MinnesotaCorn
RESEARCH & PROMOTION COUNCIL

PROGRESS REPORT

PROJECT TITLE: **Ethanol Fuel Cell**
PROJECT NUMBER: 6105-23DD
REPORTING PERIOD: Ending September 30, 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.*

During this period, AURI conducted a detailed techno-economic review of the ethanol reforming process by SBI of Edmonton, Saskatchewan, Canada. As previously mentioned, SBI is the only company AURI is aware of with a reasonably proven process technology and has completed the engineering of a larger-scale system. After a comprehensive analysis, AURI found that ethanol reforming is technically feasible and economically on par with electrolytic green hydrogen. However, certain challenges and limitations must be addressed before scaling this process.

While the technology is only established at the pilot scale (25 kg H2 per day), AURI is confident in its scalability based on the process's characteristics. SBI's proposal to scale it to 1250 kg/day reinforces this confidence. Most importantly, the catalyst's performance has been consistent over a sufficiently long period, allowing us to derive reliable data on its efficacy. AURI's Luca Zullo visited SBI's Edmonton facility to examine its pilot site and review the engineering plans for the 1250 kg/day industrial-scale reformer. Using both SBI's engineering and economic data and our independent analysis, AURI estimated the capital and operating costs of a standalone hydrogen refueling station centered around the 1250 kg/day reformer. SBI validated these data, concurring with AURI's findings.

AURI's primary objective was to explore the viability of using ethanol as a hydrogen carrier to refuel fuel cell-powered heavy-duty vehicles, such as buses and large trucks. Given the weight constraints and extended recharge times of batteries, battery electrification might be impractical for these heavy-duty vehicles. AURI hypothesizes that using ethanol as a hydrogen carrier can not only sustain but also expand the demand for ethanol in markets where the electrification of fleets might cause a decline in gasoline, and consequently, ethanol demand.

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

AURI determined that with a capital cost of approximately $15-17M ($8.5M for the core reformer, with the remainder allocated to the rest of the plant), the production of 1250 kg/day of hydrogen from ethanol could compete with green hydrogen derived from hydrolysis. This is under the assumption that power costs

$30 per MWh with a utilization factor of 35%. The unsubsidized cost of hydrogen from ethanol—assuming an ethanol delivery cost of $2.50/gal—ranges between $8 and $11 per kg. The final report will delve into the details and address the significant uncertainties surrounding the economics of green hydrogen. Nevertheless, from an economic standpoint, ethanol appears to be a promising hydrogen feedstock, particularly for distributed production. An ethanol reforming plant is relatively compact, and the SBI 1250 kg/day reformer also fits within a 40 ft container. The entire refueling station would occupy less than an acre. Additionally, a road tanker filled with ethanol carries more hydrogen than a tanker of other proposed carriers, such as ammonia, compressed hydrogen, or liquefied hydrogen. The ethanol supply chain is already well-established and extensive.

Hydrogen production has been the beneficiary of an aggressive incentive policy, as reflected in the 45V tax credit set forth by the Federal government. This policy incentivizes low-carbon-intensive hydrogen production by offering a tax credit based on the carbon intensity of the hydrogen. The exact amount of the tax credit is illustrated in the following table (Table 1). Beyond the basic carbon intensity (CI)-driven tax credit, the 45V code allow for a project-specific multiplier bonus contingent on the project incorporating components made in the US, paying prevailing wages, and employing union labor—factors currently being set aside. Electrolytic hydrogen typically qualifies for the full incentives ($3/kg), whereas blue hydrogen—hydrogen derived from natural gas with CO2 sequestration—qualifies for the most discounted incentive tier at 20% or $0.60/kg.

kg CO2e/kg H2	Tax credit (w/o bonus) $/kg H2	
2.5 – 4	$0.60	20%
1.5 – 2.5	$0.75	25%
0.45 – 1.5	$1.20	40%
0.45 or less	$3.00	100%

Table 1 - 45V Green Hydrogen Tax Credit

AURI deduced the CI of hydrogen from ethanol using average numbers for US corn ethanol CI (between 45 and 53 gr CO2e/MJ)[1]. Regrettably, while this hydrogen has a CI lower than gray hydrogen (hydrogen from natural gas without CO2 sequestration), its CI exceeds that of blue hydrogen. This means it must be reduced further to be eligible for the 45V tax credit, as depicted in the figure, which poses a significant long-term disadvantage.

