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Energy from renewable sources

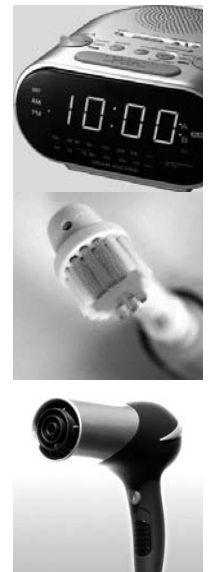
Oil, coal, nuclear power

Water, wind, sun

■ Every single day, we need an enormous amount of energy. Let's take a look at a normal day:

In the morning you are woken up by your radio alarm clock. This gets electricity from the socket. After getting up, you switch on the light, and shower with hot water, which has been heated by the oil or gas-fired central heating system. You then dry your hair with an electric hair dryer and clean your teeth using an electric toothbrush. You make yourself a tea or coffee for breakfast. You boiled the water on an electric or gas stove. The sandwich to eat during your break, which you prepared the night before, was stored in the refrigerator over night.

You take the bus or tram to get to school, or your parents drive you there by car. Buses, trams and cars consume fuel. We could carry on in this way, listing all the things for which you need energy. The list would be endless. Summing up, we all need an enormous amount of energy.



■ And where does this energy come from? We get a large part of it from fossil fuels: natural gas, oil and coal. But part of our electricity requirement is also covered by nuclear energy. Yet these types of energy production have different disadvantages:

- Fossil fuel reserves on the earth are limited.
- The combustion of oil and coal produces harmful substances (pollutants), which pollute the environment, and CO₂, which is responsible for the continuous heating of the earth's atmosphere (global warming).
- Despite high safety standards, there is always a potential risk of a radioactive accident when nuclear energy is used. The process also produces radioactive wastes, which will still be emitting radioactivity a thousand years from now.

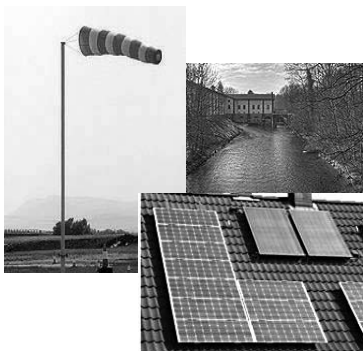
■ A good enough reason to look around for alternatives, which are environmentally friendly and of which unlimited supplies are available. These alternative forms of energy exist. They are called regenerative (renewable) energy sources, or renewables.

With your Profi Oeco Tech kit you will examine energy production from:

Water – wind – sun

Unlike fossil fuels, unlimited quantities of these energy sources are available, and none of the disadvantages described above occur when they are used.

You will use numerous models to see how these energy sources can be used to generate and store electricity and drive fischertechnik models.



■ We constantly talk about energy, but what does it mean and how can it be measured?

We need energy:

- to accelerate a body or
- to move it against a force,
- to heat a substance,
- to compress a gas,
- to get an electric current to flow and
- to emit electromagnetic waves.
- Plants, animals and human beings need energy to live.

The unit with which energy and work is measured is called the **joule (J)**.

If you want to know more about energy, you will find interesting articles on the internet and in text books.



■ The invention of the water wheel was a milestone in the development of technology. Because humans could now use mechanical energy in addition to muscle power – with the help of water power (hydropower).

■ A hammermill is a forge with a hammer driven by water power. The rotational movement of the water wheel causes periodic lifting of the hammer via a camshaft; gravity then causes the hammer to hit the workpiece held between the anvil and the hammer. The few hammer forges still in existence today and still used for production are mainly electrically operated.



Energy



Water energy

into motion ...

... with the water wheel

... with the hammer forge

Sawmill

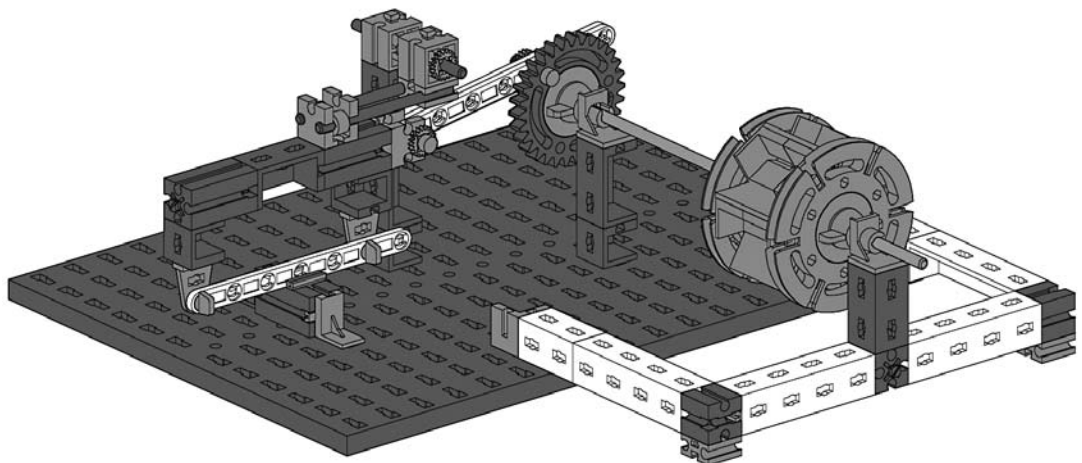
■ Sawmills (also called lumber mill, cutting mill or gangsaw) are industrial plants used to process round logs to form planks, squared timber and beams. Most of these plants were situated on strong streams or rivers, as the saws were driven by water power (hydropower).



