LIVING ARCHITECTURE SYSTEMS GROUP

Second Land: Ground Veiling

Scaffold and Power Cell Details
Domaine de Boisbuchet, 2019

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Domaine de
Boisbuchet
Design Architecture Nature

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Introduction

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Potato batteries installed at Ground Veiling workshop at Domaine de Boisbuchet, 2019

This folio documents an installation that was constructed by the members of a Living Architecture Systems Group workshop at Domaine de Boisbuchet, Poitiers, France, in 2019. Specialized organic power cells employing natural potatoes as an electrolyte source were used within the installation. The folio presents a step-by-step guide of assembly for main parts of this organic power system.

The installation, Second Land, makes use of simple natural materials including saplings and reeds, drawn locally from the riverside lands and agricultural fields of the Domaine and woven together with massed arrays of liquid-carrying vessels. Workshop participants at the Domaine worked together to construct an interwoven hybrid membrane which covers the land and creates shelter, seeking renewed qualities of hybrid fertility. The workshop included demonstration of pattern-books and open geometries from the Living Architecture Systems Group. This review established a design language that helped to unify explorations followed by individual team members.

The installation consisted of an array of electrical power cells that use common potatoes in combination with household-source metal electrodes in order to power LED lights housed in transparent lenses. The custom lenses amplified and conditioned the LED light. Pairs of battery electrodes received their electrical charge from reactions that occured between their metallic materials. The reaction flowed between the electrodes through the weak acid environment provided by the fluid-containing body of a natural potato.

The guide outlines assembly components for the installation. Step-by-step descriptions include making electrodes, preparing potatoes to receive the electrodes and connecting individual potato-electrode units together, and powering arrays of LED light by employing power created by the organic cells. Testing and research is also documented, indicating how experiments conducted during a prototyping period informed the specifications. Practical information about electricity is included with advice on how to detect differences between a circuit with low voltage and low current, and variations that might be needed to accommodate varying power sources.

The potato battery cell that was constructed within this installation consisted of an array of electrical power cells that use common potatoes in combination with household-source metal electrodes to power a LED light. Pairs of battery electrodes get their electrical charge from reactions that occur between their metallic materials. The reaction flows

above

Detailed view of potato batteries and flask/bulb assembly installed at Ground Veiling workshop at Domaine de Boisbuchet, 2019

above

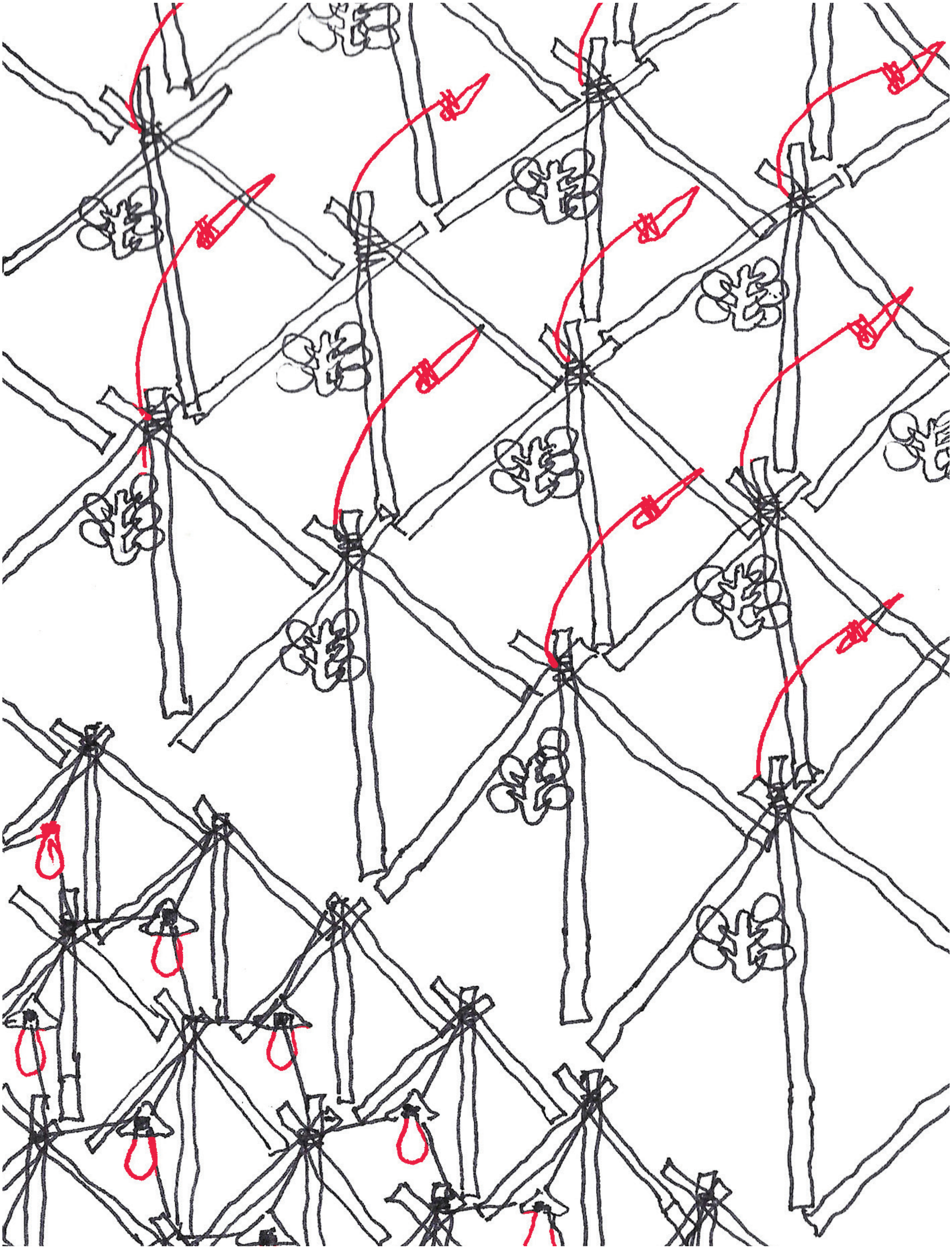
Potato batteries during install preparation for Ground Veiling workshop at Domaine de Boisbuchet, 2019