It should also be studied whether this CI is adequate to meet the requirement of the CA low carbon fuel standards and future low carbon fuel standards expected to be established at various State and potentially Federal level.

[1] Sources: RFA and DOE-Greet

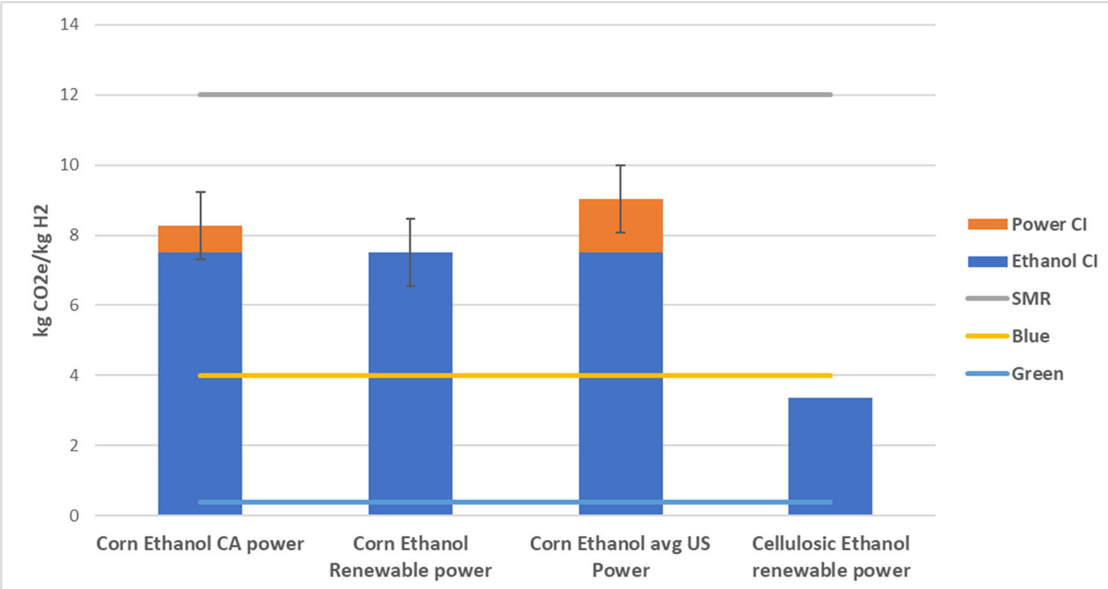

Figure 1- Carbon intensity of ethanol derived hydrogen in kg of CO2e/kg of hydrogen under current corn ethanol CI

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

The unexpectedly high CI of hydrogen derived from ethanol is the primary setback and challenge of this project. While the CI results are disheartening, especially since the method is technically and economically viable in other aspects, there is a clear path forward. Cellulosic ethanol (with a CI of approximately 22 gr CO2e/MJ) can potentially match the CI of blue hydrogen, which currently – and for the foreseeable future – stands as the main competitor in the automotive fuel cell market.

Even though cellulosic ethanol is not yet available commercially in substantial amounts, producers of conventional corn ethanol are also exploring various strategies, including carbon sequestration, to significantly reduce its CI. Moreover, capturing and recycling the CO2 generated during the reforming of ethanol could also markedly decrease the hydrogen's CI. We intend to delve deeper into this matter to determine which CI mitigation strategy might be feasible and to identify which aspect of the ethanol CI has the most significant impact on the hydrogen's CI. This will help in prioritizing mitigation strategies.

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

None. The project is on budget.

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

Ethanol as a hydrogen carrier and the opportunities presented by this technology will be discussed at the December 2023, AURI Minnesota Renewable Energy Roundtable event. AURI views the CI issue as only a temporary setback since the industry is actively working to reduce its overall CI and this can present yet another chance to advance the decarbonization of ethanol production through various methods, including reducing chemical inputs in production, employing advanced processing, increasing the use of renewable energy, and reusing CO2[2].

[2] See for example: H.Xu et al, "Life-cycle greenhouse gas emission reduction potential for corn ethanol refining in the US", Biofuel Bioproducts and Biorefining 16:671-681 (2022) DOI: 10.1002/bbb.2348