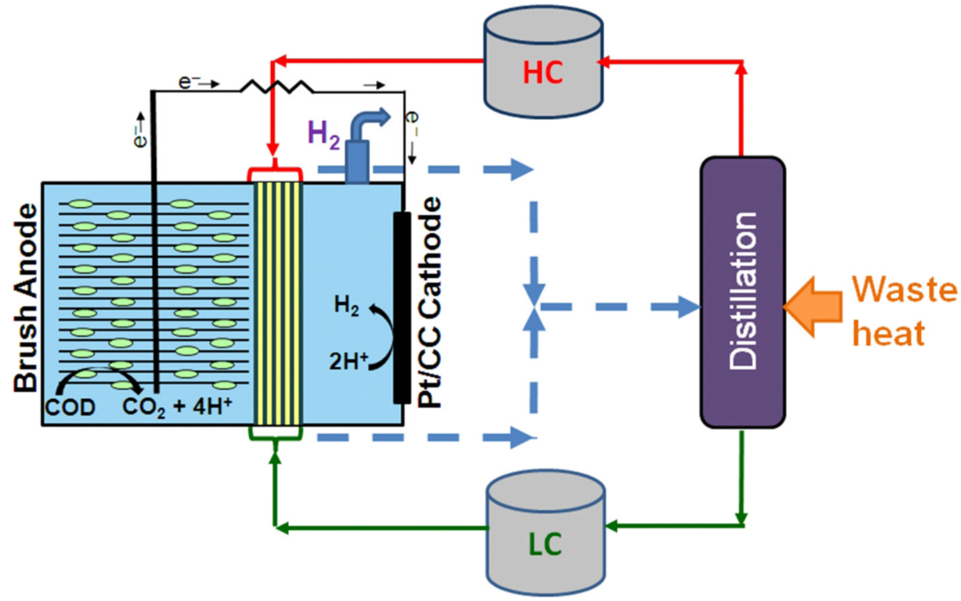
Microbial Heat Recovery Cell (MHRC) System Concept

# 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.




A schematic of the microbial heat recovery cell (MHRC) system. *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 that 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 it can 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 system 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 2% 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 with high chemical oxygen demand (COD) and low-grade waste heat sources. The pulp and paper industry and other industries are also potential MHRC users.

## Project Description

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

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

During the course of the system evaluation, a series of stochastic model runs were made of the system to evaluate the likely financial returns on the system as currently designed. The principal outcome of these studies was that the likelihood that a system could be designed that would achieve a positive return on investment is very small (less than 10%). The main factor in the unfavorable financial outlook was the cost of the ion exchange membranes used in the MHRC stack. It was determined that the cost of this component would have to be reduced by a factor of more than ten for the system to have a positive return. As membrane development was not a part of this project, Air Products and the DOE management team agreed to terminate the project.

### Milestones

This project began in 2012 and ended in 2015. Completed milestones included:

- Achievement of an acceptable power or $H_2$ yield based on total COD from at least one candidate substrate.
- Determination of a viable substrate source for integrated system laboratory studies and prototype testing.
- Completion of financial analysis and a detailed process model of the commercial-scale, integrated MHRC system with acceptable criteria.

## Commercialization

In view of the unfavorable financial outlook for the technology as currently configured, there are no plans to pursue commercialization. Air Products will continue to track the costs of system components, with special attention on the ion exchange membrane used in the MHRC stack. Air Products may resume work on the technology should the costs become low enough to justify further work.

## Project Partners

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Project final report available at *www.osti.gov/scitech*: *OSTI Identifier 1242987* ■