■ A sawmill operates with the same principle as a hammer forge. The water is routed onto a water wheel, the wheel turns and the movement is directly transferred onto the respective machine.

You will now build the sawmill model to illustrate this drive principle (see assembly instruction).

You can hold the water wheel under the faucet.



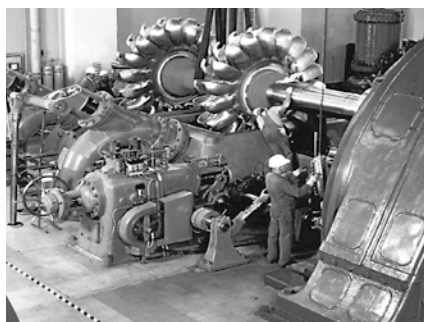
Your Task:

What are the disadvantages of this form of water energy use?

- The energy can only be used where water flows (streams or rivers).
- The energy cannot be stored. It has to be used immediately, when it is available.
- The energy is only available for a limited purpose.

■ For hundreds of years, humans have used the kinetic (working) energy of water to directly drive machines. As industrialization developed, direct use of water energy was replaced by electric current (electricity).

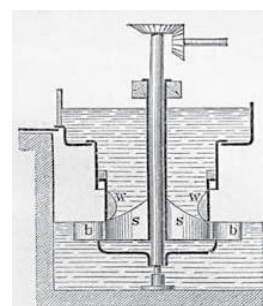
■ A water turbine is a turbine which harnesses water power to enable it to be used. In a water power plant (hydroelectric power plant), the energy from the flow of water is converted into mechanical energy by the water turbine. The turbine is rotated by the flowing water. The rotation of the turbine shaft drives a generator, which converts the rotational energy into an electric current (electricity).



The runners of such turbines have a diameter of up to 11 m.

Convert water energy into electricity

Water turbine



Engraving of a water turbine

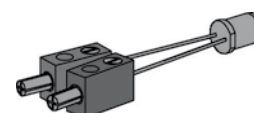
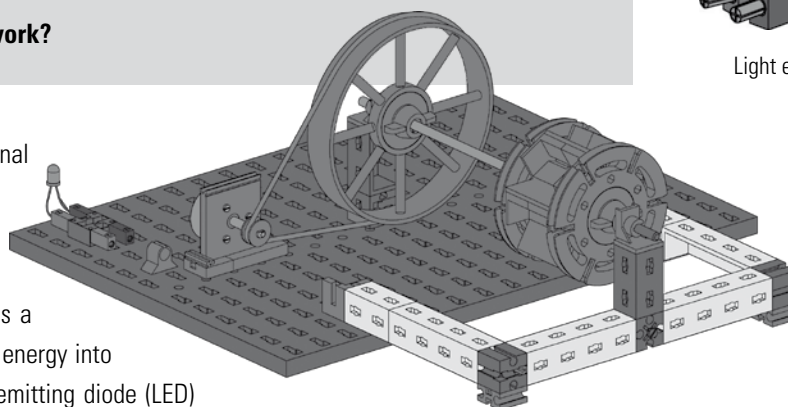
Now build the model of a water turbine (see assembly instruction).

Hold the water wheel under a faucet and let the wheel turn fast enough for the LED to light up. Note the rotational direction of the wheel given in the assembly instruction.

Your Task:

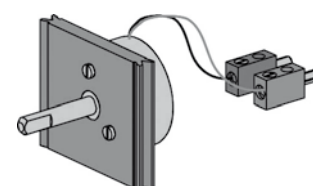
How does the water turbine work?

The water wheel transfers its rotational energy onto the transmission wheel. A V-belt (rubber band) transfers the rotational movement onto the drive wheel of the solar motor. This acts as a generator and converts the rotational energy into electric energy and causes the light emitting diode (LED) to light up.



Light emitting diode

Caution: The LED is solely intended to show how electricity can be generated with the solar motor. It may not be operated with more than 2V direct voltage maximum. It is immediately broken at higher voltages. You must also ensure that the motor does not come into contact with water.



Solar motor

Wind energy

Convert wind energy into motion

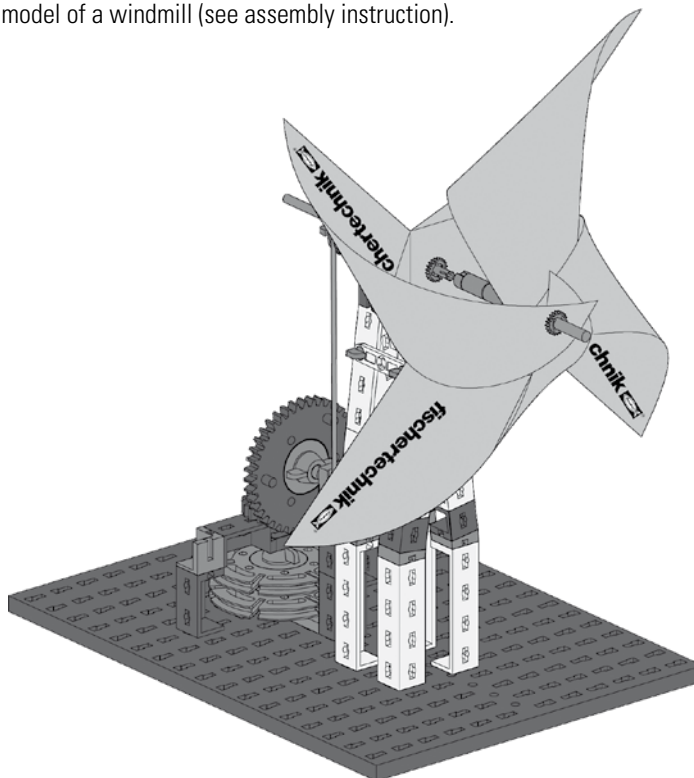


■ Humans have been harnessing wind energy for many hundreds of years. The wind was used on the one hand for transportation by sailing ships or balloons; on the other hand, wind energy was used to do mechanical work with the help of windmills and water pumps.