below

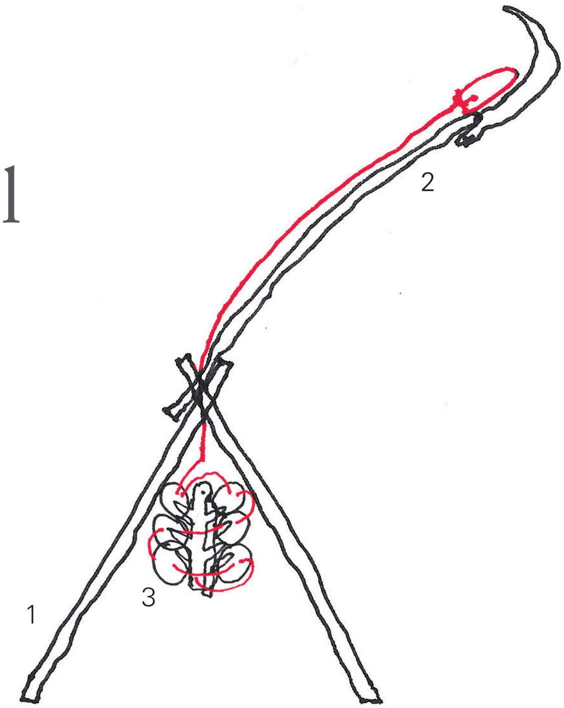
Ground Veiling at Domaine de Boisbuchet, installation view at night, 2019

between the electrodes through the weak acid environment provided by the fluid-containing body of a natural potato.

The battery assemblies were composed of chains of grouped potatoes with inserted electrodes, supported by a scaffold of salvage branch tripods obtained directly on site, and holding LEDs on antennae and within transparent bulb assemblies. The bulbs were made from recycled water bottles that were heat-expanded to achieve their final shape. The branch tripods were fastened with malleable wire loops commonly used for reinforcing rod meshes in building construction, with wire tripods strung between adjacent tripod peaks to form LED bulb supports at their centres. Grouped potato clusters providing power for these water-bulb LED lights were suspended from the tripods. An array of large tripods was positioned in the centre of the array. Antennae made from long saplings were fastened to these tripods, reaching high above the installation field. LED lights powered by the organic batteries were fastened to the tips of the antennae.



