Integration of Microbial Fuel Cell Within Algal Bioreactor

(OTT ID 1265)

Inventor: Dr. Zhen He, Ph.D., Associate Professor

Department of Civil and Environmental Engineering, Virginia Polytechnic Institute and State University

For further information please contact:

Jessica Silvaggi, Ph.D.

Senior Licensing Manager

1440 East North Ave.

Milwaukee, WI 53202

Tel: 414-906-4654

jsilvaggi@uwmfdn.org

Current Problems with Sustainability

Problems:

- Municipal wastewater treatment plants play a critical role in environmental protection
  - They consume an extensive amount of energy
  - They do not focus on energy recovery

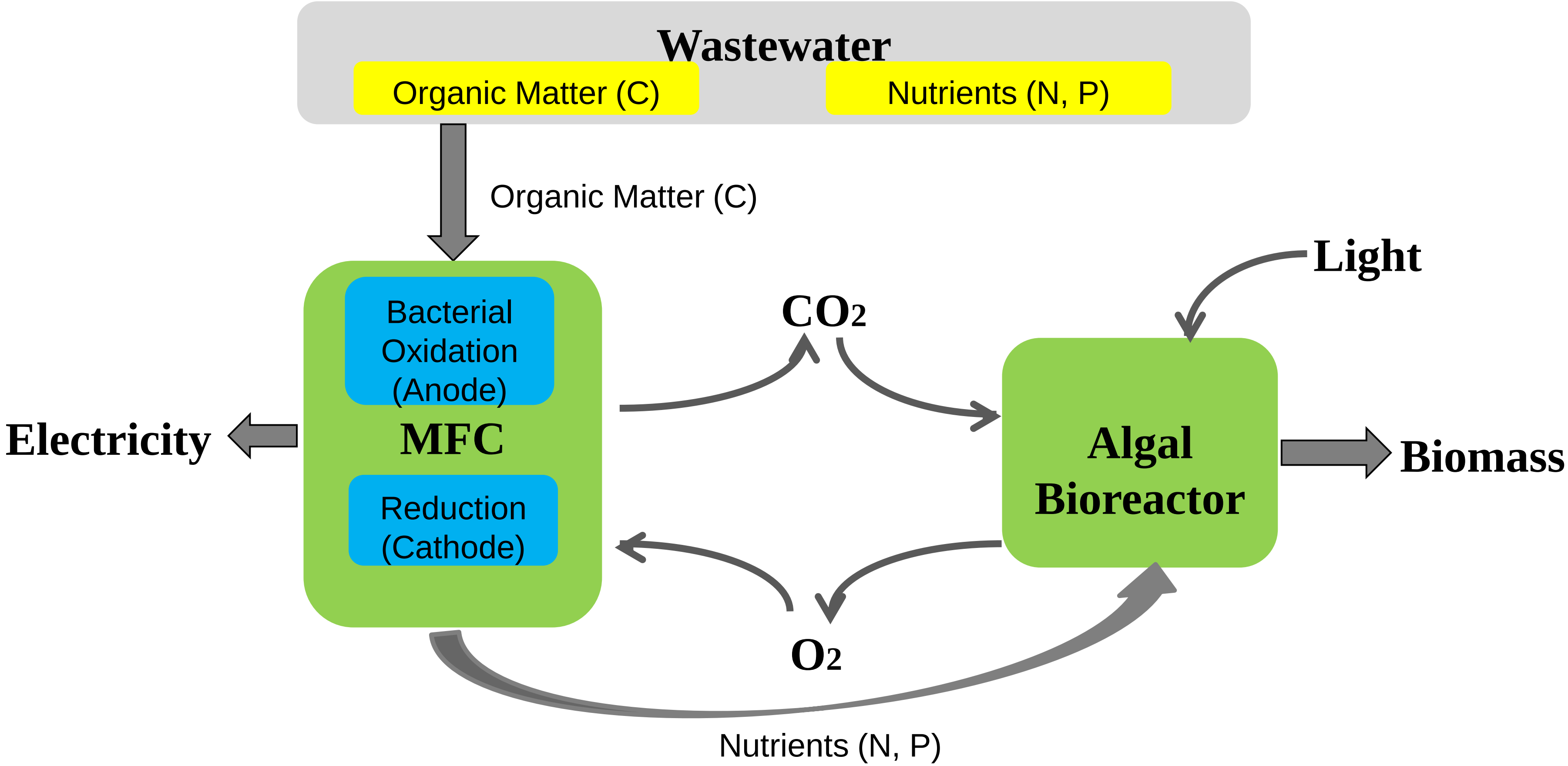
Solutions:

- Generate energy from:
  - Organic contaminants that were converted into bio-electricity using microbial fuel cells (MFCs)
  - Algal biomass for biofuels production

Integrated Photobioelectrochemical (IPB) System

Technological Solution:

- Dr. He has created an integrated photobioelectrochemical (IPB) system that combines previous methods of wastewater removal processes to achieve the most energy efficient method



Step-by-Step of IPB System

- Wastewater is fed into MFCs where organic contaminants are converted into bio-electricity
- Remaining nutrients are then discharged into an algal bioreactor for algal growth
- Installing MFCs inside an algal bioreactor yields algae producing oxygen via photosynthesis
- MFCs use this oxygen for their cathode reactions, thereby reducing the need for aeration
- MFC cathodic reactions can maintain pH if CO_2 is added into the bioreactor
- Two treatment processes are cooperatively linked for the same purpose of treating wastewater
- Two different bioenergy products: bioelectricity from the MFCs, and algal biomass for biofuels production

Key Features/Benefits of IPB System

- **Dual Use**– allows for the production of both bioelectricity and biomass simultaneously.
- **Efficient Waste Removal** – removes both organic wastes and nutrients from wastewater in one method.
- **Higher Yield** – the use of algae for bioenergy produces a higher yield than alternatives
- **Low Energy Consumption** - the treatment process by MFCs and algal bioreactors requires less energy than the conventional treatment technologies

Intellectual Property and Licensing

- U.S. Utility Patent US 9130216: Integrated photo-bioelectrochemical systems

- Looking for a development partner to:
  - Develop final product
  - Available for developmental research support/licensing under either exclusive or non-exclusive terms

Market Potential

Applications

- Biodiesel
- Biobutanol
- Bio gasoline
- Methane
- Ethanol
- Hydrogen derived renewable fuel
- Jet fuel