■ A windmill is an engineering structure, which uses its sails (blades) turned by the wind (kinetic energy) to produce rotational energy. The energy reaches the inside of the mill by a shaft. The rotational movement is transferred to the bottom part of the building by a large cogwheel or gear wheel and an output shaft. Wooden gear wheels and deflection wheels direct the rotational movement onto the millstone. The material to be ground (grist) is ground on the millstone.



Build the model of a windmill (see assembly instruction).



Experiment:

How can you get the windmill to start moving?

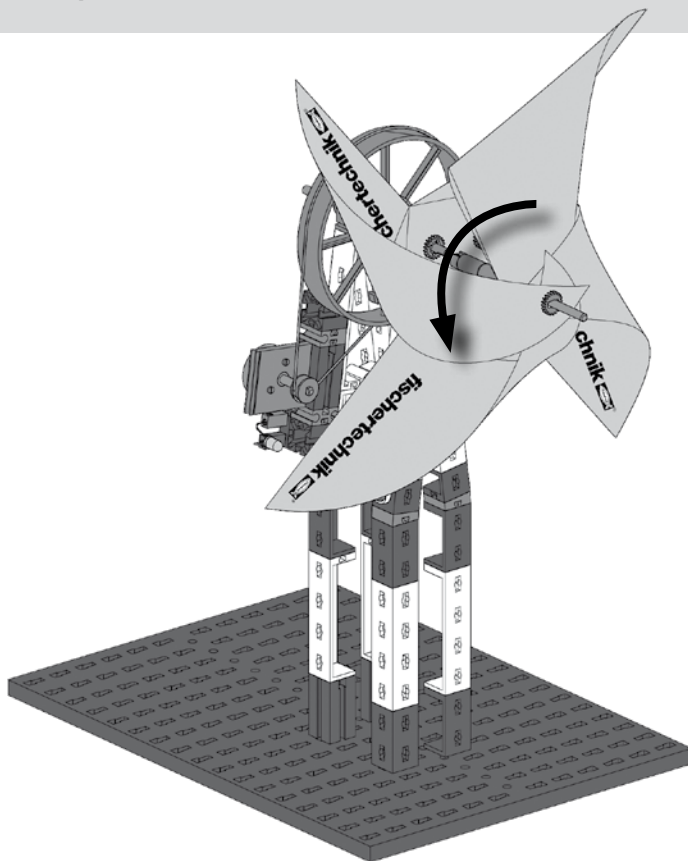
Try different techniques (blow on it, hair dryer, ventilating fan, wind or hold the model in your hand and spin in a circle as fast as you can).

■ Following the discovery of electricity and the invention of the generator, the natural idea was to use wind energy to generate electricity. Initially, windmill concepts were merely modified. Instead of converting the kinetic energy of the wind into mechanical energy, it was used for the production of electrical energy by a generator. As fluid mechanics developed, the structures and sail shapes became more specialized and nowadays they are called wind power stations. Since the oil crisis in the 1970s, there has been increased research worldwide to find alternative methods of producing energy and therefore the development of modern wind power stations was also advanced.

Your Task:

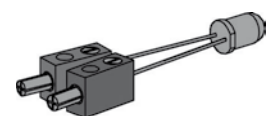
Convert the windmill model into a wind power station, which lights up a light emitting diode (LED).

(See assembly instruction)

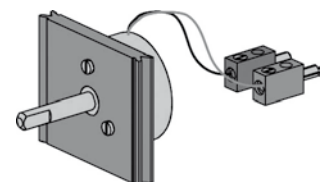


■ The wind wheel transfers its rotational energy onto the transmission wheel. A V-belt (rubber band) transfers the rotational movement onto the drive wheel of the solar motor. This acts as a generator, it converts the rotational energy into electric energy and causes the light emitting diode to light up. Before starting, check the propeller rotates in the correct direction and check for correct polarization of the LED (see assembly instruction).

Convert wind energy into electricity



Light emitting diode



Solar motor

Solar energy

Basics

■ Solar energy is the name given to energy produced by the sun through nuclear fusion, part of which reaches the earth as electromagnetic radiation (radiant energy). Most of this energy is used to heat our planet.



