Electromicrobiology

Sustainable solutions to the waste, energy and climate crisis

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About

- Since 2023: Full Professor SDU; Research team: 10-20 people (https://rotarulab.com/)
- 2023: 5-yr. Associate Prof. (Lektor) SDU
- 2018: 3-yr. Assistant Prof. (Adjunkt) SDU
- 2015: 2-yr. Research Fellow, SDU
- 2013: 3.5-yr. Postdoc, Assist. Prof. Uni Massachusetts
- 2010: 1.5-yr. Postdoc, iNANO, AU
- 2009: 4-yr. PhD Marine Microbiology Max Planck Institute, Bremen Uni
- 2005: 2-yr. MSc Marine Microbiology Max Planck Institute, Bremen Uni
- 2002: 4-yr. BSc Biochemistry Bucharest Uni

About

Past lab members

Mon Ooo Yee
PhD student

Oona Snoeyenbos-West
Postdoc

Paola Palacios
PhD student

& collaborators at AU, SDU, UFZ, Gotheborg, Umass, Aix Marseille

ELITE FORSK

erc European Research Council

MSCA

Mechanisms of interactions with...

Electrodes ← → **Conductive particles, steel, cells** ← → **Pharmaceuticals**

PRESENT TEAM

Abdalluh Jabaley
PhD student

Malene Arreborg
PhD student

Rhitu Kotoky
Postdoc

Ghazaleh Garib
Postdoc

Adrienn Groza
MSc student

Lasse Ørum-Smidt
Lab tech

Danijel Jovicic
PhD student

Karina Hernandez
PhD student

Tetyana Gilveska
Marrie Currie postdoc secondment

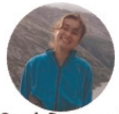
Satoshi Kawaichi
Staff Scientist ATAP

Konstantinos Anestis
Postdoc

Lorena Selak
Postdoc

Yanan Wang
Guest UCAS PhD student fellow

Sebastian Bjørnskov
MSc/PhD student



Sarah Damgaard
MSc student

DANMARKS FRIE FORSKNINGSFOND
INDEPENDENT RESEARCH FUND DENMARK

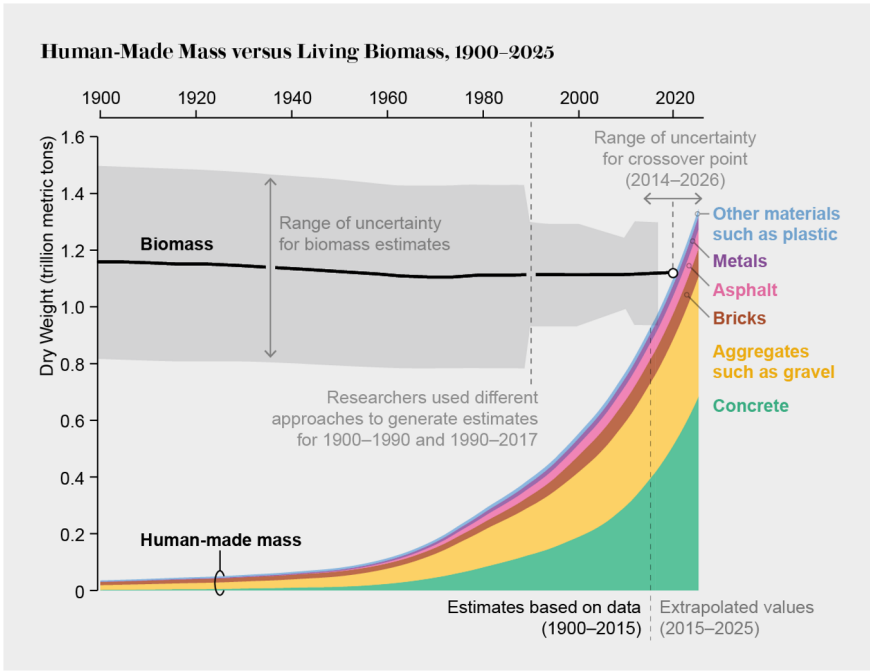
Innovationsfonden

novo nordisk fonden

The waste problem

- We make a lot of waste

Human-made objects may now outweigh all of the living beings on Earth.



The waste problem

- Not all waste is the same

-80% of wastewater worldwide is released to the environment without adequate treatment

The waste problem

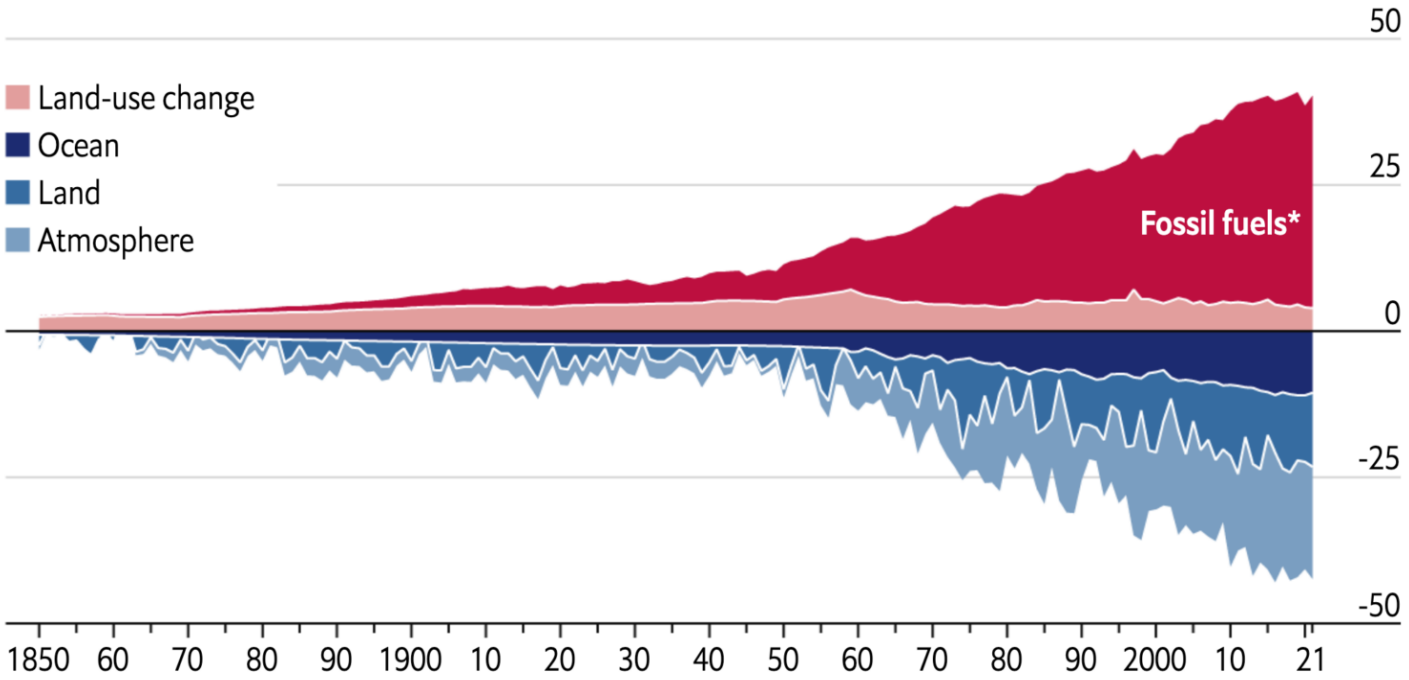
- We treat, sell, hide, send waste to outer space