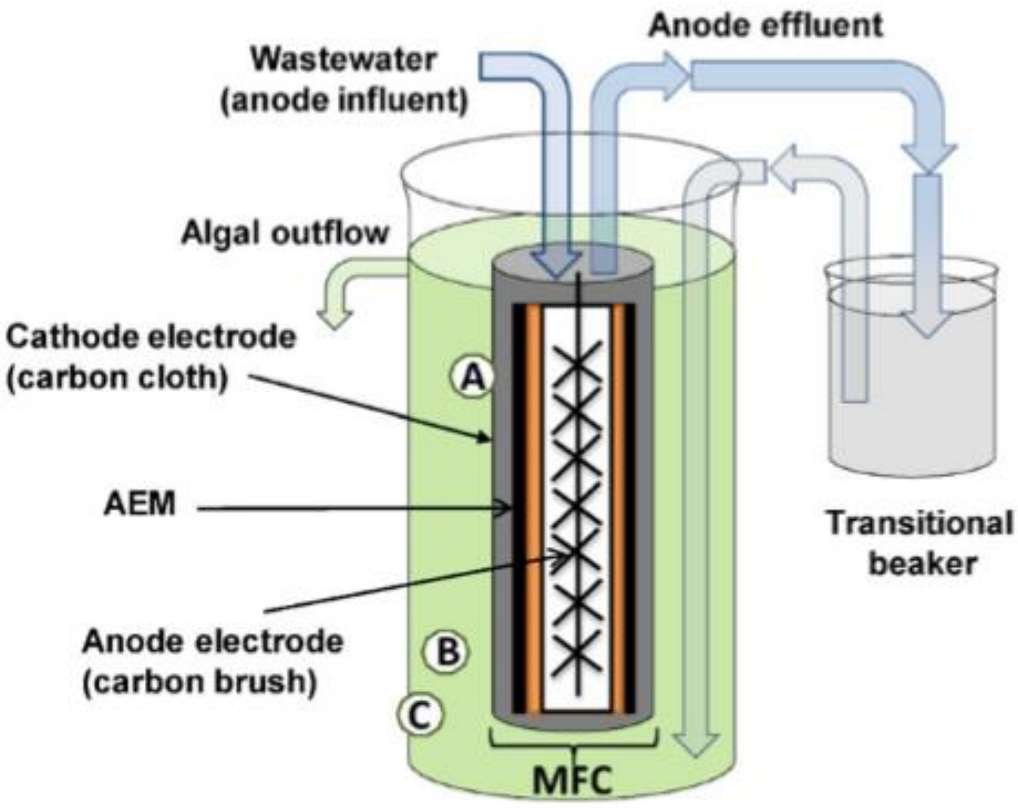
Market

- Petroleum, aviation and biofuel companies have been largely increasing their investments in the algae biofuel market
  - The United States and Europe are unable to produce corn, soy or rapeseed fast enough in order to meet their biofuel targets
- Algae costs more per unit than other biofuels however:
  - Algae is the fastest growing plant in the world and will yield 10 to 100 times more fuel per unit area than the biofuels currently on the market
- Algae biofuels market will continue to rapidly grow in the coming years and is anticipated to become the main commodity for fuels by 2020

Source: Emerging Markets, Whatech/Market Research

Schematics of IPB System

IPB system consisting of an
MFC with Anion exchange membrane (AEM) and an algal bioreactor.



a. Synthetic wastewater is fed into the anode compartment, where organic compounds are biologically degraded for generating electrons

b. Electrons move from the anode electrode (carbon brush) to the cathode electrode (carbon cloth), where oxygen reduction occurs to complete the electrical circuit

c. The treated wastewater is discharged into a transitional beaker, and this solution then is supplied to the cathode compartment(algal bioreactor), where algae grow and produce dissolved oxygen for supporting the cathode reaction

d. The final effluent from the cathode compartment is discharged containing suspended algal cells.

