

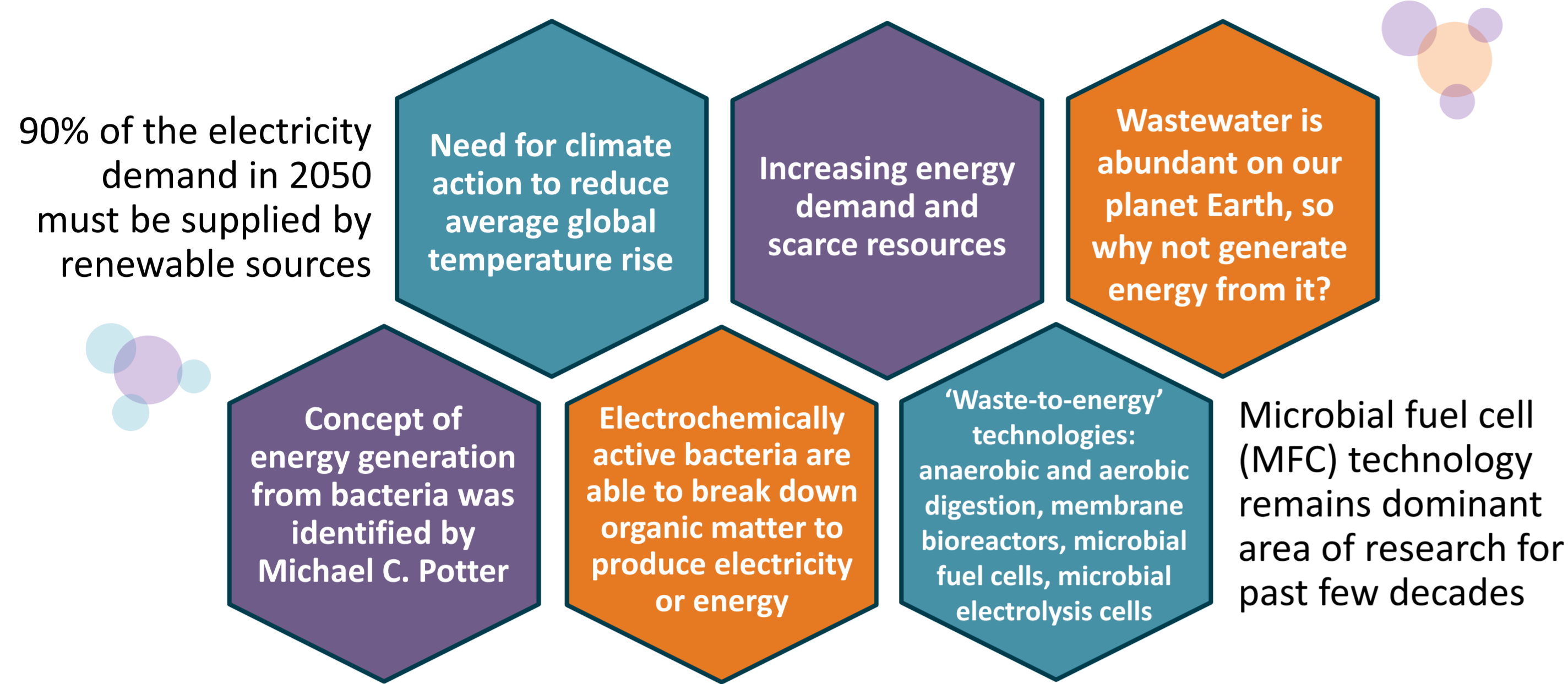
Economic feasibility of large-scale bioelectric systems for treatment of organic matter in wastewater

Laidlaw Scholar: Saranya Saravanan
Supervisor(s): Dr Luiza Campos and Enrique Arroyo