The waste problem

- We treat, sell, hide, send waste to outer space

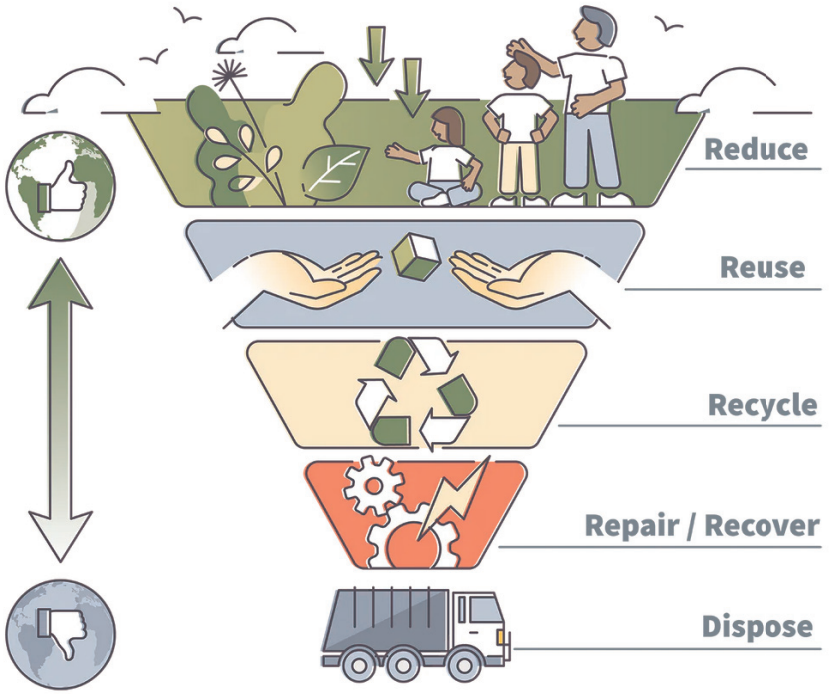
The waste problem

- We unearth carbon (fossil fuels) to make products that end up as waste & CO_2



How to solve it?

1. Reduce, Reuse, Recycle
2. Capture & Sequester



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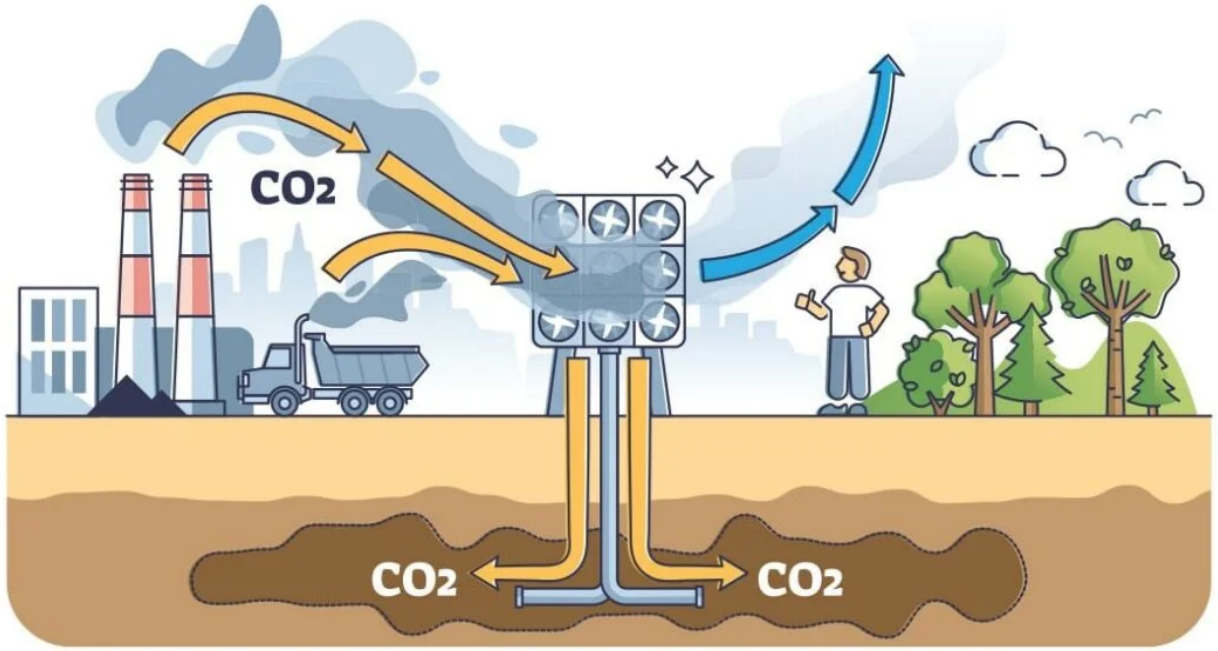


