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Utilization of organic resources and microbial electrochemistry for green hydrogen production

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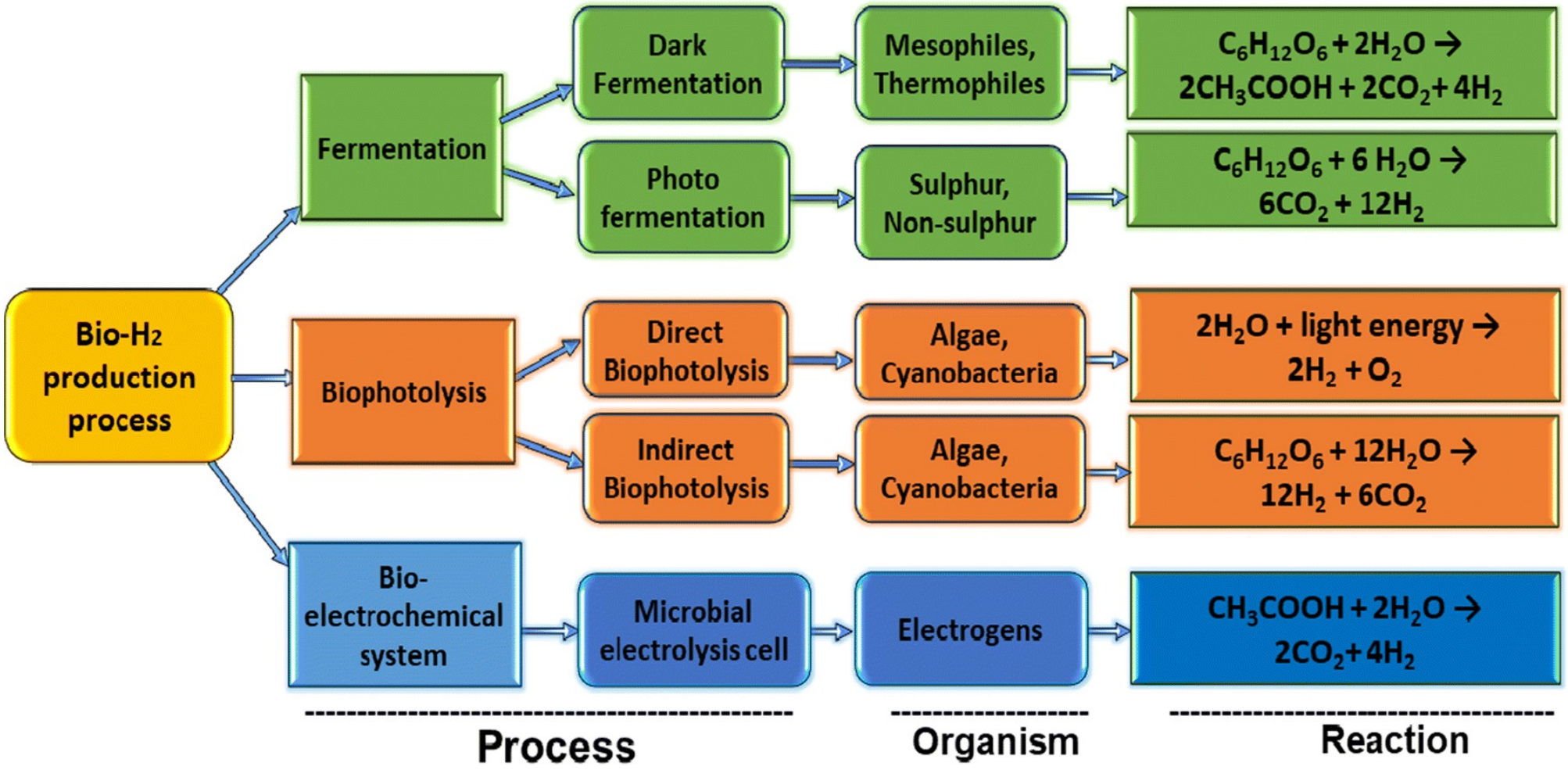
Organic Resources & Microbial Pathways

