Microbial fuel cell (MFC) building tutorial

Contents:

More info, scientific refences and materials can be found at **mi-hy.eu/diy**

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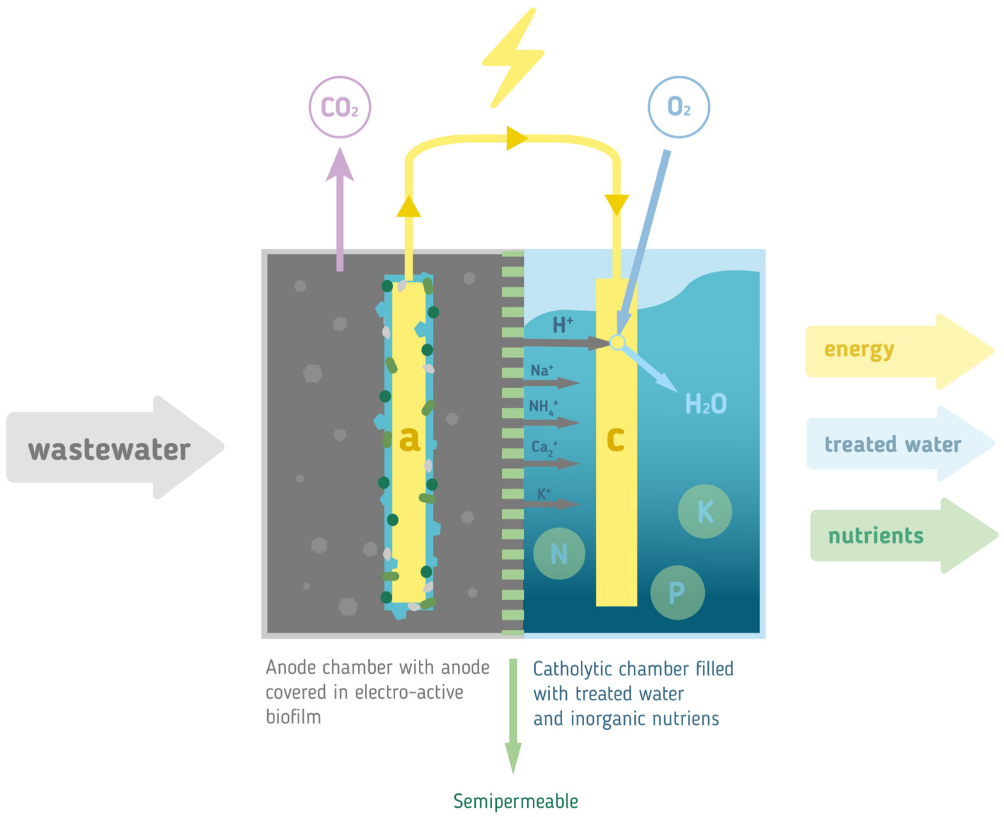
MFC technology

Microbial fuel cells (MFCs) use living microbes to convert chemical energy stored in organic matter into electrical energy.



The MFC system consists of three core components: an anode, a cathode, and a separating ion exchange membrane.

In the anode compartment, microorganisms oxidize organic compounds under anaerobic conditions, releasing electrons and protons. The electrons are collected by the anode material and transported via an external circuit, while protons and/or positively charged ions migrate internally through the membrane. At the cathode, electrons and protons recombine with oxygen to form water, completing the redox cycle.

Applications

While each MFC produces low power, individual units can be connected in series to increase voltage, in parallel to boost current and as a combination, allowing tailored configurations for different uses. Small arrays of about ten cells can power low-energy devices such as environmental sensors, microcontrollers, LoRa (long range) communication nodes, and LEDs for continuous, ultra-low-power operation.

