NREL
NATIONAL RENEWABLE ENERGY LABORATORY

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

Electrolyzer/Bioreactor Integration (EBI)

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FY2020 • Project ID#: H2057

RELEVANCE

The growing penetration of renewable electricity sources requires a long-duration energy storage solution which can include hydrogen (H_2) generated via water electrolysis. One potential opportunity to accelerate renewable H_2 production is to combine the gas with carbon dioxide (CO_2) in a biomethanation process. In a bioreactor, CO_2 from our waste streams (e.g., dairies, wastewater treatment, landfills) are biologically combined with H_2 to produce renewable natural gas (RNG). RNG is a 100% direct drop-in replacement for fossil natural gas and faces no material compatibility or end-use issues.

OBJECTIVES

Reduce to practice innovations in the non-provisional U.S. and International (PCT) patent that aim to improve capital cost and efficiency of the electrolyzer, while increasing the productivity of the organisms in the bioreactor. This work starts with a modeling effort, design, integration and operations of the scaled-down electrolyzer/bioreactor system to determine the impact of the IP as systems are scaled to 5 – 10 MW.

SUMMARY

CRADA 19-809 agreement executed in August 2019.

- CRADA modification in process to add SoCalGas 700L bioreactor system to this agreement
- This new project started in FY20 that leverages (not duplicating) objectives of a BETO-funded Biopower project.
- NREL and SPXFlow modelers will use computational fluid dynamics to inform a scaled-down (10 – 30L) pressurized bioreactor design.
- IP developed at NREL and licensed to SoCalGas will be investigated to validate the expected improvements in capital cost, efficiency and organism productivity with a 10 kW electrolyzer the bioreactor funded by the Biopower project.

Co-funding breakdown;

- $700K Southern California Gas Company
- $100K DOE HFTO
- $600K DOE BETO

PARALLEL WORK

DOE BETO awarded a complementary project, called Biopower, that is focuses on the production of pipeline quality renewable natural gas from biogas sources. In particular, the Biopower project, while complementary with this EBI project, focuses on techno-economic analysis, life-cycle analysis, carbon intensity, analytical methods and the scale-down (10 – 30L) bioreactor.

In contrast, this EBI project is focused on the design and fabrication of a low-cost electrolyzer, improved H2 mass transfer and further developing the IP of a closely-coupled electrolyzer bioreactor system for improved efficiency, organism productivity and cost.

Any proposed future work is subject to change based on funding levels

APPROACH

In collaboration with Southern California Gas Company, Electrochaea GmbH, University of Chicago and SPXFlow, an industry-leading gas mixing company, this project focuses on systems integration to improve H_2 mass transfer by implementing NREL IP.

INTELLECTUAL PROPERTY

A licensing agreement has been completed with SoCalGas.

The international ("PCT") patent application corresponding to NREL Record of Invention No. 18-48 was published in January 2020 by the World Intellectual Property Office (WIPO). This publication is available to the public.

Relevant data for this patent application are below:

- Publication No.: WO 2020/018998 A1
- Application No.: PCT/US19/42861

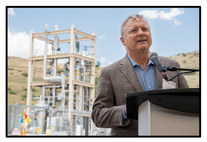
To facilitate commercial production of this technology at scale (5 - 10 MW), validation of the capital cost and efficiency improvements are needed prior to scaling to MW-scale.

PARTNERSHIPS

To accelerate the commercial deployment of thus technology, NREL has teamed with Southern California Gas Company (SoCalGas) and the DOE HFTO and BETO programs to further develop the intellectual property (IP) originated in an earlier research & development (R&D) agreement.

Southern California Gas Company
A Sempra Energy utility

Electrochaea



Ron Kent

Doris Hafenbradl

TECHNOLOGY

The process of biomethanation, the biological conversion of hydrogen (H_2) and carbon dioxide (CO_2) to methane (CH_4), spans key programmatic efforts including; the Hydrogen Fuel Technologies Office (HFTO) H_2@Scale initiative, the Bioenergy Technologies Office (BETO) waste-to-energy and CO_2 utilization programs and NREL's Electrons-to-Molecules (E2M) strategic.