1. Organic waste (household)
2. Wastewater
3. Produced water
4. Volatile fatty acids

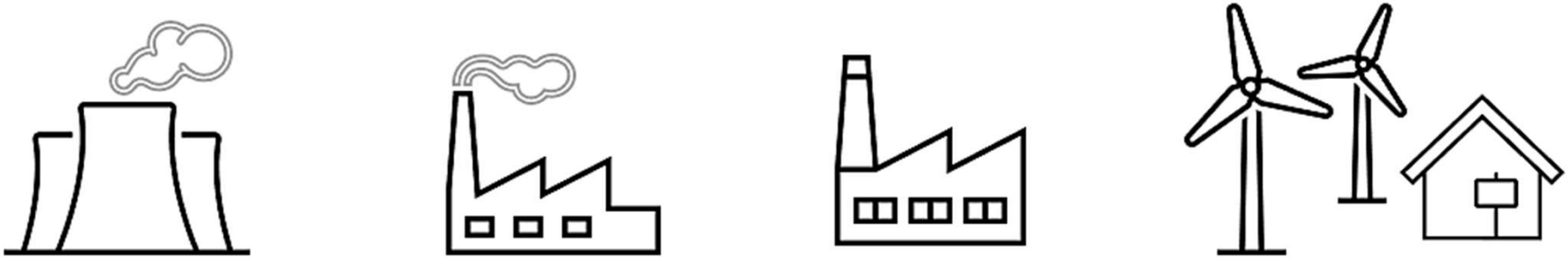
1. Biofermentation
2. Biophotolysis
3. Bioelectrochemical system
4. Gasification

Microbial Pathways



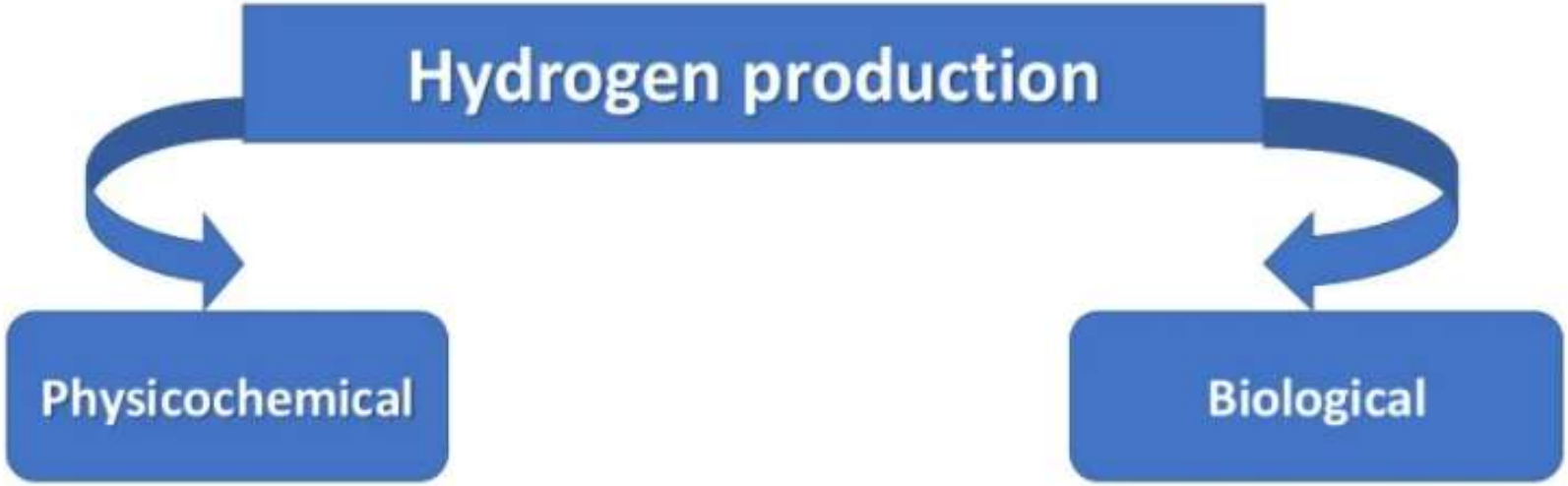
Ref: Osman, A.I., Deka, T.J., Baruah, D.C. et al. Critical challenges in biohydrogen production processes from the organic feedstocks. Biomass Conv. Bioref. (2020).

