

compost computer

More-Than Human Design through Critical Climate Computing

The Compost-Powered Computer Toolkit

This toolkit will guide you through the steps of how to create a Microbial Fuel Cell (MFC)-powered webserver. This is a low-cost, low-power solution for hosting websites using compost as a power source.

Who are we?

Critical Climate Computing is a research group based at the University of the Arts London. We work to advance research and creative practice that explores topics such as low-carbon and de-growth computation, permacomputing, and green-transition technologies within creative and critical arts and design practice.



Why have we made this?

This toolkit is part of a UK Arts and Humanities Research Council-funded project called More-Than-Human Design Through Critical Climate Computing. This project's aim was to produce a proof-of-concept compost-powered webserver, and redesign the UK arts and culture organisation FutureEverything's website using low carbon design logics. We have been working in collaboration with the Manchester-based urban growing cooperatives Sow the City (StC) and Manchester Urban Diggers (MUD), and FutureEverything (FE). Through these collaborations we developed an MFC-powered webserver fuelled by MUD's compost, and used it to host a new low-carbon website that we designed for Future Everything.

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The Microbial Fuel Cell

Step-By-Step Guide

Materials needed

- Compost (or soil)
- Carbon felt (with good conductivity)
- Non-corrosive wires (with good conductivity and low internal resistance: example - marine grade stainless wire 0.75mm. It could be stainless conductive threads)
- Zinc plate (with high purity)
- Container (food-grade plastic, we used 510ml cylindrical ones)
- Thin plastic films (food-grade, e.g. cut up freezer bags)
- Crocodile clips
- Natural Water Source (e.g. pond or rain water)

Optional materials (to make the MFCs more robust and safer to use)

- Prototyping wires with insulation
- Heatshrink wire insulation wrappers
- Solder (non-lead)
- Electrical cable connectors (such as Wago 221 Series)

Equipment

- Multimeter
- Power drill
- Wire cutters/strippers
- Thin protective gloves
- Metal Sieve (for compost preparation)
- Soldering iron
- Scissors (or cutting tool for plastic film and carbon felt)

1. Build two types of electrodes

To generate electrical current in a microbial fuel cell, you require two electrodes: an anode and a cathode, where bioelectrochemical reactions take place. At the anode, microorganisms oxidise organic substrates and transfer electrons to the electrode surface. At the cathode, electrons combine with an electron acceptor (typically oxygen) and protons from the electrolyte solution to complete the reduction reaction. The flow of electrons from anode to cathode through an external circuit, driven by microbial metabolism of organic matter, creates the electrical output of the MFC

For our MFC we used carbon felt as the cathode and zinc as the anode in each container. It is important to use carbon felt that has good conductivity - some carbon felt is not conductive.

Select an appropriate container and cut the carbon felt electrode to fit its dimensions. Attach a non-corrosive conductive wire to the carbon felt by threading it through the material in a stitching pattern to ensure secure electrical contact. You could use a non-corrosive conductive thread with low internal resistance, such as silver-plated copper or stainless steel wire, to minimize power losses in the electrical connection.

For the anode electrode, cut the zinc plate to fit the container dimensions. To establish electrical contact with the zinc plate, drill a small hole and insert a prototyping wire through it. Secure the connection by soldering the wire to the plate surface, ensuring the solder completely covers the wire to prevent exposure. Apply heat-shrink tubing over the soldered joint to provide protection against corrosion.

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Compost selection

We used MUD's compost, which we screened and filtered through a metal sieve to remove large chunks and get a consistent material. If you don't have access to compost, you can use store bought bags without added perlite or vermiculite (these create unwanted air bubbles). You could then mix the compost with bokashi pre-compost or other conditioning materials for enriching microbes in the soil, such as biochar.

Glossary of Terms

Webserver

Software that distributes web content via HTTP protocol, serving website files stored on a computer to the internet where browsers can access them online.

Compost

Organic matter used as fertilizer for growing plants, made from materials such as vegetable matter, manure, or compostable paper.

Microorganism/Bacteria

Single-celled organisms that metabolize organic matter and facilitate electron transfer in microbial fuel cells.

Substrate

The organic material (compost) that microorganisms consume for energy and metabolic processes.

Microbial Fuel Cell (MFC)

A bioelectrochemical system that converts chemical energy from organic substances into electrical energy through microbial metabolism.