Source and adaptation of the setup

The experimental design presented in this tutorial is based on the work of Gajda et al. (2015)[1]

In our accessible version device dimensions slightly differ. In Gajda et al.'s setup, the ceramic membrane measured 10 cm in height with outer and inner diameters of 4.2 cm and 3.6 cm, respectively; the reactor volume was 200 mL, and the anode surface area was 2430 cm^2.

In our adaptation, we tested two membrane types:

→ A commercial ceramic membrane (conveyed by Southhampton University) (height – 5 cm, outer Ø – 3 cm, inner Ø – 2.2 cm).

→ A 3D-printed ceramic membrane (height – 8.5 cm, outer Ø – 2.6 cm, inner Ø – 2.1 cm).

The container volume was 100 mL with a sealable lid; the anode surface area was 300 cm^2.

These geometric changes affect electrochemical performance, as MFC efficiency depends on several interrelated factors – particularly membrane porosity and thickness[2] and the **cathode-to-anode surface area ratio** (a **1:27 ratio** was reported as highly efficient in the 2015 study).

Cathode size is calculated according to the inner dimensions of the membrane: height x circumference with some overlap. Anode is folded to fit around the outside of the membrane.

In our configuration, the open-circuit voltage reached approximately **max. 0.4 V per unit**, compared to about **0.5 V per unit** reported in the reference. This lower output reflects both the modified geometry and the locally available materials.

[1] Gajda *et al.* (2015) Simultaneous electricity generation and microbially-assisted electrosynthesis in ceramic MFCs, Bioelectrochemistry, *104*, 58-64. https://doi.org/10.1016/j.bioelechem.2015.03.001

[2] see Salar-García and Ieropoulos, J. Power Sources 451 (2020) 227741, https://doi.org/10.1016/j.jpowsour.2020.227741

List of supplies

General:

Lab gloves
1 x 500 ml beaker
fine scale with 0.01 g accuracy
2 x measuring cups
spoon
1 L distilled water

Culture and maintanance:

(per l of nutritious solution)
100 g Sludge
1.64 g Natrium acetate
5 g yeast extract
10 g L-Tryptophan

(per unit)
1 x resistor 64 Ohm
2 x crocodile clips
1 x voltmeter/data logger
1 x pressure cooker
1x heating plate

MFC casing:

(per unit)
300 cm^2 carbon veil
45 cm mickel chrome (stainless steel) wire (approx 0.5 mm diameter)
1 g activated charcoal powder
0.25 g 60% PPTE solution*
1 x ceramic membrane
1 x plastic casing with lid (ca. 100 mL, the lid needs an opening for the cathode chamber)
2 sheets of baking paper
1 x household iron
activated coal coating proportion calculator (see mi-hy.eu/diy)

*check the PTFE concentration calculator on mi-hy.eu/diy

General info

This tutorial is developed to use easy-access materials and doesn't require laboratory equipment. Still, working with microbial fuel cells involves biological materials and liquids, so basic lab safety is a must. Always wear gloves and eye protection, especially when handling PTFE in liquid form, any concentrated solutions containing bacterial colonies and cutting the carbon veil.

Work in a well-ventilated area, avoid touching your face, and never eat or drink near your setup. Immediately clean up spills, dispose of liquids and solid materials according to local regulations, and wash your hands thoroughly after each session. If irritation, unusual odors, or unexpected growths occur, stop the experiment, secure the materials, and seek guidance from a qualified expert.

The tutorial is divided into six parts, with the first two including actiones that should be done in advance as they require several stages with long wainting periods (up to 12 hours).

PART 1: Prepare the microbial substrate (inoculum)

Step 1: Collect microbes

1. Collect 100 g wet mud from 15–20 cm depth or sediment from a local pond or riverside. Avoid debris.

2. Use a clean spatula.

3. Store it in a sterilised bottle with the lid closed.

Step 2: Prepare the nutrient solution

Mix in 1 L distilled water:

Tryptophan – 10.0 g

Yeast extract – 5.0 g

Sodium acetate – 1.64 g

Autoclave it with the pressure cooker.

