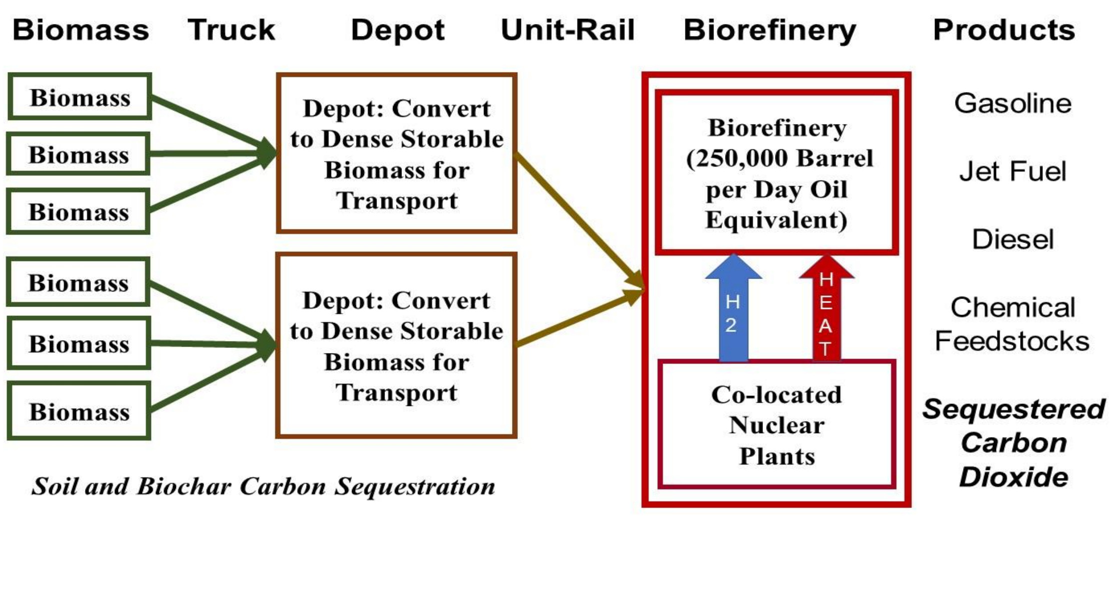
A workshop is being organized to address the question: *Can a nuclear biofuels system enable liquid biofuels as the economic low-carbon replacement for all liquid fossil fuels and chemical industry hydrocarbon feedstocks where nuclear energy provides the low-carbon heat and hydrogen at the biorefinery?*

Lignocellulosic biomass has long been used as an energy source but it is also a source of renewable carbon that can be converted into hydrocarbon fuels. If external heat and hydrogen from nuclear plants are provided to the biorefinery, rather than using biomass as both the heat and hydrogen source, the energy content of the biomass-derived hydrocarbon fuels can be more than double the energy content of the biomass itself. External energy inputs from a nuclear plant enable (1) a much smaller land base to supply the necessary biomass for a desired amount of biofuels and (2) using biological carbon sources that are poor fuels to provide the necessary carbon. External heat and hydrogen (1) becomes the enabling mechanism for biomass to replace crude oil for a fast transition off fossil fuels and (2) may be 15% of total U.S. energy consumption—the second biggest nuclear market after electricity.

System economics require very large biorefineries (equivalent to 250,000 barrel/day oil refineries). Very large biorefineries in turn require (1) conversion of locally-produced biomass within intermediate processing facilities called "depots" into energy-dense storable intermediates that can be economically shipped from these depots to the biorefineries and (2) massive low carbon, concentrated energy inputs at the biorefinery that are only available from nuclear power or fossil fuels with carbon capture and sequestration. Large refineries enable a variable product slate with time including variable carbon dioxide for sequestration depending upon market prices for liquid fuels and negative carbon emissions. A simplified system schematic is shown below.



System Design (Webinar 1: August 4, 2021)

1. **Welcome**: The Challenge. Charles Forsberg (MIT)/Bruce Dale (MSU)

   Modern civilization exists because of the remarkable properties of liquid fossil fuels—affordable, easily stored, dense energy source that are easy to transport. It is the chemical form of liquid fossil fuels [$(CH_2)_x$] that creates these remarkable properties. The problem is that the burning of fossil fuels adds carbon dioxide to the atmosphere that drives climate change. Biomass can provide an alternative source of carbon. Because plants remove carbon dioxide form the air, burning biomass does not change the carbon dioxide content of the atmosphere. The question is: Can we fully replace fossil hydrocarbons using carbon from biomass? If we can accomplish this, the proposed nuclear biofuels system provides a fast route to decarbonization because we do not have to rebuild the entire fossil fuel use infrastructure from transportation to industry to home heating.

