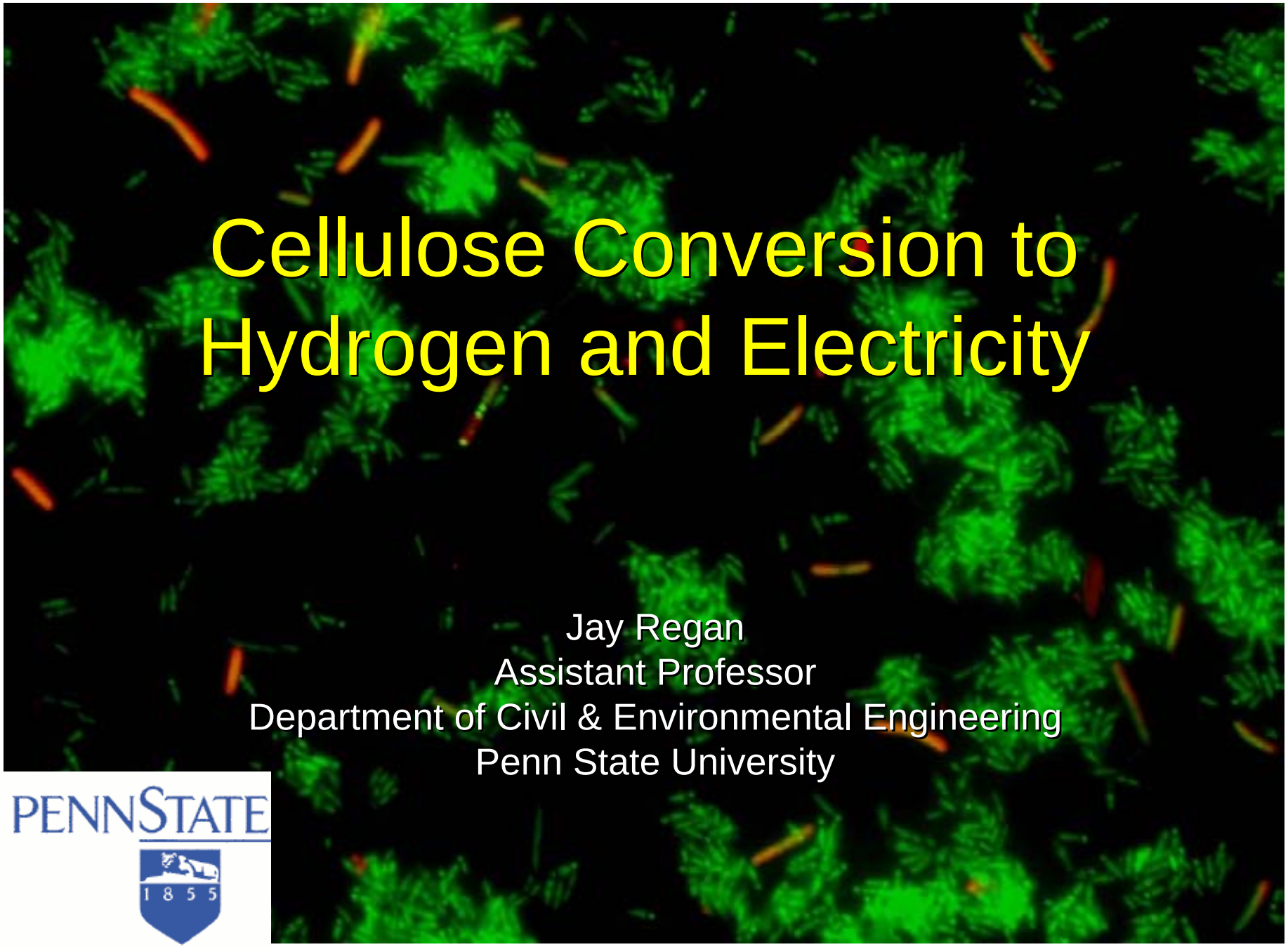

Cellulose Conversion to Hydrogen and Electricity

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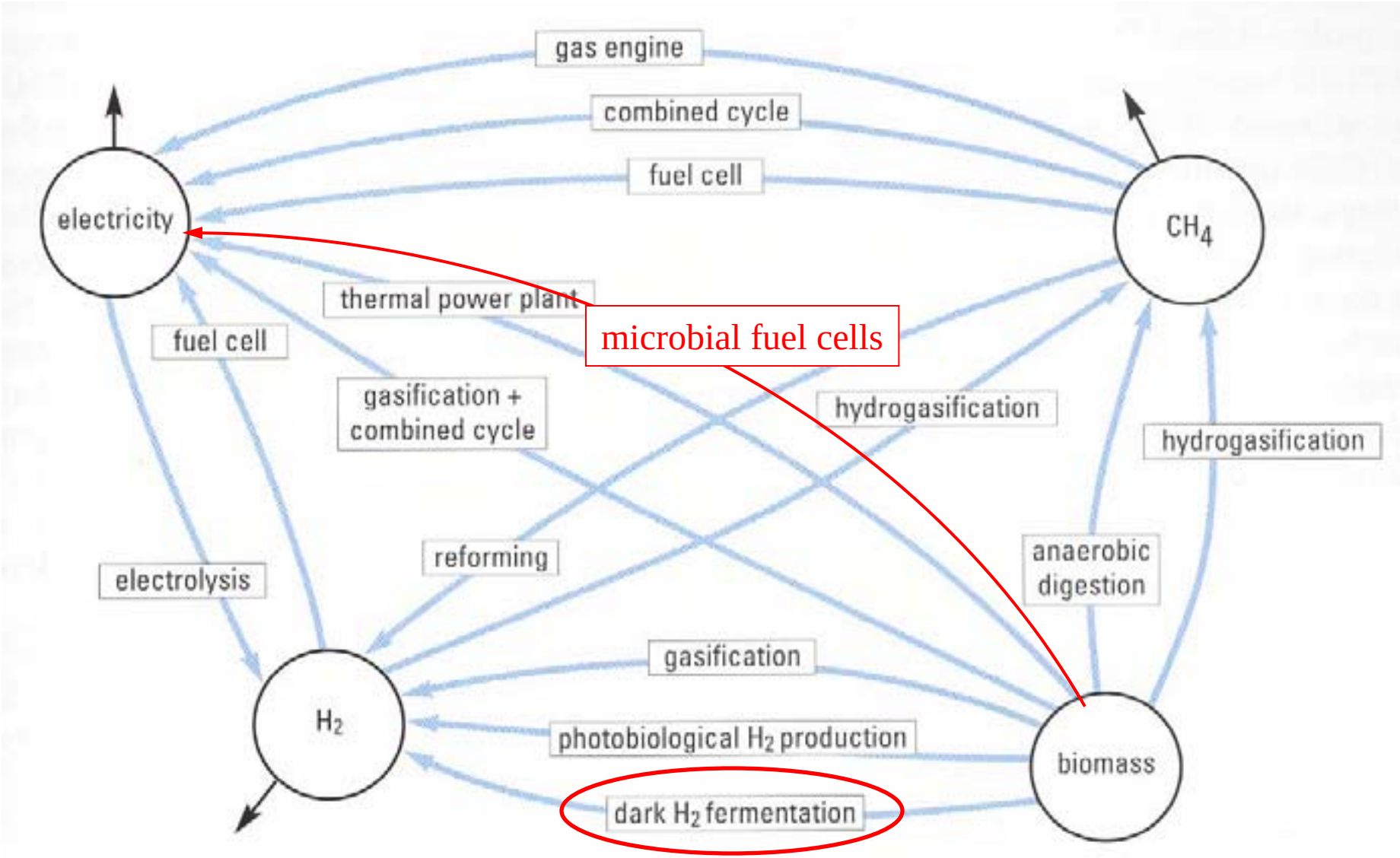
Biomass to Secondary Energy Carriers

