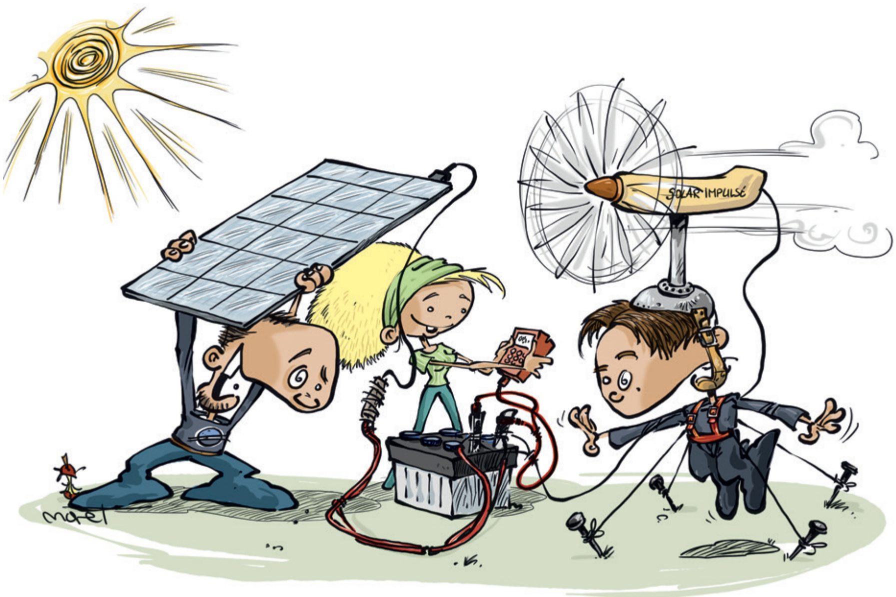
SOLAR CELLS
From light to electricity

Solar Impulse uses nothing but light to power its motors. The effect of light on the material in solar panels allows them to produce the electricity that is needed for the airplane to fly.

This guide will help you discover how electricity can be produced from light and, if you're patient, you will be able to build a battery that produces a higher voltage when it is held under a lamp.



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ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

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SOLAR PHOTOVOLTAIC PANELS OR SOLAR CELLS

Solar Impulse gets all of its energy from the Sun using solar cells, or photovoltaic panels.

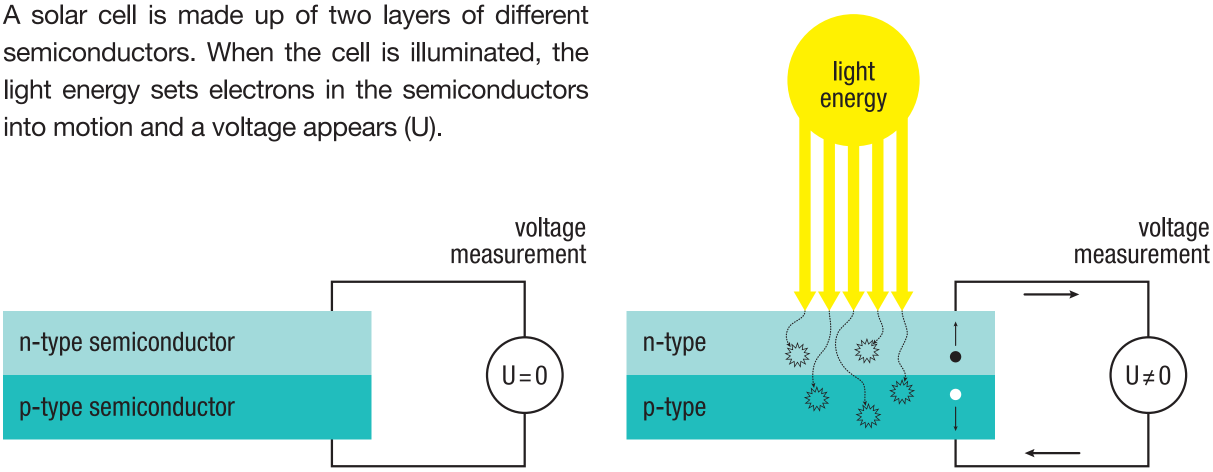
This is the challenge that Solar Impulse set for itself: “By writing the next pages in aviation history with solar energy, and voyaging around the world without fuel or pollution, Solar Impulse’s ambition is for the world of exploration and innovation to contribute to the cause of renewable energies, to demonstrate the importance of clean technologies for sustainable development; and to place dreams and emotions back at the heart of scientific adventure.” [1]

Solar cells transform light energy into electric current. To understand how they work, let’s study how this transformation takes place. To learn more about light itself, refer to the guide entitled LIGHT.