With the help of solar technology, solar energy can be used in different ways:

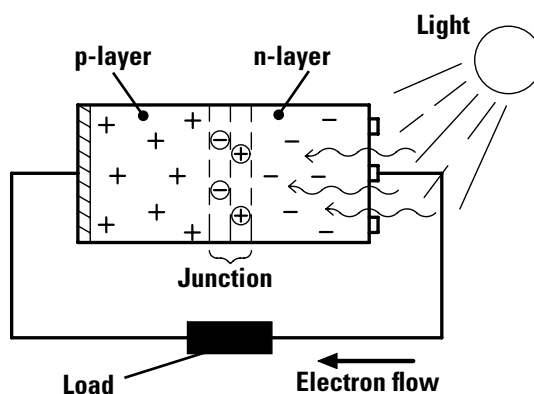
- Solar collectors produce heat or thermal energy (to heat water or for space heating)
- Solar power plants generate electric energy by converting heat into water vapor (steam)
- Solar cookers or solar stoves heat meals
- Solar cells generate direct electric current (photovoltaics)

Convert solar energy into electricity

■ A solar cell or photovoltaic cell is an electrical component, which directly converts the radiant energy in light (usually sunlight) into electric energy. The physical principle of this conversion is called the photovoltaic effect. Solar cells should not be confused with solar collectors, with which the solar energy heats up a transfer medium (mostly hot water for heating).

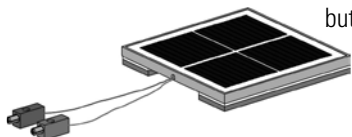
■ Solar cells are made from silicon. The silicon blocks are sawn into approximately 0.5 millimeter thick layers (aka wafers or discs). In the next step, the wafers are then doped (contaminated) with different foreign atoms (dopants), that is to say they are deliberately contaminated with impurities, which causes an imbalance in the silicon structure. This produces two layers, the positive p-layer and the negative n-layer.

■ In simple terms, the electric current flow is produced by electrons from the n-layer, excited by the incidental light, moving through the connected load (e.g. solar motor) to the p-layer. The more light (that is energy) that falls on the cell, the more mobile the electrons become. When a solar cell is connected to a load, the electrons preferably move in this direction. As you can imagine the current flow as being like a cycle, electrons constantly arrive at the n-layer and then travel back to the p-layer. This flow of electrons causes electric current to and the motor rotates.



Silicon solar cell

■ The solar module used in the Profi Oeco Tech kit consists of two solar cells connected in series. It supplies 1.2 V voltage and a maximum current of 440 mA. The solar motor has a nominal voltage of 2 V, but starts to turn with 0.3 V (at no-load, that is, without the motor's shaft having to drive a model).



Build the ventilating fan model for the first experiments using the solar module (see assembly instruction).

Experiment 1:

Find out what brightness is needed for the motor to turn. You can use a lamp with bulb to do this. Test the experimental setup outdoors in the sunshine too.

Experiment 2:

If you have an amperemeter and voltmeter, you can use it to measure the voltage from which the motor begins to turn and what current is flowing then.

Now build the Ferris wheel model (see assembly instruction).

Your Task:

Why does the Ferris wheel turn more slowly than the ventilating fan?

The model contains a gear system (worm and large gear wheel). This gear system is needed, because otherwise the motor would not have enough power to drive the model.

You can also use the kit to build a helicopter and a bicycle rider with solar drive.

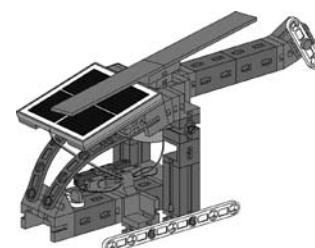
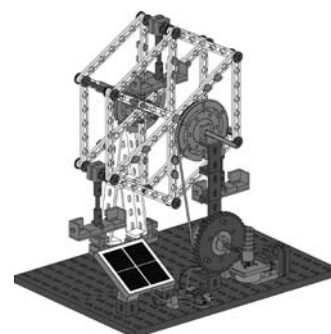
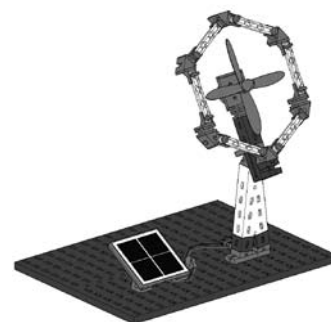
Experiment 3:

Perform experiments to find the answers to the following questions:

- How light must it be for the motor to turn sufficiently?
- Which light sources are suitable for producing energy?

	Yes	No		Yes	No
Light bulb			LED spotlight		
Energy-saving lamp			Fluorescent lamp		
Halogen spotlight			Sun		

