Microbial Fuel Cells

Applications and Prospects

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Bioelectrochemistry - Novel Discovery?

Electrical Effects accompanying the Decomposition of Organic Compounds.

By M. C. Potter, Sc.D., M.A., Professor of Botany in the University of Durham.

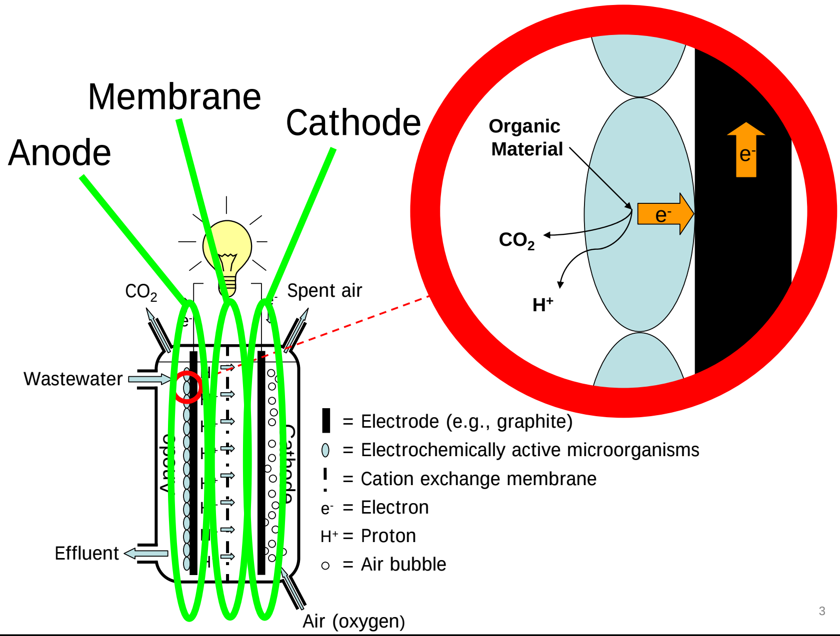
(Communicated by Dr. A. D. Waller, F.R.S. Received July 14, 1911.)

18. *The Bacterial Culture as an Electrical Half-Cell.* Barnett Cohen, Department of Physiological Chemistry, Johns Hopkins Medical School, Baltimore, Md.

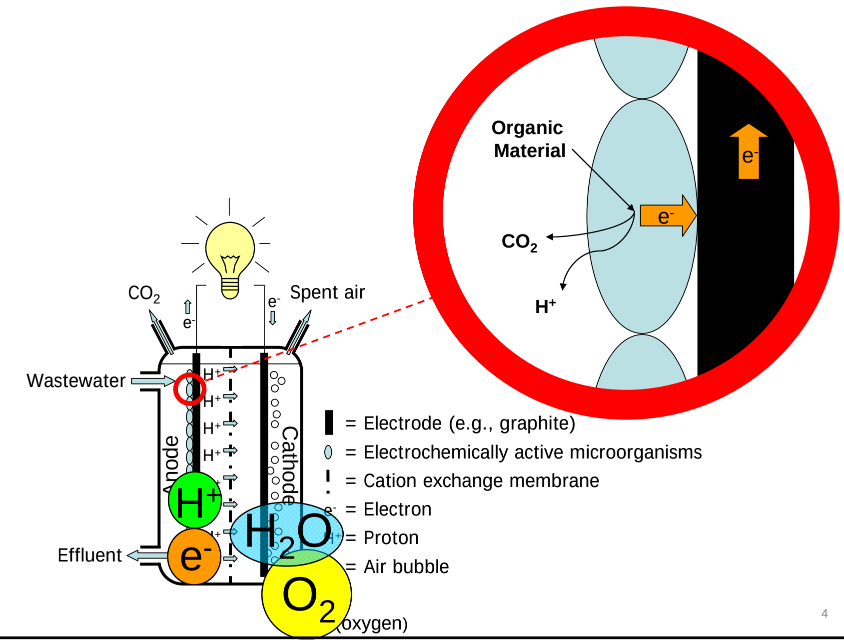
It is well known that bacterial growth is accompanied by a chemical reduction of the culture medium together with a loss of heat and the liberation of oxidation products such as H_2O and CO_2, etc. The measurement of the over-all intensity of the reduction can be made potentiometrically; and it can be shown that, when the neutralizing effects of atmospheric oxygen are eliminated, the reduction potential mounts appreciably.