The word “photovoltaic” can be divided into two parts: “photo” and “voltaic.” The term “photo” comes from the Greek word for light. A “volt” is a unit of measure for electric current. Thus “photovoltaic” literally means “electricity from light.” And that’s exactly what the word describes: capturing solar energy in the form of light and transforming it into electricity.

So, how can we transform sunlight into electrical energy? We use a material known as a “semiconductor.” In simple terms, a semiconductor is a material that acts as an electrical insulator, but which is also capable of conducting electricity in certain conditions, primarily associated with the purity of the material and its temperature. This property is used when solar energy is converted into electricity. Photons, particles of light, collide with the surface of the semiconducting material (typically silicon, but in our experiment we will use copper oxide), setting electrons in the solar panel into motion and creating a continuous electric current. [2]

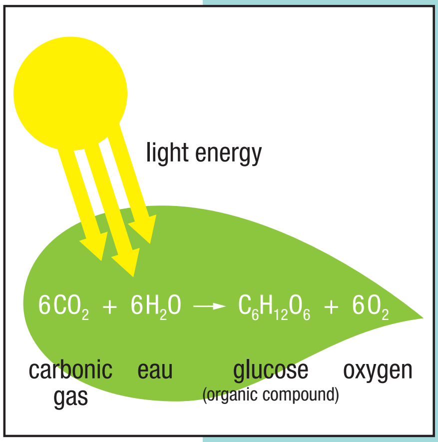
A solar cell is made up of two layers of different semiconductors. When the cell is illuminated, the light energy sets electrons in the semiconductors into motion and a voltage appears (U).



[1] Source : www.solarimpulse.com/fr/message (consulted on December 2012).

[2] Source : mondiasolar.com/index.php?option=com_djcatalog2&view=itemstable&cid=1&Itemid=7 (consulted on January 2013).

A sugar factory!



Photosynthesis is the process by which plants make organic matter using the sun's energy. To do so, they also need carbon dioxide and water. Photosynthesis is the main way in which mineral carbon is transformed into organic carbon.

There are solar cells that imitate photosynthesis (known as dye-sensitized or Graetzel cells). These cells were developed during the 1990s by EPFL professor M. Graetzel.

These cells are easy to make – you can find a guide on portail.umons.ac.be/FR/universite/facultes/fpms/applicasciences/Documents/RessourcesPedag/CelluleGratzel.pdf

What solar cells should be used? How can they be integrated into the structure? What are the most appropriate materials and how can they be combined to make the solar panels as light, strong, and efficient as possible?

LAURE-EMMANUELLE PERRET-AEBI

After several years of research, Laure-Emmanuelle Perret-Aebi wanted to work on a practical project that would connect fundamental research with an industrial application. While she was looking for an ambitious project that would demonstrate that technology can have a positive impact on the environment, she heard about Solar Impulse and sent in her application. Her training as a chemist, and her knowledge on the chemical reactions at the interface between different materials made her the perfect candidate to join the team of EPFL professor Christophe Ballif, who is working in partnership with Solar Impulse on the issues of integrating and encapsulating solar cells into the plane's photovoltaic panels. The opportunity perfectly matched what Laure-Emmanuelle was looking for.
Laure-Emmanuelle graduated from UNI Neuchâtel in 2000, did her PhD in Fribourg on molecular motors (molecules that can be made to move), followed by four years of research in Edinburgh and Neuchâtel. Since her project with Solar Impulse, she has been working on photovoltaics, helping companies improve their products, solve problems, and come up with new products that will be developed over the next five years.