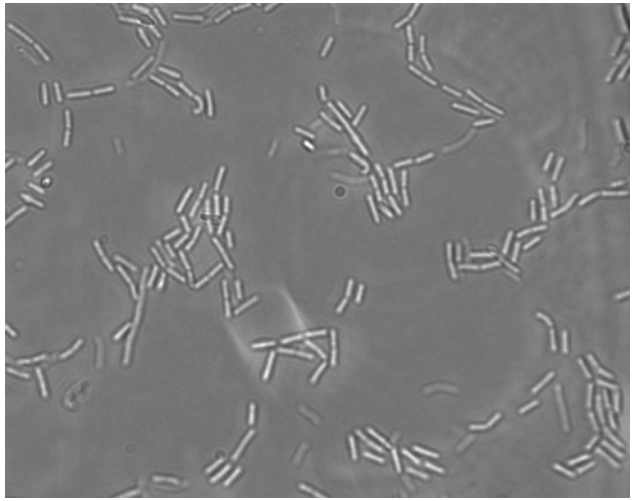


de Groot (2003). In: Bio-Methane & Bio-Hydrogen.

1) Fermentative production of H_2 from sugars

- Full oxidation of glucose to H_2:

$$C_6H_{12}O_6 + 6\ H_2O \rightarrow 12\ H_2 + 6\ CO_2$$



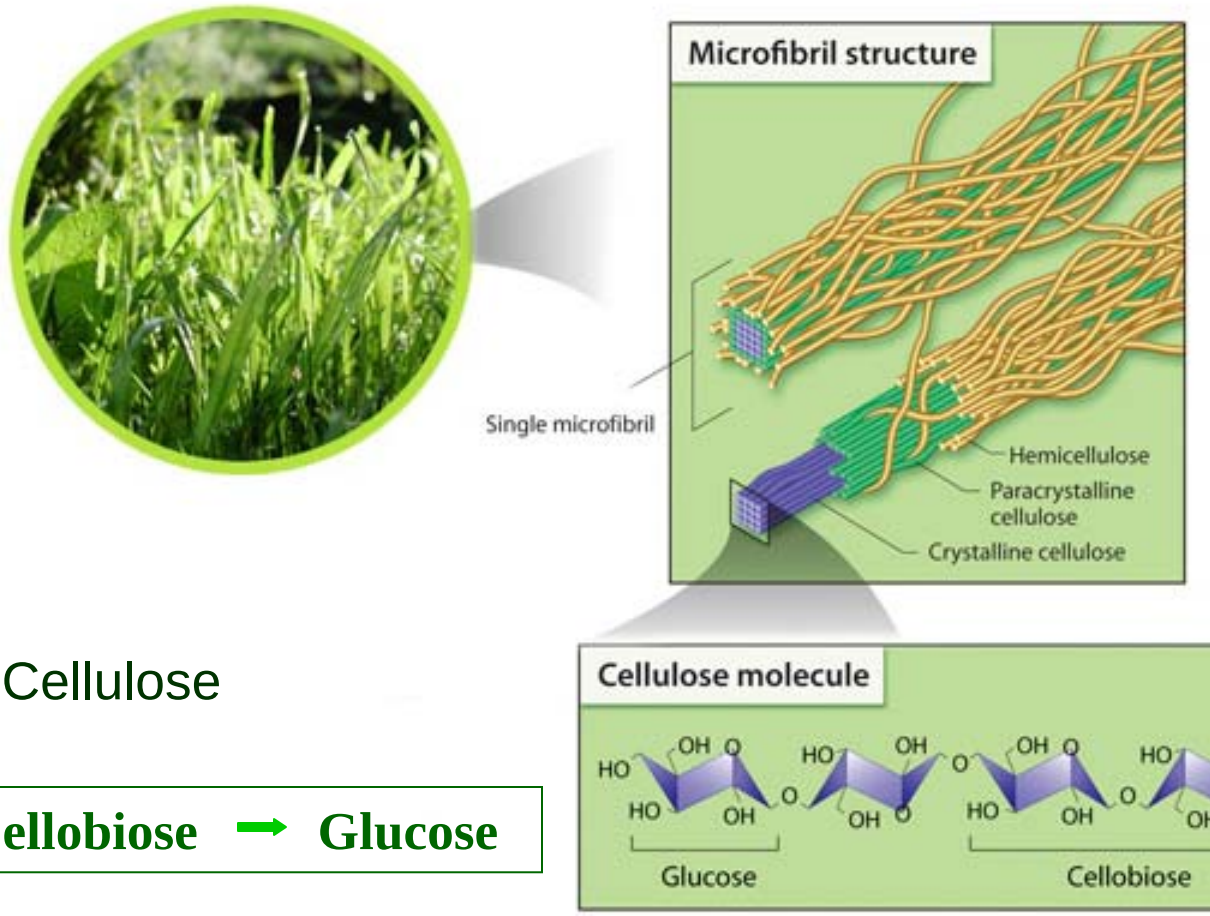
- Known pathways:

$$C_6H_{12}O_6 + 2\ H_2O \rightarrow 4\ H_2 + 2\ C_2H_4O_2 + 2\ CO_2$$

$$C_6H_{12}O_6 \rightarrow 2\ H_2 + C_4H_8O_2 + 2\ CO_2$$

- Typical yield < 2 mol H_2/mol glucose

Cellulosic biomass is more recalcitrant to biological treatment



Hydrolysis of Cellulose

Cellulose → Cellobiose → Glucose

(DOE, 2006)