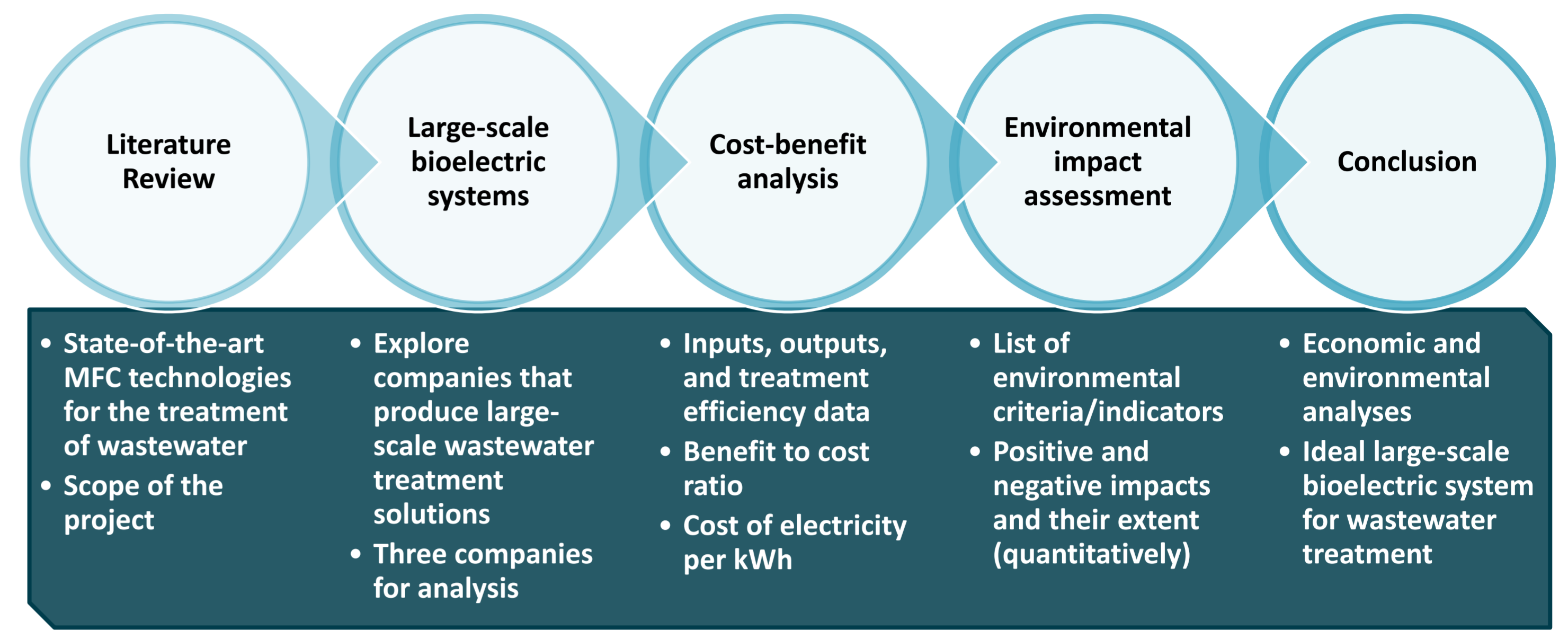
Departments: Chemical Engineering; Civil, Environmental and Geomatic Engineering
The Laidlaw Research and Leadership Programme – UCL