Proc. R. Soc. London Ser. B ***1911, 84,*** 260-276.

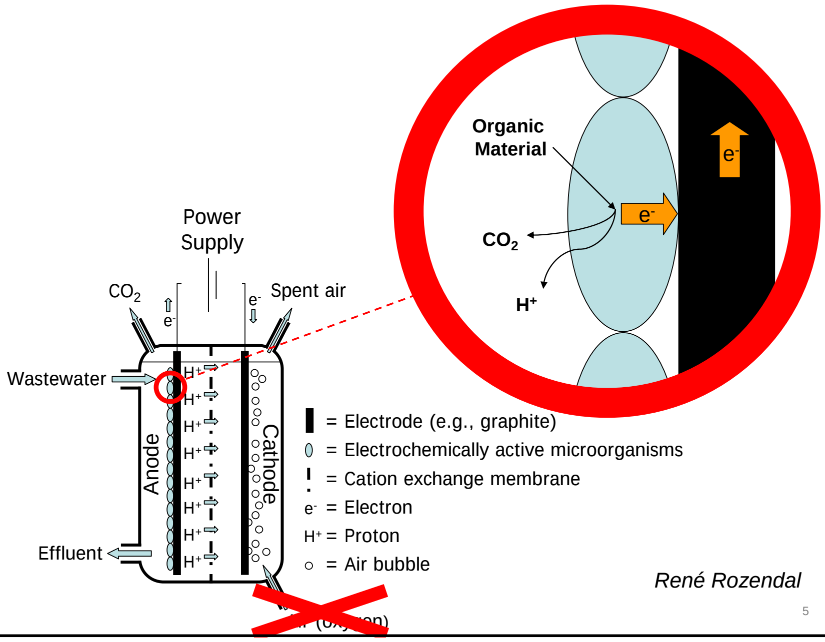
Microbial fuel cell



Microbial fuel cell



Microbial electrolysis cell



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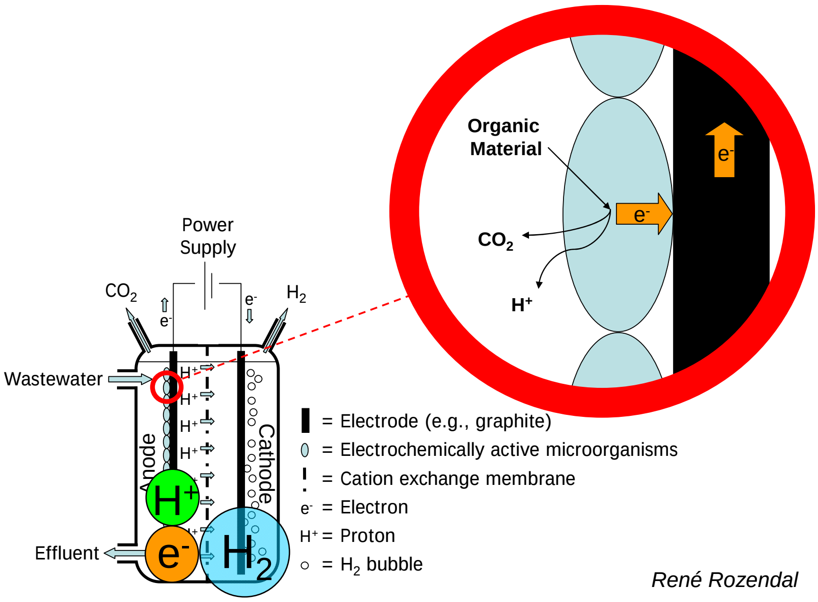
Microbial electrolysis cell