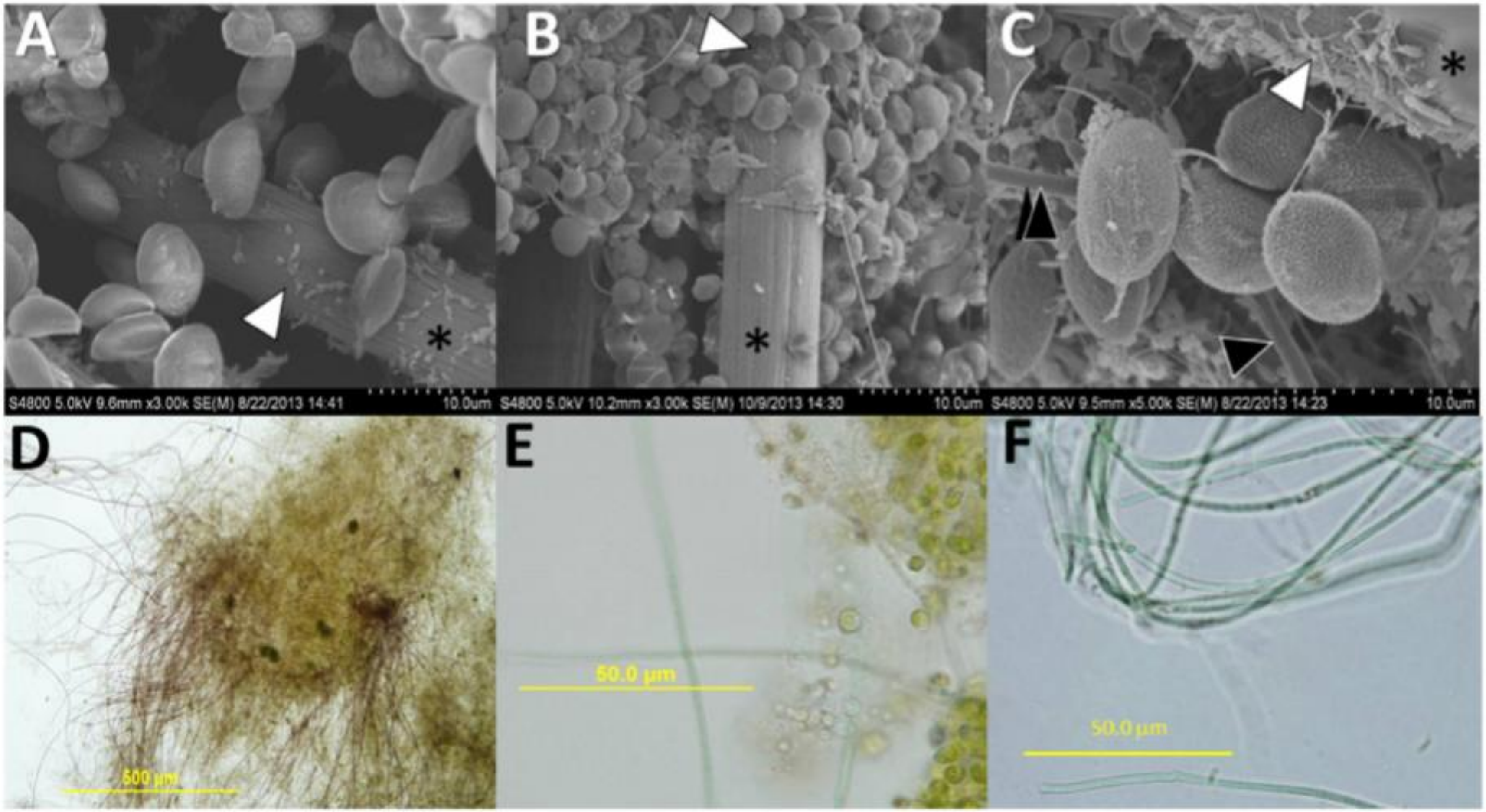
Recent Study

Objectives:

1. Examine IPB System with different sources of algal inoculum sampled from several different wastewater treatment facilities
   - Sherwood, OH (IPB-S)
   - Fransicville, ID (IPB-F)
   - WWExp: Mixed sample from wastewater treatment facilities in Indiana and Ohio (IPB-W)
2. Analyze the energy balance and production of algal biomass
3. Characterize the microbial community in the cathode related to the different algal sources

Images of Algae Growth in IPB System

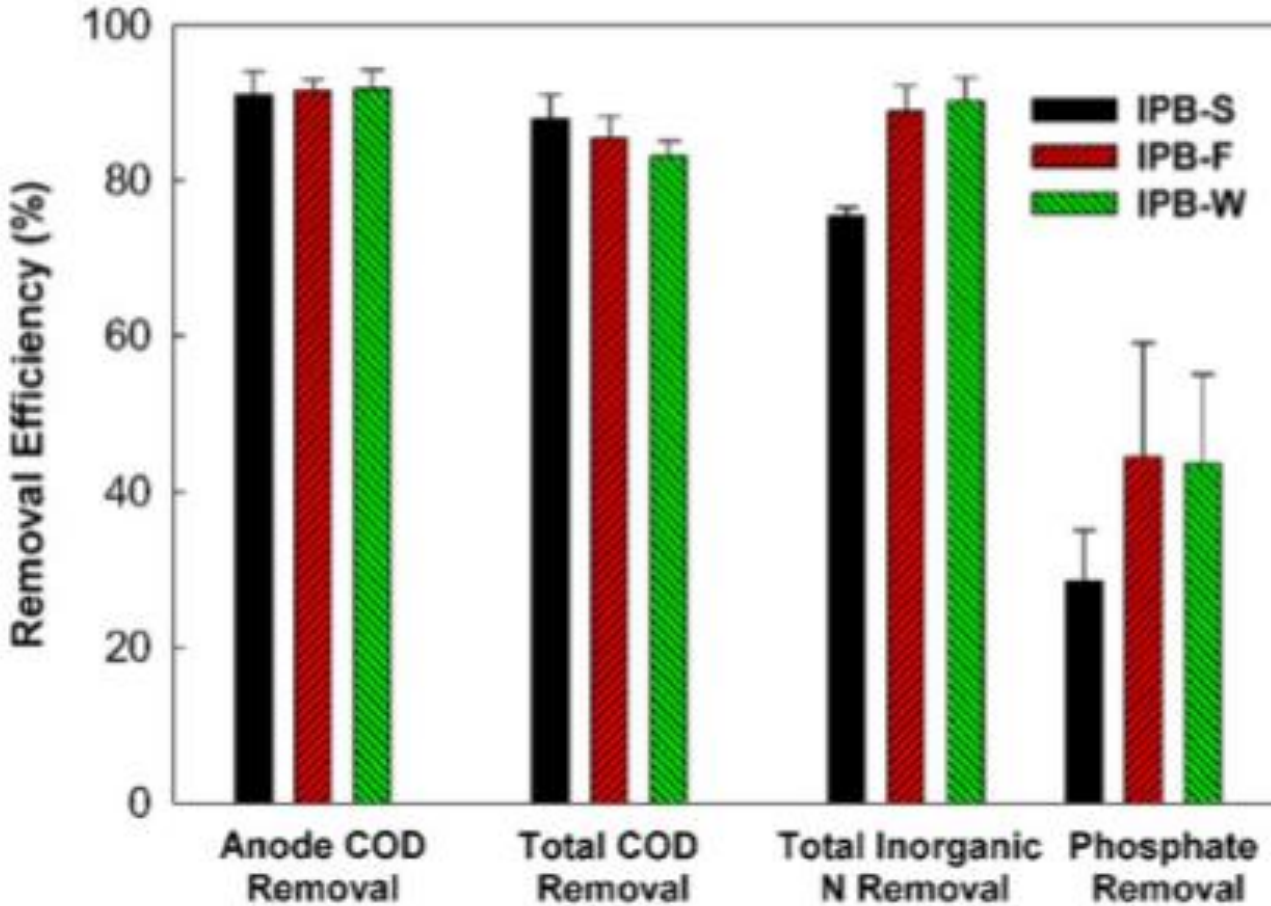
Images of Algae Growth on Cathode Electrode Membrane