Let the solution cool to room temperature.

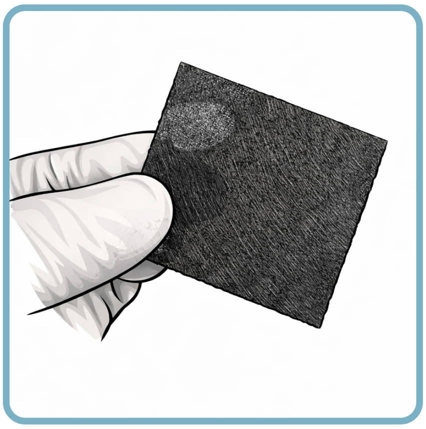
Step 3: Grow the microbes

1. Combine wet soil and nutrient solution in a 1:10 ratio.

2. Close the bottle. Incubate at room temperature for approximately 12 hours (overnight).

Part 2 - Cathode

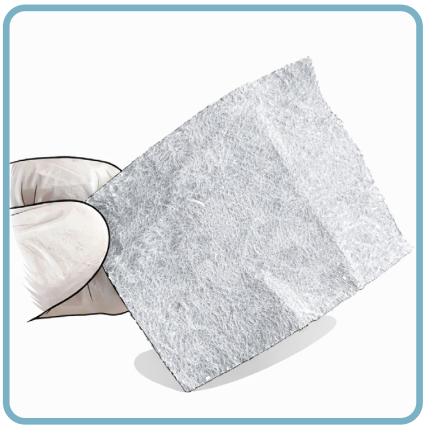
Step 4. Prepare the carbon Veil



1. Cut a piece of carbon veil: 6.9 cm x 4.6 cm. Protect your hands and eyes from the particles while cutting and don’t breathe them in.

2. Coat the entire sheet with a 30% PTFE solution*. For calculating the solution proportions, use our online calculator at mi-hy.eu/diy

*This step can be skipped. Protect you skin, eyes and avoid inhaling the medium while handling PTFE.



3. Let it air-dry completely (can take a few hours). This makes the material stronger and more water-resistant.

Step 5: Prepare the activated carbon coating

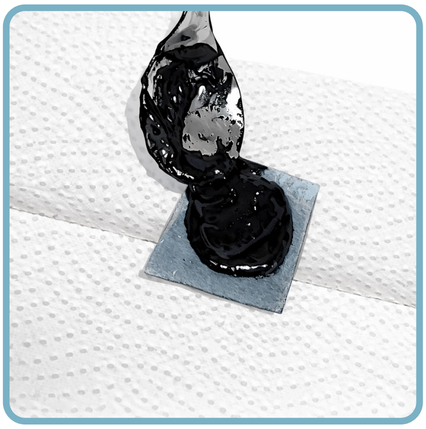
1. Mix 80 g activated carbon powder
20 wt% PTFE (from a 60% PTFE water dispersion).

Use our online calculator to find correct proportions (mi-hy.eu/diy).

Add distilled water slowly.

2. Stir until you get a thick, spreadable paste.

Step 6: Apply the coating



1. Place the dried carbon veil flat on a surface.

2. Using a spatula, spread the paste on one side only.

3. Aim for an even layer (about 60 mg per cm^2). Place on baking sheet to prevent from sticking.

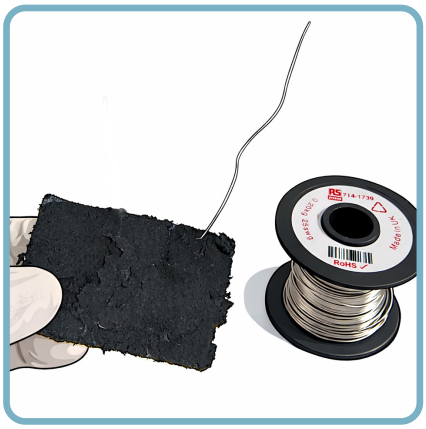
Step 7: Dry and fix the coating

1. Cover with a sheet of baking paper. Use a household iron set to 150–200 °C, no or low steam mode.

2. Press the coated side carefully until all moisture is gone and the layer sticks firmly to the carbon veil.

Do not burn the material!