Cellulose-derived hydrogen:

Inoculum	H_2 Yield (mol/mol hexose)	Reference
Clostridium cellulolyticum	1.66 (6.7 g/L initial)	Desvaux et al (2000)
	0.33 (29.1 g/L)	
Heat-shocked sludge	0.36 (12.5 g/L)	Lay et al (2001)
	0.08 (50 g/L)	
Heat-shocked soil	0.005 (4.0 g/L)	Logan et al (2002)
Activated sludge	0.07 (5.0 g/L)	Liu et al (2003)

Characterization of Cellulolytic, H_2-Producing Clostridia

- ***Clostridium* species**

  acetobutylicum, cellulolyticum, cellobioparum, celerecrescens, populeti, phytofermentans

- **Substrates**

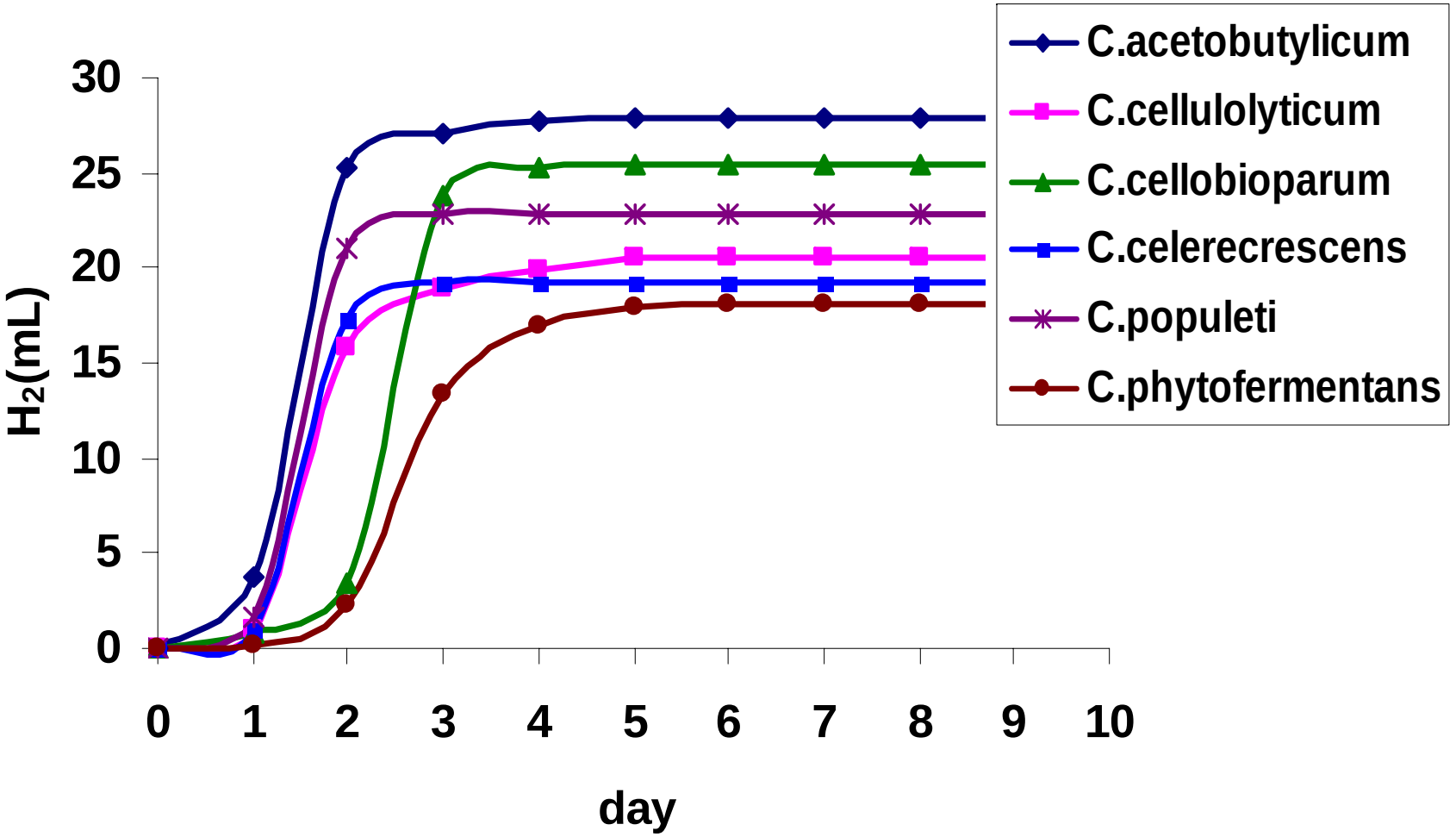
  Cellobiose (disaccharide)

  MN301 cellulose (mixture of amorphous and crystalline)
  Avicel (microcrystalline)