A/D: IPB-Sherwood B/E: IPB-Francisville C/F: IPB-WWExp

*SEM Imaging used for A-C *Light microscopy used D-E

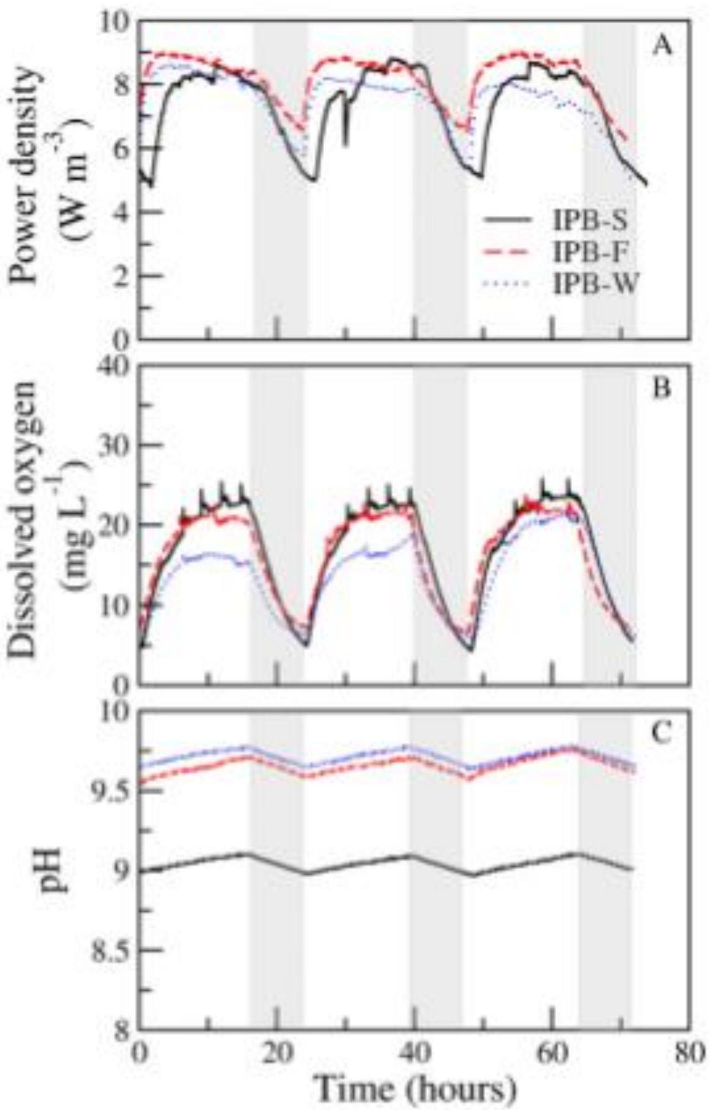
Removal Efficiencies of three IPB Systems



COD: Chemical Oxygen Demand

- The IPB with anion exchange membrane (AEM) and integrating different natural wastewater algal inocula could effectively remove both organic compounds and nutrients from synthetic wastewater