EU to become climate neutral by 2050

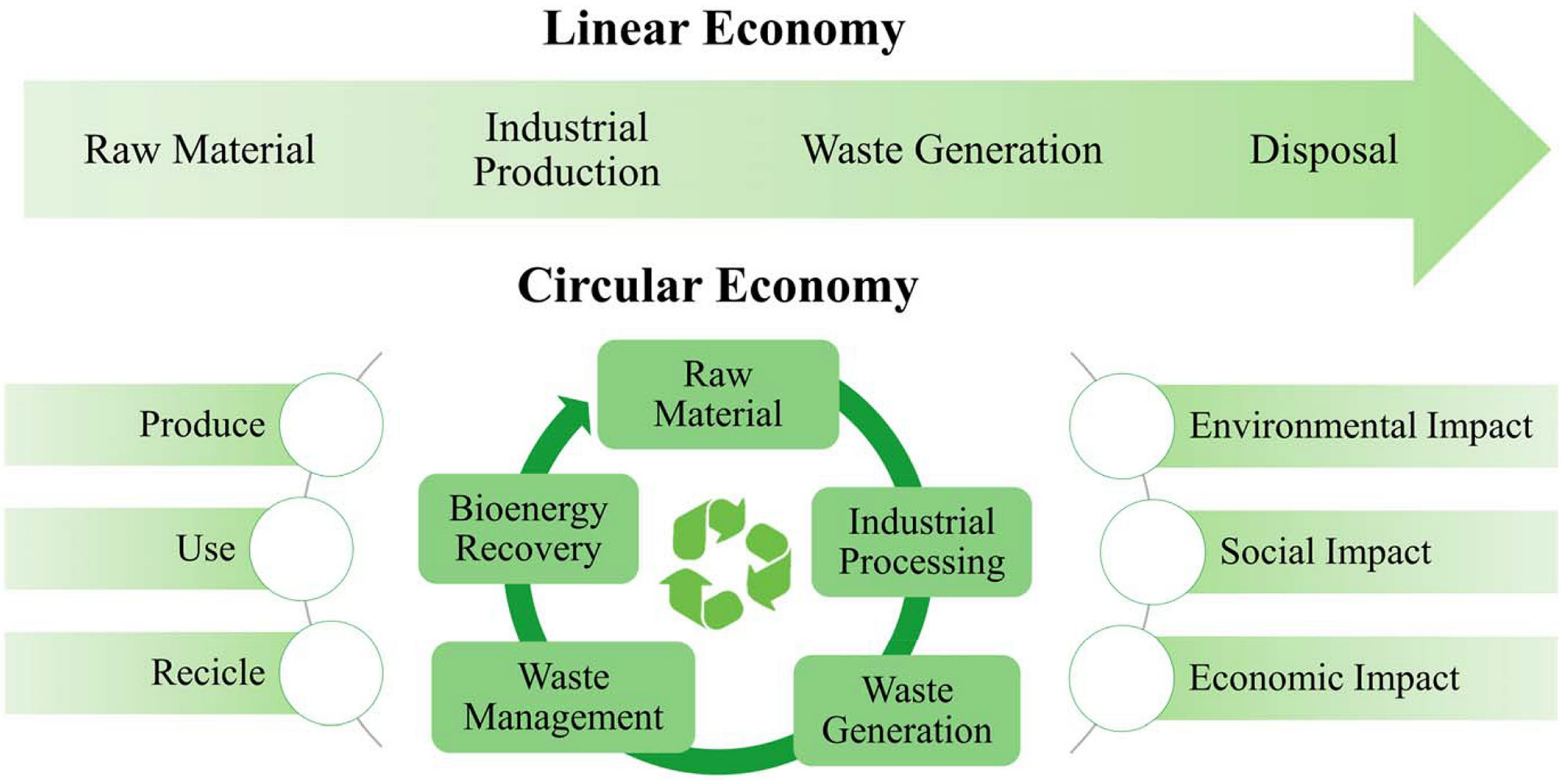
Become climate-neutral by 2050

Protect human life, animals and plants by cutting pollution

Help companies become world leaders in clean products and technologies

Help ensure a just and inclusive transition

Circular bio-economy

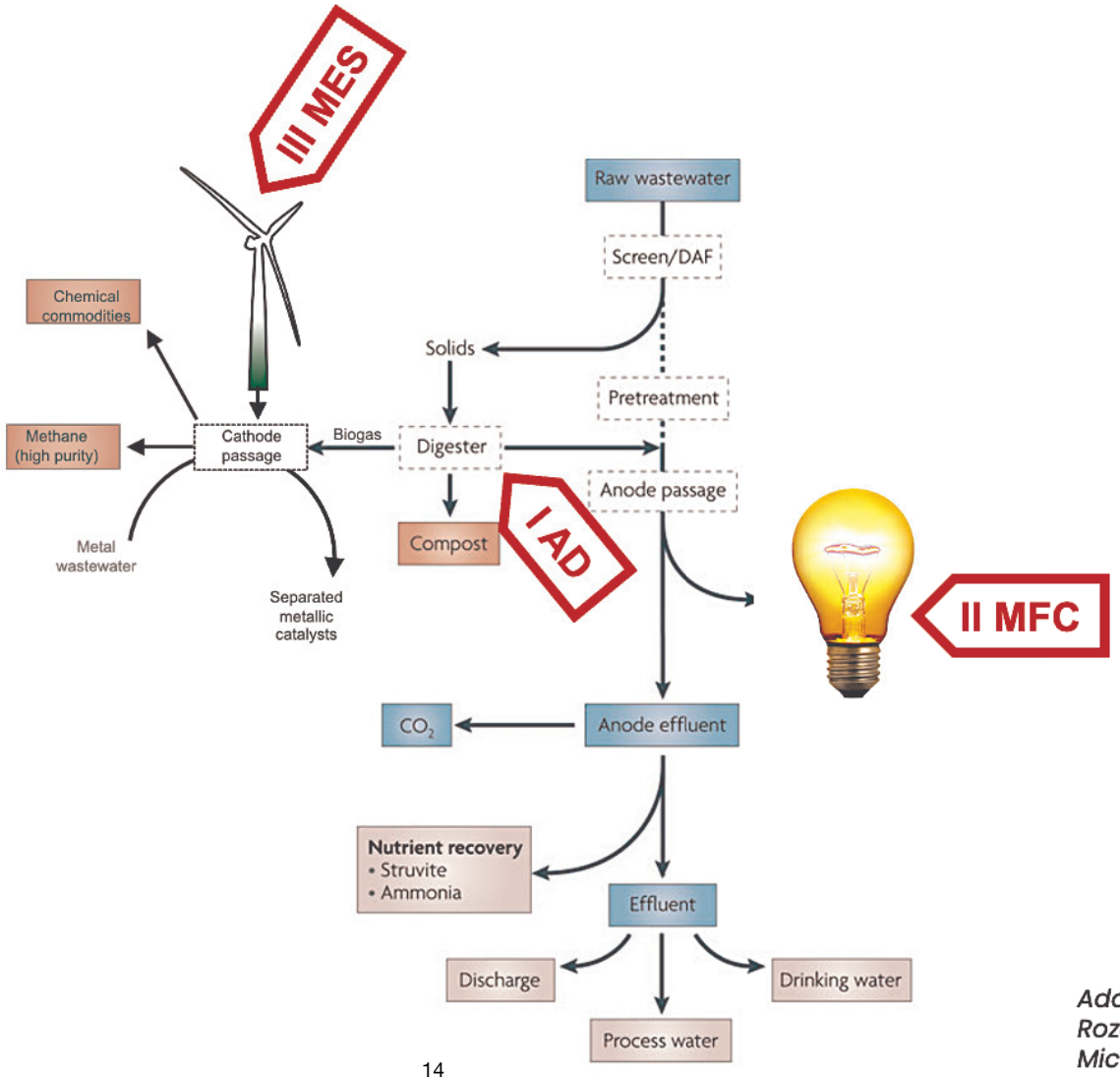


Ferreira 2020

Microbes can help solve the wastewater problem

-80% of wastewater worldwide is released to the environment without adequate treatment