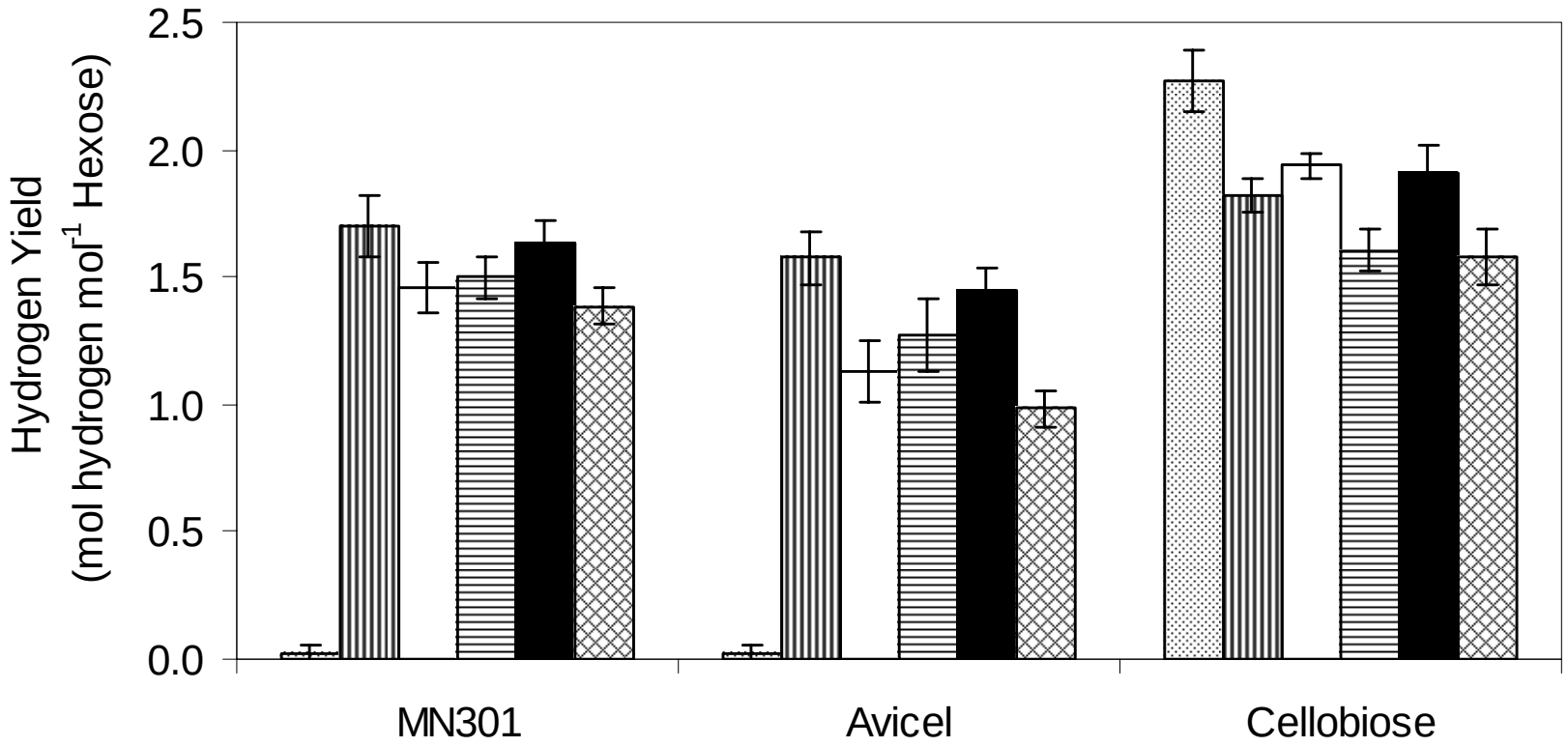
- **Analyses**

  Biogas, Hydrogen, CO_2, Biomass protein, Substrates, Fermentation products

Gas production from cellobiose



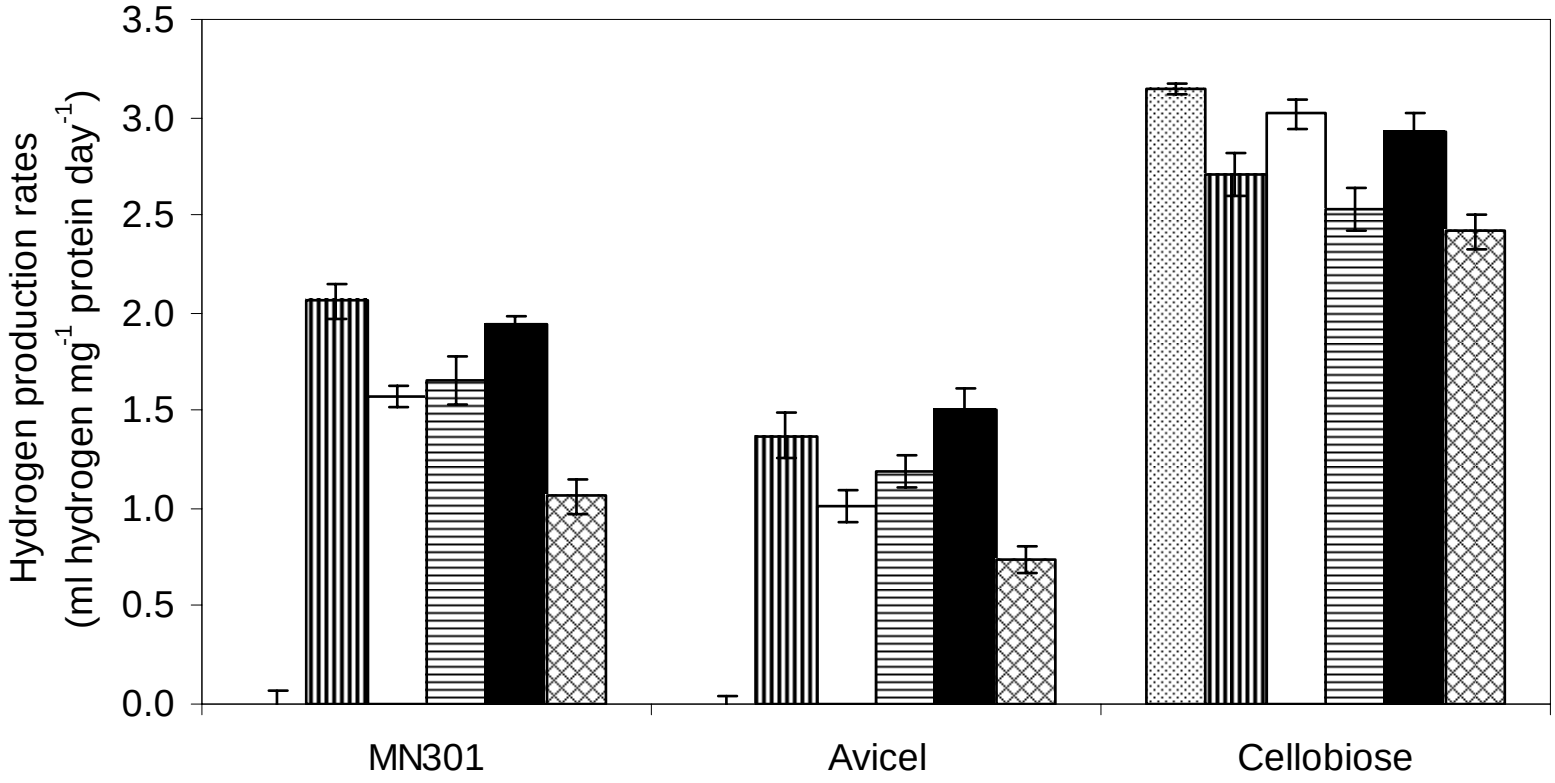
H_2 yield comparison



Clostridium species: *acetobutylicum*, *cellulolyticum*, *cellobioparum* *celerecrescens*, *populeti*, *phytofermentans*

