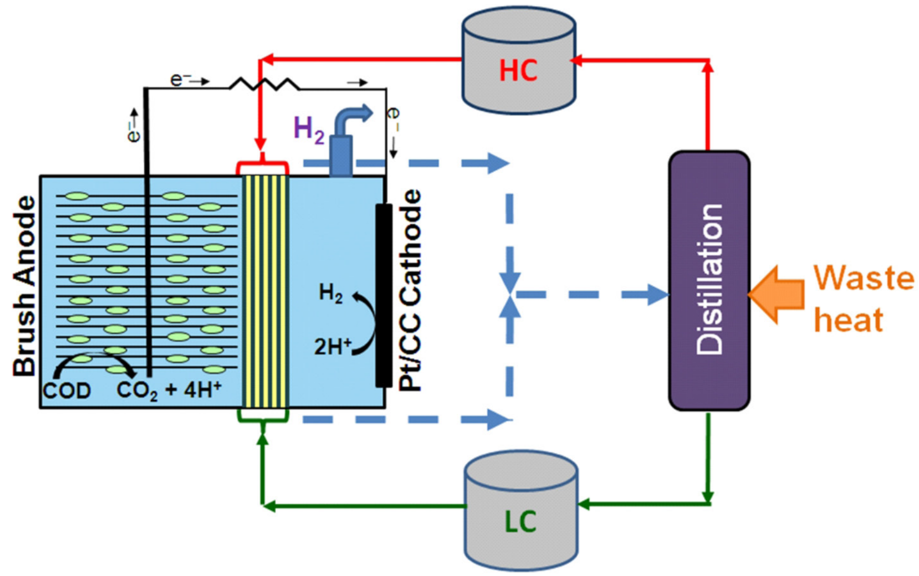
Bioelectrochemical Integration of Waste Heat Recovery, Waste-to-Energy Conversion, and Waste-to-Chemical Conversion with Industrial Gas and Chemical Manufacturing Processes

Advancing a Novel Microbial Reverse Electrodialysis Electrolytic System



The MHRC System Concept. *Graphic courtesy of Nam, Cusick, Kim & Logan (2012) Environment Science and Technology*

Many current manufacturing processes produce both low-grade waste heat and wastewater effluents which contain organic materials. A microbial reverse electrodialysis electrolytic cell, designed to integrate waste heat recovery (i.e a microbial heat recovery cell or MHRC), can operate as a fuel cell and convert effluent streams into electric power, or operate as a microbial electrolysis unit and produce hydrogen.

The driving force in a reverse electrodialysis system is the energy that is captured using the concentration difference between streams with high- and low-salinity, such as seawater and fresh water. In a novel improvement, industrial waste heat will regenerate the salt streams using a volatile salt in a closed loop system.

In a further novel improvement, integrating a microbial electrolytic cell with waste-heat-driven reverse electrodialysis eliminates the need for an external power source to provide the electric potential required to produce hydrogen. This same technology can be applied to a microbial fuel cell for electric power production. Integration of reverse electrodialysis with microbial electrolysis can increase overall system performance relative to independent operation of the individual systems.

Benefits for Our Industry and Our Nation

MHRCs could increase industrial energy efficiency, reduce emissions of greenhouse gases and environmental pollutants, and reduce solid and liquid wastes. As a result, this technology could reduce manufacturing costs across all applicable industries. In addition, MHRC technology is expected to be operable with lower-grade waste heat that would otherwise be unsalvageable by conventional waste heat recovery processes. Compared to existing wastewater treatment processes, the MHRC technology is expected to have much higher efficiency, higher yield, and a significantly smaller footprint. With successful deployment, MHRC technology could generate over 1% of total industrial electricity demand, or alternatively, could be employed to produce high-value hydrogen.

Applications in Our Nation's Industry

MHRC is compatible with current and future manufacturing infrastructure. It requires only low-grade waste heat and can be retrofitted into existing operations. Therefore, it is quite possible to integrate this technology into many manufacturing applications. MHRC is most applicable to manufacturing facilities in the chemical, food, pharmaceutical, and refinery markets, which typically have effluent chemical oxygen demand (COD) and availability of low-grade waste heat sources. The pulp and paper industry and other industries are also potential MHRC users.

Project Description

This project will develop an MHRC system prototype using wastewater effluent samples from candidate facilities to produce either electric power or hydrogen.

Barriers

- Practical challenges associated with using substrates obtained from chemical and other industrial manufacturing processes.
- Scale-up of the system to industrial levels.

Pathways

An initial laboratory study will determine suitable characteristics of effluent substrate candidates and waste heat sources. Sample substrates from different source locations will be screened in the laboratory. Methods to remove organics and COD and generate electricity will be tested. Process modeling will be conducted concurrently to assess economic feasibility. Site selection will be made based on requirements for prototype testing and optimal process configuration.

Once the site has been selected, the optimum level of subsystem integration between all MHRC components will be determined based on the laboratory results. Implementation plans will be developed for prototype construction, installation, startup, and operation.

Later efforts will involve the construction, operation, and testing of a prototype system for a subsequent (post-project) pilot-scale demonstration. The prototype MHRC system will be installed, undergo shakedown testing to ensure equipment integrity, and then go through operational testing to collect data for at least three months. Performance improvement opportunities will be identified, and results will be used to develop 1) an optimized operating configuration, 2) a scale-up strategy, 3) a technology risk plan, and 4) recommendations for pilot plant scale-up and testing.

Milestones

This project began in 2012.

- Achieve an acceptable power or H2 yield based on total COD from at least one candidate substrate (2013).
- Determine a viable substrate source for integrated system laboratory studies and prototype testing (2013).
- Complete financial analysis and a detailed process model of the commercial-scale, integrated MHRC system with acceptable criteria (2014).
- Construct and test the prototype MHRC system (2015).

Commercialization

As a world-wide leading producer of hydrogen, Air Products possesses significant marketing and commercialization experience and is well-positioned for MHRC commercialization due to experience with both large- and small-scale hydrogen production facilities. Air Products is also highly qualified for commercialization because of extensive experience with implementation of energy efficiency productivity improvements. To help commercialization strategy development, Air Products will prepare a technology and market risk management plan to assess market uncertainty; identify customer specifications; define a business model; and identify remaining unresolved technical risks, associated consequences, and any required mitigation. Broad commercialization would be expedited following technology implementation and demonstration at multiple Air Products facilities.

Project Partners

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