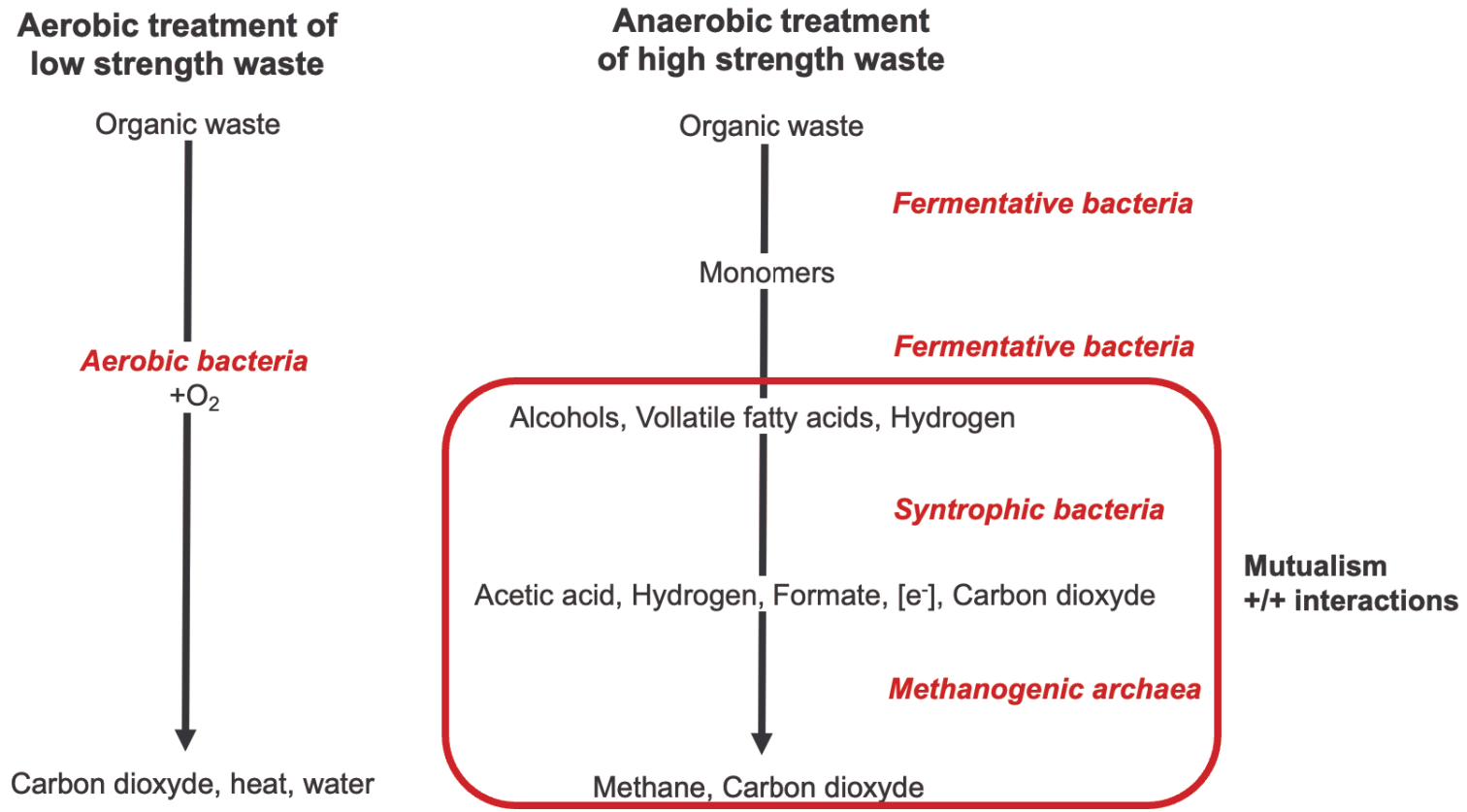
Microbes as key players in the ‘waste to resource’ conversion