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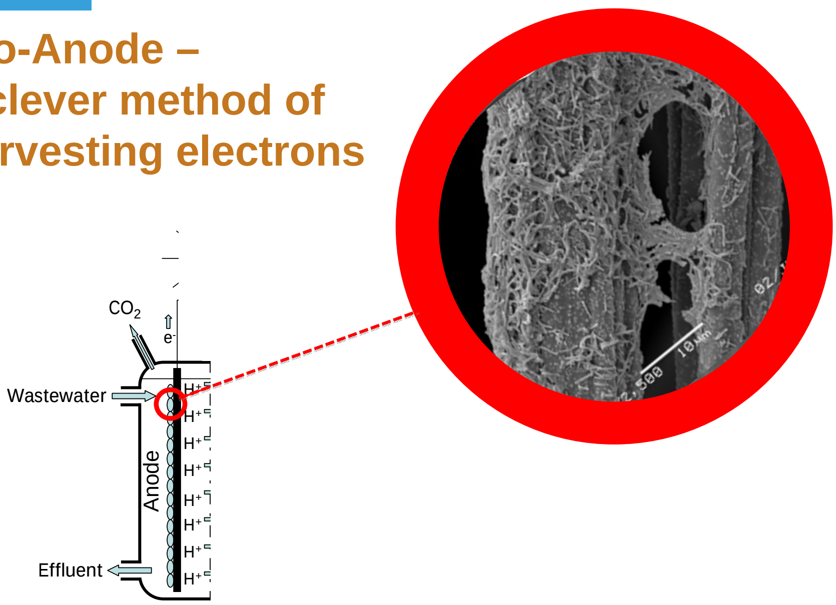
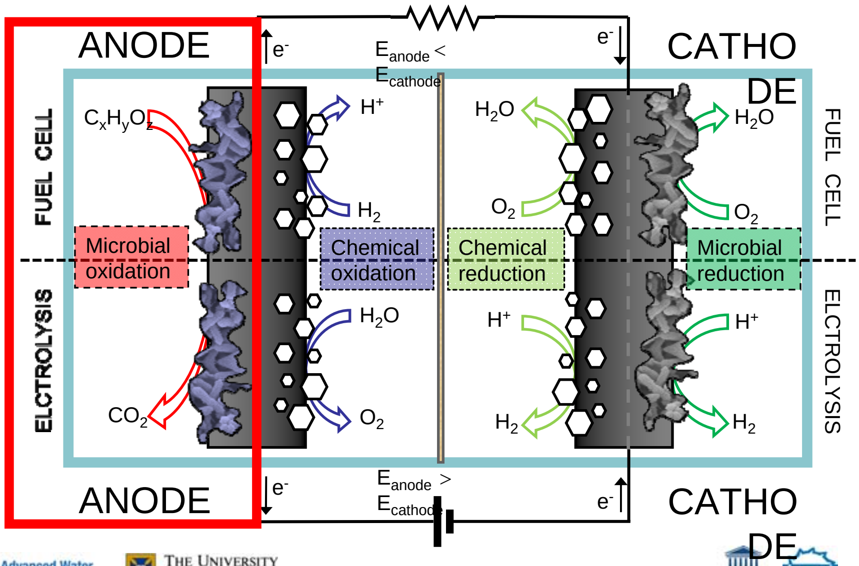
Bio-Anode – a clever method of harvesting electrons



Bio-Electrochemical systems:

