Microbial electrochemical cells for wastewater treatment: challenges and outlook

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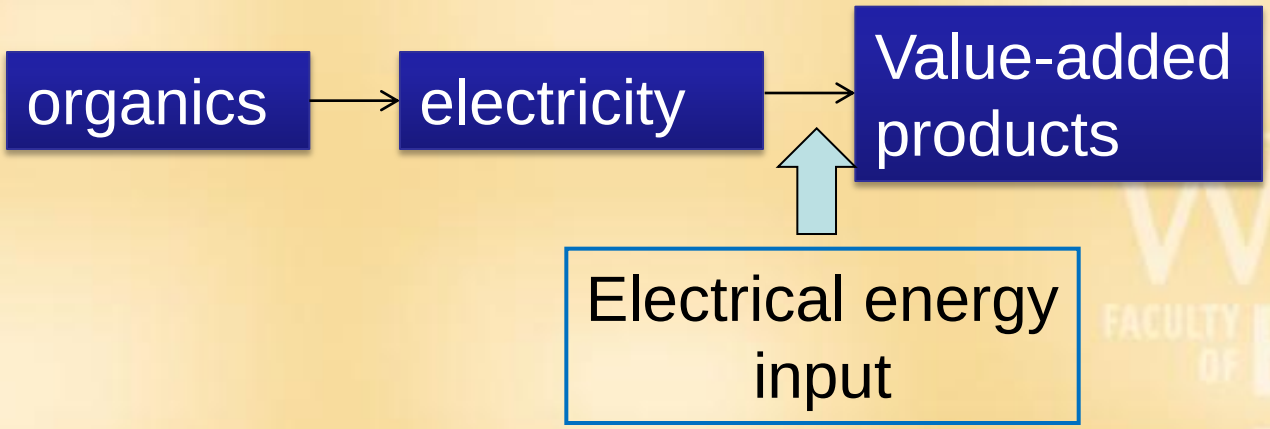
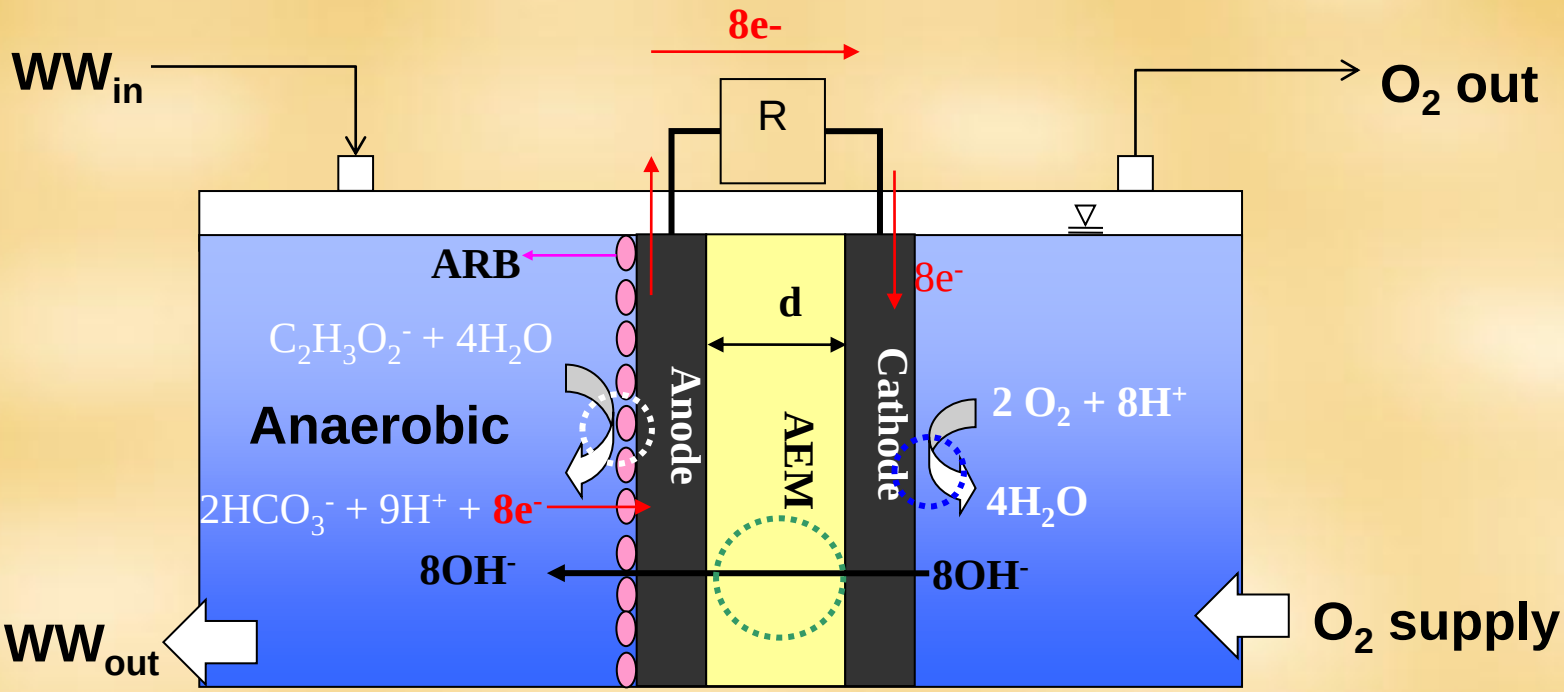
Microbial electrochemical cells (MECs)