‘Colors’ of Hydrogen



Brown hydrogen	Grey hydrogen	Blue hydrogen	Green hydrogen
Hydrogen produced using fossil fuels	Hydrogen as a product of industrial processes	Hydrogen produced using fossil fuels but with CO_2 capture	Hydrogen produced using electrolysis and renewable energy or nuclear
Higher carbon		Lower carbon	Zero carbon

Biohydrogen Pathways



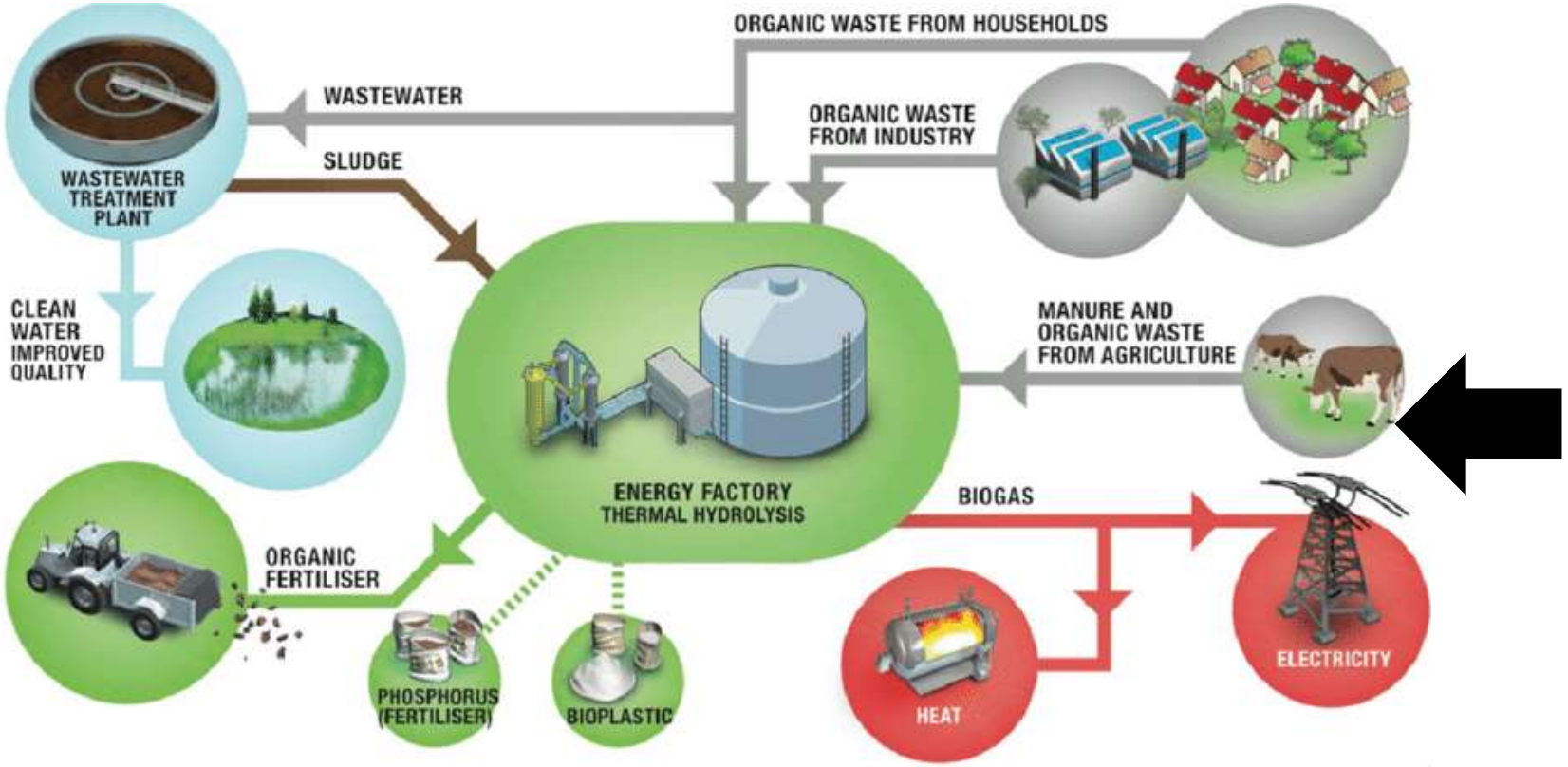
1) Steam reforming of light HCs
2) Thermal cracking of natural gas
3) Partial oxidation/gasification of heavier HC or coal
4) Electrolysis of water

1) Dark fermentation
2) Photo fermentation
3) Bio-photolysis
4) Integration of dark + photo fermentation