Alternatively, thread a non-corrosive conductive wire through the hole and mechanically secure it to the zinc plate using the same connection principles.



<Cut up carbon felt in containers and zinc plate electrodes>

2. Prepare the Container Lid

Create two small holes in the container lid, positioning them to align with the electrode wire locations while maintaining adequate spacing to prevent electrical contact between connections. Thread the electrode wires through their respective holes, ensuring a snug fit to minimize air exposure and maintain the anaerobic environment required for optimal microbial activity at the anode.

3. Build the Microbial Fuel Cell

Fill the container with compost to approximately halfway or at least 2 cm from the bottom. Position the carbon felt electrode (cathode) within this compost layer, ensuring the attached wire extends through the hole in the container lid. Add additional compost around and partially over the carbon felt electrode, leaving space for the separator layer.

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Glossary of Terms (continued)

Electrode

Conductive material serving as a site for electrochemical reactions, facilitating electron transfer between chemical compounds and external circuits.

Anode

The electrode where oxidation occurs, releasing electrons from microorganisms or chemical compounds into the external circuit.

Cathode

The electrode where reduction occurs, accepting electrons from the external circuit to complete the electrochemical reaction.

Electrolyte

Conductive solution containing dissolved ions that enables charge transport between the anode and cathode electrodes.

Oxidation

Electrochemical process involving the loss of electrons, occurring at the anode in microbial fuel cells.

Reduction

Electrochemical process involving the gain of electrons, occurring at the cathode in microbial fuel cells.

Bioelectrochemical

Describes electrochemical reactions driven by biological organisms, particularly microorganisms that transfer electrons to electrodes.

Anaerobic

Oxygen-free conditions at the anode chamber enabling bacteria to transfer electrons to electrodes rather than using oxygen.

Cut a plastic film to fit the container's interior dimensions and place it over the compost to create a physical barrier between the two electrodes. Add more compost above the plastic film to establish the upper chamber. Insert the zinc plate electrode (anode) into this upper compost layer, threading its wire through the second hole in the lid.

Ensure the plastic film maintains complete separation between the two electrodes and their conductive wires, as direct contact will cause a short circuit that prevents proper cell operation.

If the zinc anode has a sufficiently corrosion-resistant connection with the wiring, the positions of the anode and cathode can be swapped so that the electrodes can work even more effectively. This is due to the fact that the cathode faces air (oxygen) and the anode is buried deeper for an improved anaerobic condition.



<Containers with compost, electrodes and plastic film>

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Glossary of Terms (continued)

Aerobic

Oxygen-rich conditions at the cathode chamber allowing oxygen to accept electrons and complete the electrochemical circuit.

Series Connection

Configuration connecting cells end-to-end to increase total voltage output while maintaining constant current capacity.

Parallel Connection

Configuration connecting cells side-by-side to increase total current output while maintaining constant voltage.

Voltage (V)

Electrical potential difference between two points in a circuit, measured in volts.

Current/Amperage (mA)

Rate of electrical charge flow through a circuit, measured in milliamperes.

Capacitor

Energy storage device that accumulates and releases electrical charge for powering intermittent electronic operations.

Energy Harvester

Circuit component that captures, manages, and optimizes electrical energy from low-power sources like microbial fuel cells.

4. Add water

Add water to the container until the compost reaches is thoroughly hydrated but not waterlogged. Use naturally sourced water such as pond water, rainwater, or water from natural waterways including rivers and lakes, as these sources host diverse microbial communities that can be beneficial to encourage microbial activity. Avoid treated water, tap water or chemically treated sources, as chlorine and other additives can inhibit the microbial populations essential for electron transfer processes in the fuel cell.

5. Check the voltage and close the lid

Connect a multimeter to the electrode wires to measure the cell's electrical output, ensuring proper polarity by attaching the negative probe to the zinc anode and the positive probe to the carbon felt cathode. The initial voltage reading should range between 300-1100 mV, depending on the electrode materials, compost composition, and microbial activity levels. Then secure the container lid to maintain the sealed environment and prevent moisture loss, which is essential for sustained microbial fuel cell operation.

It is worth noting that the zinc electrode can corrode over time in our current setup through oxidation. Electrode materials should be biocompatible, corrosion-resistant, conductive and as cost-effective as possible. We selected the zinc despite the danger of it corroding, because of its higher power output. There are likely multiple other great materials and different approaches to building the electrodes - if you have recommendations, please let us know!