Solar models



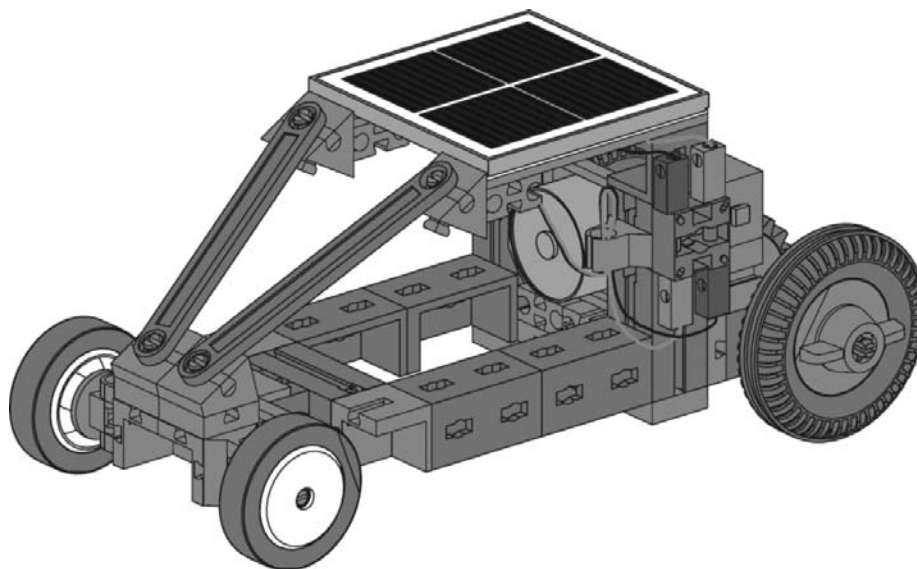
Solar vehicle



■ Solar vehicles get most of their propulsion energy directly from the sun. The surface of the vehicles is equipped with solar cells, which convert the solar energy on the vehicle into electric current. As electric cars, they frequently also carry an energy store (mostly accumulators) with them, so that they can stay roadworthy even in poor light conditions or cloud cover, at least for a limited time.



Build the model of a solar vehicle (see assembly instruction).



Experiment 1:

Find out what brightness is needed for the vehicle to travel.

Experiment 2:

Test what effect the light intensity has on the vehicle's speed.



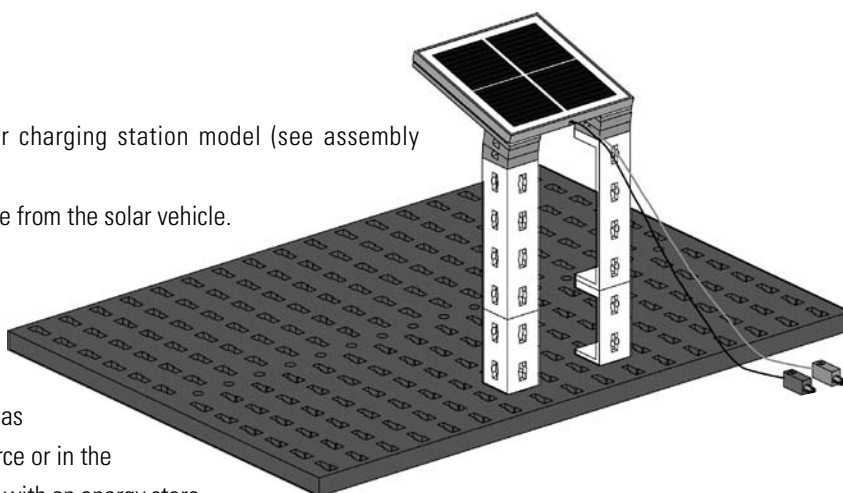
■ A vehicle which runs on "solar electricity" is not automatically a solar vehicle. If a vehicle, for example, only "refuels" its electricity at a solar charging station, the electricity is produced from sunlight, but the vehicle itself is only an electric vehicle.

Store electric energy

Solar charging station

In addition to the solar vehicle, build the solar charging station model (see assembly instruction).

To do this, you will have to remove the solar module from the solar vehicle.

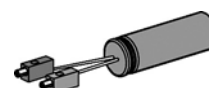


■ During your experiments with the solar module, you have probably found that this form of energy production has a disadvantage. The models stop as soon as they are outside the range of the light source or in the shade. It is therefore important to equip the models with an energy store for this period; the energy store is charged with solar energy.

■ The Goldcap in the kit is just such an energy store. It consists of two pieces of activated carbon, which are only separated by a thin insulating layer. The characteristic feature of the Goldcap is its extremely high capacity. The capacitor used by you has a capacity of 10 F (farad).

You can use the Goldcap like a small rechargeable battery. The advantage of the Goldcap over a rechargeable battery is that the Goldcap can be very quickly charged, it cannot be overcharged and it cannot be over-discharged.

Goldcap energy store



Goldcap*

Caution, danger of explosion!



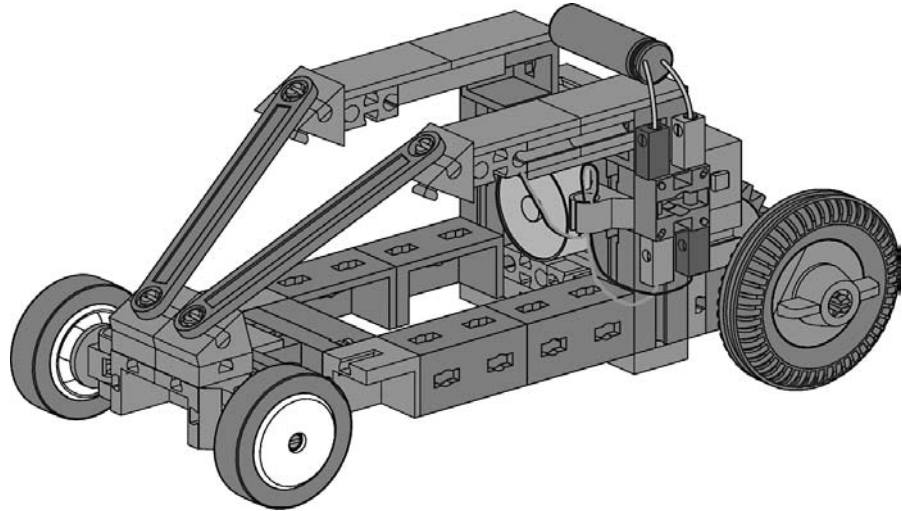
Never connect the Goldcap to a voltage higher than 2.3 V, otherwise there is a danger of explosion! This means the Goldcap must never be connected to a usual 9 V fischertechnik power supply.