- An emerging technology to convert chemical energy of compounds (mostly organics) into electrical energy or value-added products (H_2, H_2O_2, acetate, ethanol, butanol, or propanol)

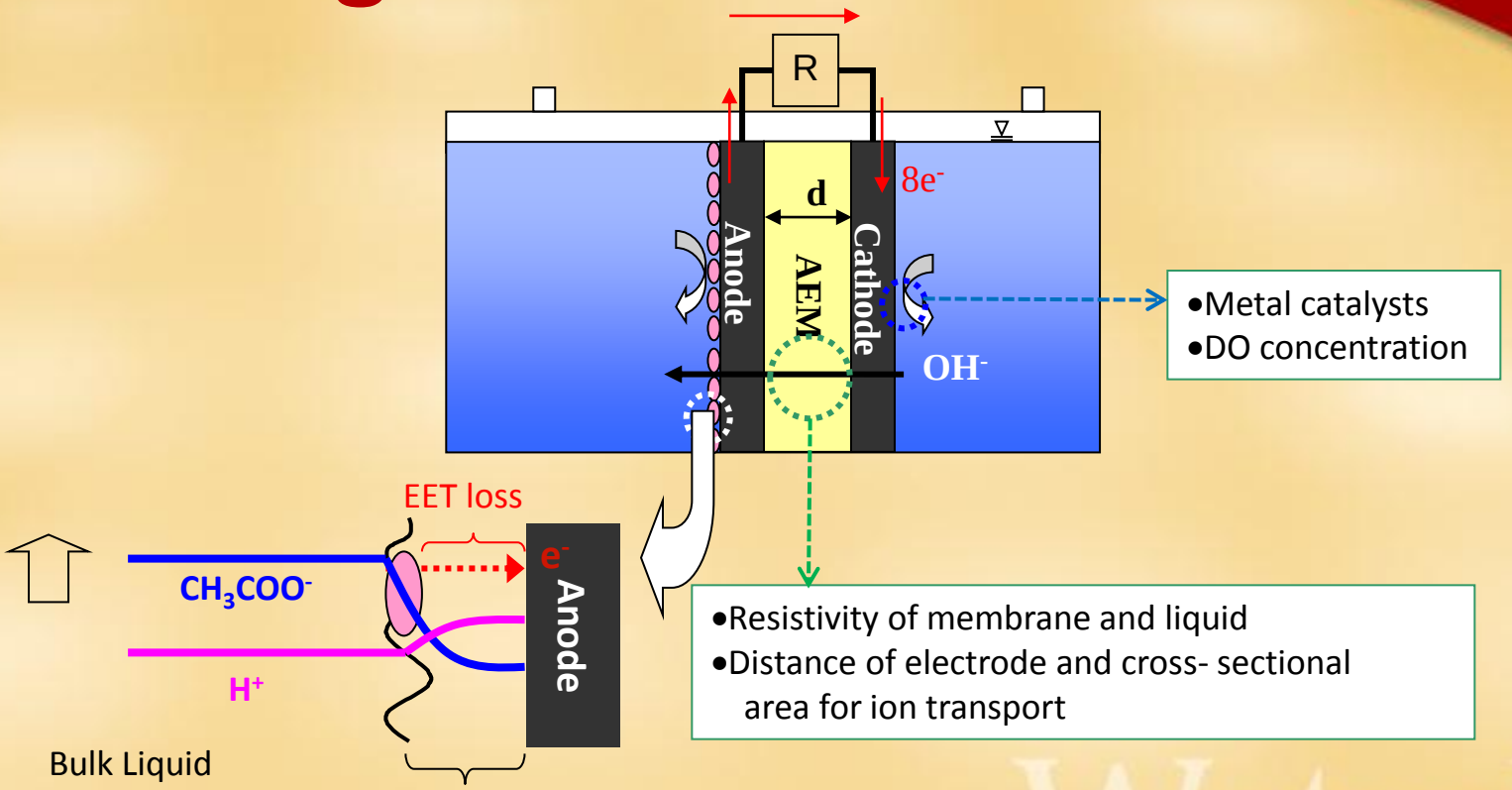


MECs for electricity production



AEM: anionic exchange membrane
ARB: anode-respiring bacteria
R: resistor

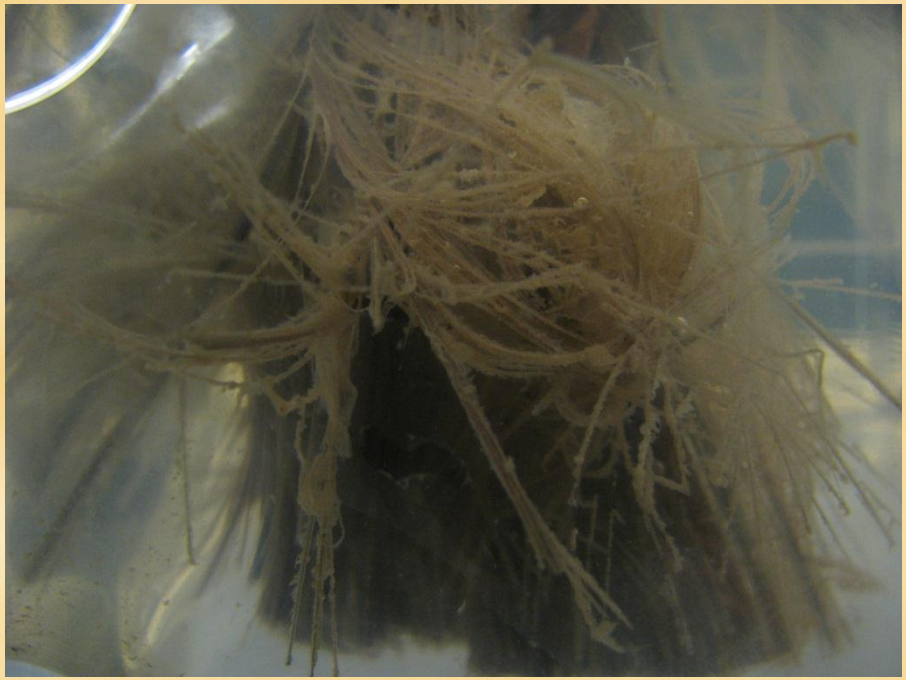
Limiting factors…