Making a Structural Cell

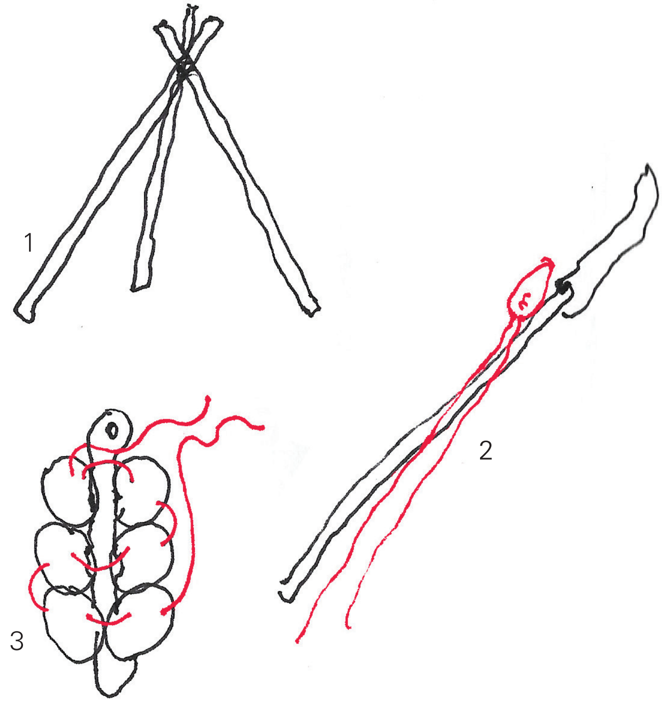


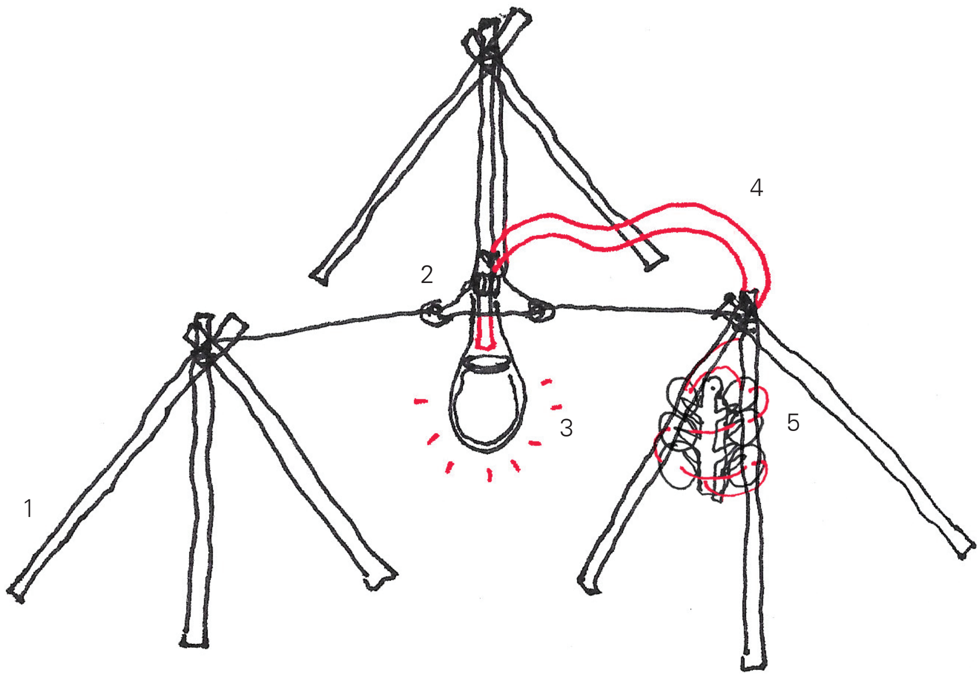
LED Antennae Assembly

1 Salvage branch tripods

2 LED bulb and salvage branch, cable ties, electrical tape

3 Potato battery





LED Bulb and Flask Assembly - Complete

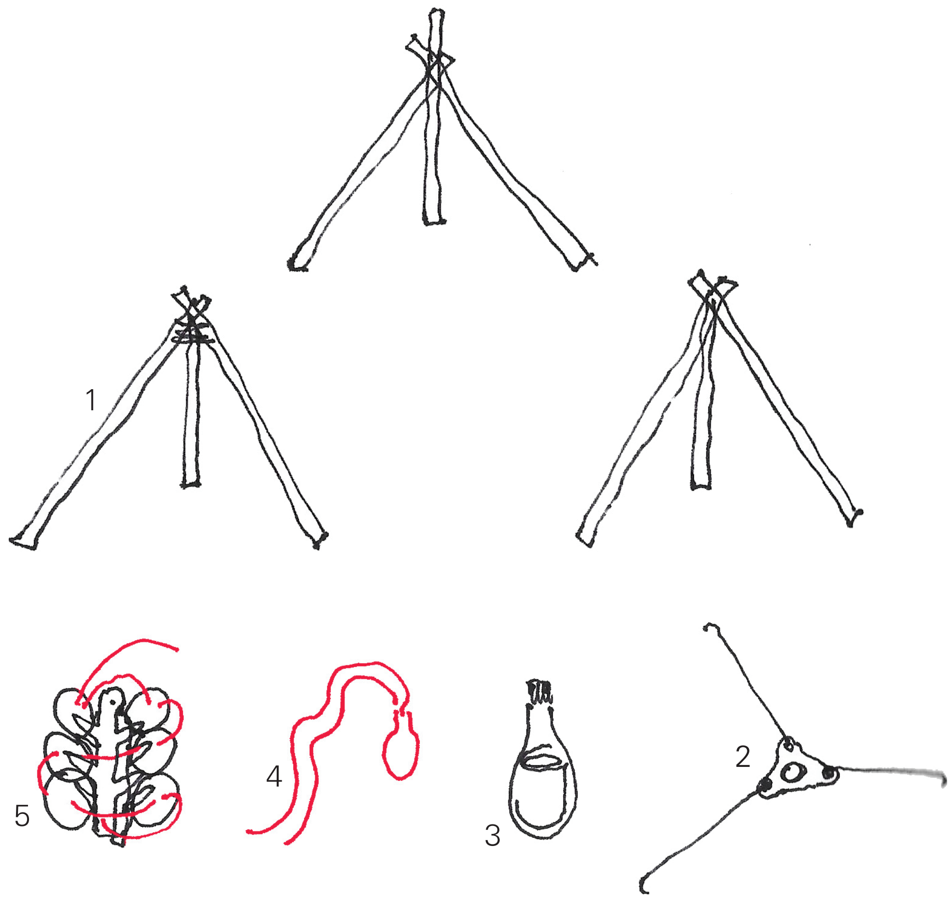
1 Salvage branch tripods

2 Polymer sheet support collar with stiffened wire bridge support

3 Thermaformed water bottle flask

4 LED bulb and wiring