The benefits of this approach include;

- Recycles CO2 from waste steams like landfills
- Can be carbon negative when projects are located at carbon sources like dairies
- Can participate in carbon markets like LCFS and RFS when RNG product is sold into transportation
- Drop-in replacement fuel with fossil natural gas and 100% compatible with pipeline, welds and equipment

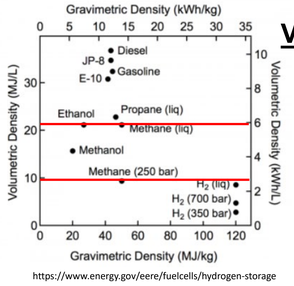
CHALLENGES & BARRIERS

Emerging Markets & Drivers

- H_2 production may enable higher penetrations of renewable electricity, helping states and regions achieve their renewable portfolio standards
- A growing number of utilities have decarbonization goals that include producing RNG
- Existing carbon markets from California's Low Carbon Fuel Standard and Federal Renewable Fuel Standard and 45Q are helping to incentivize a move towards low- and negative-carbon fuels for transportation and heat

Hydrogen Production & Mass Transfer

- Electrolyzer systems, both alkaline and polymer exchange membrane (PEM), capital cost range from $750 - $1000 per kilowatt (kW), today
  - Only the cost of electricity is a greater contributor to the final cost of hydrogen ($ / kilogram (kg))
- Hydrogen has very solubility and biological performance is limited by the systems ability to get the gas dissolved in water



https://www.energy.gov/eere/fuelcells/hydrogen-storage

Volumetric Energy Density

- Producing renewable methane at 250 bar from low-cost H2 increases the energy to above liquid H_2

PROGRESS

This co-funded project started October 1, 2020. To date, we've traveled to and developed scopes of work with SPXFlow and the University of Chicago.

- The Rochester, NY-based company features a 50 square-foot water basin for detailed testing, refinement, and development of advanced water and wastewater treatment mixing systems.

- 16' long trailer was designed and built
- ~ 2kW of photovoltaic modules will help power the electrolyzer stack
- A separate control room will monitor & control the system

MILESTONES

Milestone	End Date	Type
Complete a detailed statement of work for SPX Flow to perform CFD and other modeling tools on the existing 700L and scaled-down 18 bar bioreactor systems.	12/31/2019 (Completed)	Quarterly Progress Measure (Regular)
Complete a detailed statement of work to perform work in the area of water management in the bioreactor system from the reaction and the intellectual property being developed at NREL.	3/31/2020 (Completed)	Quarterly Progress Measure (Regular)
Complete the integrated system design and PHA/HAZOPS ready for vendor build proposals, of the closely-coupled electrolyzer stack to the scaled-down 10-30L bioreactor system.	6/30/2020 Likely delayed 1Q	Quarterly Progress Measure (Regular)
Complete the SPX Flow agitator and gas mixing modeling of the 700L pilot & 10-30L scaled-down system so to show at least 13 g CH_4/ L-h organism productivity from the 10 – 30L design.	9/30/2020 Likely delayed 1Q	Annual Milestone (Regular)
Reduce IP to practice to achieve 5 – 10% capital cost reduction, 3 -5% efficiency gains and 0 – 20% productivity gains from IP developed for integrated electrolyzer/bioreactor system.	9/30/2021	Annual Milestone (Regular)

TASKS

- IP Development - Reduce to practice innovations contained in the non-provisional patent to improve the capital cost and efficiency of the electrolyzer while increasing the productivity of the organisms in the bioreactor
- This work starts with a modeling effort, design, integration and operations of the scaled-down electrolyzer/bioreactor system to determine the impact of the IP.

SUBCONTRACTORS

Name	Responsibility	Planned Cost ($)	Type	Start Date
SPX Flow	Model and develop a scaled-down gas mixing system for the 10-30L bioreactor system	$75K	All Other	6/1/2020
University of Chicago	Proof-of-concept data for either biomethanation water management through producing hydrogen within the bioreactor using a full-culture electrolyzer or utilizing syngas as a feedstock for RNG production	$75K	Private Higher Education	6/1/2020