Differences in Results of 3 IPB Systems



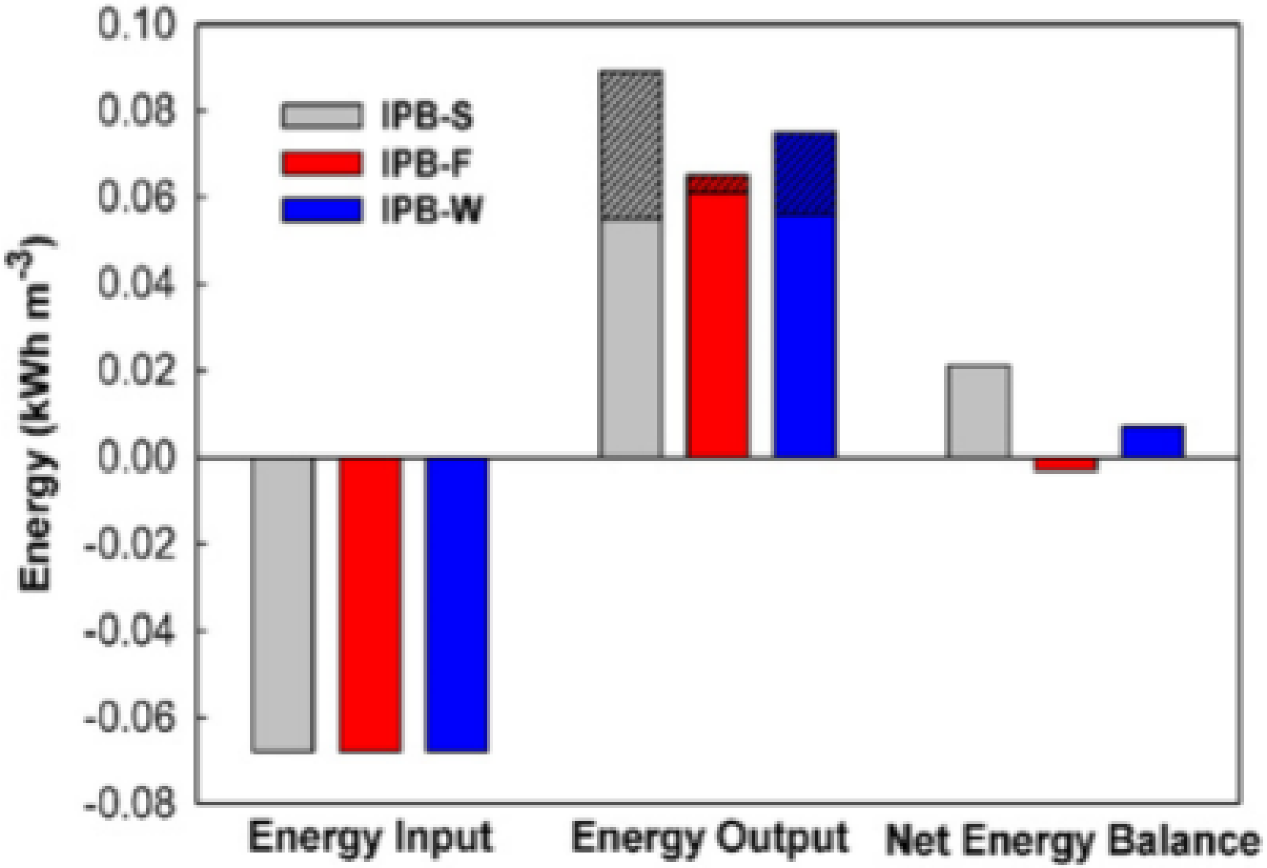
Testing over 3 Day-Night Cycle

- The performance and operating parameters of three IPB systems based on the different wastewater algal sources over selected three day–night cycles:

  (A) Power density
  (B) Dissolved oxygen
  (C) CatholytepH

- The white indicates the illuminated period(16 h) and the shadow indicates the dark period (8 h).

Net Energy Balance using IPB with



- Energy input (consumption), output (production), and the net energy balance in the three IPB systems based on different wastewater algal inocula
- IPB-F had a negative net energy balance while other two systems had a positive net energy balance

Conclusions from Recent Study

Conclusions:

- Energy production, both electricity and biomass, was significantly affected by algal sources
- Energy analysis demonstrates that the IPB System is energy-efficient process for wastewater treatment
  - Potential to be energy neutral technology (IPB-S/IPB-W)

Next Steps:

- Perform energy analysis of IPB System on a larger scale

Summary

- Municipal wastewater treatment plants play a critical role in environmental protection
- New IPB system combines previous methods of wastewater removal processes to achieve the most energy efficient method while protecting the environment

- Looking for a development partner to develop final product
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