5 Potato Battery



LED Bulb and Flask Assembly - Breakdown

1 Salvage branch tripods

2 Polymer sheet support collar with stiffened wire bridge support

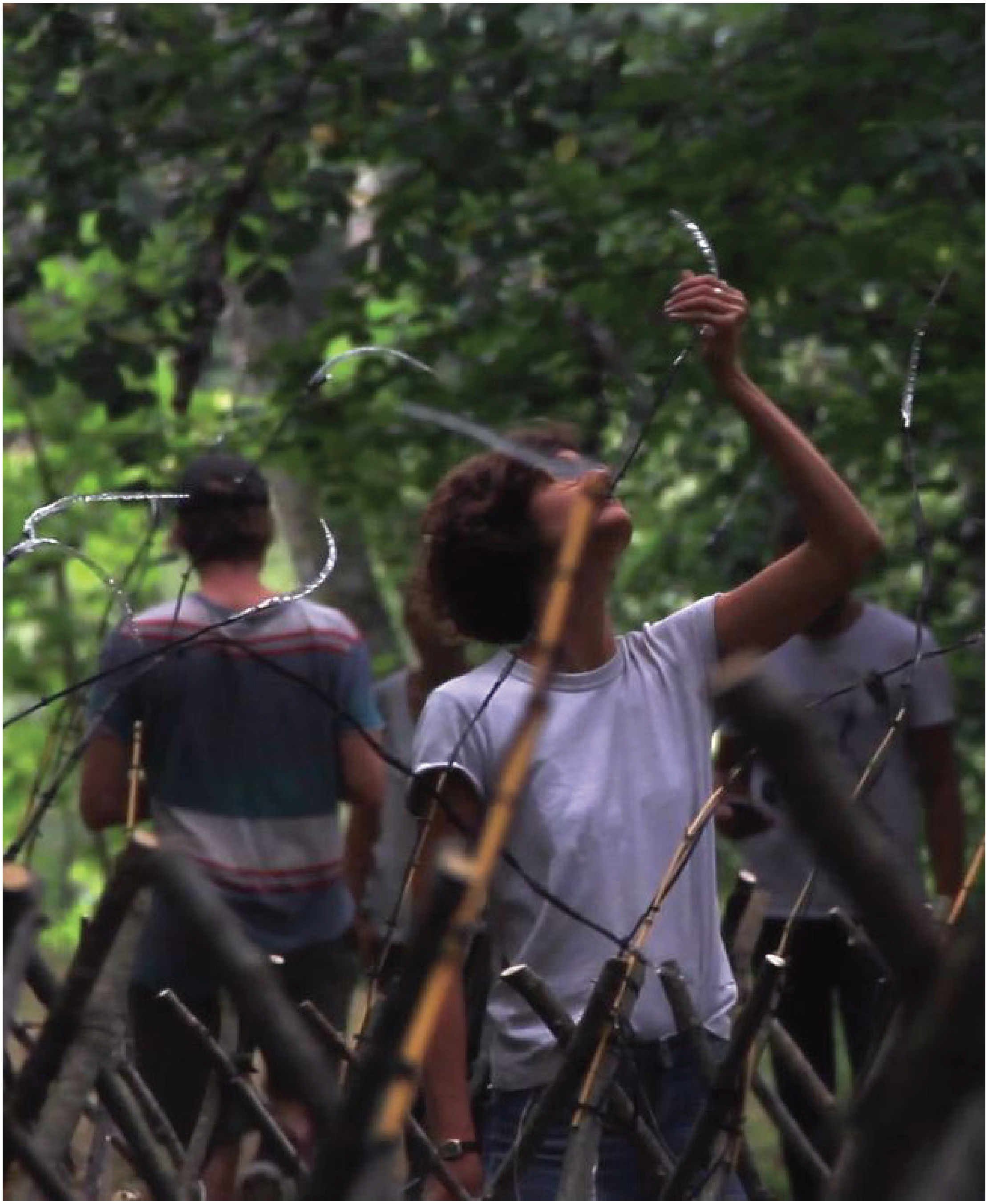
3 Thermaformed water bottle flask

4 LED bulb and wiring

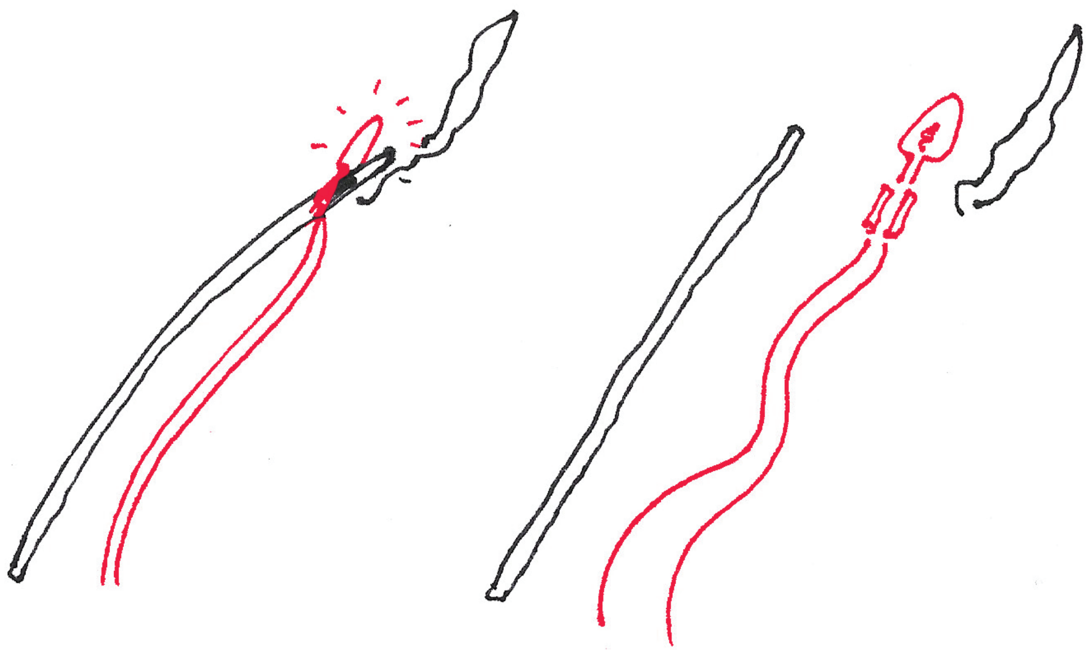
5 Potato Battery

facing page

Potato batteries during install preparation for Ground Veiling workshop at Domaine de Boisbuchet, 2019. Photo: Domaine de Boisbuchet