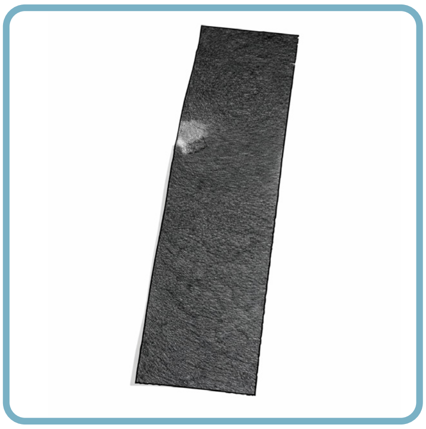
Step 8: Cut and prepare for installation



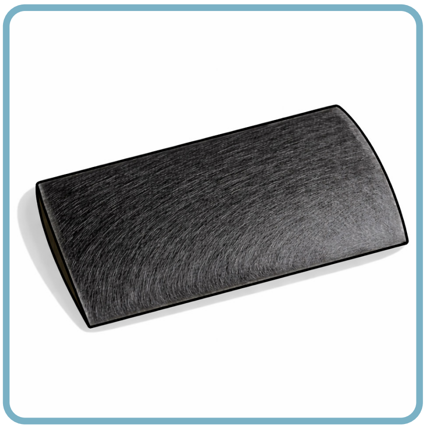
Attach nickel-chromium wire to the carbon veil by weaving it in.

PART 3: Build the anode (outside electrode)

Step 9: Prepare the carbon veil anode



1. Take a carbon veil (20 g/m²). Use 10 cm x 30 cm to reach a total surface area of about 300 cm². Protect your hands and eyes from the particles while cutting and don't breathe them in.



2. Fold the veil to fit the outer surface of the membrane with a light overlap.

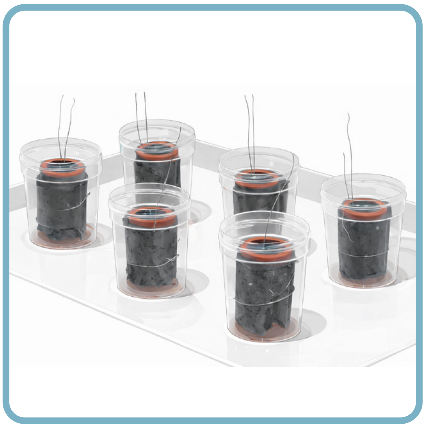
Step 10: Attach the anode

1. Wrap the carbon veil around the outside of the terracotta membrane. Fix it in place tightly by wrapping a nickel-chromium wire around.

2. Make sure the wire touches the carbon veil well for good electrical contact. For this you can weave some of it into the veil.

PART 4: Assemble the MFC Reactor

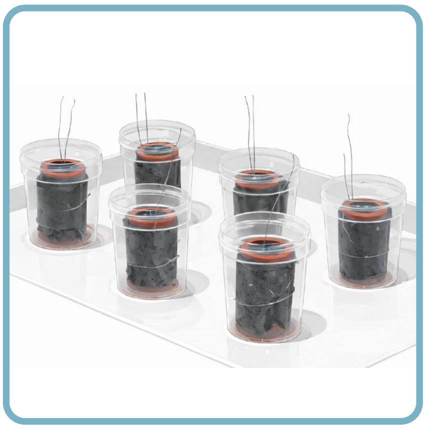
Step 11: Install the electrodes



Place the cathode inside the ceramic cylinder. The activated carbon side must face the cylinder wall. Make sure the contact is tight. The anode stays outside, wrapped around the cylinder.