The Biorefinery Approach

Biorefinery: Refinery that converts **biomass to energy** and other beneficial **byproducts (such as chemicals).**

Biorefining is defined as "the sustainable processing of **biomass** into a spectrum of bio-based products (food, feed, chemicals, materials) and bioenergy (biofuels, power and/or heat)"



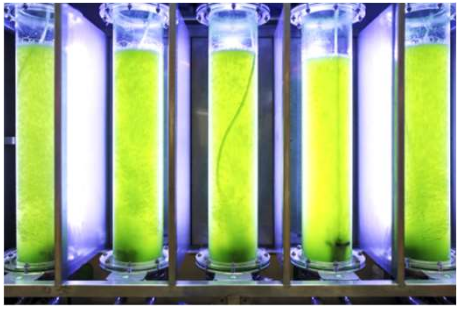
Billund Biorefinery

Type of Biorefineries

Municipal Solid Waste

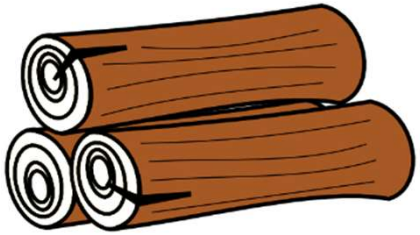
Whole Crop

Green



Marine

Lignocellulosic



FLEXI-GREEN FUELS

https://flexigreenfuels.eu/

Project budget	Project partners	Project Start	Project Duration
~4 Mio €	13 Partners	January 1st 2021	36 Months

Ref: This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 101007130.

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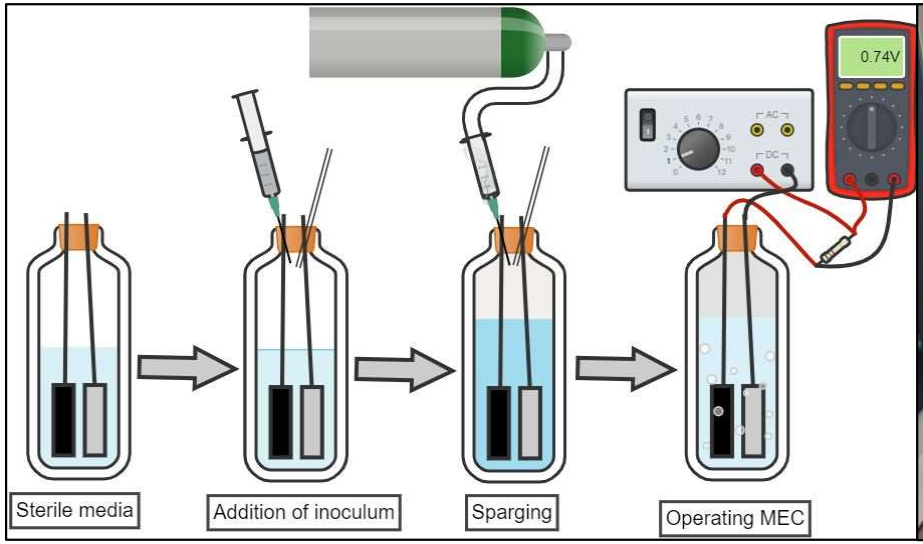
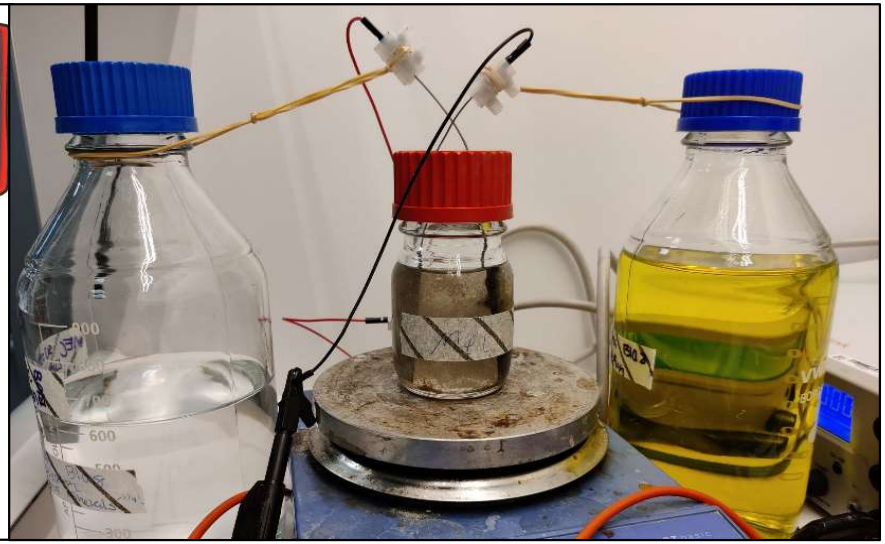
The Consortium