Introduction



Methodology

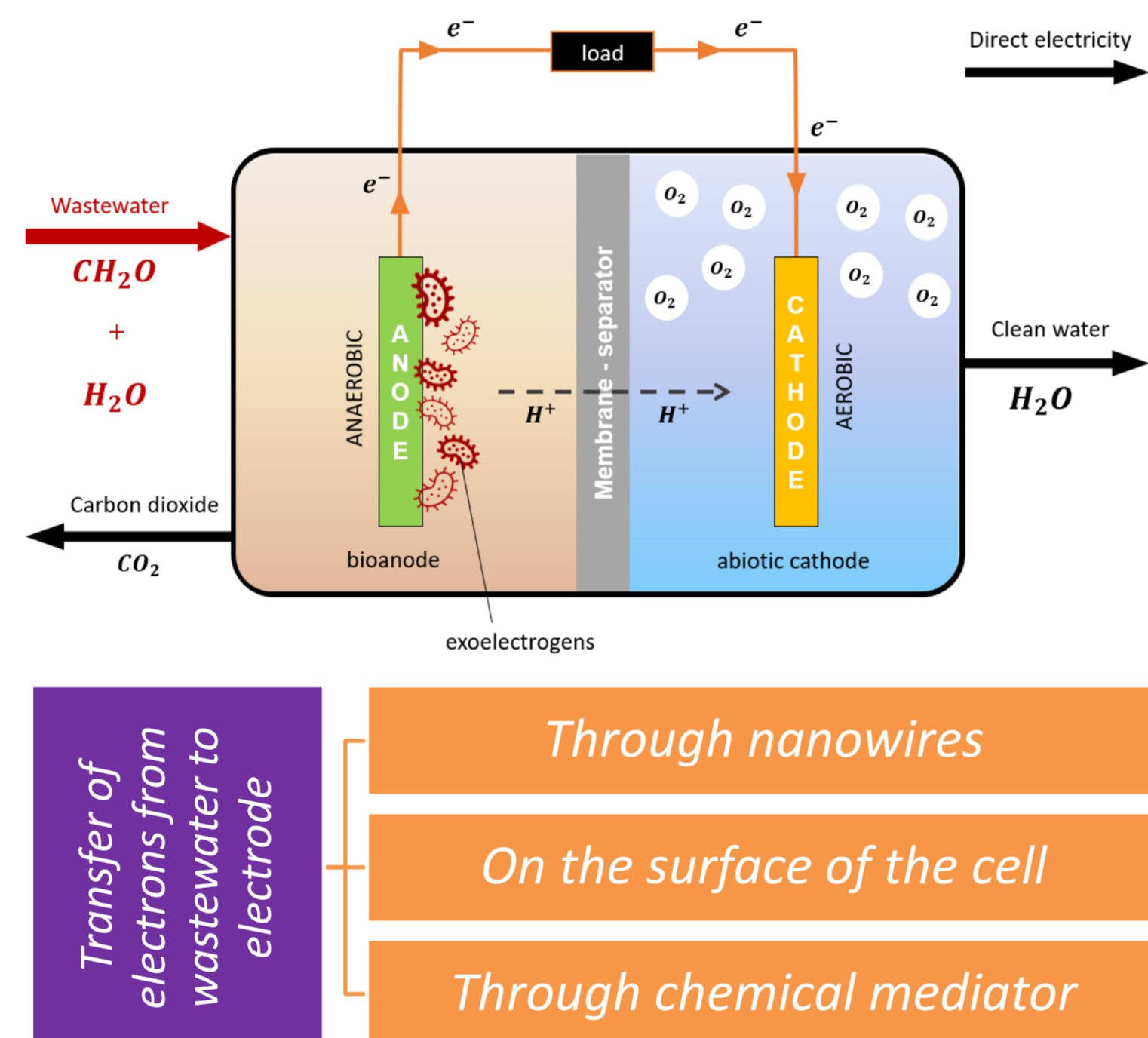


Aims and objectives

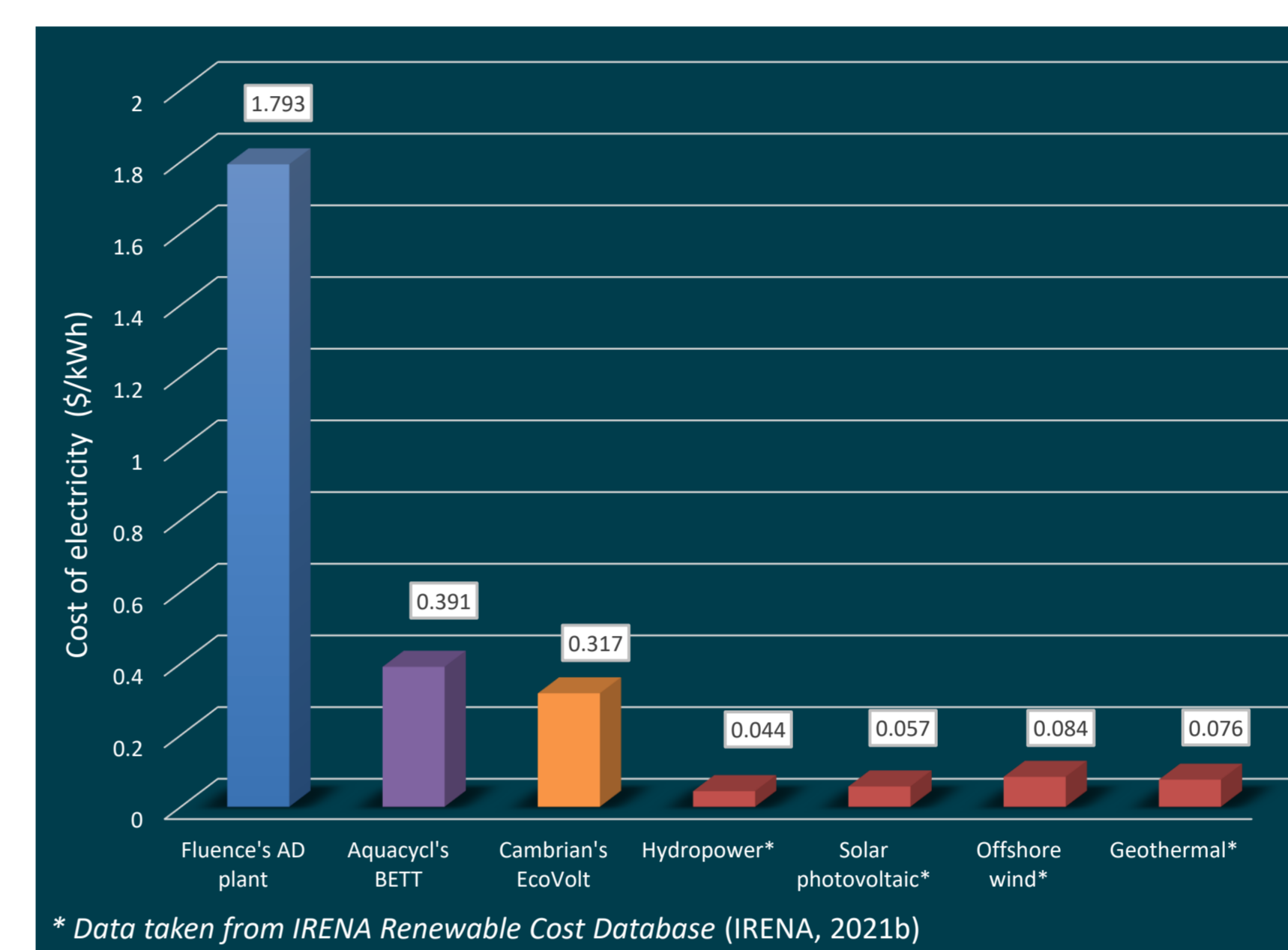
- What is the economic feasibility of bio-electrochemical systems to deliver electricity from wastewater?
- What is the environmental footprint of bio-electrochemical systems compared to other technologies?

Function of a typical MFC

- Microbes in the wastewater grow on the electrode(s).
- Electrons travel from anode to cathode externally.
- Protons transfer through the membrane.
- Depending on the design, cathode can be aerobic/anaerobic; abiotic or bio-cathode (microbes).
- Depending on thermodynamic balance, power supply may be required – if so, they are known as microbial electrolysis cells (MECs).
- A type of MEC design where CO_2 is reduced to methane using a separate set of microbes on the cathode is an electro-methanogenesis (EM) cell.