Adapted after Rabaey & Rozendal, Nat. Rev. Microbiol. 2010

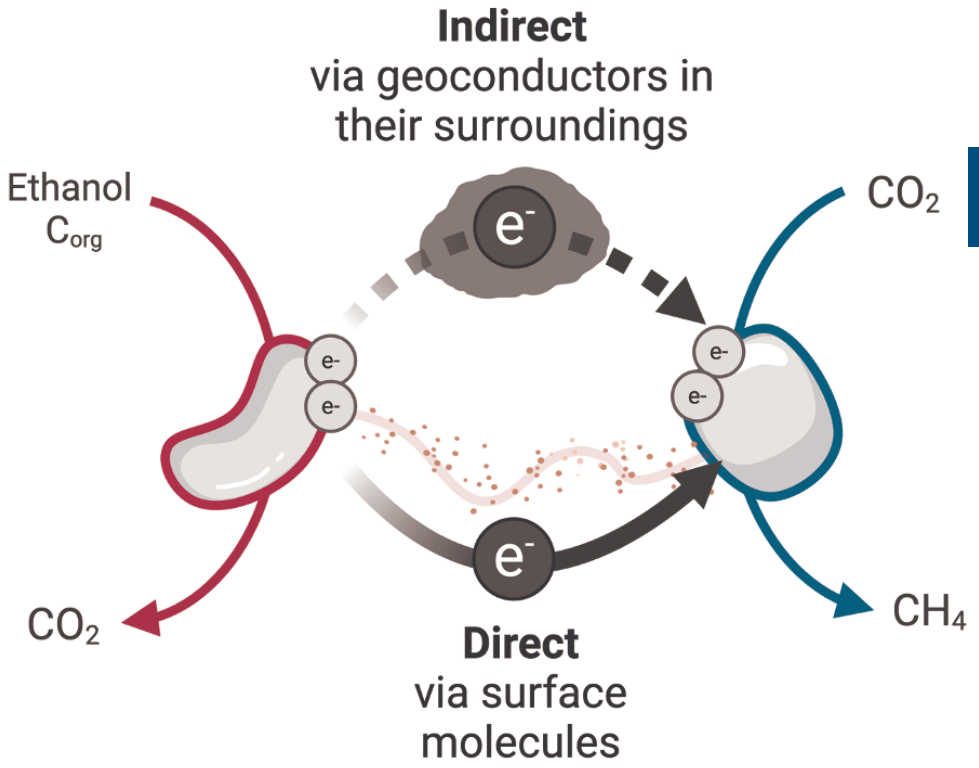
I. Anaerobic digestion

I. AD



Interspecies interactions

I. AD

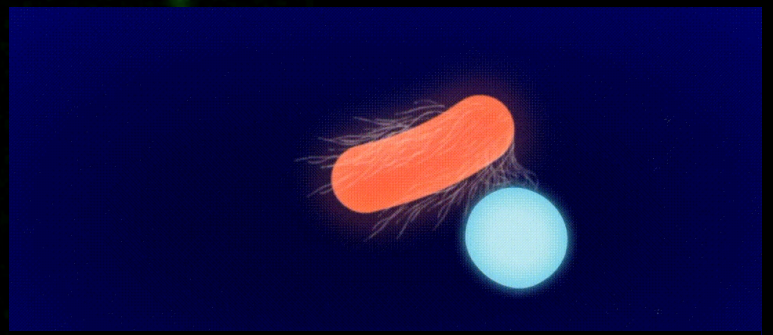


ΔG0'<0 (favourable) if there is an e- donor

ΔG0'>0 (unfavourable) without e- being removed

Liu, Rotaru et al. Energy & Environmental Science 2012
Rotaru et al. Energy & Environmental Science 2013
Rotaru et al. Applied & Environmental Microbiology 2014

I. AD

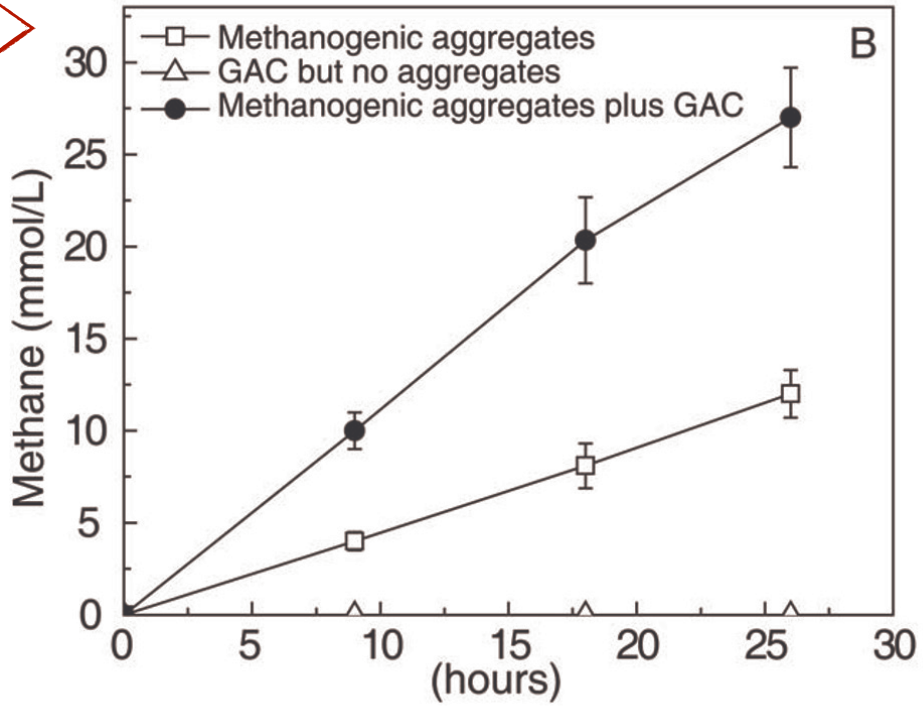


An interaction typical in some anaerobic digesters, rice paddies and lake or coastal marine sediments