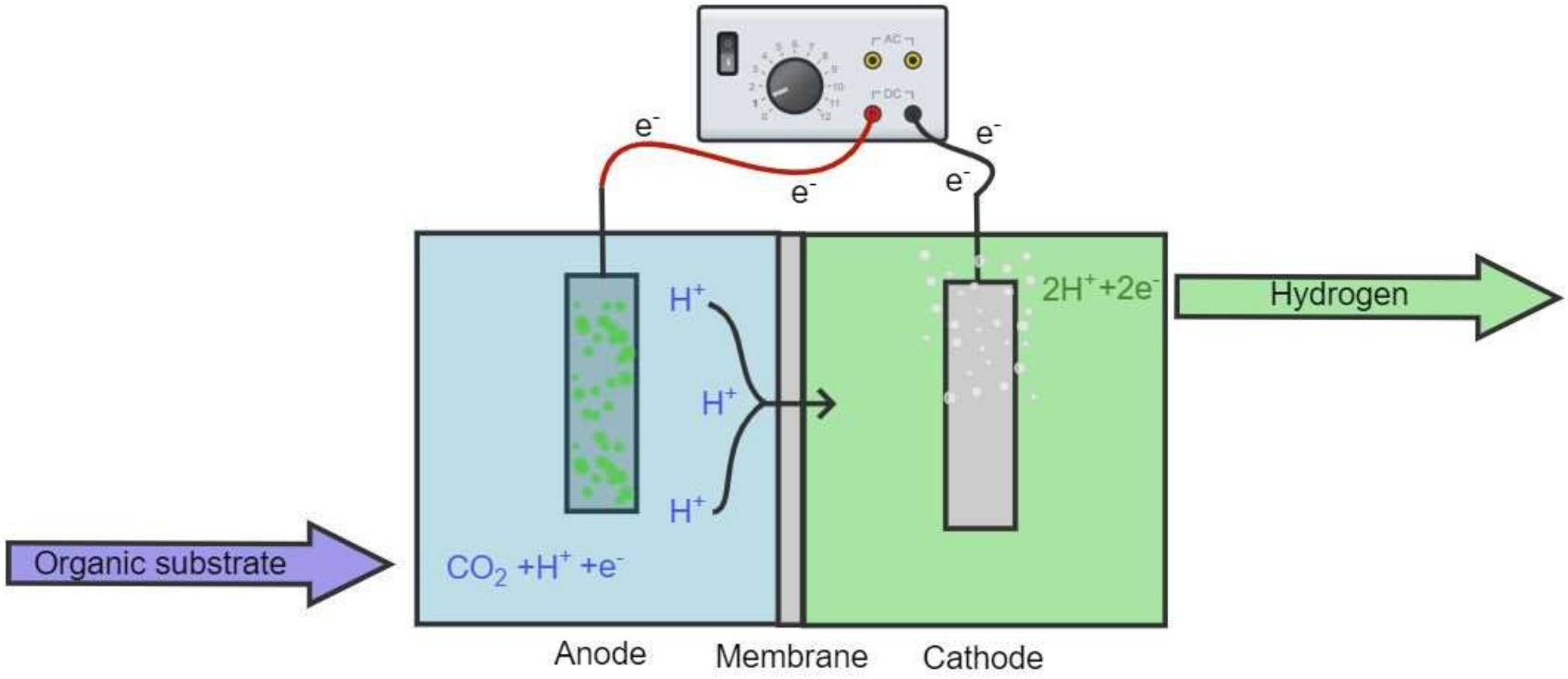
A Microbial Electrolysis Cell (MEC)

- Breakthrough in 2005
- Architecture:
  - Anode: A microbial anode
  - Cathode: An “almost conventional” hydrogen evolution
  - Electrolyte: microorganisms and the culture medium
  - Catalyst: electroactive biofilm i.e. electro-catalyst
- The microbial anode can oxidize a large variety of low-cost carbon compounds