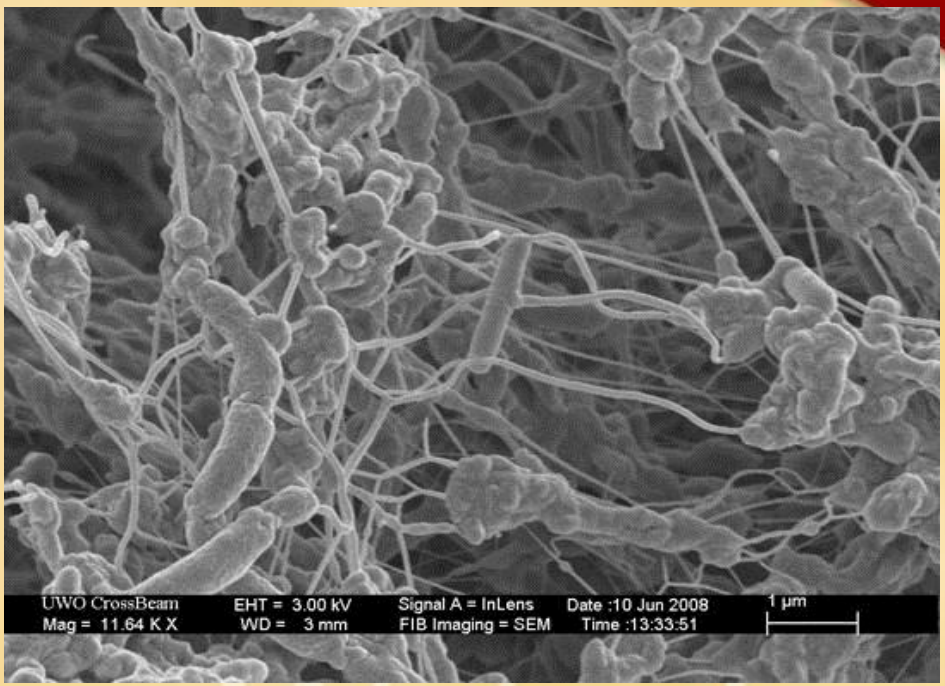


Conductive biofilm:
the biofilm causes concentration energy loss

Max. current density: 14A/m^2 @ 0.3V (~4W/m^2)

Significant limiting factor- ARB kinetic





Monod Kinetics

Nernst-Monod Kinetics

EET

(extracellular electron transfer)

e^-

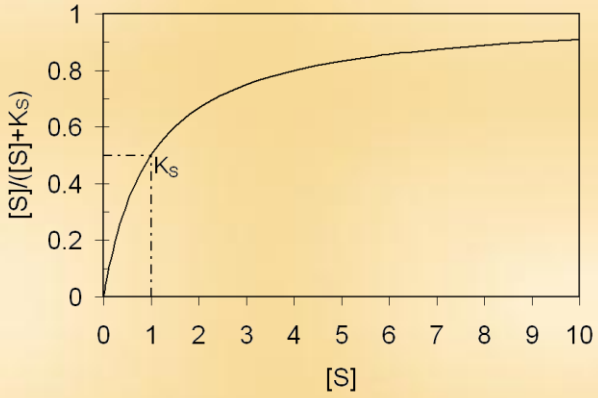
Substrate

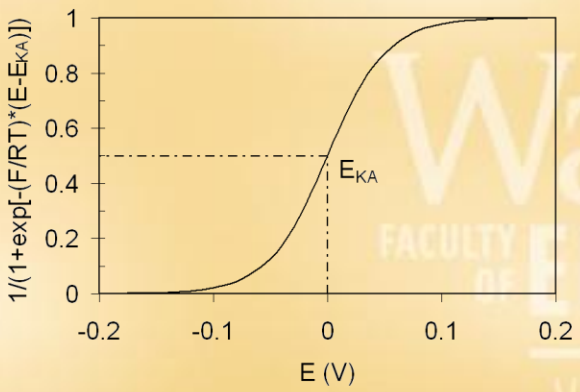
CO_2

E_{OM}

E_{anode}

Anode





Current challenges

- Anode-respiring bacteria (ARB) are poor at oxidizing complex forms of organics
- ARB are sensitive to environmental factors (temperature and pH)
- Low DO concentration in cathode
- Separator maintenance
- Maximum power is too small (small current and voltage due to significant energy losses)
- Still bench scale experiments (two pilot tests failed…)

MECs as power supplier?