Results

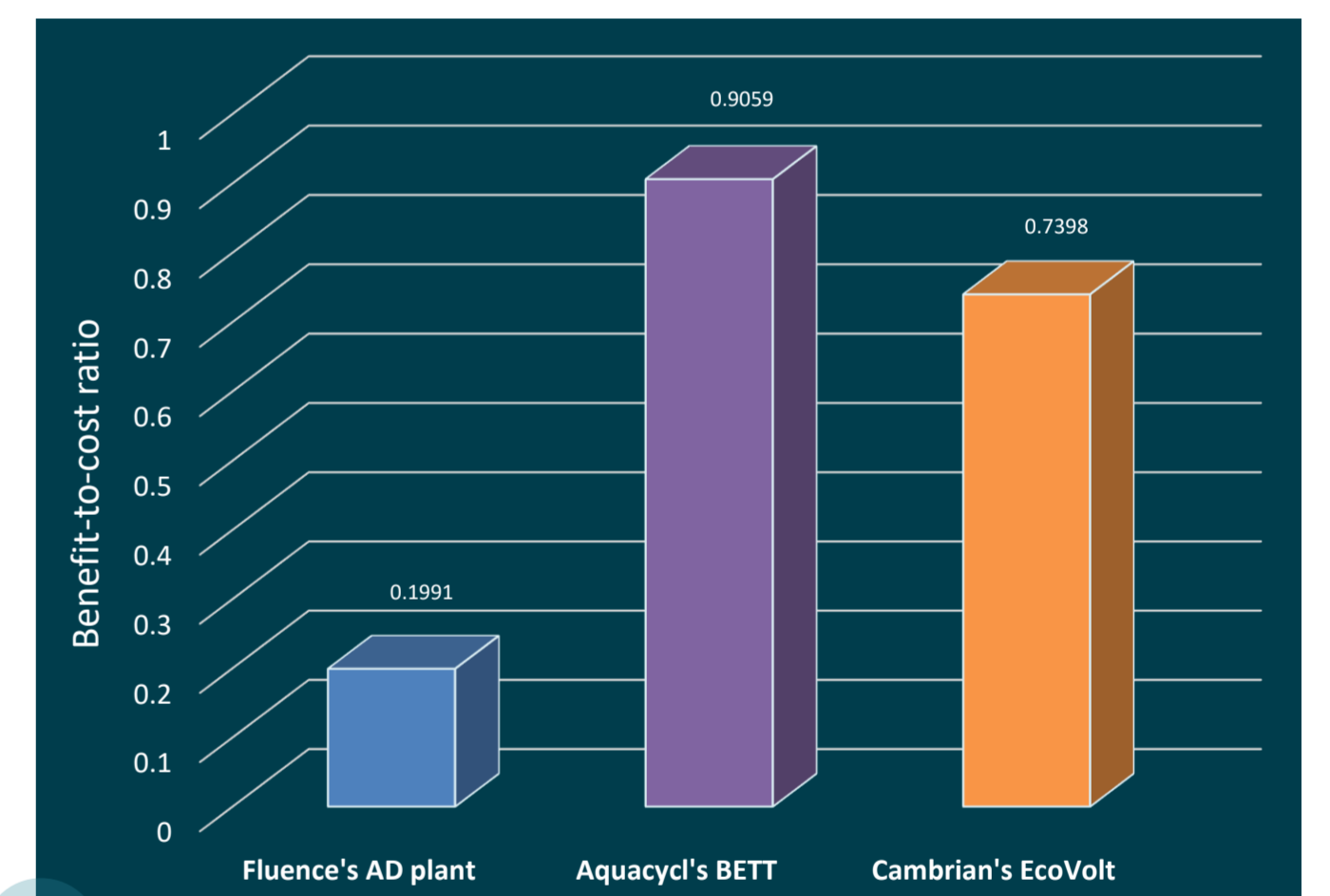


- Total amount of electricity generated from bioelectric systems (Aquacycl's BETT and Cambrian's EcoVolt) were three to nine times greater than anaerobic digestion plants.
- Anaerobic digestion yielded high maintenance costs and very low energy production.
- MFC systems show great potential in the field of renewable energy.
- Solar, wind, geothermal and hydropower energy have much lower costs due to years of development compared to emerging MFCs.