2. ***Roadmap***. Charles Forsberg (MIT): Roadmap for Replacing Liquid Fossil Fuels and Chemical Plant Feedstocks with a Low-Carbon Nuclear Biofuels System

3. ***Availability of Biomass as a Carbon Source***. Bruce Dale (MSU): Biomass Feedstock Resources vs Price, Accessing the Potential of Biomass from Semi-arid Lands

4. ***Carbon Dioxide Sequestration and Negative Carbon Emissions***. Howard Herzog (MIT): Cost and Constraints of Carbon Dioxide Sequestration

5. ***Refinery Economics and Operations***. (**Speaker Invited**)

6. ***Feedstocks and Utilities Supply and Quality for the Biorefinery*** **(Speaker Invited)** The biomass and hydrogen/electricity suppliers have business requirements that must be balanced with the business needs of the biorefinery.

7. ***Roundtable Discussion with Audience Participation***

   How well do we understand the biomass resource base in the context of liquid fuel needs? What policies would accelerate the demonstration and commercialization of the technologies?

Biomass Supply Chain to the Refinery (Webinar 2: August 11, 2021)

The biomass supply chain is from the farm/forest to the nuclear biorefinery front gate. The depot converts low-density biomass into a high-density, storable, shippable product. However, it has other impacts. Depot processes generate secondary streams that in many cases enable recycle of nutrients back to farm and forest to improve long-term sustainability and soils.

8. ***Wet versus Dry Biomass Intermediate Products.*** Lynn Wendt (Idaho National Laboratory, US Dept. of Energy) Wet versus dry storage and transport of biomass: what are the options and constraints? Woody versus non-woody biomass: options and constraints?

9. ***Depot Processing Options: Densification of Energy Content, Fractionation and Blending***. Richard Hess (INL): Depot Processing Options for Economically Transportable and Storable Feedstocks. Blending various feedstocks for uniform formats.

10. ***Conversion of Biomass to Digestate, Methane and Carbon Dioxide.*** Lisa Schulte-Moore (Iowa State University) Biomass is converted to biomethane and carbon dioxide by anaerobic digestion of biomass at the depot (local) level for pipeline shipment to the biorefinery..

11. ***Carbon-Negative Electrobiofuels from Regional Pyrolysis Depots*.** Christopher Saffron (Michigan State University) Fast pyrolysis in small-scale rural depots densifies biomass in the form of bio-oil, a mixture of organic oxygenates and water.

12. ***Transportation from Depot to Biorefinery*** (Dani Jones, North Carolina State University) Logistics Costs and Challenges for Large-Scale Biofuels: Truck, Unit Train and Barge. Transportation drives system design because it is uneconomic to transport low-density biomass long distances to large nuclear biorefineries. What are the economics and constraints?

13. ***Roundtable Discussion with Audience Participation***
    What is the commercialization strategy for the depots? What are the tradeoffs between agriculture and biomass fuels? What policies would strengthen agricultural sustainability given the capabilities of some depot options?

Nuclear Biorefinery Options (Webinar 3: August 18, 2021)

14. ***Ethanol Upgrading to Hydrocarbon Fuel Blendstocks***. John Hannon (Vertimass) Ethanol to hydrocarbons route via the Guerbet ethanol oligomerization reaction.

15. ***Direct Hydrodeoxygenation of Lignocellulosic Biomass to Hydrocarbons***. Ana Rita C. Morais (University of Kansas). Conventional catalysts can convert biomass directly to fossil fuel equivalents via hydrodeoxygenation.

16. ***Fisher-Tropsch Liquid Fuels***. (**Speaker Invited**) The Fischer-Tropsch process can convert almost any carbon-containing feedstock into a synthetic crude oil that is then the feedstock to the refinery.

17. ***Nuclear Hydrogen Production***. Eric Ingersoll (Lucid Catalyst): Nuclear hydrogen may be the low-cost hydrogen production option. The biorefinery requires massive amounts of heat and in some cases oxygen.

18. ***Hydrogen Production with Carbon Capture and Storage***. (**Speaker invited**) Hydrogen production from methane combined with sequestration of carbon dioxide

19. ***Matching Nuclear Reactors to Biorefinery Requirements***. (**Speaker invited**) Different nuclear biofuels systems have different temperature and size requirements that drive preferred rector choices.

20. Roundtable Discussion with Audience Participation

What does the nuclear biorefinery look like? What is the transition path? Is it build out at existing refineries?