Ren, Ward, Logan, and Regan (2007) *J. Applied Microbiol.*

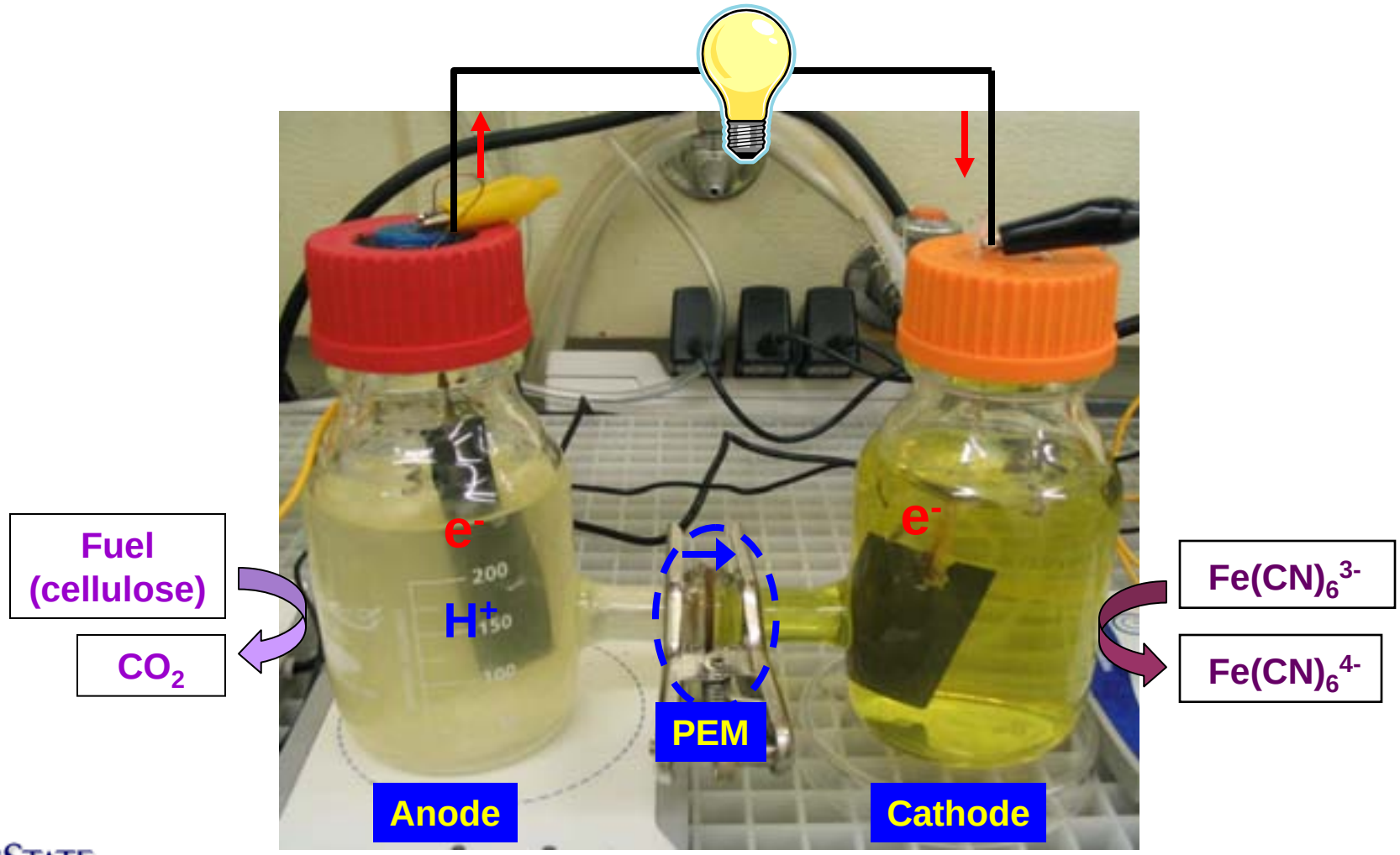
H_2 production rates



Clostridium species: *acetobutylicum*, *cellulolyticum*, *cellobioparum* *celerecrescens*, *populeti*, *phytofermentans*

Ren, Ward, Logan, and Regan (2007) *J. Applied Microbiol.*

2) Microbial fuel cells for production of electricity from biodegradable organic matter



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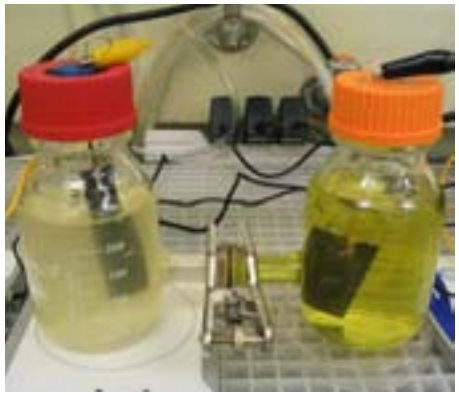
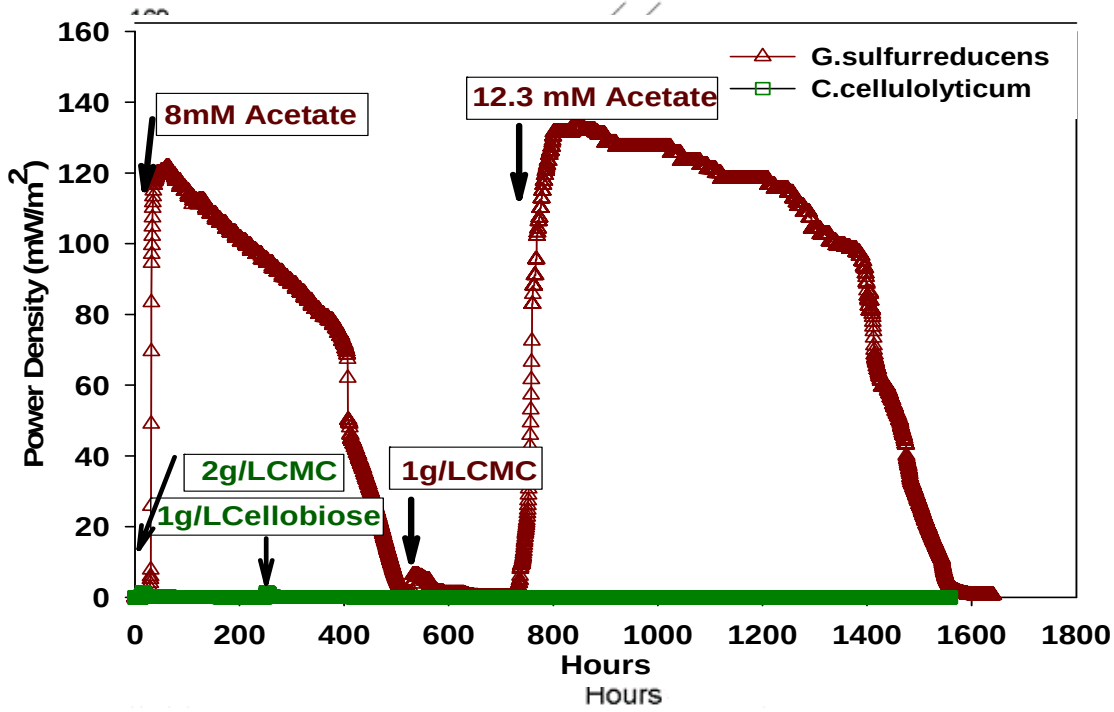
Co-culture can be used to make electricity from cellulose