PART 5: Start the MFC

Step 13: Fill the System



1. Place the assembled MFC into a container.

2. Fill the anode chamber with 100 mL of the prepared inoculum.

Step 14: Close the fuel cell and start operation

1. Place the lid on top of your MFC unit. The lid must have a cut-out hole in the middle: This keeps the anode chamber closed and without oxygen (anaerobic). The bacteria at the anode need anaerobic conditions to work properly.

The cut-out opening exposes the cathode chamber to air: oxygen from the air is needed for the cathode redox reaction. Make sure the anode stays sealed from air as much as possible. Bring all the wires outside through the opening.

The cathode side can "breathe" and stays in contact with the atmosphere.

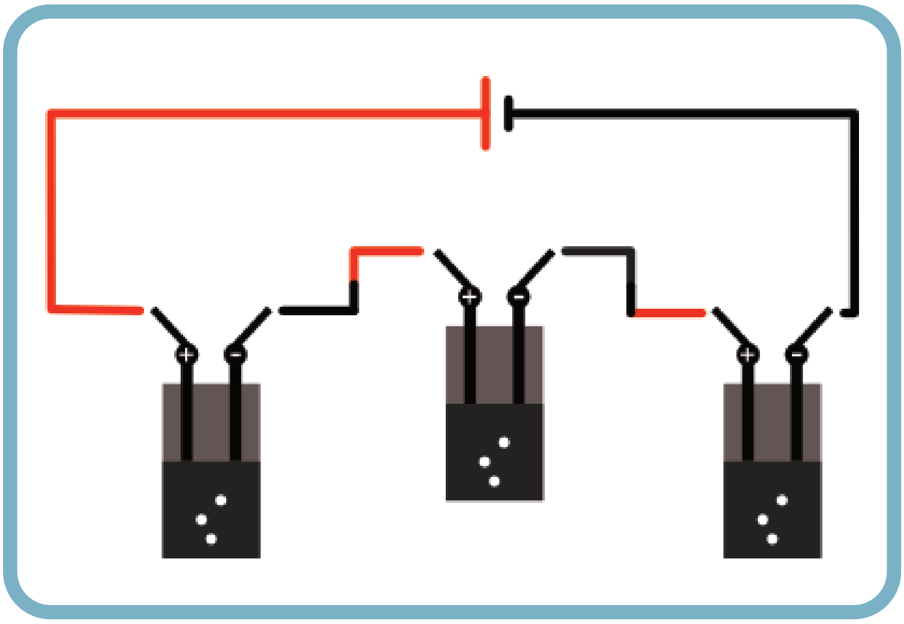
Once filled and not connected to a device use the alligator clips with a resistor (64 Ohm) to enable the bacteria's metabolism:

Microbes form a biofilm on the anode, electrons flow through the circuit, electricity is generated, catholyte starts forming on the cathode side.

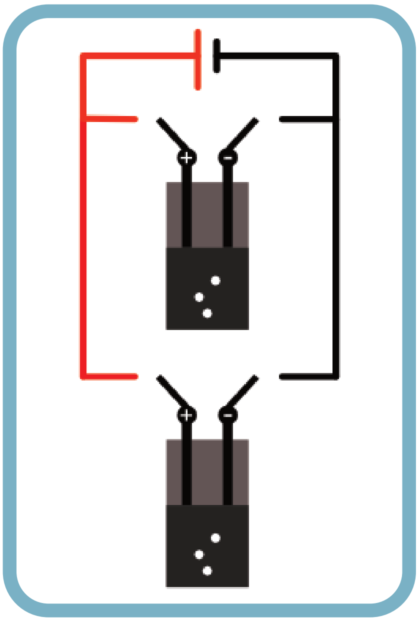
Step 14: Wiring

Connect the MFC units:

In series to increase voltage (connect cathode of one to anode of the next), in parallel to increase current (connect all anodes and all cathodes)