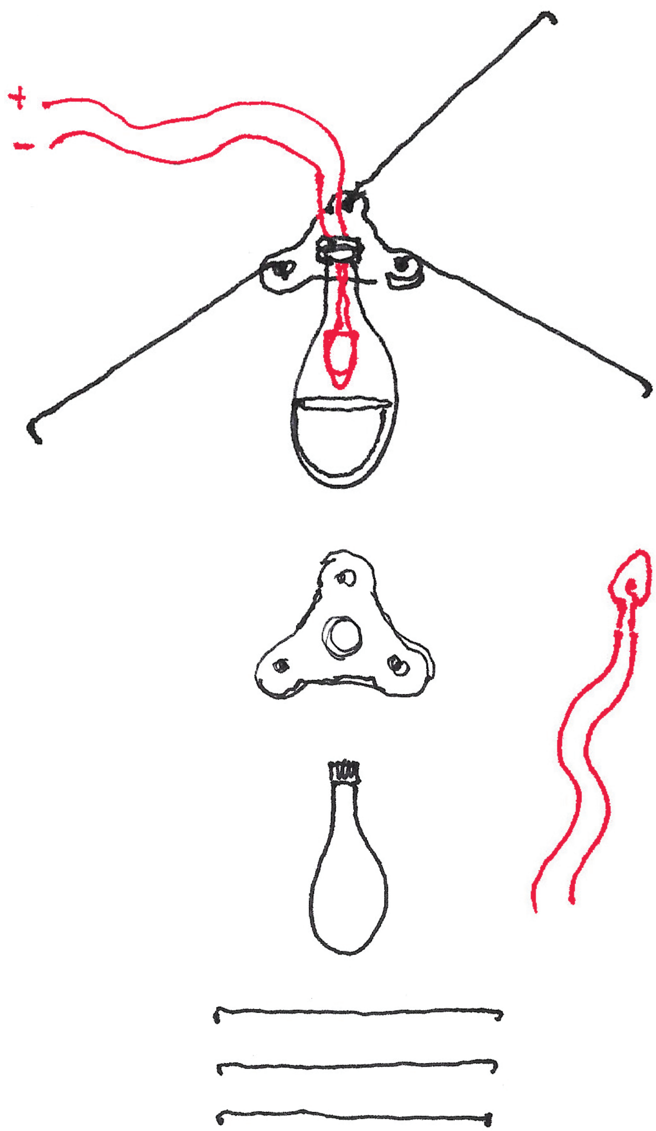
LED Antennae Assembly

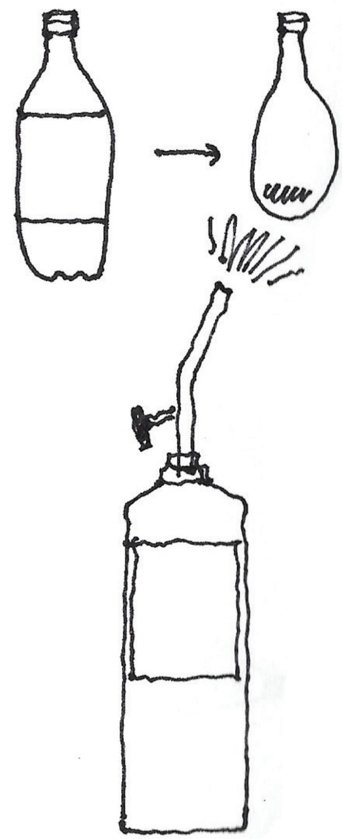


facing page

LED Antennae Assemblies - Potato batteries during install preparation for Ground Veiling workshop at Domaine de Boisbuchet, 2019. Photo: Domaine de Boisbuchet

LED Bulb and Flask Assembly





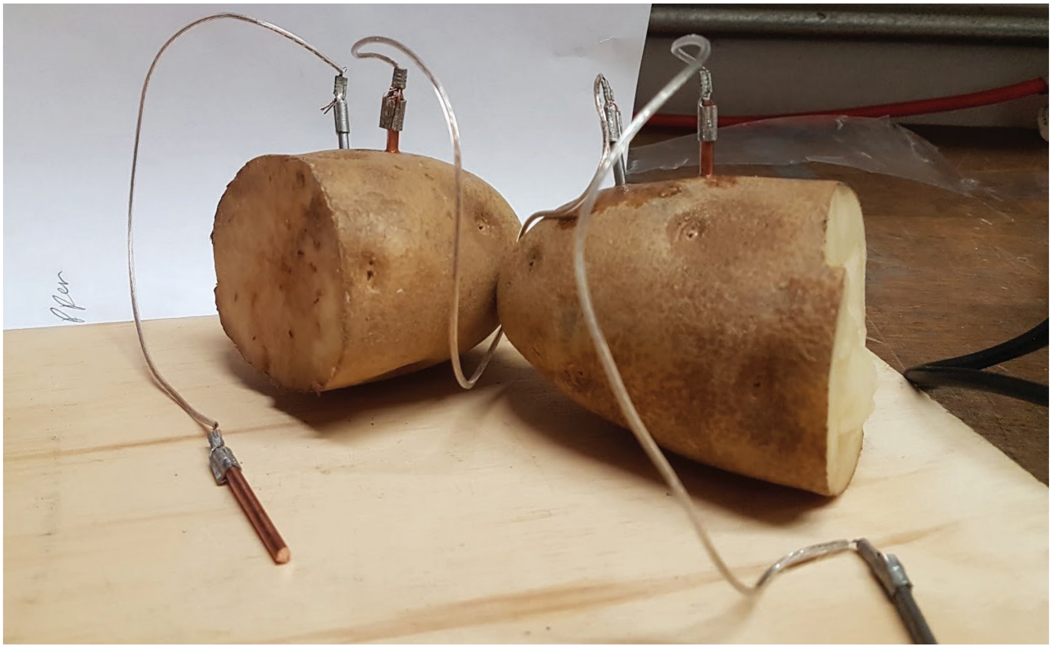
above

Salvage plastic water bottles are thermaformed with a heat source to achieve desired bulb shape

facing

LED Bulb and Flask Assemblies - Potato batteries during install preparation for Ground Veiling workshop at Domaine de Boisbuchet. Photo: Domaine de Boisbuchet