When installing the plugs on the Goldcap, you must make sure the polarity of the plugs is correct (connect green plug to minus). It is advisable to cut the two connections of the Goldcap to the same length.

* Despite the name, there is unfortunately no gold in it! Goldcap is a product name which the manufacturer has given the special capacitor.

Charge the Goldcap with solar energy

■ Convert the solar vehicle into an electric vehicle. To do this, connect the Goldcap instead of the solar module.



You can now charge this vehicle at the solar charging station:

To do this, disconnect the motor from the Goldcap and connect the solar module to the Goldcap. Make sure that the red plug of the Goldcap (+) is connected to the red plug of the solar module. Charge the Goldcap for approximately 10 min, for example, under a 100 W light bulb at a distance of 30 cm or in sunlight.

Caution!

If the distance between the solar module and the light source is too small, the module overheats and can be damaged.

After charging, reconnect the motor to the Goldcap.

Experiment 1:

If you have a measuring device, you can measure the voltage at the Goldcap while it is charging. In this way you can read off how far the charging progress has progressed.

Experiment 2:

- **See how long the car runs with on a "full tank".**
- **What speed does it reach?**

Note:

If the Goldcap is charged using the solar module, it is discharged again through the connected solar module as soon as it gets dark. The Goldcap should therefore only stay connected to the solar module as long as the solar module is illuminated (by the sun or light source).

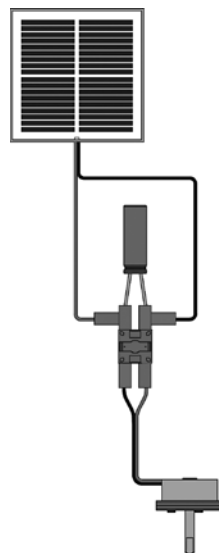
You have probably found that the vehicle only runs for a relatively short time on a "full tank".

■ You can optimize the vehicle by installing the solar module again and by connecting the Goldcap parallel to the solar module.

Make sure that the "red" plug of the Goldcap (+) is connected to the "red" plug of the solar module.

The solar module drives the motor and charges the Goldcap at the same time. When the vehicle is in the shade or in a tunnel, the motor is driven by the Goldcap.

If the Goldcap is discharged, most of the electricity supplied by the solar module is used to charge the Goldcap. It can therefore take a while for the vehicle to start.

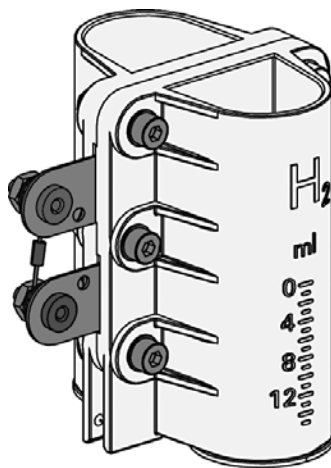


Parallel connection of Goldcap and solar module

Experiment:

Test how long the vehicle has to drive in the light so that it can then cover a certain distance in the shade or a tunnel.

■ Apart from the renewable energy sources introduced in this kit, the supplementary Hydro Cell kit provides a real highlight when it comes to renewable energy – the fuel cell. You can use this energy source to run models from the Oeco Tech kit as well as other technically interesting models.



Fuel cell preview

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Profi Oeco Tech + Hydro Cell Kit



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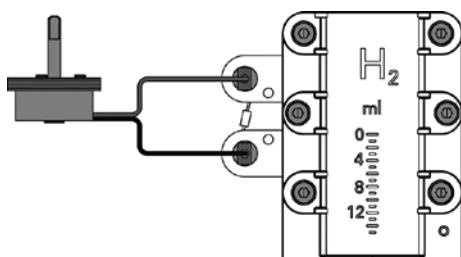
Experiments using the Profi Oeco Tech + Hydro Cell Kit

Ventilating fan

■ Read the Hydro Cell kit instruction manual first and familiarize yourself with how the fuel cell works. Then, as the first experiment, use the Oeco Tech assembly instruction to build the ventilating fan model. However, you do not have to install the solar modul.

Experiment 1:

Fill the fuel cell with distilled water and produce hydrogen and oxygen (see Hydro Cell kit instruction manual). Then connect the motor of the ventilating fan to the jacks of the fuel cell. The model is now driven by the fuel cell.



Your Task:

Observe how much hydrogen is consumed during a certain time while the model is running. You can read off the consumption from the scale on the hydrogen storage cylinder.

What can you determine?

The longer the model runs, the more hydrogen is consumed. This means, if the model runs twice as long, it will also need twice as much hydrogen.

Experiment 2:

Now perform experiment 1 with other models too, for example the bicycle rider or the Ferris wheel from the Oeco Tech kit.

Compare how much hydrogen each of the models consumes during a specific time.

You will find that the models consume different amounts of hydrogen. The more energy a model needs, the more hydrogen is consumed.