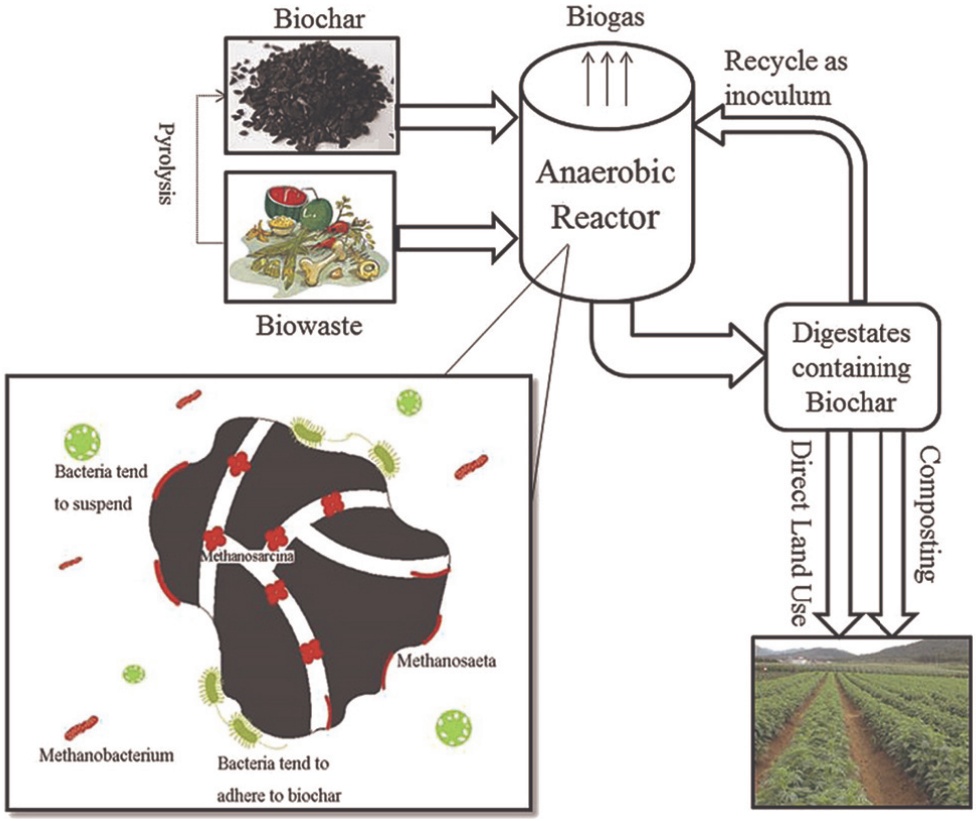
Rotaru AEM 2014

I. Promoting methanogenesis in AD

I. AD



Liu, Rotaru et al. Energy & Environmental Science 2012

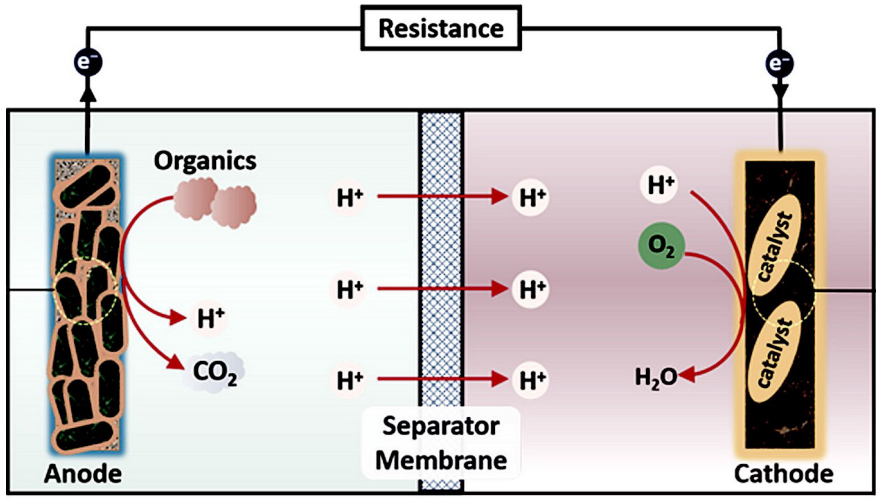


Luo et al. Water Research 2015

II. Microbial Fuel Cells MFC

II. MFC

- Oxidise recalcitrant organics
- Produce electricity
- Waste-carbon recovery



Zhu 2021

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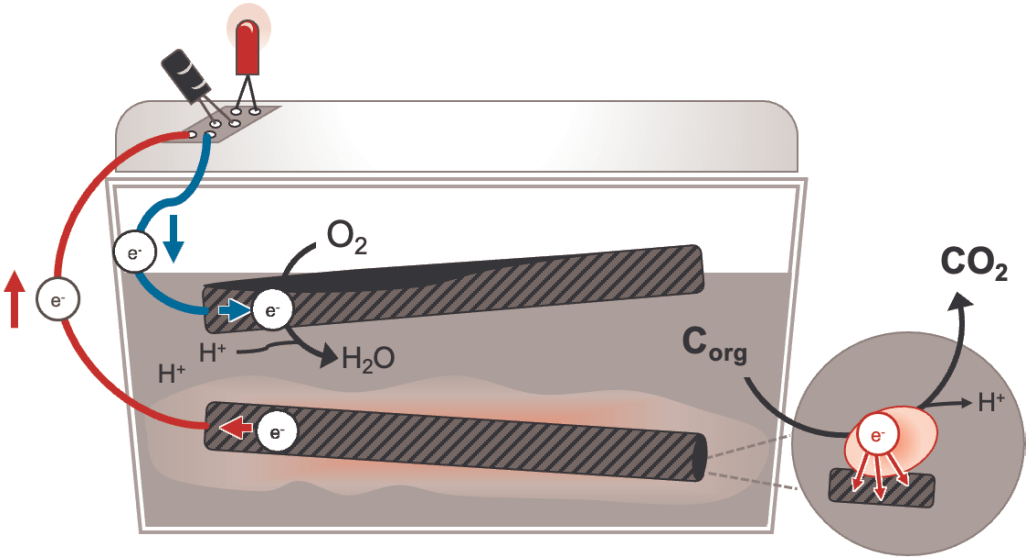
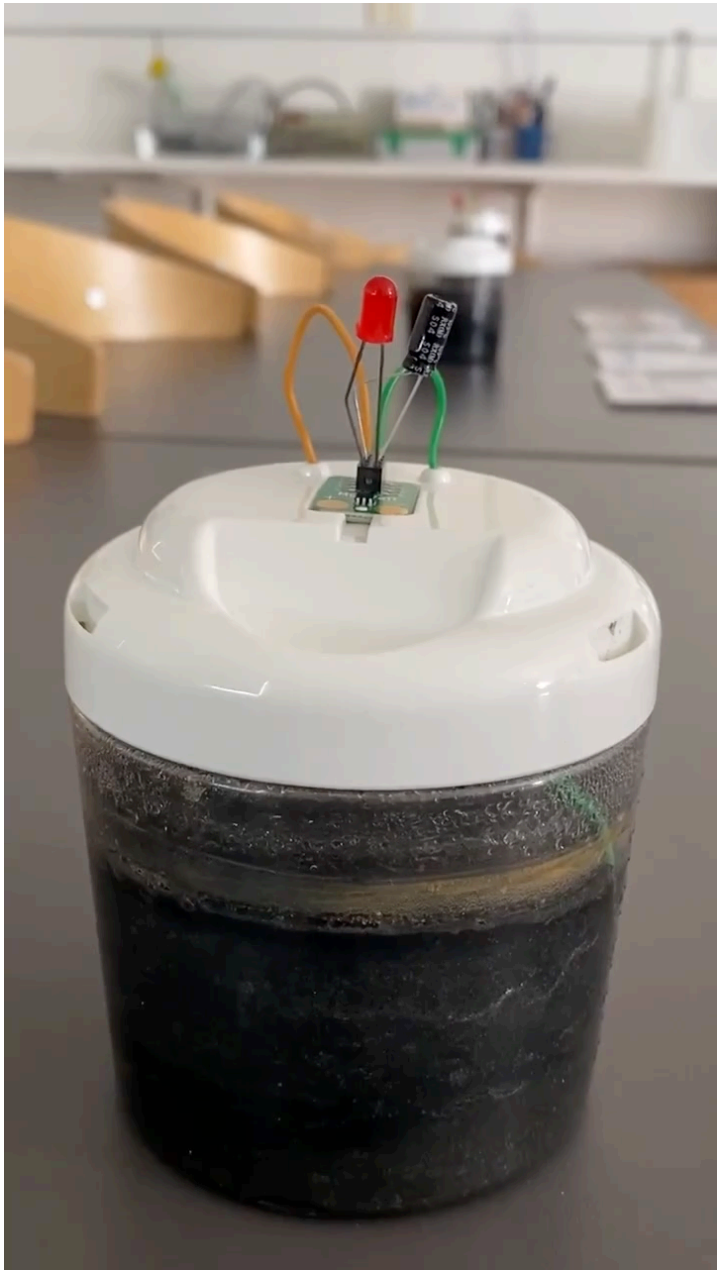
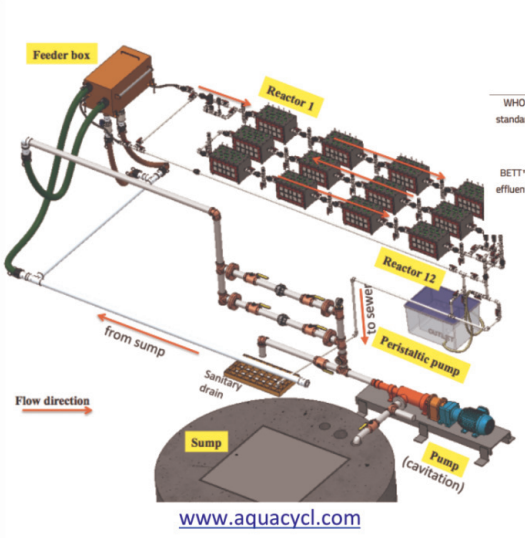