MFC & MEC & other bio-electrochemical processes

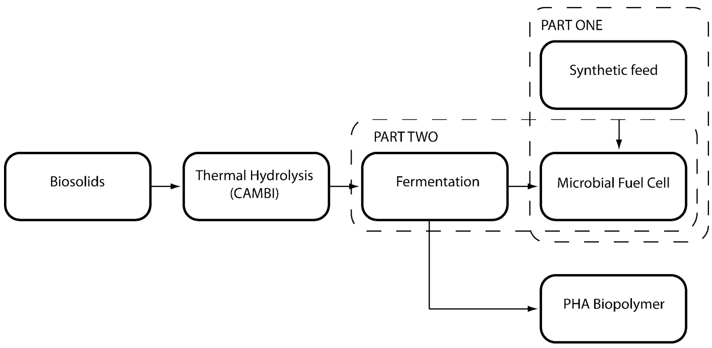


Established anode applications

Anode substrate	Cathode reaction	$P_{max, cont}$ (W/m³ MFC)	$I_{max, cont}$ (A/m³ MFC)	Reference
Acetate	Bio – O_2	83	251	Clauwaert et al., 2007
Hospital wastewater	Ferricyanide	0.5	16	Aelterman et al., 2006
AD influent	Ferricyanide	11	33	Aelterman et al., 2006
AD effluent	Ferricyanide	8	80	Aelterman et al., 2006
Glycerol	Bio – O_2	26	117	Clauwaert et al., submitted
L-glutamine	Bio – O_2	95	225	Clauwaert et al., submitted
L-asparagine	Bio – O_2	68	190	Clauwaert et al., submitted
L-aspartic acid	Bio – O_2	52	167	Clauwaert et al., submitted
L-aniline	Bio – O_2	59	178	Clauwaert et al., submitted
Clover sap	Bio – O_2	70	193	Clauwaert et al., submitted

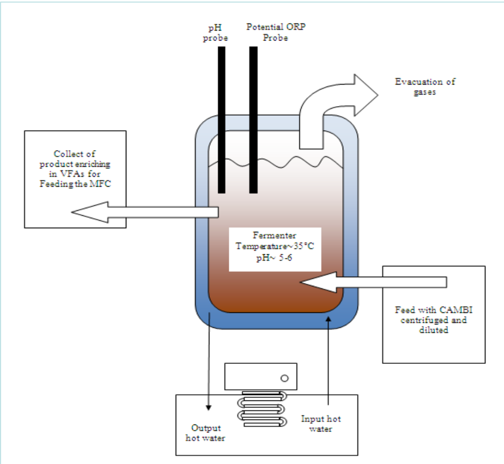
Various organic substrates can be converted to electricity
Biodegradability determines the maximum power output

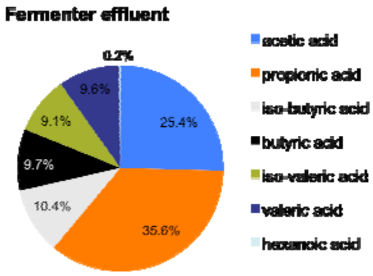
AWMC - Neptune MFC Objectives



- Investigate removal of VFA as produced by fermented CAMBI in MFC
- Investigate fuel cell operational parameters (set-point anode potential and loading)
- Investigate scalability of the technology with pilot plant trial on brewery effluent

Fermenter

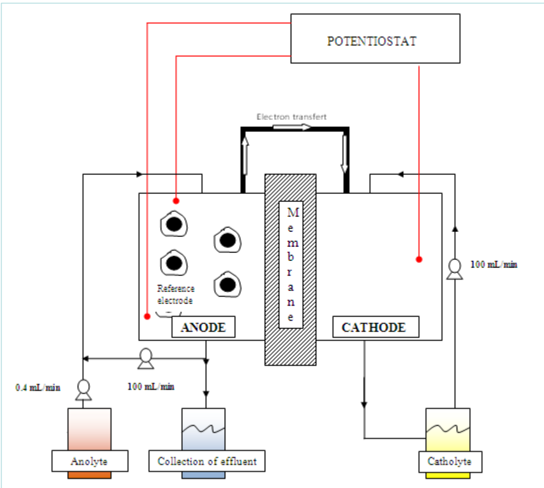




	VFA [mg/L]	pH	K [mS]
Infl.	289	5.52	1.781
Effl.	1072	6.07	1.047

Optimal: one day HRT and control pH [solids contribution minimal]

MFC set-up

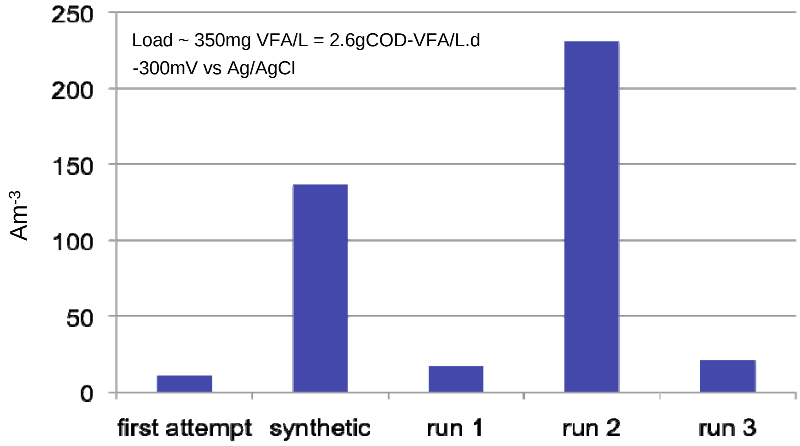


Anolyte: synthetic and 'real' feed
Catholyte: ferricyanide

Controlling: potential of the anode (working electrode) versus Ag/AgCl electrode [-400, -300, -200, -100, 0, 100, 200 mV]