Making a Potato Cell



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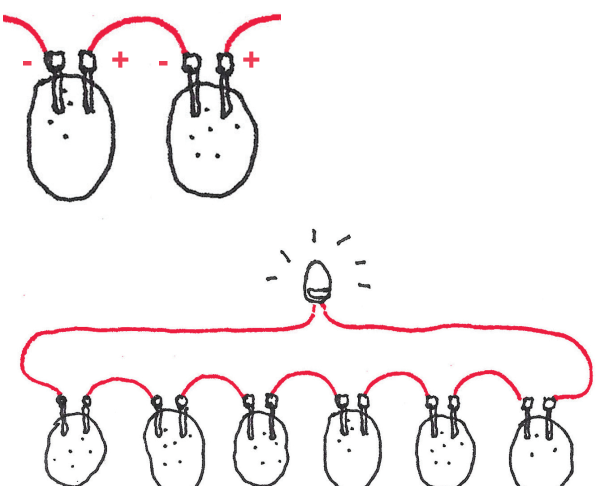


2

making a potato cell

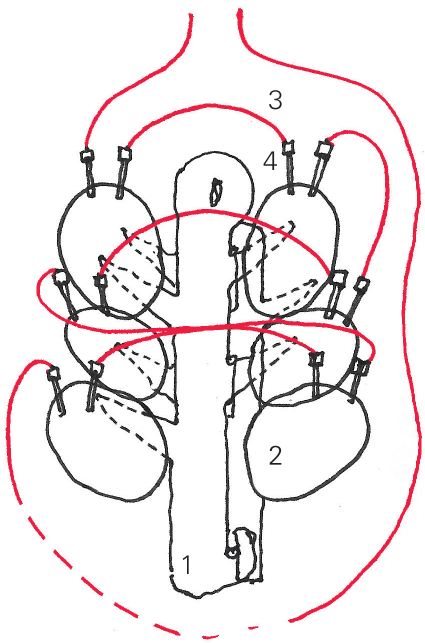
1 This arrangement creates two potato cells connected in series, together with loose electrodes ready for further connections.

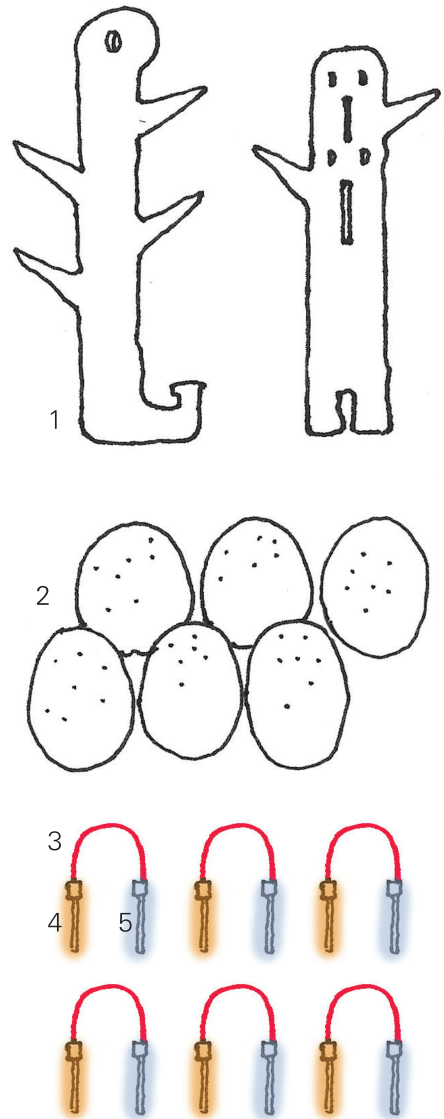
2 The arrangement should resemble this diagram. A negative wire is connected to a zinc electrode, and a positive wire is connected to a copper electrode.

Each block represents a potato; note the polarity arrangement of each one. To connect to the LED, use one of the miniature barrel crimps such that one end goes over the LED leg and the other over the wire end. On the LED, one leg will be longer and the other shorter. The longer leg needs to be connected to the positive node. The shorter leg should connect to the negative node.

