Microbial Electrolysis Cells (MECs) for High Yield H_2 Production from Biodegradable Materials

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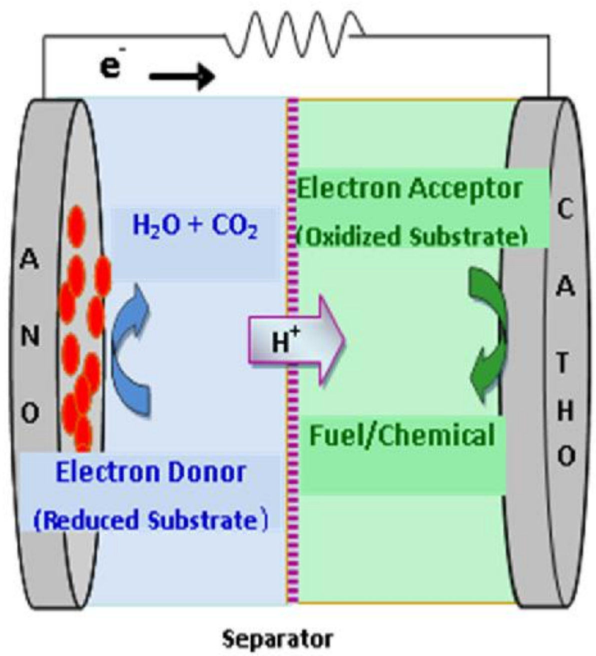
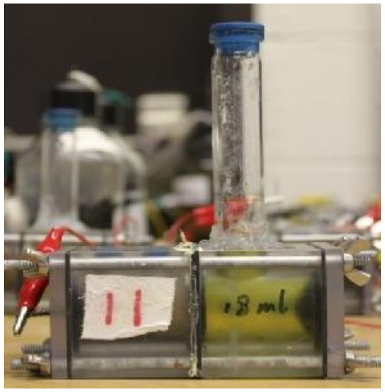
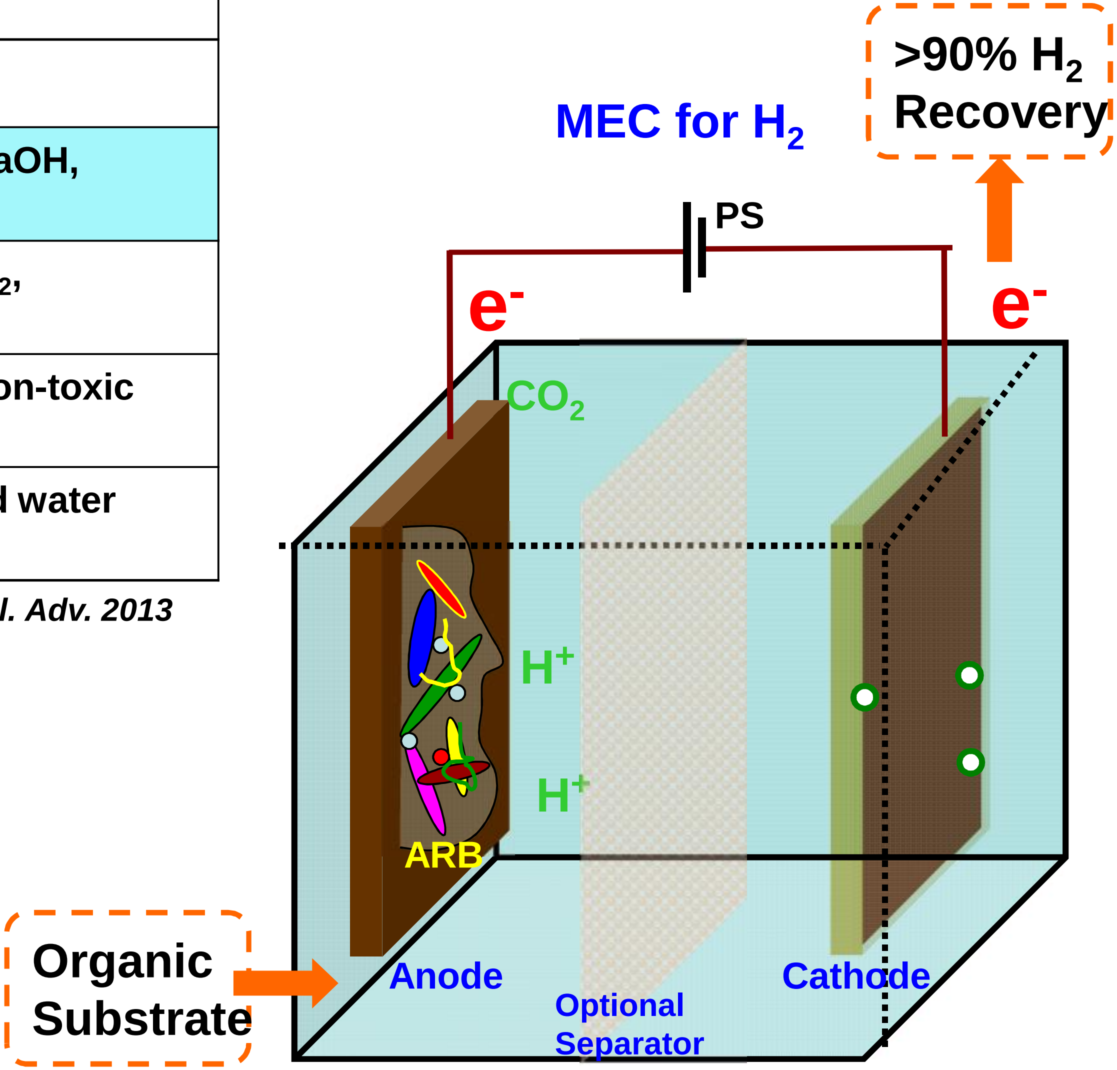