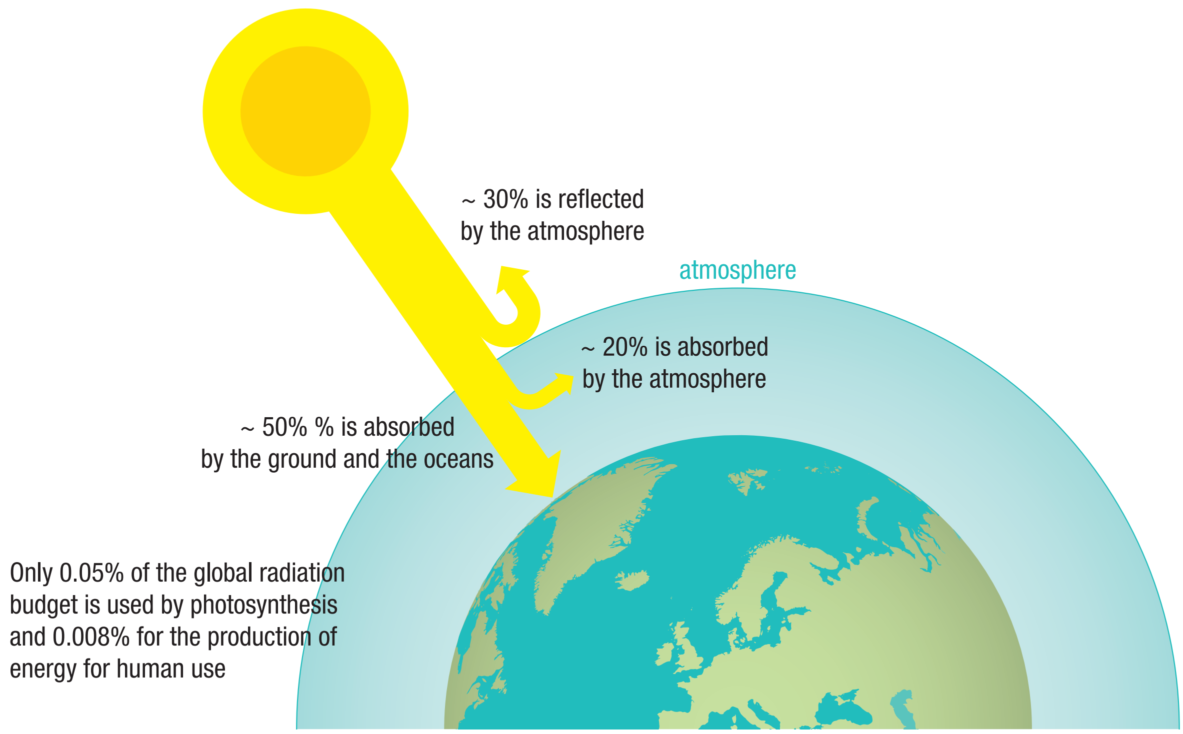
ALL THIS IN NUMBERS…

Exercise 1

The total amount of energy from the sun that hits the earth is estimated to be 170,000,000 GW.

- **30 %** is reflected by the atmosphere.
- **20 %** is absorbed by the atmosphere, mostly by ozone which absorbs UV radiation particularly well.
- **50 %** is absorbed by the ground or the oceans, of which:
  - 40 % is immediately re-emitted in the form of infrared radiation
  - 40 % goes to evaporating water (hydrological cycle, etc.)
  - 20 % is transmitted to the atmosphere by thermal conduction or is used in other ways (photosynthesis, heat collectors, etc.)

Only 0.05% of the global radiation budget is used by photosynthesis and 0.008% for the production of energy for human use.



Based on this information, calculate:

a) The proportion of the total radiation that is used for evaporating water.

b) The energy absorbed by the atmosphere.

c) The energy that is re-emitted in the form of infrared radiation.

Assuming that energy is absorbed homogeneously across the surface of the earth (mean terrestrial radius is 6,371 km):

d) Calculate the energy received per square meter in a 24-hour day.

e) Is this hypothesis realistic? Explain.

On average per m^2 and per year, the energy produced by solar radiation in Switzerland is 1,200 kWh. According to the IEA-PVPS (International Energy Agency Photovoltaic Power System Programme), 140 km^2 of rooftops could be made available for energy production.

f) Calculate the energy produced assuming an average efficiency of 20 % for photovoltaic panels.

g) Compare this energy to that produced in a year by the Grande Dixence dam (2,400 kWh) and the energy output of the Leibstadt nuclear power plant, Switzerland's most powerful nuclear plant (1,200 MW).

Exercise 2

The challenge posed by Solar Impulse pushed companies that manufacture photovoltaic cells to improve their technology. The efficiency of the cells is very good, but the emphasis has been on minimizing the weight over the covered surface, so that the airplane can be as light as possible. Calculate the maximum electric power that the panels can produce when the plane is in flight.

Information

The sun provides an average energy of 250 W/m^2 over 24 hours. The surface area of Solar Impulse's panels is 200 m^2.
The energy efficiency of the cells is 12 %.