above

Potato cells within a pair of potato batteries





Potato Battery

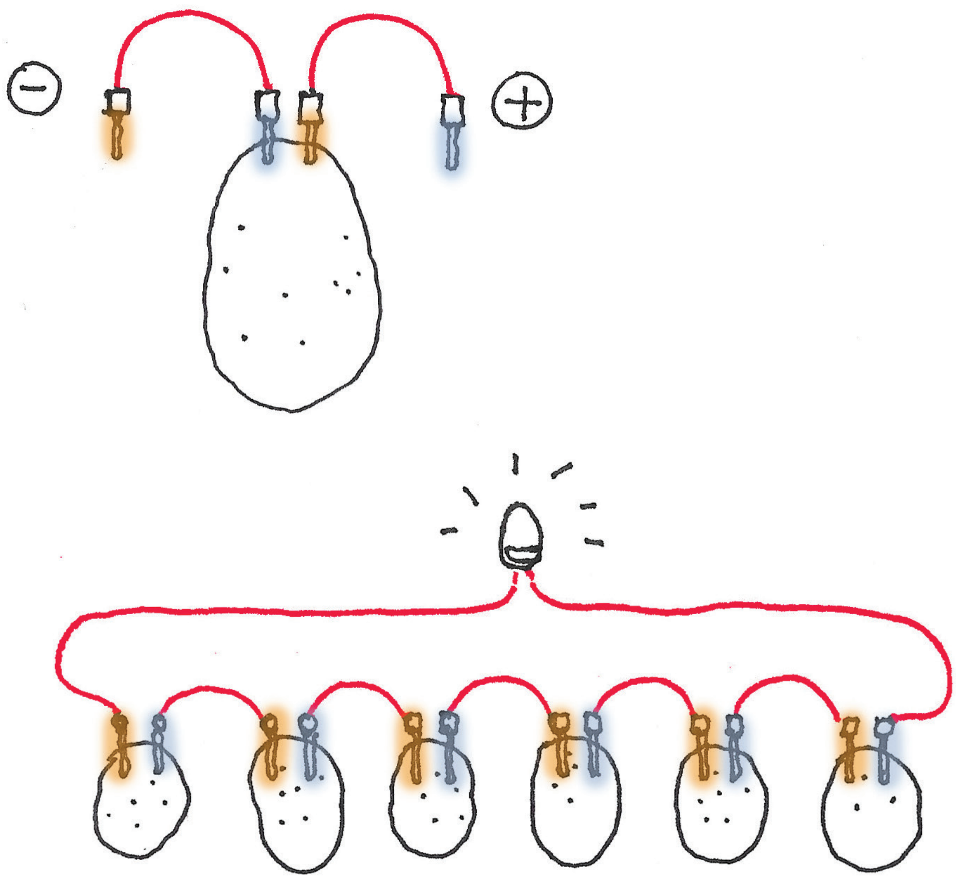
1 Laser-cut barbed potato holder

2 Potato

3 26g stranded insulated wire

4 1/8" ID copper tube, 1/2" lengths

5 Zinc rod, 1/2" lengths



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Eight potatoes connected in
series as in one potato battery

Making Electrodes

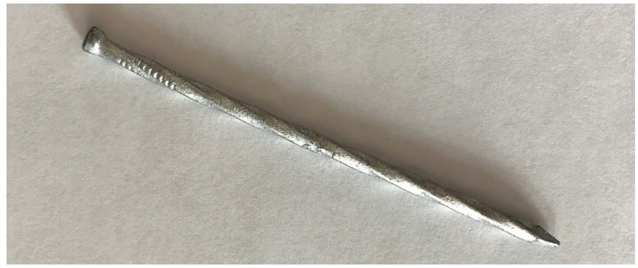
left

Crimping nail and wire for electrodes - Potato batteries during install preparation for Ground Veiling workshop at Domaine de Boisbuchet, 2019.

Electrical batteries have positive and negative terminals. In the organic batteries illustrated here, these terminals are referred to as electrodes. The metals shown here are copper, acting as the positive electrode, and zinc, acting as the negative electrode.

The copper electrode was made from solid copper wire salvaged from common household electrical cable. The wire filament measures approximately 2mm in diameter. The zinc electrode was made from a common household galvanized steel finishing nail. Finishing nails have small pin heads. Their galvanized zinc coating is used for prevention of rusting in damp applications such as in roofing.

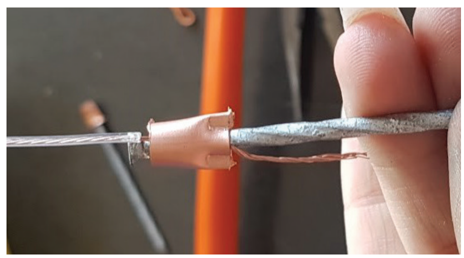
1 The zinc electrode uses a galvanized nail with a small head.


1

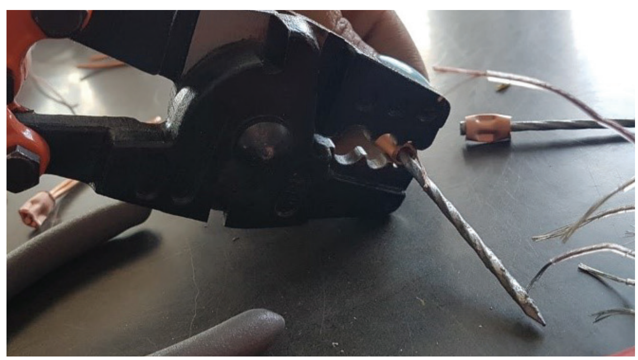
2 Connect the stripped wire to an electrode, line up the stripped portion of the wire next to the electrode, slide the sleeve crimp over both (be sure to put some of the wire jacket in the crimp sleeve, which helps to mitigate breakage at the crimp), and crimp the assembly with a crimping tool.


2

3 Crimp the assembly with a crimping tool.


3

4 Do the same thing using galvanized nail, crimping the nailhead to the wire by using a copper tube crimp to clamp the nail and wire together, while leaving the sharp end of the nail free. Create a pair of connected electrodes connected by the short length of flexible wire, with one electrode made of copper and the other electrode made of the zinc-coated nail.


4

Troubleshooting

The LED isn't turning on

- Try reversing the polarity on the LED (switch the attached wires).
- Take the multimeter and set it to DC voltage. Put one end of the measuring lines (long red and black cables ending in small metal tips) at the positive end (be sure the metal is touching a stripped portion of the wire). Put the other wire at the negative end. The multimeter will read the voltage. Don't be concerned if the number is negative, that just means you reversed the polarity. The LED needs 2.8 volts to shine, so if a series line is reading below that, it will not turn on. Add another potato (and a half electrode pair to complete the circuit) to increase the voltage up to 2.8V or higher.

The LED is dim

- Try adding additional potato cells to increase the power. Not enough surface area of each electrode is in the potato. Be sure to put each electrode as far into the potato as possible.
- Add more vinegar to the connecting slit. This speeds up the reaction and can help to boost the voltage as well as the current.

Additional Test Results

Why copper and zinc?

Certain materials are more inclined to hold onto their electrons than others. These tendencies are what determines traits such as conductance and voltage difference. There is a multitude of factors that influence a material's tendencies, such as pH of environment (say, the pH of a potato, 6.1, or of the water in humid air, ~7), temperature, impurities, and many others. There are ways of determining a material's willingness to give up its electrons, and one related property is the material's voltage.

But voltage is electric potential difference, doesn't that only work as a comparison?

The following list (next page) is taken using hydrogen as 0.