MxC or Microbial Electrochemical System (MES) is a platform technology for energy and resource recovery

Main type of MXC	Products
Microbial Fuel Cell (MFC)	Electricity
Microbial Electrolysis Cell (MEC)	H_2, H_2O_2, NaOH, Struvite
Microbial Chemical Cell (MCC)	CH_4, $C_2H_4O_2$, Organics
Microbial Remediation Cell (MRC)	Reduced/non-toxic chemicals
Microbial Desalination Cell (MDC)	Desalinated water

Wang and Ren, Biotechnol. Adv. 2013

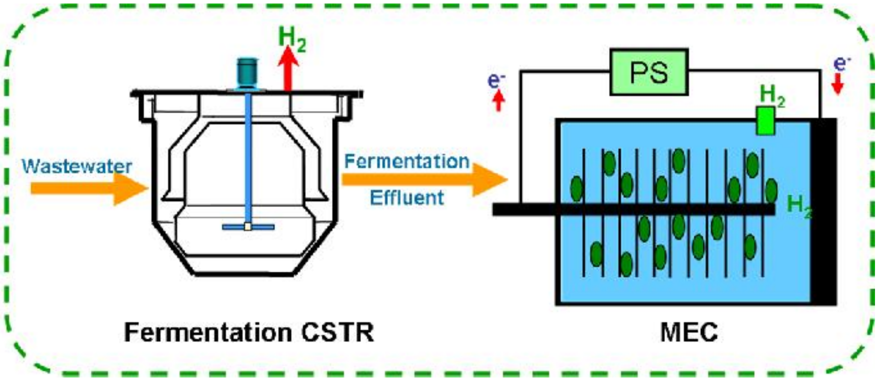




MEC for H_2 production – Features and Current Status

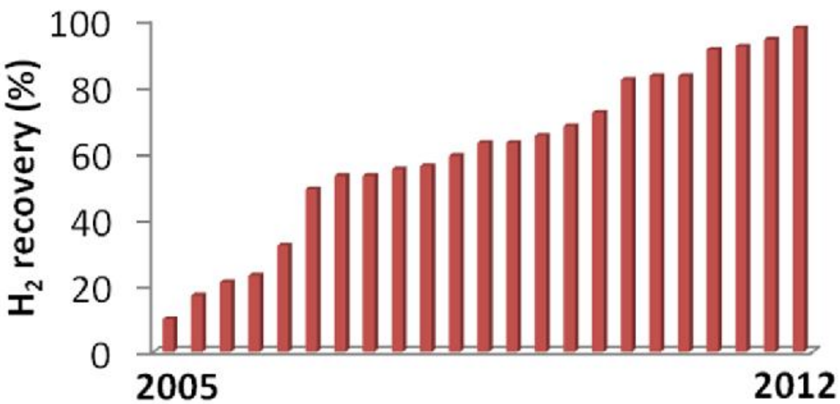
1. Any biodegradable material theoretically can be used in MECs for H_2 production

- Cellulosic biomass, fermentation products, wastewater, etc.

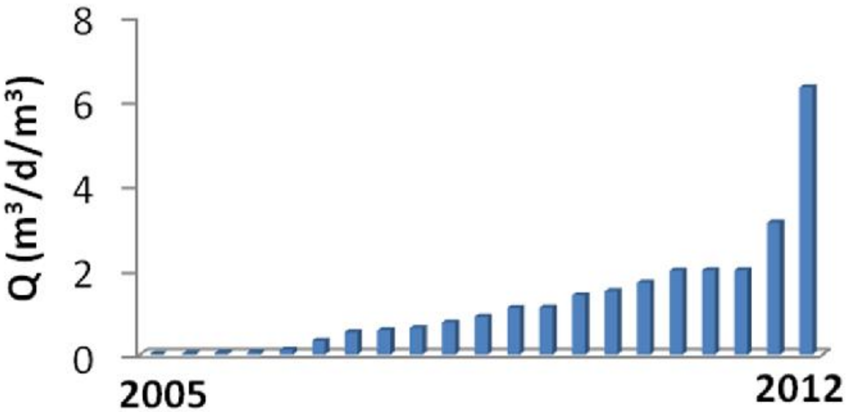


