PROGRESS REPORT

PROJECT TITLE: Technoeconomic Analysis of Carbon Dioxide to Fuel in Corn Ethanol Plants
PROJECT NUMBER: 6081-22D
PROJECT PERIOD: April 2022 - March 2024
REPORTING PERIOD: April 2022 – March 2023
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1.) PROJECT ACTIVITIES COMPLETED DURING THE REPORTING PERIOD. (*Describe project progress specific to goals, objectives, and deliverables identified in the project workplan.*)

This research seeks to set the groundwork for large-scale projects to capture carbon dioxide (CO_2) emitted from corn ethanol plants and convert it to renewable fuels using solar or wind energy. In the project, the University of Minnesota (UMN) will collaborate with the Chippewa Valley Ethanol Company (CVEC) plant to determine the energy and cost benefits of converting waste CO_2 to methanol and so-called "e-gasoline", a hydrocarbon blend with similar properties to petroleum-derived gasoline. The primary goals of the one-year effort will be to determine the energy requirements, capital costs and financial benefits of installing a CO_2-to-fuel system as an external facility attached to one or multiple corn ethanol plants. As part of the work scope, different blending levels of e-gasoline with ethanol will be considered from using the generated fuel as a denaturant through creating a fully renewable blending stock to create renewable E85. Additional modeling work will estimate the benefits of custom renewable E85 blends on spark-ignition engine efficiency and CO_2 emissions. The objectives relevant to this reporting period are in **bold** below:

- **Build plant model for hydrogen production, methanol synthesis, and M2G processes on top of already validated CVEC plant model.**
- Conduct parametric studies using developed model for renewable ethanol blends and fuel quantities.
- Determine optimal E85 blending hydrocarbons for internal combustion engine performance through engine modeling.
- Finalize cost benefits and return on investment at various scales of implementation.
- Revise reactor as needed and disseminate findings through conference presentations, journal publications, and discussions with plant operators.

Progress Update:
In the first year of the project, the team made significant progress on the first project objective.

Lit Review: on M2G.Under the first objective, we studied the existing literature on the M2G topic to understand the state-of-the-art and identify the potential areas where further improvements or analysis can be useful. The MTG process needs improvement in yield and efficiency before it can be commercially viable. Research areas for the MTG process include catalyst development, process optimization, feedstock selection, scale-up and commercialization, and evaluation of environmental impact. Future research directions involve developing catalysts that minimize coking, validating reactor designs, exploring the feasibility of using some recycled streams, and improving the conversion of biomass to high-octane gasoline. Though progress has been made in these areas, there are still research gaps that need to be addressed to improve the process further, such as finding ways to convert biomass into high-octane gasoline using thermo-chemical processes, developing catalysts to minimize coking, and validating reactor designs.

Lit Review: on other avenues. During the literature review process, we also found various other avenues that are being researched to capture carbon dioxide from industrial units. These alternate methods may or may not lead to reusable product, nevertheless they are incentivized under section 45Q tax credit. Some alternate cases that might be beneficial to be implemented in CVEC are listed in Table-1. Further analysis will be conducted to evaluate and compare the environmental and financial incentives associated with each of the pathways.

Sr. No.	**Product**	**Reaction**	**Key Benefits**
1	Denaturant/Natural Gasoline	M2G + Blend with Ethanol	High-value product
2	Methane	Sabatier Reaction	Methane can be internally reused for distillation reducing energy cost
3	Carbon	Methanation and Pyrolysis	Potentially Higher Tax Incentive, Hydrogen recirculation reduces power requirement in electrolysis
4	Syngas	Using Solid Oxide Fuel Cell	Single step reaction, Syngas can be internally reused for distillation,
5	Gasoline from ethanol	Same as MTG	We already have plenty amount of ethanol to be converted to gasoline

Modeling:

We have started developing models to replicate the process found in literature. On the M2G process side we have established that for the purpose of our analysis a thermodynamic model based on stoichiometry would be required. This will be achieved thru “R-yield” reactor block in Aspen. On the renewable hydrogen production, we completed modeling an alkaline electrolyzer. This model will now be updated to make a custom, physics based, Proton Exchange Membrane (PEM) cell model which offer better performance and higher output pressure (up to 40 bar) of hydrogen. We are using AspenTech software suits for making these models.

Next steps:

The next steps include the completion of the Aspen models corresponding to various pathways and integrating with validated CVEC model. These sets of models will be used to generate data. Consequently, this data will be used to conduct an economic analysis for various pathways.

2.) IDENTIFY ANY SIGNIFICANT FINDINGS AND RESULTS OF THE PROJECT TO DATE.

The preliminary analysis conducted based on the literature survey has helped us establish the gasoline blend that is desired for E-85 and denaturant applications which is highlighted in Fig-1.

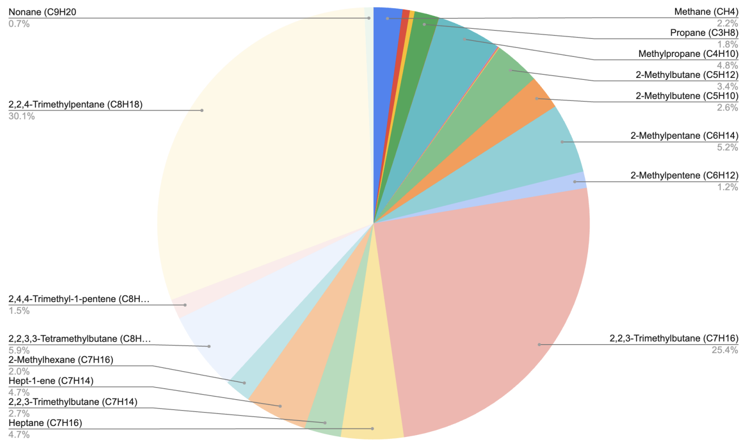

Figure 1: Desired gasoline blend derived from the literature.

During the study of the validated CVEC model, we have identified areas where waste heat can be leveraged to save energy. Further analysis will be conducted to optimize waste heat recovery. As a result of literature study and analysis, 4 new pathways apart from making vehicle grade E-85 have emerged. Further modeling and analysis will be conducted to optimize carbon capture and economic aspects to choose the viability of these approaches.

3.) CHALLENGES ENCOUNTERED. (*Describe any challenges that you encountered related to project progress specific to goals, objectives, and deliverables identified in the project workplan.*)

This project was extended through a no-cost extension for one year from the original final date due to staffing issues at UMN. The project has been staffed since the beginning of calendar year 2023 and is now well underway.

4.) FINANCIAL INFORMATION (*Describe any budget challenges and provide specific reasons for deviations from the projected project spending.*)

No budget challenges were encountered during this period.

5.) EDUCATION AND OUTREACH ACTIVITES. *(Describe any conferences, workshops, field days, etc attended, number of contacts at each event, and publications developed to disseminate project results.)*

No significant outreach activities were associated with the project during the reporting period.