SOLARIMPULSE

The tops of Solar Impulse's wings and stabilizers are dark blue, the characteristic color of solar cells. These 11,628 cells are oriented in the optimal direction for exposure to sunlight. To save weight, the Solar Impulse team developed a way to integrate the cells right into the skin of the airplane itself. It was a manufacturing challenge to make the structure both strong enough and as light as possible.

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TECHNOLOGY: MAKE A PHOTOBATTERY

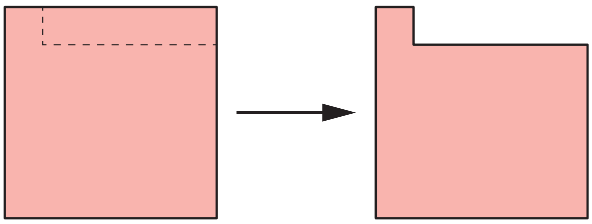
Let's make a battery that can produce electricity from light, which is the principle behind photovoltaic cells. For it to work well, this experiment takes a long time to complete – at least one week.[3]

Material required

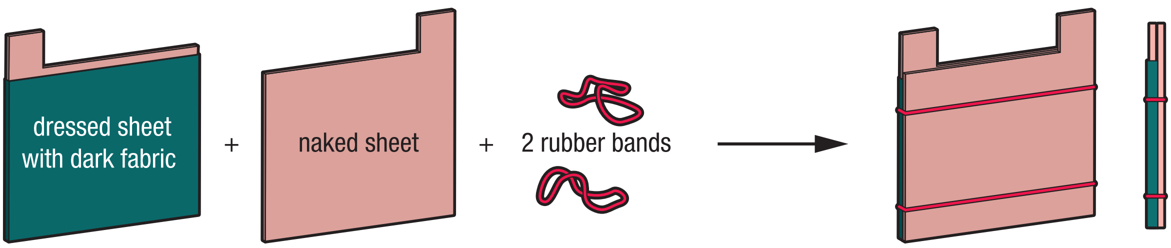
- chemicals: a saturated NaCl (salt) solution[4], prepare enough to fill the container that you will be using
- 2 copper plates
- 1 piece of dark fabric (an old t-shirt, for example)
- 2 rubber bands
- 1 small plastic or plexiglas container (not glass)
- 1 multimeter
- 2 insulated copper wires
- 2 paper clips
- 1 lamp

Marche à suivre

1) Cut 2 copper plates into a surface of at least 80 cm² (for example 10 × 10 cm). These plates will be used as electrodes for our battery. Clean the sheets with steel wool to completely strip the metal (don't use cleaning products like soap, but only abrasive products). Cut out a tab on each electrode. This is where you will attach the paper clips.



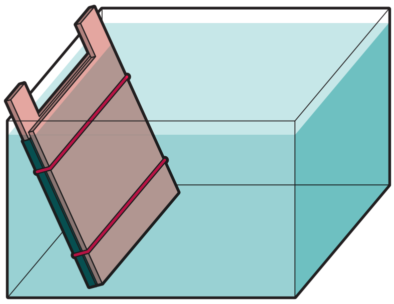
2) "Dress" the two faces of one of the sheets of copper with the dark fabric so that there is only one layer of fabric between the two electrodes. Hold them together using the rubber bands, as indicated in the figure below.



The naked sheet will be the one exposed to the light, while the other will be kept in the dark by the fabric around it. Before continuing, make sure that the two sheets are not touching anywhere.

[3] Source : Science & Vie N°858, Mars 89, page 138.

[4] NaCl (sodium chloride) is kitchen salt. To prepare a saturated salt solution, pour small amounts of salt into hot (ideally distilled) water and stir until it is completely dissolved. Continue adding salt until it no longer dissolves in the solution. This means that the solution is saturated. Let the salt water rest at room temperature, and you're good to go! At 25 °C, your solution should contain about 350 g/l.



3) Put the whole thing in the container, making sure that the sheets are leaning at an angle, and then pour the saturated salt solution into the container until the plates are covered up as much as possible.

4) If at this point you hook a digital multimeter to the terminals (tabs), you will notice that the battery is producing a current of a few millivolts. This is due to impurities in the metal that are not uniformly distributed across the two sheets. This occurs even if you cut them from a single sheet of copper.

You will have to be patient to detect a variation in current under the effect of the light. It will take up to a week for superficial oxidation to build up a semiconducting layer on the exposed sheet of the active electrode. At this point, it will become light sensitive and the photobattery will have higher voltage when it is exposed to light. Depending on the lamp used, you should measure between 2 and 10 mV.

Because water will evaporate while you are waiting, be sure to top up the container regularly.