Processes	H_2 yield (mol H_2/mol hexose)	H_2 rate (m^3 H_2/m^3d)
Fermentation	0.57-2.2	2.5±4.3 Max. 64.5
MEC	5.7-11.2	2.1-6.3 Max. 17.8
Integration	> 10 feasible	> 10 achieved

2. The H_2 yield is higher than dark fermentation, and the rate is getting faster



Progress on H_2 recovery or yield from biomass
(based on 12 mol H_2/mol hexose or 4 mol H_2/mol acetate, etc)



Progress on H_2 production rate
Highest was 17.8 m^3 H_2/m^3d at 1V in a small reactor

Ren, et al., 2007; Logan, et al., 2008; Lu, et al., 2009; Lalaurette, et al, 2009; Tartakovsky, et al, 2009; Lee, et al., 2010; Liu, et al, 2010; Lu, et al, 2011; Cheng and Logan, 2011; Chookaew et al., 2013

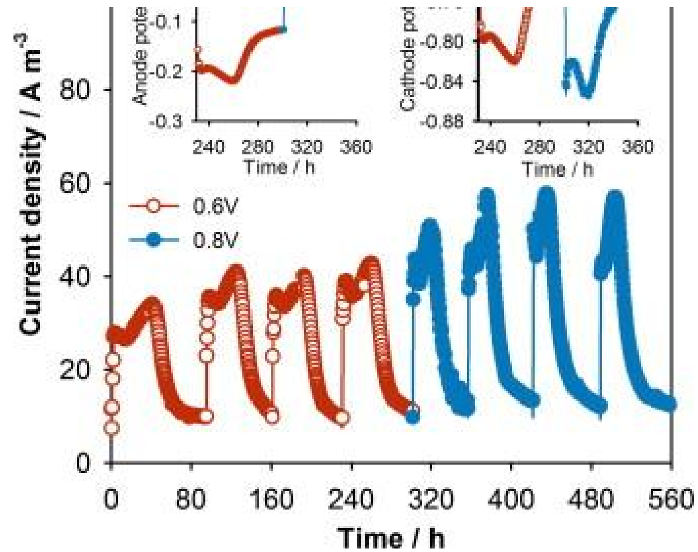
MEC for H_2 production – Features and Current Status