Series



Parallel

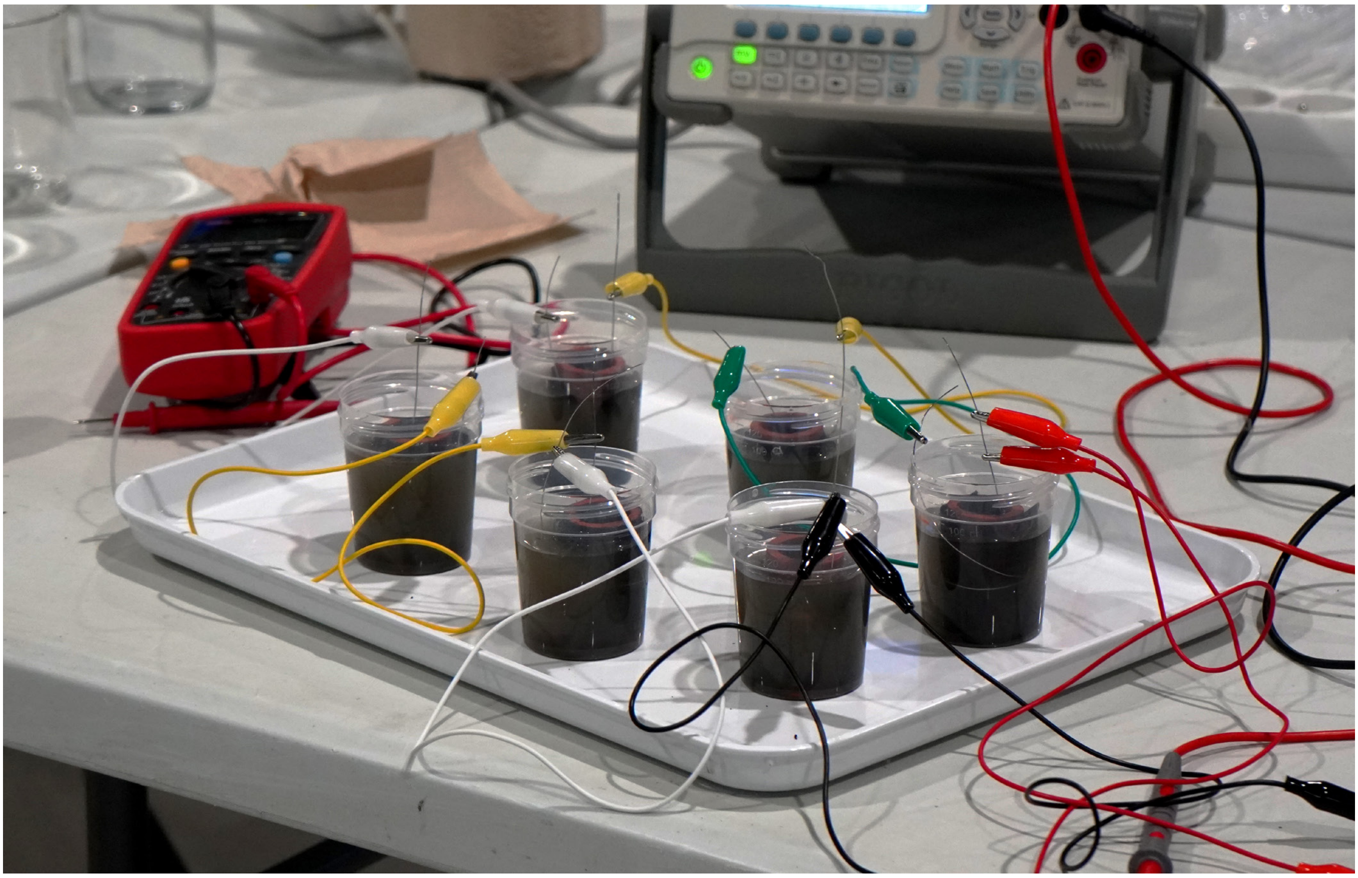
PART 6: Maintenance

Step 15: Keep it running

1. Every 7 days add fresh substrate, wastewater or urine.

2. Regularly collect catholyte production (liquid in the central space inside the terra-cotta cylinder).

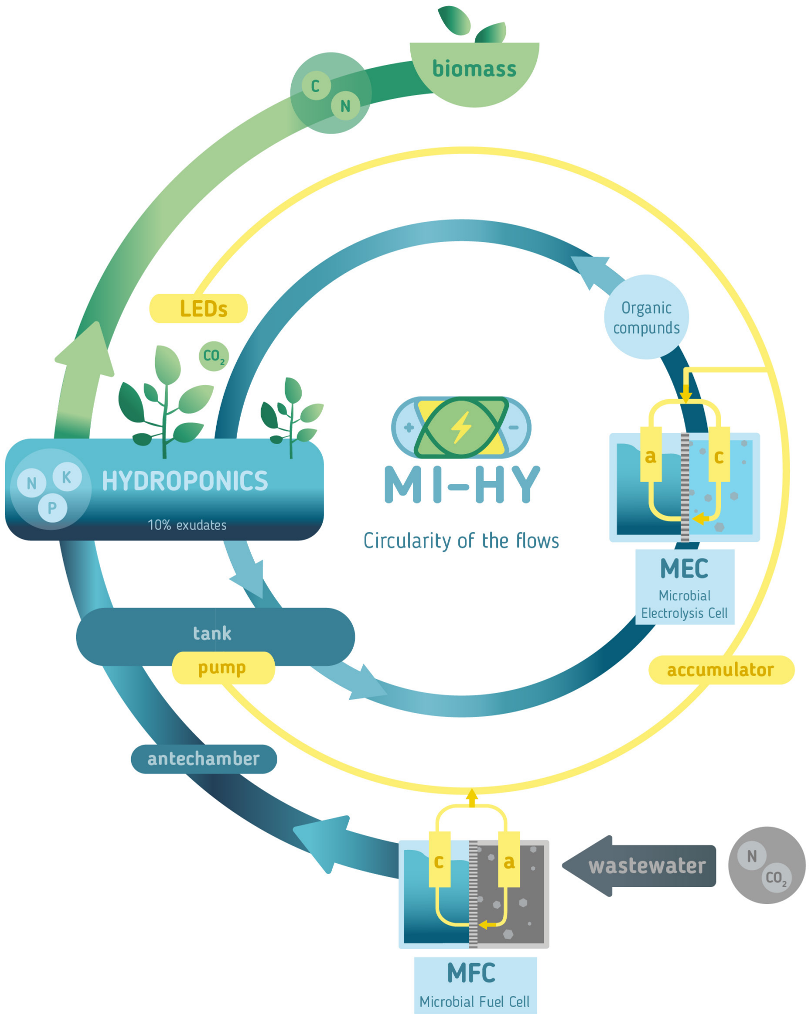
3. Measure voltage and current with different resistor loads (e.g. between 10 and 100k Ohm) to calculate power output.



About Mi-Hy

This tutorial has been developed within Mi-Hy project. It brings together Microbial Fuel Cell (MFC) technology and hydroponics. The Mi-Hy system recycles nitrogen forms and mobilises phosphorous, averting the need for chemical fertilisers. This circular, sustainable platform turns carbon into biomass and electricity, and reclaims nitrogen from wastewater streams.

The project brings together seven international partners coming from different disciplines and is funded by the Horizon Europe program.



Looking ahead, scaling microbial fuel cells up, like at wastewater treatment plants or live stock farms – could turn existing organic “waste” streams into distributed power sources that support on-site monitoring systems, communication networks, and other infrastructure. This raises a compelling question for the near future: if microbial fuel cells were deployed at large scale wherever organic waste emerges, what else in our built environment could quietly run on this steady, microbe-driven trickle of electricity?

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