Fuel cell vehicles

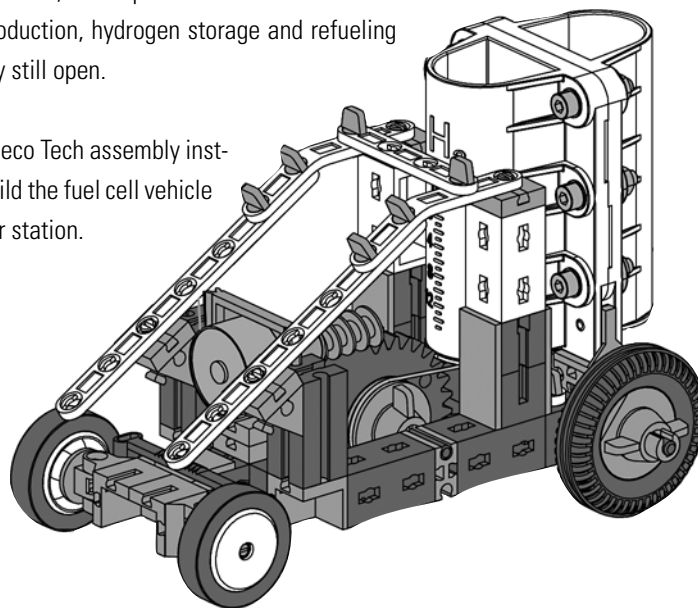
■ Fuel cell vehicles are means of transportation with an electric drive, in which a fuel cell is used to produce the required electric energy from hydrogen or methanol as energy sources. This form of propulsion is still considered to be experimental by most people and current development is in competition with battery-powered electric drives; nevertheless, series production of the first vehicles began in 2008.



Problems with the range and the economic efficiency of the rechargeable batteries (price and life) have resulted in several car manufacturers favoring the fuel cell as the technology of the future at the present time. However, development of the infrastructure for the hydrogen production, hydrogen storage and refueling is essentially still open.

Fuel cell vehicle with solar station

■ Use the Oeco Tech assembly instruction to build the fuel cell vehicle and the solar station.



Experiment 1:

Fill the fuel cell with distilled water and connect it to the station's solar modules, in order to produce hydrogen and oxygen.

Experiment with the fuel cell vehicle.

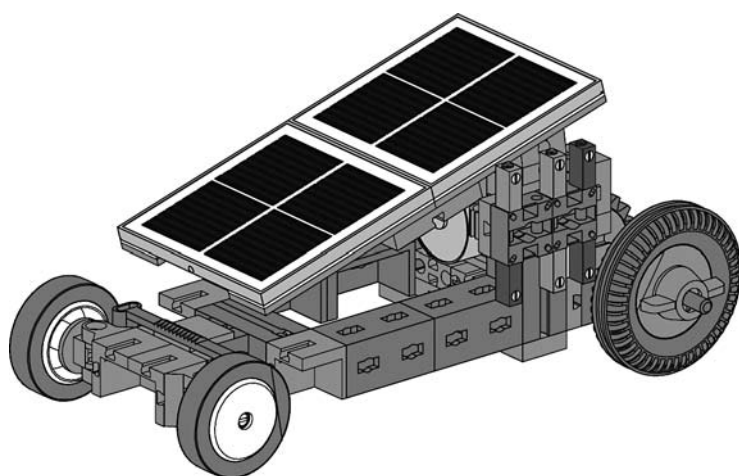
- **How much hydrogen does the fuel cell consume in a certain time?**
- **What distance can be covered with a "full tank"?**
- **When does the vehicle run longer on a full tank - when it travels straight ahead or when it travels in a circle?**

The longer the vehicle runs, the more hydrogen is consumed. When the vehicle travels around a tight curve, the motor needs more energy than when the vehicle travels straight ahead. Therefore, more hydrogen is also consumed when the vehicle travels in a circle.

■ The difference between the parallel connection and series connection of solar modules is that in the parallel connection the voltage remains the same but more electricity is supplied than with one module. In the series connection the current remains the same but instead the voltage of the two solar modules is added together.

■ Build the solar vehicle II model (see assembly instruction). You will need two solar modules for this. As the Profi Oeco Tech kit only contains one module, use the module from the Hydro Cell kit.

You can use the solar vehicle to perform the following experiments on the parallel and series connection of solar modules.



Experiment 1:

Test which light intensity is needed for the vehicle to travel. When is less light needed – when the solar modules are connected in series or when the solar modules are connected in parallel?

The solar modules connected in parallel need less light. With the parallel connection the voltage is the same as with one solar module. Instead, because of the larger solar cell surface, this "double module" can supply more electricity with the same light intensity.

Parallel and series connection of solar modules

Solar vehicle II

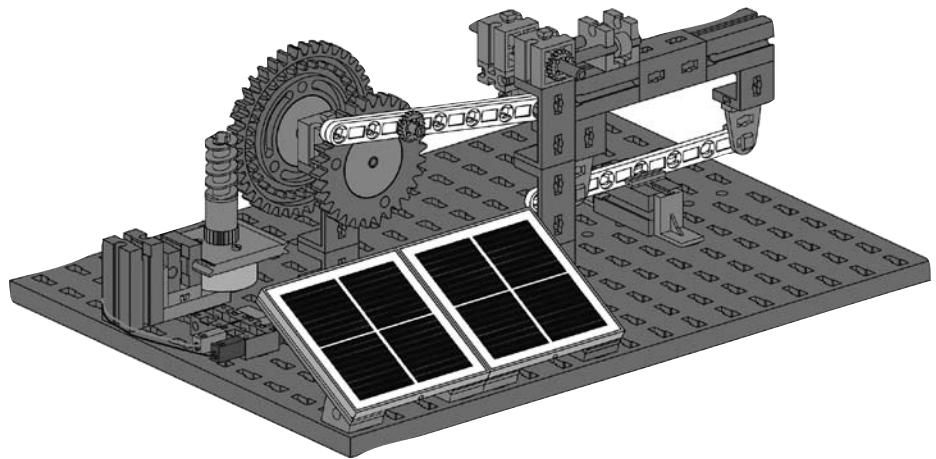
Experiment 2:

Test whether the vehicle travels faster when the solar modules are connected in series or when the solar modules are connected in parallel.