- *Clostridium cellulolyticum*
  - Converts cellulose to H_2 and volatile acids
  - Can not produce electricity
- *Geobacter sulfurreducens*
  - Produces electricity from acetate and H_2
  - Can not degrade cellulose

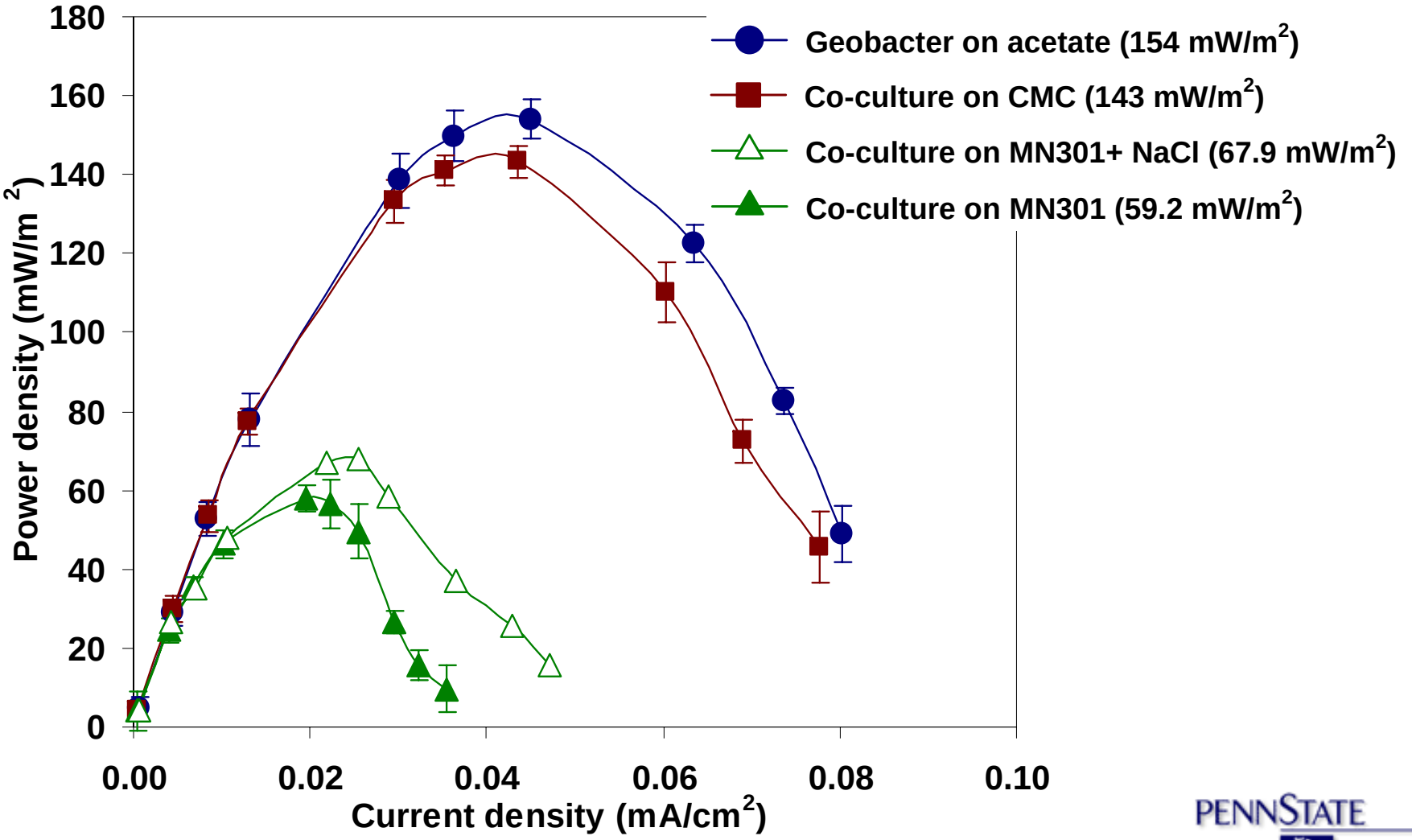




Electricity produced by fermenting cellulose

Ren, Ward,and Regan (2007) ES&T

Co-culture achieved comparable power on CMC as *Geobacter* on acetate