- Max. current density: 14A/m^2 @ 0.3V (~4W/m^2)
- Need 250 MEC units to provide 1kW (MEC unity: 1m×1m)
- Construction cost for unit MEC: ~ $600, so 1 kW-MECs requires $0.15 M investment

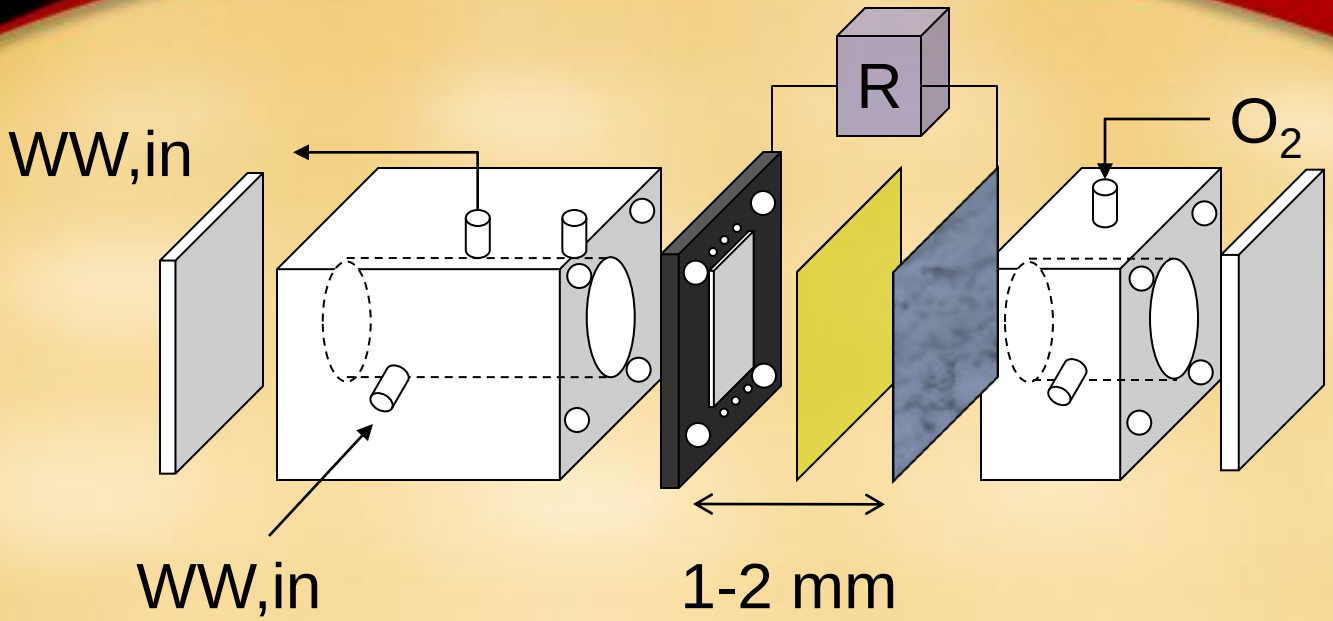
- $ 600/yr annual profit against $0.15M
  (0.4% pay-back per year)
- Electric power using MECs is negligible!

That means MECs are useless?

