Hydrogen, Hydrocarbons, and Bioproduct Precursors from Wastewaters Workshop Summary Outline

Introduction

The U.S. Department of Energy's (DOE's) Bioenergy and Fuel Cell Technologies Offices sponsored a workshop on Hydrogen, Hydrocarbons, and Bioproduct Precursors from Wastewaters on March 17-18, 2015 in Washington DC. It gathered experts to share information and identify the current status and research, development and demonstration (RD&D) possibilities for production of hydrogen and higher hydrocarbons (containing four or more carbon molecules) from wastewaters using biological, biochemical, and other techniques. In particular, the workshop focused on Microbial Fuel Cell-based technologies (MxCs) and Anaerobic Membrane Bioreactors (AnMBRs). This draft summary is intended to provide participants in the April NSF-EPA-DOE Energy Positive Water Resource Recovery Workshop with initial highlights of the previous workshop's output. The ideas provided here represent a snapshot of the perspectives and ideas generated by the individual participants in attendance at the workshop.

Two expert panels provided information on the status of the fields and key issues and challenges. Presentations were given by Jason Ren, University of Colorado Boulder; Art Umble, MWH Americas; Bruce Logan, Penn State; Mark Ramirez, DC Water; Perry McCarty, ReNUWit program at Stanford/UCB; Derek Lovley, UMass Amherst; Jason He, Virginia Tech; and Meltem Urgun-Demirtas, Argonne National Laboratory. The presentation slides can be found at http://energy.gov/eere/fuelcells/hydrogen-hydrocarbons-and-bioproduct-precursors-wastewaters-workshop.

In the breakout sessions, participants discussed and identified system characteristics, key technical and non-technical challenges, possible solutions to the challenges, key RD&D activities, market opportunities and obstacles in the near and long term, and steps needed to connect RD&D activities with market opportunities.

Major Themes

Throughout the workshop, a number of themes emerged. A number of technical challenges and solutions identified are specific to a particular technology, and often to only a subset of systems. These will be addressed in greater detail in the workshop report. Common issues are described below.

Common technical themes

- **Better modeling**. Improved model covering: chemical reactions, microbial interactions, system integration with existing facilities, and other topics, were identified as a need for MxCs and AnMBRs, as well as to connect the technologies to market applications. The needs identified included more data, validation and calibration, and the ability to integrate models for different system aspects. Technoeconomic analyses and better understandings of the characteristics needed for market and industry acceptance are related needs.

- **Relevant demonstrations**. The need for real-world demonstrations, at relevant scales and using real wastewaters, was discussed for a range of technologies. This encompasses not only demonstrating that systems work at larger dimensions, but also issues such as cost-effectiveness at scale, the ability to manufacture designs at scale, and that required operations and maintenance are appropriate to the intended installation site.
- **Granular Activated Carbon (GAC).** Incorporating GAC into treatment systems seems be a solution that spans both MxCs and AnMBRs, and may merit further investigation.
- **Microbial communities**. Both MxCs and AnMBRs utilize microbial communities. Better understanding of the microbial activities and interactions, and methods to improve control of and optimize microbial communities were identified as important areas of RD&D for both technologies.
- **Nutrient recovery**. Both AnMBRs and MxCs offer possibilities for nutrient recovery, which could be an additional benefit to the use of these technologies for wastewater treatment.

Larger themes

- **Innovation challenges**. Regulatory, financial, and other risks constrain innovation in the field of municipal wastewater treatment.
    - Financial: Scaled up demonstrations may be needed to prove viability to get funding for further development, but those demonstrations would themselves require funding.
    - Regulatory: Treatment facilities that are regulated may be hesitant to have on site scaled-up demonstrations due to concerns that the system may result in discharged water that does not meet regulatory requirements, but demonstrations are needed to prove performance.
    - Interagency mission gaps: While technologies that can provide clean water while producing fuels may have many benefits, they do not fall clearly within the purview of a single funding source – for example, on the federal level, clean water and energy production are covered by different agencies.
- **Municipal utilities challenges**. Since municipal utilities generally do not seek profits, they do not offer the kinds of returns necessary to motivate private investment. Municipal water utilities are driven more by the needs for stable performance, rate stability, and discharge permit requirements than profit opportunities, and thus have limited incentive for RD&D. Some potential alternatives discussed include dedicated RD&D surcharges, methods to pool resources, and other ways to incorporate RD&D into budgets.
- **Collaboration, cooperation, and communication.** Mechanisms that encourage and support collaborative interactions between groups involved in all aspects of the technologies and wastewater applications were identified as a need, in order to better share information and allow cooperation rather than competition. Participation from industry through the sharing of information and expertise as well as financial support would be particularly welcomed, as would other kinds of public/private partnerships.

- **Early Markets.** Certain wastewater applications may provide better markets for early entry. In particular, industrial wastewater applications may offer attractive opportunities. Commonalities of suggested early markets include:
    - Wastewaters with characteristics that play to the strengths of the respective treatment technologies, such as combinations of high salinity and organic contamination as is seen in flowback and produced waters from oil and gas operations for MxCs, waters with high chemical oxygen demand (COD), or with the need for removal of contaminants of emerging concern, such as pharmaceutical manufacturers.
    - Situations where disposal costs are more of a driver, and are less subject to regulatory restrictions (e.g., food and beverage producers that discharge wastewaters to municipal systems).
    - Bioproduct precursors such as succinic acid, lactic acid, 1-4 butanediol, and many others may offer more lucrative initial markets than drop-in biofuels for light-duty vehicle applications, at least at the outset. Participants voiced the notion that support for these higher –value products might be a useful first step towards higher fuels volumes in the future.
    - Participants also voiced the need for market-driven applied RD&D. In addition to research that works towards developing technology with relevant cost, quality, quantity, performance, and other requirements, market assessments and analysis will be needed to identify the relevant needs. These needs will likely vary by niche market; research aimed at commercialization has to target a set of performance criteria tailored to particular applications.

These technologies offer many possible benefits including reducing energy needs for water treatment, fuel production, nutrient recovery and treatment of recalcitrant wastewaters. Many challenges remain, and further RD&D activities, techno-economic analyses, and possibly policy explorations, are needed to address these challenges.

This workshop was explicitly designed to feed into the event jointly sponsored by the National Science Foundation (NSF), Environmental Protection Agency (EPA), and DOE on “Energy-Positive Water Resource Recovery”, which will take place April 28-29, 2015 at the NSF. The collaborating agencies intend to produce a joint report that combines the outcomes of the two workshops into a single document. The overarching goals are to minimize the amount of energy required to treat organic wastewaters, and to maximize the energy output from those same waters, whether that energy is produced in the form of combined heat and power (CHP), hydrogen, or higher hydrocarbons as precursors to biofuels and bioproducts.