Measuring:
- current
- VFA, sCOD, tCOD, pH, κ, buffering capacity [influent, MFC1, MFC2]
- Volume passed every hour
- NH4-N, PO4-P, Ca, Cu, Fe, K, Mg, Mn, Na, P, S, Zn, Al
- Steady-state and dynamic behaviour

Influence of Buffer and Conductivity



run 1 = 1/3 ferm.eff + 2/3 MQ

run 2 = 1/3 ferm.eff + 2/3 MQ + synthetic phosphate buffer

run 3 = 1/3 ferm.eff + 2/3 MQ + NaCl/KCl mix

Results with Anaerobic Digestion Effluent

Run		VFA [mg/L]	MFC effluent pH	Current density [Am^{-3}]	Coulombic Efficiency {COD-VFA} [%]
Syn	**Synthetic sample**	360	6.77	137	50
4	1/3 ferm.eff + 2/3 **syn buffer**	398	7.1	155	85
5	1/3 ferm.eff + 2/3 AD effluent	390	7.7	191	84
6	1/2 ferm.eff + 1/2 AD effluent	656	7.6	216	82
7	3/4 ferm.eff + 1/4 AD effluent	800	7.2	215	96

Set-point potential of -300mV vs Ag/AgCl

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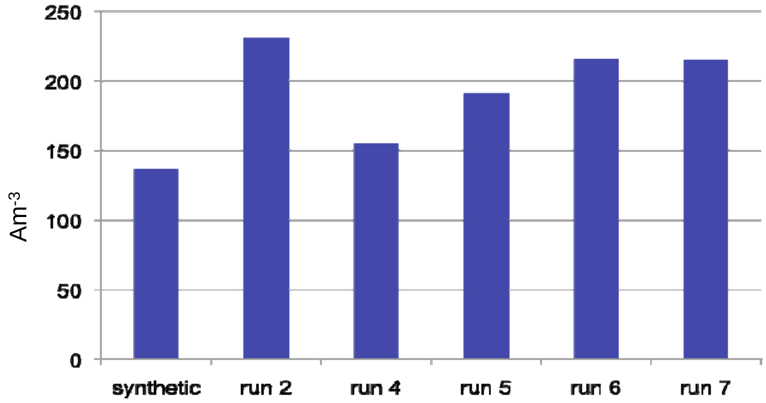
Results with Anaerobic Digestion Effluent



run 2/4 = 1/3 ferm.eff + 2/3 MQ + synthetic phosphate buffer (run 2 → 0.22 μm filtered)
run 5 = 1/3 ferm.eff + 2/3 AD eff.
run 6 = 1/2 ferm.eff + 1/2 AD eff.
run 7 = 3/4 ferm.eff + 1/4 AD eff.

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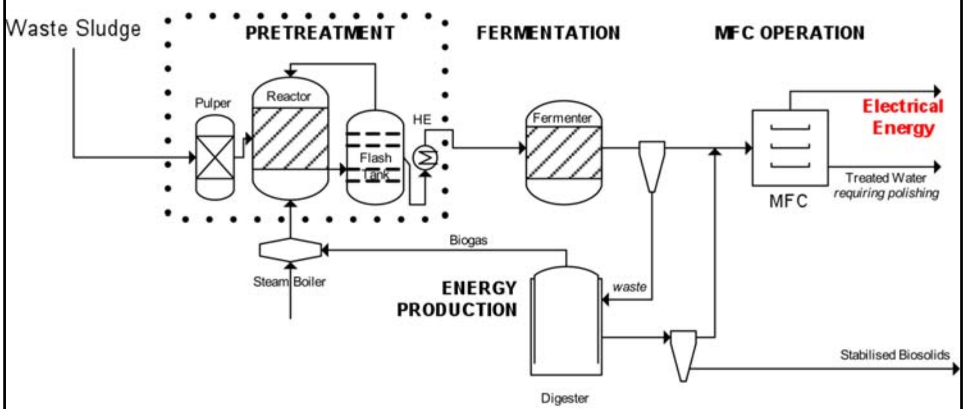
Integrating Concept into WWTP



What cathode product – energy or value-added products?