MEC Setup



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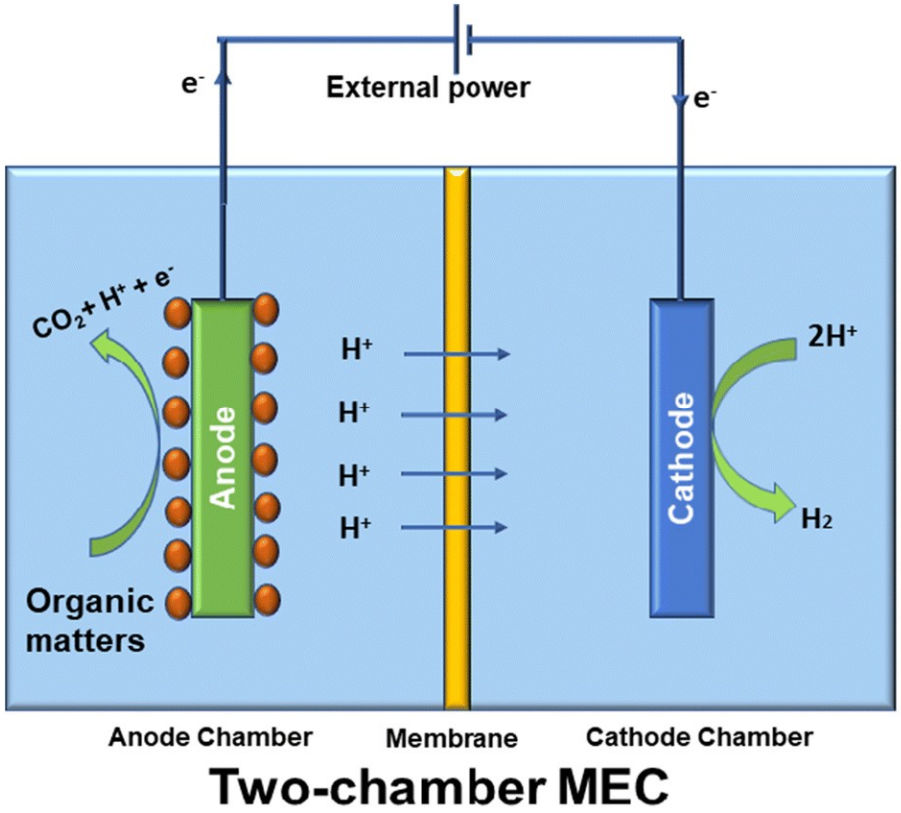
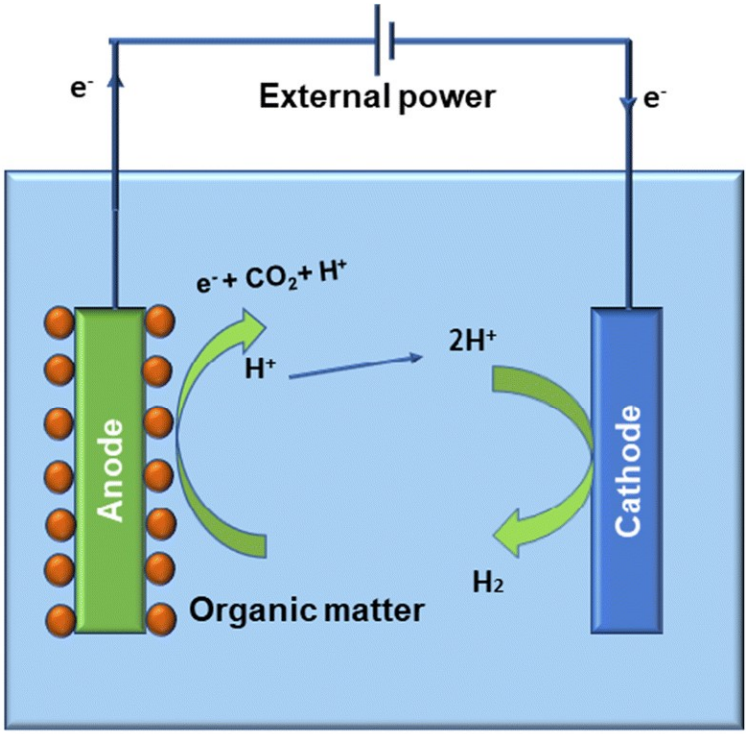
MEC Design Configurations