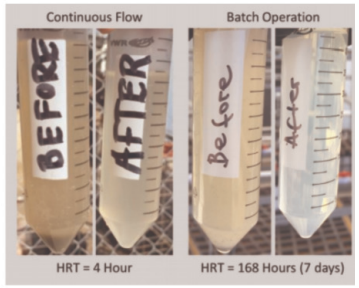
II. Companies employing MFCs

II. MFC

- Treat high strength wastewater
- Produce clean water for agriculture



		BOD5 (mg/L)	COD (mg/L)	TSS (mg/L)	pH	Nitrate (mg-N/L)	Total N (mg-N/L)	*E. coli*	Intestinal helminth eggs
WHO standard	Field crops, industrial crops, and forestry	300	500	150	6.0-9.0	45	70	NA	≤1.0
BETT™ effluents	Treated swine wastewater (4hr HRT)†	NA	≤ 500*	280‡	7.2-8.1	< 5*	< 25*	NA	NA



II. Where could this be especially useful?

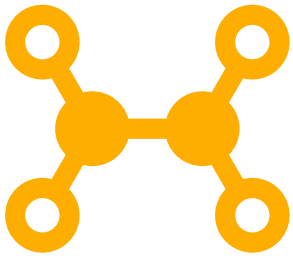
II. MFC

- Third world
- Remote farms
- Remote military bases
- Soda companies (high-strength waste)

Other uses for MFCs

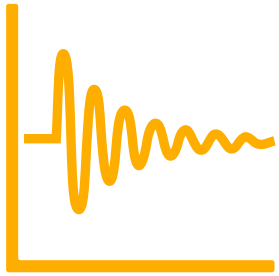
II. MFC

Bioremediation



Powering remote devices

Sensing



Other uses for MFCs - bioremediation

II. MFC

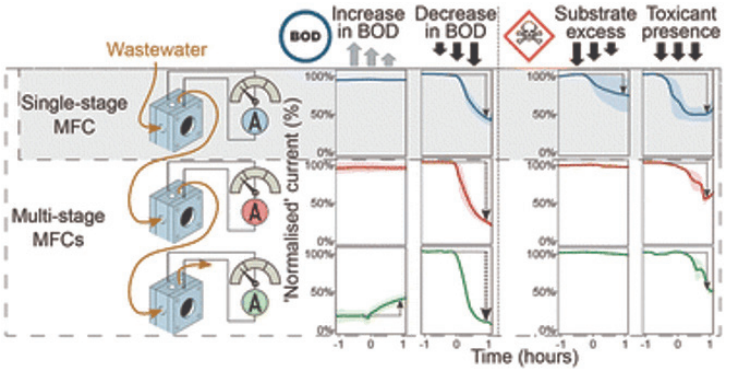
- 22-24% petroleum HC from contaminated marine sediment (Viggi 2015)
- 63-74% diesel & engine oil from waterlogged contaminated soil (Lu 2014)
- 74-92% Polycyclic aromatic HC from lake & river sediments (Li 2017)
- 64% azo dye from planted wetland soils (Fang 2015)
- 94% herbicide from rice paddy soil (Dominguez-Garay & Esteve-Nunez 2018)



Other uses for MFCs - bioremediation

II. MFC

- Sensing toxic chemicals:
  - Metals & metalloids (i.e, Hg, As)
  - Antibiotics (i.e., Ampicilin)
  - Organic toxins (e.g., PCBs)
  - Inorganic toxins (e.g., ammonia)



Spurr 2020

Other uses for MFCs - bioremediation

II. MFC

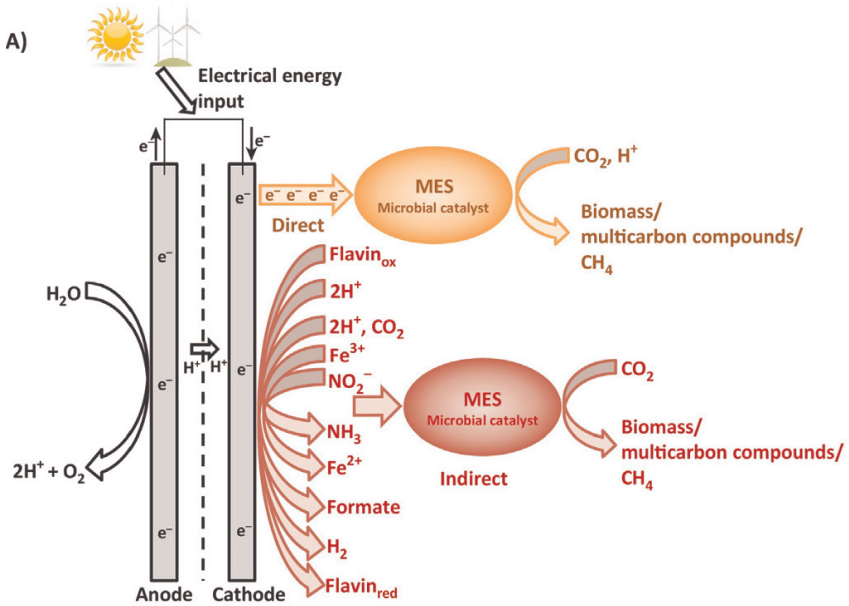
- Powering remote devices:
  - Field deployment in a salt marsh powering a meteorological buoy

Tender 2008

III. Microbial Electrosynthesis Cells MES

III. MES

- Store electricity
- Capture CO_2 from waste
- Chemical synthesis
- Bioremediation