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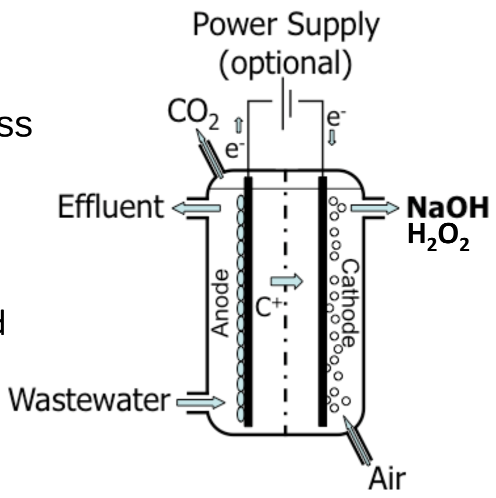
Caustic Production: Problem turned into Product

MFC - Problems

- Poor pH balancing
- Slow, low value process

$NaOH/H_2O_2$ Production

- Fast process
- Reducing energy retained
- Production of valuable product(s)



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Economic Implications

Standard Module
Size ~ 1 m^3

Module price
$25,000

Wastewater
1-100m^3/day

Wastewater
(with reduced organic content)

$1/day
Electricity Input

Caustic soda / Hydrogen peroxide

$7000-24,000/year

Bilexys

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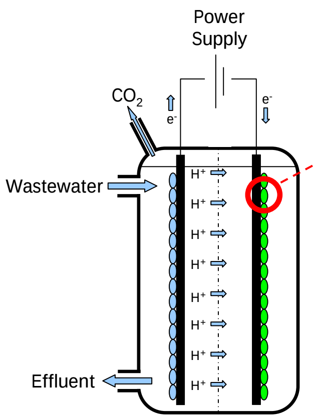
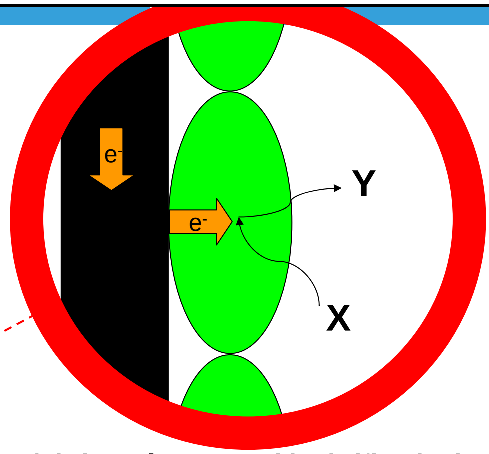
Innovative biocathodes





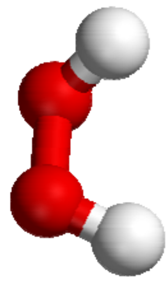
Nitrate/nitrite → **N_2 (denitrification)**

Glycerol → **1,3 propanediol**
\$0 - \$0.60/kg → ***\$1.68/kg***

Butyrate/propionate → butanol/propanol
waste org.& \$0.05/kg →\$1.1/kg

Product value per m³ (@ 1000 A/m³)

- Electricity: ~\$1/day
- Methane: ~\$1/day
- Hydrogen: ~\$5/day
- Hydrogen peroxide: ~\$20/day
- Sodium hydroxide: ~\$30/day
- Mix NaOH/H_2O_2 ~\$50/day
- 1,3 Propanediol ~\$40/day



Excluding electricity costs (\$1-3/day)!

Conclusions

- Bio-electrochemical systems have wide range of potential applications
- Targets have to be set and met:
  - Energy production: 1 kW/m^3 (bio-refinery)
  - Water treatment technology: 1-10 kg COD/m^3.d
  - Product generation: 1000A/m^3
- Operating conditions & integration critical
- Economics will influence developments

Acknowledgments

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- **Project teams at AWMC, UQ and LabMet, UGent**