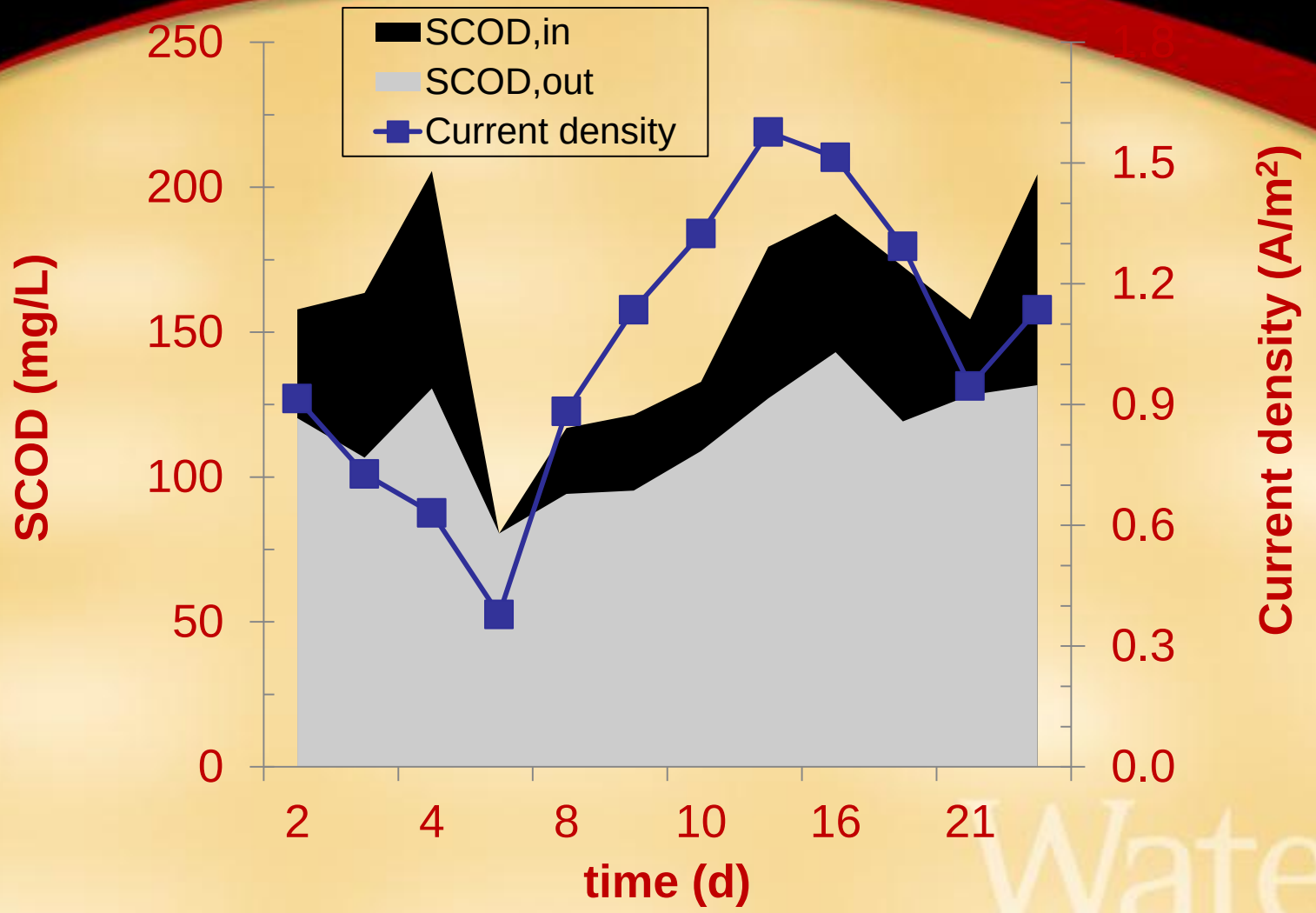
- Recall ARB (Anode-Respiring Bacteria) partially oxidize organics into CO_2 via anaerobic citric acid cycle → less oxygen demand!
- The growth yield of ARB is 0.05 to 0.1 g VS/g BOD → less sludge production!
- Main O & M costs in WWTPs are air blower and sludge disposal

- Hence, MECs can save O & M costs significantly in WWTPs

Experiments with domestic WW



Anode: carbon fibers
Cathode: stainless steel
Separator: AEM
Feed: Mesa WW
HRT: 4 h



- **SCOD removal up to 40% in 4 h**
- **able to achieve 50% BOD removal**

Energy-efficient WWTPs using MECs

Estimated with 10^5 m^3/d WWTP

- Average energy consumption: 1.2 kWh/m^3

So, O & M costs are ~ $3M/yr ($0.07/kWh)

- Assumed that electricity consumption and sludge disposal fees are half of total O & M costs, respectively, in WWTP
- Given that 50% BOD removal and 20% less sludge production with MECs

- We can save ~ $1M/yr of $0.75M (from air blower) + $0.3M (from sludge disposal) for 10^5 m^3/d WWTP

Future study required…

- What would be construction costs of MECs to achieve 50% BOD removal in WWTPs?
- MEC configuration applicable for existing WWTPs
- Clogging issue on a separator between electrodes (backwash? Chemical cleaning?)
- Life-span of separators ?