3. H_2 purity from MEC can be high, and the production can continue in low temperature (> 4 ºC)

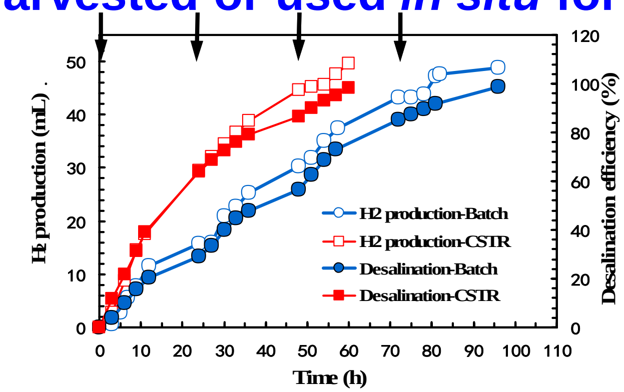
- In two chamber MECs, the H_2 content can be > 99% when using a good separator.

- In single chamber MECs, H_2 is mixed with CO_2

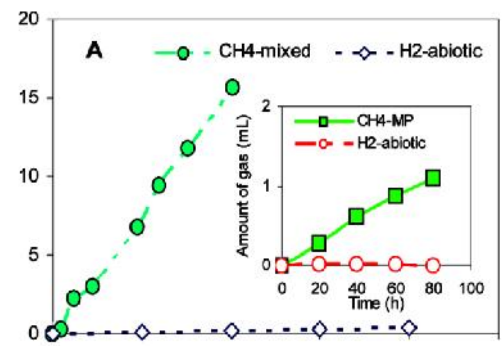
- MECs can be operated at low temperature without significant performance drop, but methanogenesis can be effectively inhibited.



4. MEC can be integrated with other processes, and H_2 can be either directly harvested or used *in situ* for organic generation.



Simultaneous H_2 production (2 m^3/m^3 d), waste removal (90%), and Desalination (99%) - Energy Positive System

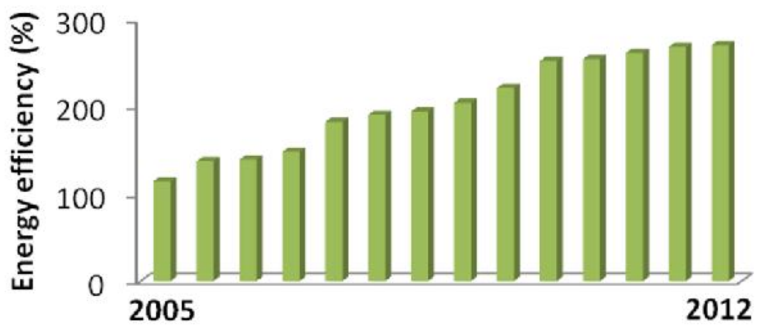


CH_4 and other organics can be produced through H_2 oxidation

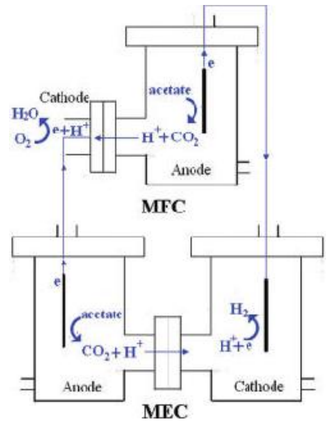
Cheng, et al, 2009; Luo, et al., 2011; Lu, et al., 2012;