The vehicle travels faster when the solar modules are connected in series. In a series connection the voltages of the two solar modules are added together, and the higher the voltage is the faster the motor rotates.

Solar saw

■ Build the solar saw model (see assembly instruction). This model also needs two solar modules. One is included in the Profi Oeco Tech kit and the other is in the Hydro Cell kit.

**Experiment:**

Use this model too, to experiment with the differences between solar modules connected in parallel and those connected in series.

If the light intensity remains the same, what are the advantages and disadvantages of the two different types of connection?

Parallel connection:

The saw moves more slowly, but needs a lower light intensity.

The motor rotates more slowly, but in exchange it rotates with very little light.

Series connection:

The saw moves faster, but also needs a higher light intensity.

The motor now needs far more light to rotate – but when it rotates, then really quickly.

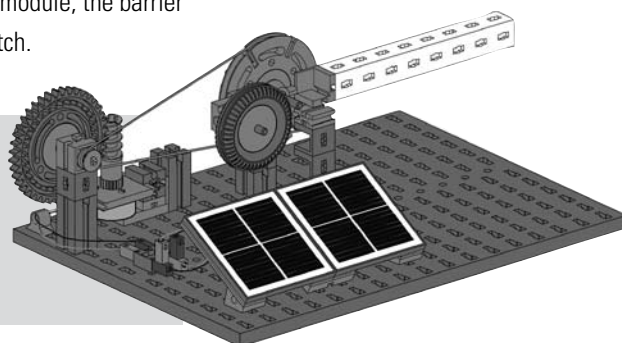
■ What does this mean? It simply means that two solar modules are connected in parallel so that the plus pole of one solar module is connected to the minus pole of the other solar module.

■ Use the Oeco Tech assembly instruction to build the model of the barrier.

With this model, you can use solar energy to open and close a barrier. The trick here is that the motor does not move if both solar modules are illuminated with the same brightness. If you cover up one module, the motor starts to move and closes the barrier. If you darken or black out the second module, the barrier opens again. In this way, you can use this connection to replace a pole-reversing switch.

Your Task:

Draw a sketch to clearly show you how reversing the rotational direction of the motor (or the current direction in the motor) in this model occurs when one solar module is darkened.



Inverse-parallel connection of solar modules

Barrier

If both modules are illuminated with the same intensity, the voltages cancel each other out and the motor remains at a standstill. If one module is covered, the voltage of the illuminated module acts on the motor. The motor turns and closes or opens the barrier.

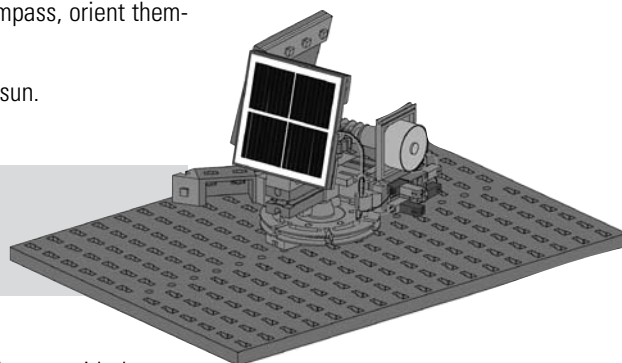
■ Another application of inverse-parallel connection is the solar tracking model. Use the Oeco Tech assembly instruction to build the model.

This simple device ensures that the solar modules move with the sun and, like a compass, orient themselves to the sun.

The point at which the two solar modules meet always points in the direction of the sun.

Your Task:

How does this simple principle of solar tracking work?



Solar tracking

The same principle applies here as in the barrier. If both modules are illuminated by the sun with the same intensity, the voltages cancel each other out and the motor does not rotate. If the sun moves, one module is more strongly illuminated and a positive or negative voltage is applied to the motor. This causes the motor to rotate until the light comes from the front again.

Important: When wiring the model, ensure you connect the cables correctly, otherwise the model might move away from the sun instead of towards it.

Parallel connection of fuel cell and solar modules

Pump



- Build the pump model for the following experiments (see Oeco Tech assembly instruction).

Experiment 1:

Fill the fuel cell with distilled water and place the model in the sunlight or illuminate the solar modules with a suitable light source (e.g. 100 W light bulb at a distance of 30 cm).

What can you observe?

The pump moves and at the same time, hydrogen and oxygen are produced in the fuel cell. The motor and the fuel cell are connected in parallel. Both are therefore supplied with electric energy from the solar modules. The energy is sufficient to drive the motor and at the same time to produce hydrogen and oxygen.

Experiment 2:

Now wait until a certain quantity of oxygen has been produced and then cover up the solar modules or switch off the light source.

What can you observe now? Pay attention to the hydrogen storage cylinder too.

The model runs more slowly, but it does not stop. The fuel cell consumes hydrogen.

If the light intensity reduces, the model is driven by the fuel cell. The pump now continues running, even after sunset or if the sun is concealed by a cloud. The reason why the model now runs more slowly is that the fuel cell supplies a lower voltage than the solar modules. An electric motor rotates more slowly if it is supplied with a lower voltage.