	Metal	Electrode Potential E^0 (Volts)
Anodic	$Li^+ + e^- \rightarrow Li$	–3.05
	$Mg^{2+} + 2e^- \rightarrow Mg$	–2.37
	$Al^{3+} + 3e^- \rightarrow Al$	–1.66
	$Ti^{2+} + 2e^- \rightarrow Ti$	–1.63
	$Mn^{2+} + 2e^- \rightarrow Mn$	–1.63
	$Zn^{2+} + 2e^- \rightarrow Zn$	–0.76
	$Cr^{3+} + 3e^- \rightarrow Cr$	–0.74
	$Fe^{2+} + 2e^- \rightarrow Fe$	–0.44
	$Ni^{2+} + 2e^- \rightarrow Ni$	–0.25
	$Sn^{2+} + 2e^- \rightarrow Sn$	–0.14
	$Pb^{2+} + 2e^- \rightarrow Pb$	–0.13
	$2H^+ + 2e^- \rightarrow H_2$	0.00 — (defined)
	$Cu^{2+} + 2e^- \rightarrow Cu$	+0.34
	$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$	+0.40
	$Ag^+ + e^- \rightarrow Ag$	+0.80
	$Pt^{4+} + 4e^- \rightarrow Pt$	+1.20
	$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$	+1.23
Cathodic	$Au^{3+} + 3e^- \rightarrow Au$	+1.50

1

By adding up the electrode potential of two metals, we get a voltage between them. The greater the voltage, the more likely they are to corrode each other. This corrosion is what releases electrons and creates a current flow. As mentioned above, the pH of the environment influences the electrode potential.

above

1 Electrode Potential of metals, using hydrogen as 0

facing page

2 Order of metals from anodic to cathodic in seawater

Active, Anodic End	Magnesium and Mg alloys
	Zinc
	Galvanized steel
	5052 aluminum
	3003 aluminum
	1100 aluminum
	Alclad
	Cadmium
	2024 aluminum
	Low-carbon steel
	Cast iron
	50% Pb-50% Sn solder
	316 stainless steel (active)
	Lead
	Tin
	Cu-40% Zn brass
	Nickel-based alloys (active)
	Copper
	Cu-30% Ni alloy
	Nickel-based alloys (passive)
	Stainless steels (passive)
	Silver
	Titanium
	Graphite
	Gold
	Platinum
	Noble, Cathodic End

(*After ASM* Metals Handbook, *Vol. 10, 8th Ed., Copyright 1975 ASM International.*)

This is the order of metals from anodic to cathodic in seawater. Notice that some of the metals which appear to pair better together in the previous electric potential list are closer together on this list, meaning they have less potential difference and are therefore less effective for making a battery. So, according to the first list, it would seem we should have used aluminum and copper, but during testing, it was observed that copper and zinc had a larger potential difference (voltage) between them, making them the better pairing. A few factors to consider: Vinegar was added in some cases. It is possible the acidity change was enough to change the galvanic series shown above, but in all cases the vinegar increased the voltage potential. It is more likely the vinegar simply made the electrolyte better at moving electrons as opposed to being able to alter material tendencies.

3

Electrode combination	Voltage w/o Vinegar	Voltage w/ Vinegar
Copper rod (3mm) & Aluminum rod (3mm) 1	0.660	n/a
Copper rod (3mm) & Aluminum rod (3mm) 2	0.35	0.87
Copper rod (3mm) & Aluminum rod (3mm) 3	0.466	0.496
Copper rod (3mm) & galvanized nail (3mm) 1	0.485	n/a
Copper rod (3mm) & galvanized nail (3mm) 2	0.675	0.78
Copper rod (3mm) & galvanized nail (3mm) 2	0.773	0.82
Copper Strip & Aluminum Strips 1	0.5	0.484
Copper Strip & Aluminum Strips 2	n/a	0.468

As is shown here, the numbers vary. This is likely due to potato variation. These tests were also done over the course of 2 days. 3 tests were done to determine what was better between aluminum and copper strips, and copper and zinc (galvanized nails) rods. This was chosen because it is known that surface area increases the speed of galvanic corrosion, which would potentially affect voltage, and most definitely affect current. However, zinc overall seemed to be performing better than aluminum, and the most readily available source of zinc is galvanized nails. For ease of construction, these two cases were put on the table for testing. In each case, a potato was cut in half and either half was used to compare. Vinegar was added to both potato halves. The test was repeated for 3 different potatoes.

Surface area between paired electrodes were paired. Each strip was inserted to 15cm2 of exposed electrode. Each rod was inserted to 0.96cm2 of exposed electrode. Each potato was prepared as described in the instructions above.

above

3 Voltage comparisons

facing page

4 Voltage comparisons

	Aluminum & Copper Strips (15cm2)	Galvanized nail and Copper rod (0.96cm2)
	0.468 volts	0.82 volts
	0.428 volts	0.662 volts
4	0.413 volts	0.890 volts

The results generally showed that galvanized nails and copper rods were more effective. Likely the pH inside the potato (combined with the vinegar) changed the galvanic series enough to give zinc and copper a better potential difference. In each case, measurement of current was attempted but it was too small for the multimeter to detect (this was even true with the entire assembled battery). Based on these results and ease of assembly, the chosen pairing was galvanized nails (zinc) and copper.

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Second Land: Ground Veiling
Assembly Details and Power Cells

This folio documents an installation that was constructed by the members of a Living Architecture Systems Group workshop at Domaine de Boisbuchet, Poitiers, France, in 2019. Specialized organic power cells employing natural potatoes as an electrolyte source were used within the installation. The folio presents a step-by-step guide of assembly for main parts of this organic power system.

Domaine de Boisbuchet is a French country estate where Alexander von Vegesack, co-founder and director of the Vitra Design Museum from 1988 to 2011, established a non-profit center for design education. For the past twenty years, the Domaine de Boisbuchet has hosted workshops on design and related disciplines conducted by internationally acclaimed experts and organized design seminars and competitions.

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