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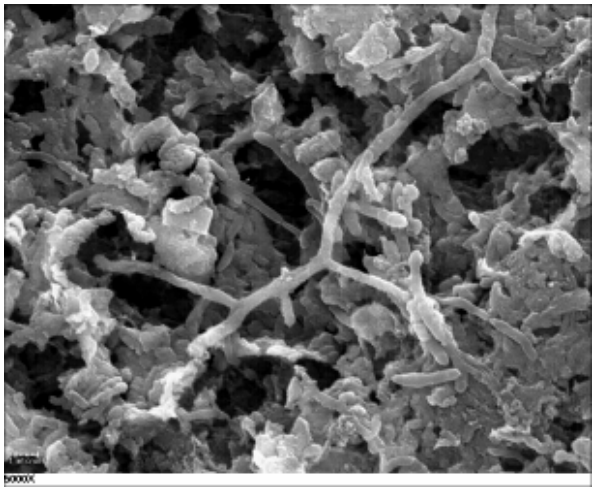
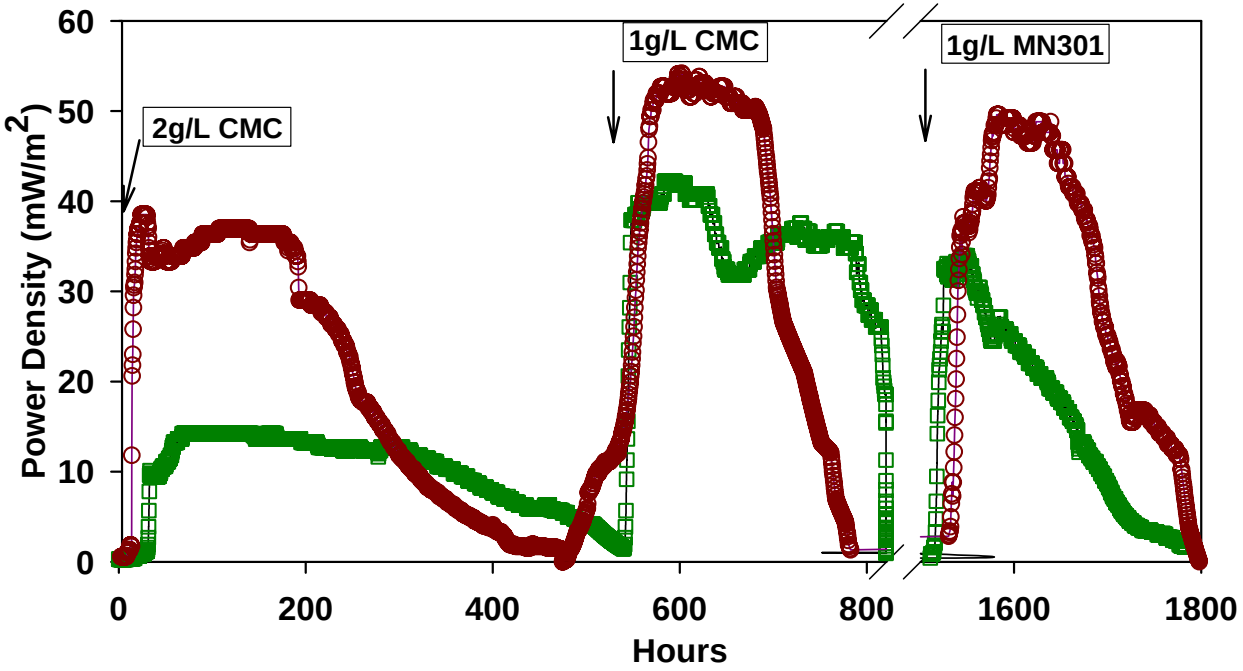
Electricity from cellulose: undefined mixed culture



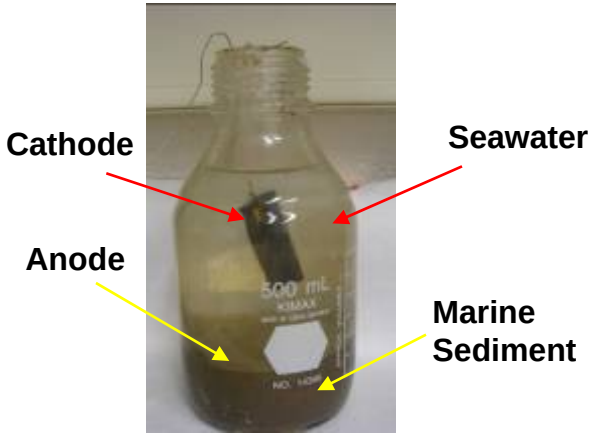


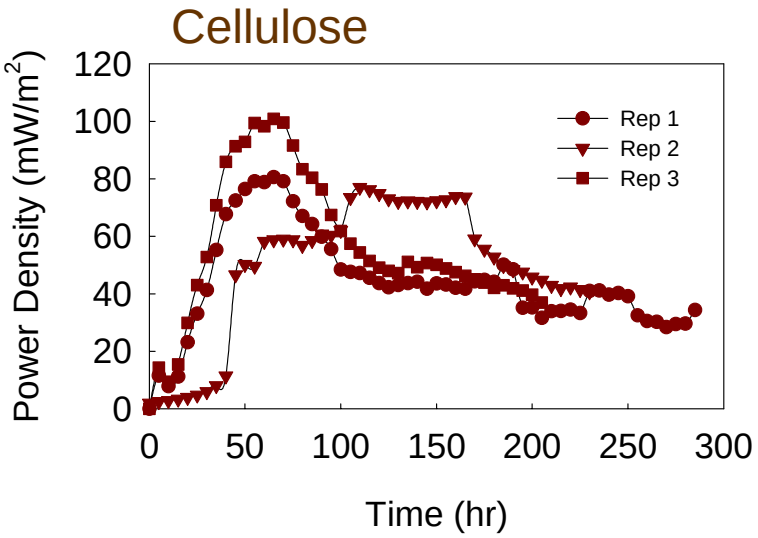
- Inoculum is wastewater (bacteria naturally present in the environment)
- *C. cellulolyticum* enhanced power production:

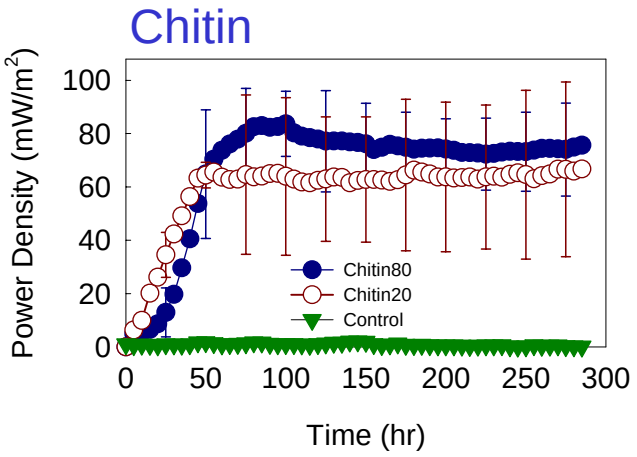
Max. Power: **Enhanced MFC: 53.8mW/m^2**
Sludge only MFC: 40.8mW/m^2