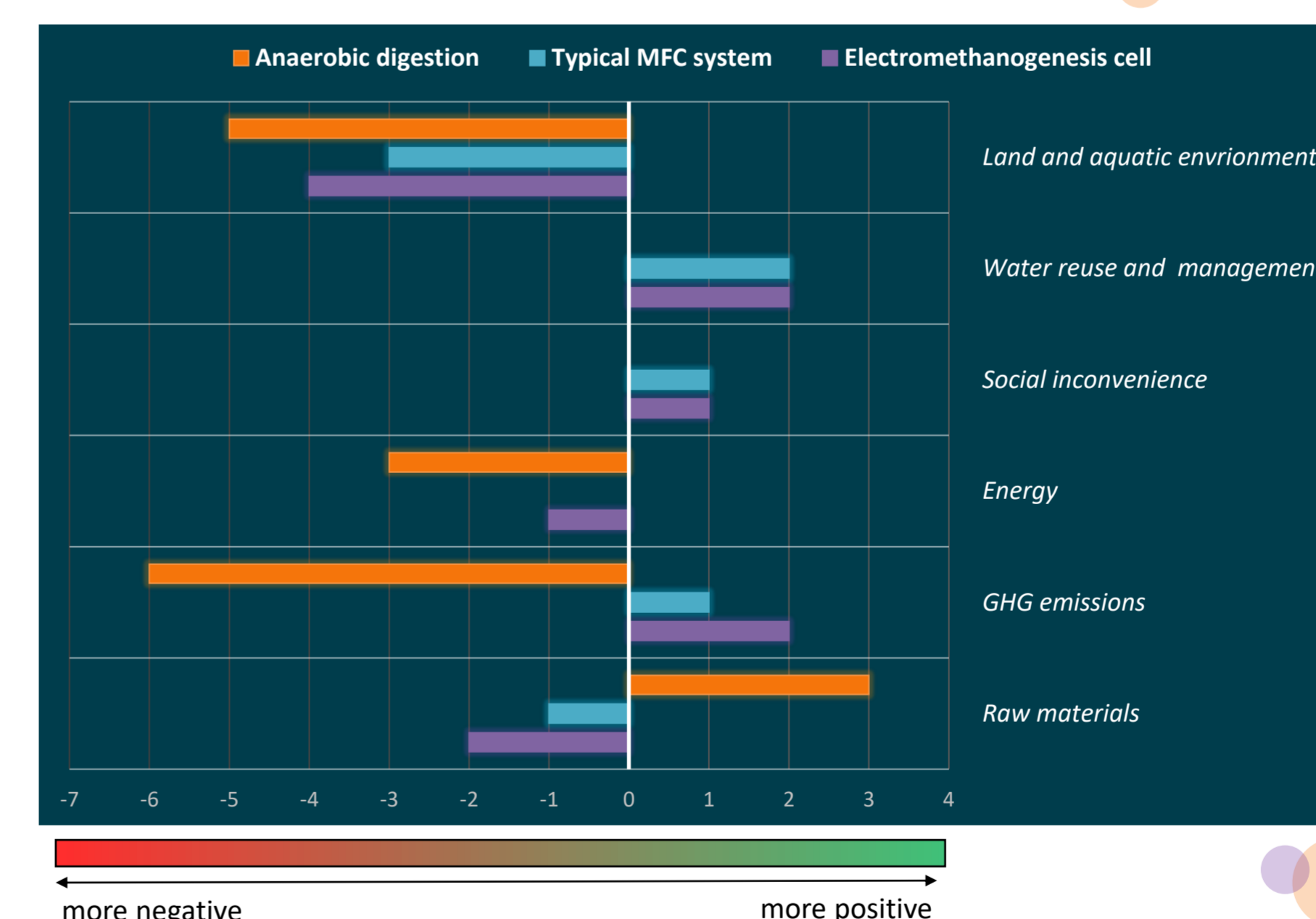
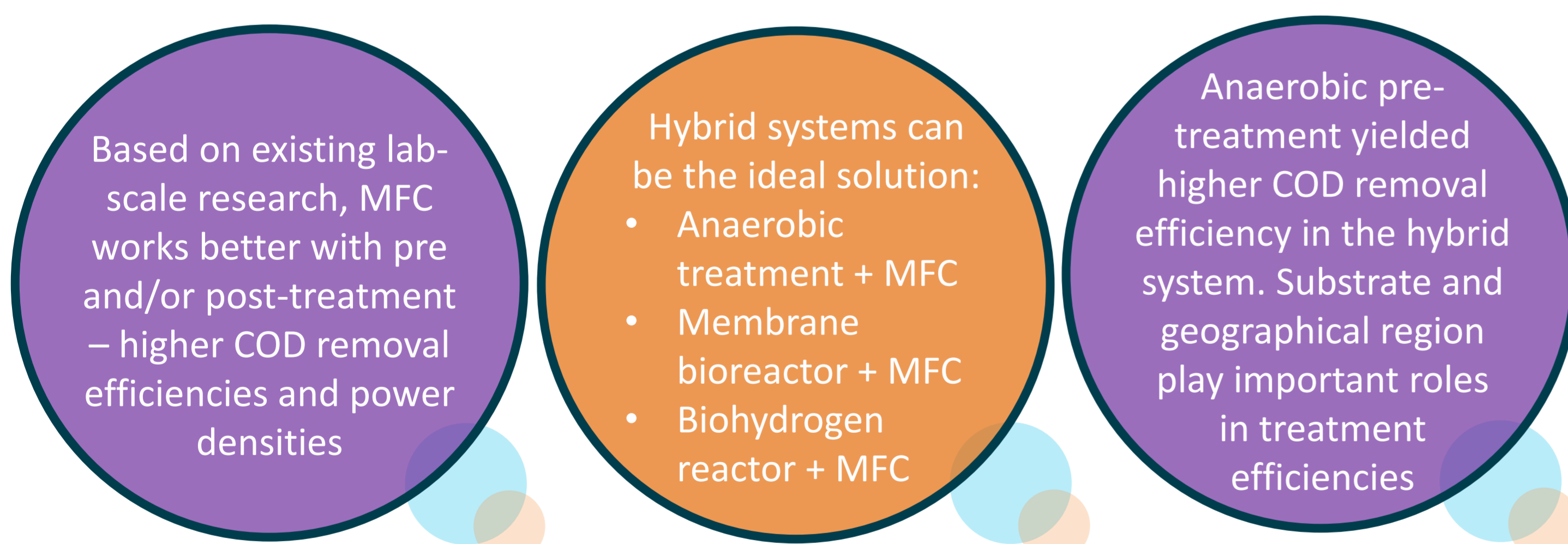
Key assumptions and observations