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Components Needed

- A multiple of the Components you need for the MFCs – we built 21 cells (see materials list above)
- AEMLIC board (solar energy harvester circuit designed by J. Sikken)
- Lithium-ion capacitor (90 mAh capacity or equivalent)
- 5V voltage regulator
- XIAO nRF52840 microcontroller
- USB cable (for powering the XIAO microcontroller)
- Breadboard or PCB (for circuit assembly)
- Jumper wires or connecting wires (for circuit connections)

Scaling up:

The modular stack, a series-parallel configuration of the MFCs to power a microcontroller

1. Connecting cells in series, and connecting series into parallel configurations

Individual MFC units generate relatively low power output, and we therefore needed to configure multiple cells to achieve useful voltage and current levels. Connecting cells in series increases the overall voltage. To increase amperage, multiple series-connected strings can be arranged in a parallel configuration, creating an array that combines the voltage benefits of series connection with the current capacity of parallel connection. This modular stacking approach enabled us to produce scalable power generation, with the total output determined by the number of cells and their arrangement within the series-parallel configuration.



<Connected MFC stacks>

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2. Connecting the MFC stack to a solar energy harvester

We directed the electrical output from the MFC stack to a solar energy harvester circuit (specifically, the AEMLIC board designed by J. Sikken) connected to a lithium-ion capacitor for energy storage. This configuration accumulates the low, continuous power generated by the MFC stack within the capacitor until sufficient charge is achieved. Once the capacitor reaches the threshold voltage, it discharges through a 5V voltage regulator to provide stable USB power to our XIAO nRF52840 microcontroller. Alternatively, the AEMLIC board can provide a 3.3V regulated output. The above energy harvesting approach enables intermittent operation of low-power electronic devices despite the MFC's limited instantaneous power output.



<Li-ion capacitors and energy harvest boards>

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Relevant resources for building MFCs and their power management system

<https://titipi.org/pub/MFC.pdf>

<https://www.magicalmicrobes.com/collections/kits/products/mudwatt-clean-energy-from-mud>

https://cdn.shopify.com/s/files/1/0598/6373/files/Dunaj_et_al..pdf?3779876606660569562

<https://dergipark.org.tr/tr/download/article-file/380305>

<https://www.power-sonic.com/blog/how-to-connect-batteries-in-series-and-parallel/>

<https://www.youtube.com/watch?v=OlphRgaxItY>

Project Considerations

The MFC stack configuration generated approximately 3.0-3.15V output voltage. When charging the lithium-ion capacitor through the AEMLIC solar harvester circuit, the system delivers approximately 4.5-5.1 mA charging current. At full charge, the capacitor provides energy storage capacity equivalent to 90 mAh.

We designed the power management system to supply power to the XIAO microcontroller, which draws 15-22 mA at 5V during operation. The system initiates power delivery when the capacitor voltage reaches 2.85V and terminates discharge at 2.6V to prevent over-discharge and extend capacitor lifespan. Under these operating parameters, the MFC stack requires 6.5-8.5 hours to recharge the capacitor, enabling 25-40 minutes of continuous microcontroller operation per cycle.

System performance could be scaled through several approaches, for example by increasing the number of series-parallel connected MFC cells, which elevates both voltage and current output, thereby reducing capacitor charging time. Alternatively, implementing dual MFC stacks with independent energy harvester circuits and capacitors would enable alternating power delivery, where one capacitor discharges to power the microcontroller while the second capacitor simultaneously charges. This configuration would extend operational runtime and reduces system downtime between charging cycles.

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<Experimental setup for powering the XIAO with two Li-ion capacitors with a power switching system>

As it is, the system can power similar low-power development boards, such as XIAO MG24 and similar microcontrollers with comparable power requirements. For example, it could control a lighting system or power other components, such as LEDs and small digit clock screens.

Our proof-of-concept powered webserver lives in its current form and for the near future at MUD in Manchester. We are looking forward to developing it further, building it into a resilient and scalable project in the future. We welcome collaboration and technical input from researchers, practitioners, and community members interested in advancing compost-powered computing systems and sustainable electronic infrastructure. Please get in touch with us @critical_climate_computing