Two-chamber MEC



Single-chamber MEC

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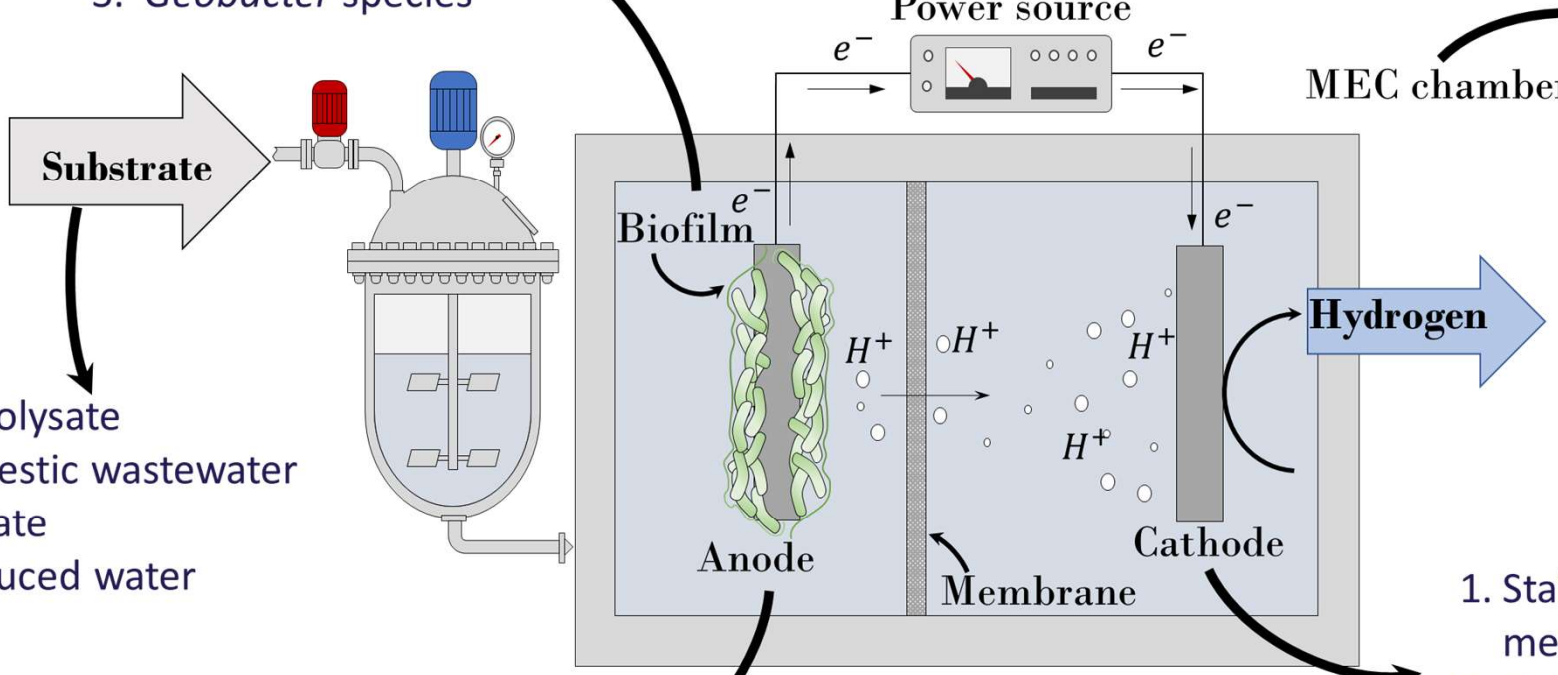
Various challenges in MEC research