MEC for H_2 production – Challenges and Opportunities

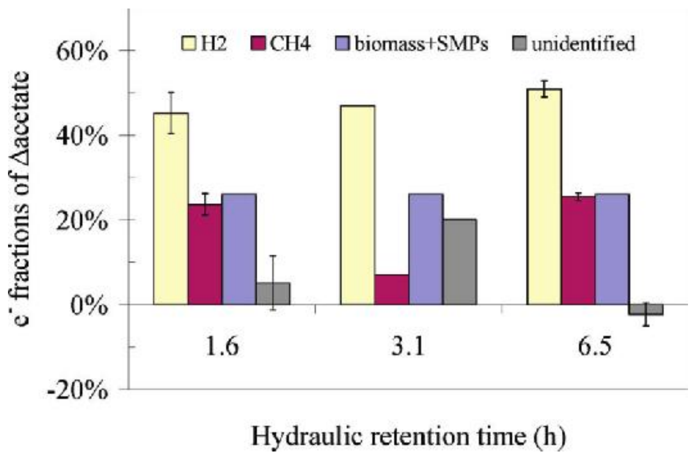
1. Despite it's energy positive nature, an external power source is needed for MECs, and many renewable sources have been used.



Renewable power sources, such as microbial fuel cell, salinity gradient, waste heat, etc. have been used to provide the additional potential for H_2 production in MECs.



2. H_2 consumption by methanogenesis, ARB H_2 recycle, and other undesired electron sinks in single chamber MECs



Removing the membrane from MECs attenuates pH and ohmic energy loss, therefore increasing production rate. However, it also makes H_2 available for anode microbes to consume, decreasing H_2 yield.

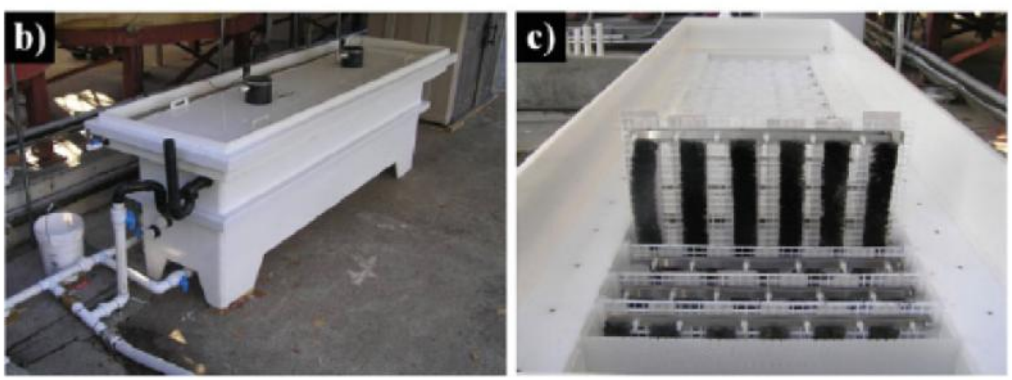
Sun, et al., 2008; Lee, et al., 2010; Nam, et al, 2012

MEC for H_2 production – R&D Needs

1. Develop new materials and reactor configurations to increase H_2 production rate and reduce system and operational costs.

2. Explore microbial and engineering approaches to reduce/remove competitive H_2 consumption and increase H_2 harvesting rate or utilization.

3. System scale up and integration with other complementary processes.



An 1000 L pilot MEC reactor treating winery wastewater and producing H_2

One study estimates a break-even point of 7 years for a full-scale MEC wastewater systems, with the following assumptions:

- Current density of 5 A/m^2
- Energy consumption of 0.9 kWh/kg-COD
- A cost of €1220/m^3 anode chamber

Cusick, et al, 2011; Escapa, et al, 2012