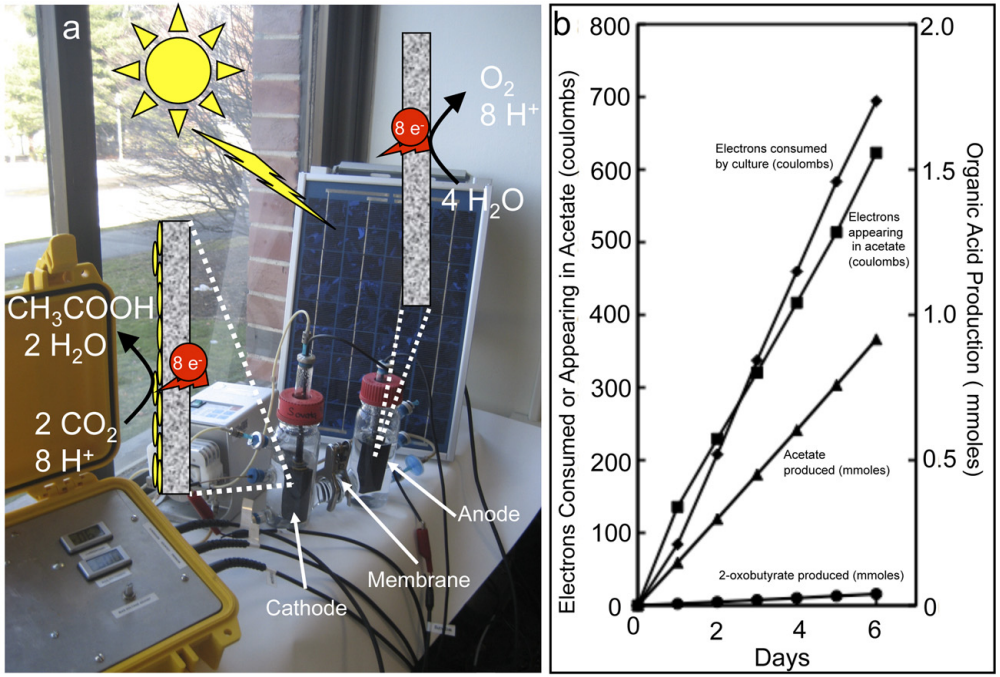


Tremblay 2017

Electroacetogenesis

III. MES

Biofilms of *Sporomusa ovata* **converted electricity and CO_2 to acetate**

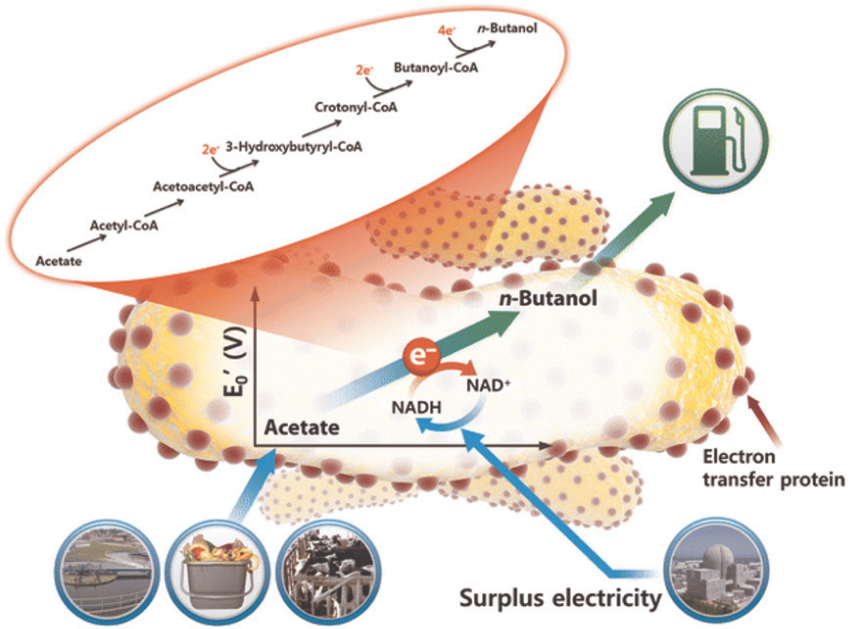


Nevin 2010

Genetic engineering for MES

III. MES

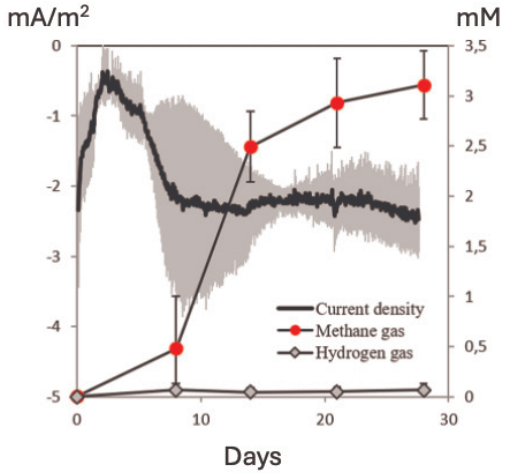
Entire pathways can be introduced to synthesise chemicals of interest

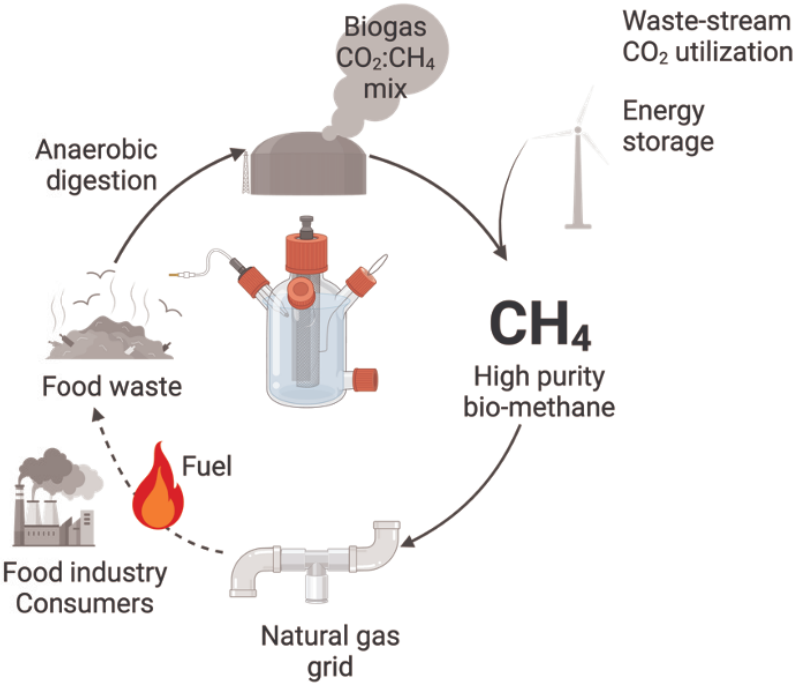


Choi and Sang 2016

Electromethanogenesis

III. MES





Yee 2019

Electrostimulation of C_{org} removal from waste streams

- Identified key microbial players
- We enhanced Corg removal and methane buildup using electrochemical stimulation

III. MES

Collaboration with local industry on Fyn (Nature Energy)

Take home message

- Recycle C & other nutrients from waste (water & gas) using electromicrobiology
- MFC to recycle C from wastewater, remove & sense toxins
- MES to recycle C from waste gas, store electricity into useful chemicals
- Towards a fossil-fuel free chemical industry