1. Wadden sea sediment
2. Domestic wastewater
3. *Geobacter* species



MEC chamber

1. Single chamber
2. Two chamber
3. Continuous flow

1. Hydrolysate
2. Domestic wastewater
3. Acetate
4. Produced water

1. Carbon cloth
2. Graphite plate

1. Stainless steel mesh
2. Carbon paper with Platinum catalyst

Antagonistic Problems

Sustaining microbial growth in a culture medium

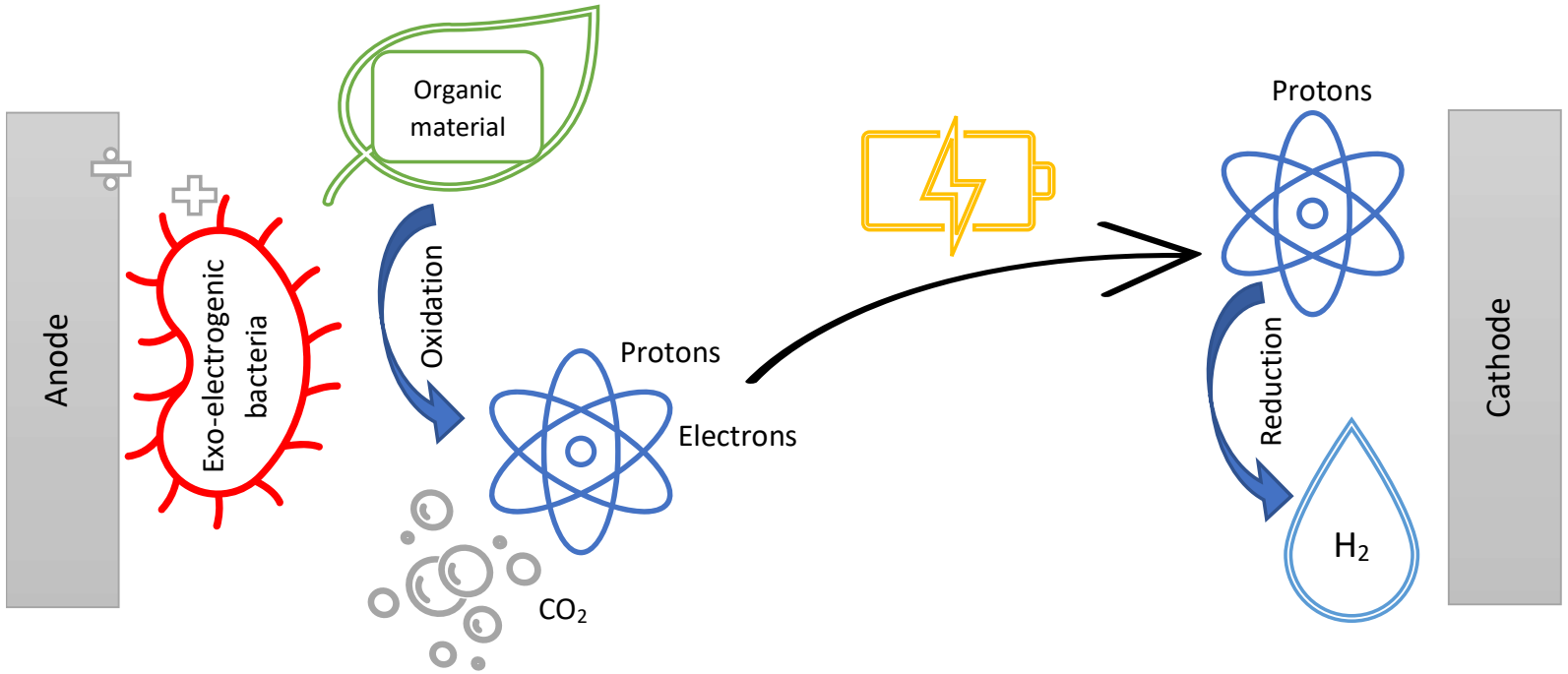
vs

an electrolyser for large-scale hydrogen production are two antagonistic objectives.

- Electrochemical processes : Clean electrolytes, minimal inhibition of the electrode catalysts, high energy input.
- Sustaining microbial growth: Neutral pH, chemically rich media, slow start-up time .

Strengths of a MEC

- Low equilibrium cell voltage 0.123 V vs 1.23 V for water electrolysis
- Possibility to work at high pressure
- Anode: low-cost, self-assembled and self-sustained; heterogeneous organic electrolytes.
- Potential for methane (anaerobic digestion applications)



Areas of Improvement

- Hydrogen can be consumed at the bioanode
- Ca^{2+} , Mg^{2+} and other ions can cause local alkalinization on the cathode
- Saline electrolyte increases the risk of corrosion
- Anode: Morphology and bioanodes
- Cathode : Homogeneous catalysis of hydrogen evolution reaction

Amalgamation of Research Areas

- Chemical Engineering
- Electrochemistry
- Sustainable Energy Systems
- Advanced Electronics
- Microbiology
- For Biological systems
  - Process Modelling
  - Machine Learning

THANK YOU FOR YOUR ATTENTION

QUESTIONS