- 50% sludge produced is assumed to be sold for agricultural purposes, and rest is dumped in landfills.
- Tipping fees in the USA are less than in Europe – \$55 compared to €115.
- Fluence AD plant is assumed to be located in Italy (Europe) while both bioelectric systems are based in USA.
- Clean water effluent from treatment plants are reused for irrigation purposes – accounted as a benefit.
- Net energy production is the amount of energy remaining after meeting the energy demand for the plant.

- In terms of the most energy positive solution – electromethanogenesis cell design (EcoVolt) is the best.
- Aquacycl is the most treatment efficient solution – for every 100 m³ wastewater treated, 60 m³ of clean water is gained.
- Despite low energy production, electricity generated from AD contributes most towards its total benefits.
- Sludge production in all technologies were very similar.
- Different assumptions were made for two bioelectric systems regarding lease agreement and capital costs – so, Aquacycl yielded lower costs than Cambrian solution.
- Highest benefit-to-cost ratio (0.9059) --- Aquacycl's BETT technology – typical MFCs stacked like 'LEGO bricks'.



Literature Review



- Noise pollution - anaerobic digestion reactors can be loud compared to bioelectric systems.
- EcoVolt (EM cell) reduces CO_2 to useful CH_4 at the cathode – contributing positively towards climate change and GHG emissions.
- Typical MFC systems do not require power supply – only spontaneous reactions take place.
- EM cell needs constant energy supply to drive reactions – however, total consumption is less compared to anaerobic digestion.
- High COD removal efficiency and clean water disposal to natural water bodies prevents eutrophication.

Conclusions

- Bioelectric systems operating on the concept of MFC will neither be sustainable nor achieve maximum extraction of energy on its own – pre/post treatment may be required
- AD as pre-treatment to MFC presented improved results in lab-scale – scaling up may not be economically desirable but increased energy production is achieved
- Based on assessment, Aquacycl's BETT solution is the most desirable solution – followed by EcoVolt by a small difference in benefit-to-cost ratio
- Large-scale bioelectric systems are far more economically feasible and desirable than conventional anaerobic digestion wastewater treatment plants – high maintenance costs for AD plants
- A typical MFC system (stacked for large-scale systems) contributes lowest total negative environmental impact – most preferable solution from an environmental perspective too



Improvements and extensions

- Compared to other renewables, there is still long way to go with research and cost reduction of MFC technologies – for instance, improvements to reduce energy consumption and achieve lower maintenance
- Benefit-to-cost ratios calculated were less than 1 – consider other positive and negative externalities such as CO_2 emissions and social benefits
- Severity of environmental impacts should be assessed using a better method - assessment used in this research may be biased
- A life-cycle assessment needs to be executed on bioelectric systems (typical MFC and electromethanogenesis cell) – to gain detailed insight based on reliable databases