Ren, Ward,and Regan (2007), ES&T

Electricity from cellulose and chitin in a sediment MFC

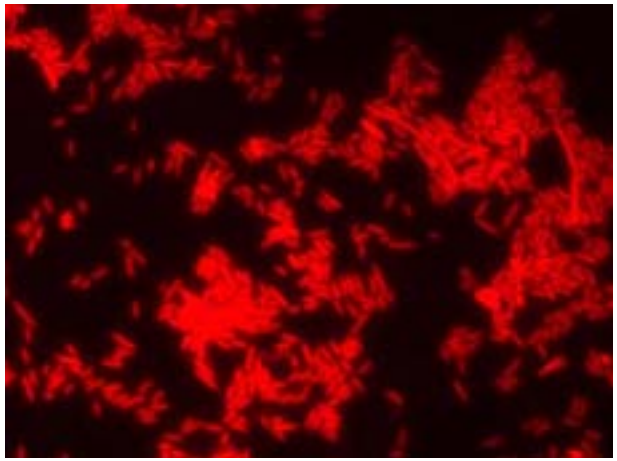




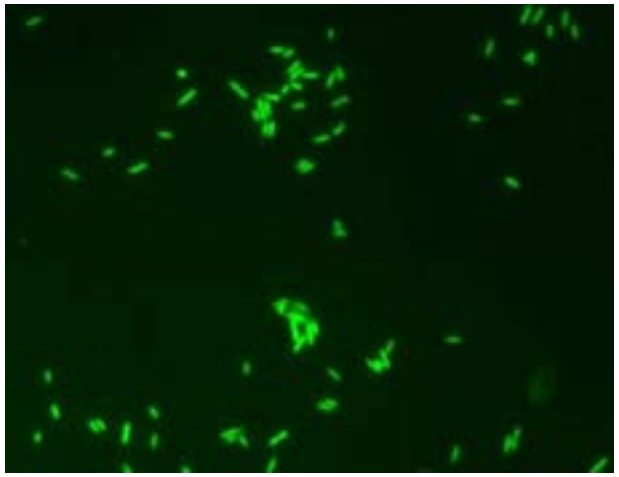


Rezai, Richard, Brennan and Logan, *ES&T* (2007)

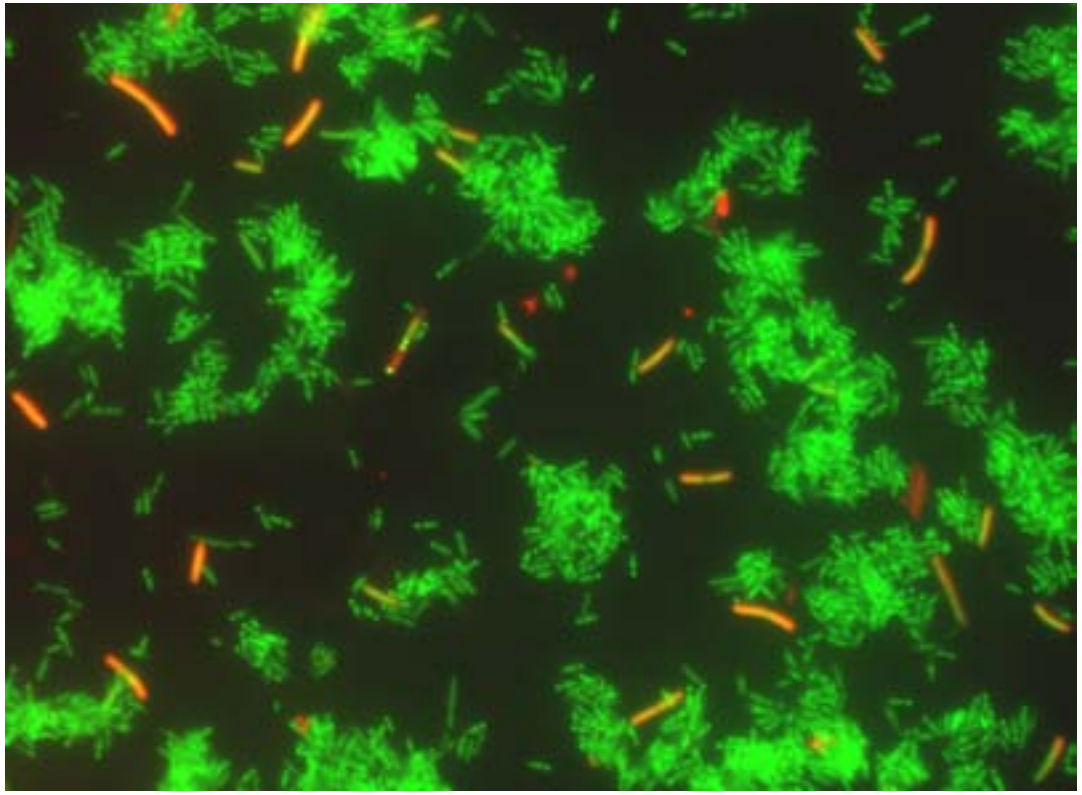
Microbial identification by fluorescent *in situ* hybridization (FISH)



Geobacter (SRB385)



Clostridium (SYTO 9)



Suspended sample of coculture from CMC-fed MFC

Geobacter (yellow/red) - Clostridium (green)

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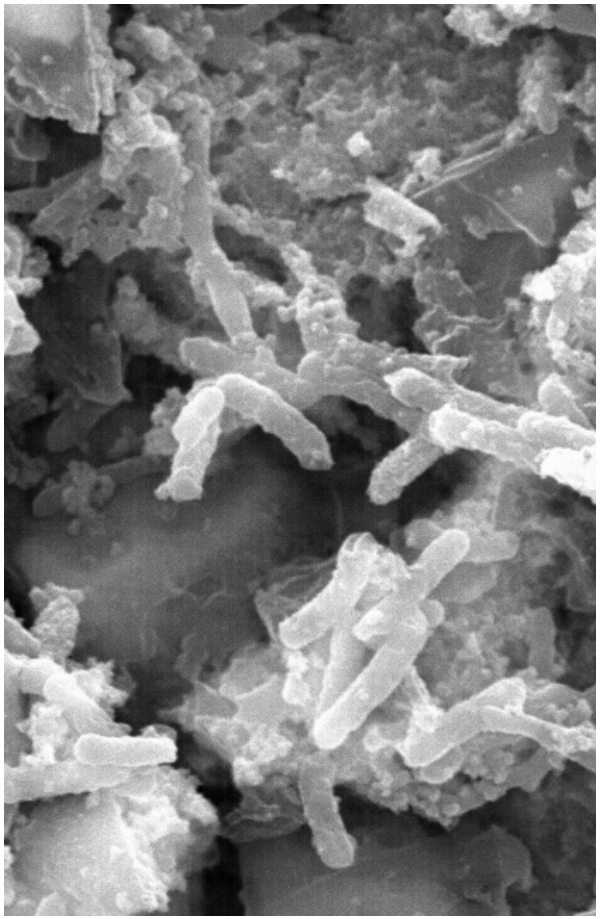
Summary

- *C. cellulolyticum* and *C. populeti* showed the highest hydrogen production rates and yields from solid cellulose
- H_2 yields (~1.6 mol/mol) comparable to typical values with glucose, but rates were only 50-70% that of cellobiose
- Cellulose conversion to electricity is possible in microbial fuel cells through pairing of cellulolytic and anode-reducing phenotypes



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