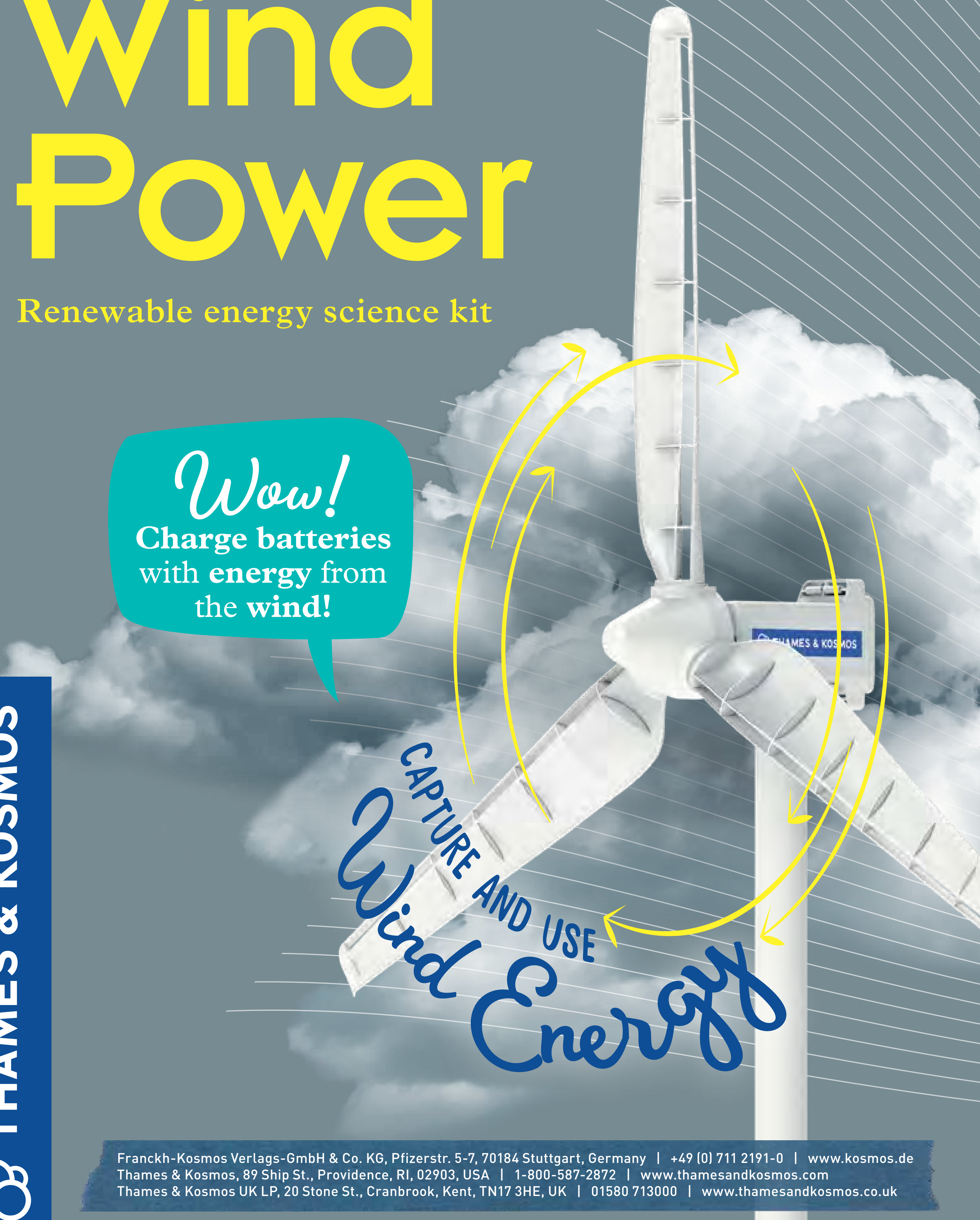
Experiment Manual

Wind Power

Renewable energy science kit

Wow!
Charge batteries with **energy** from the **wind!**



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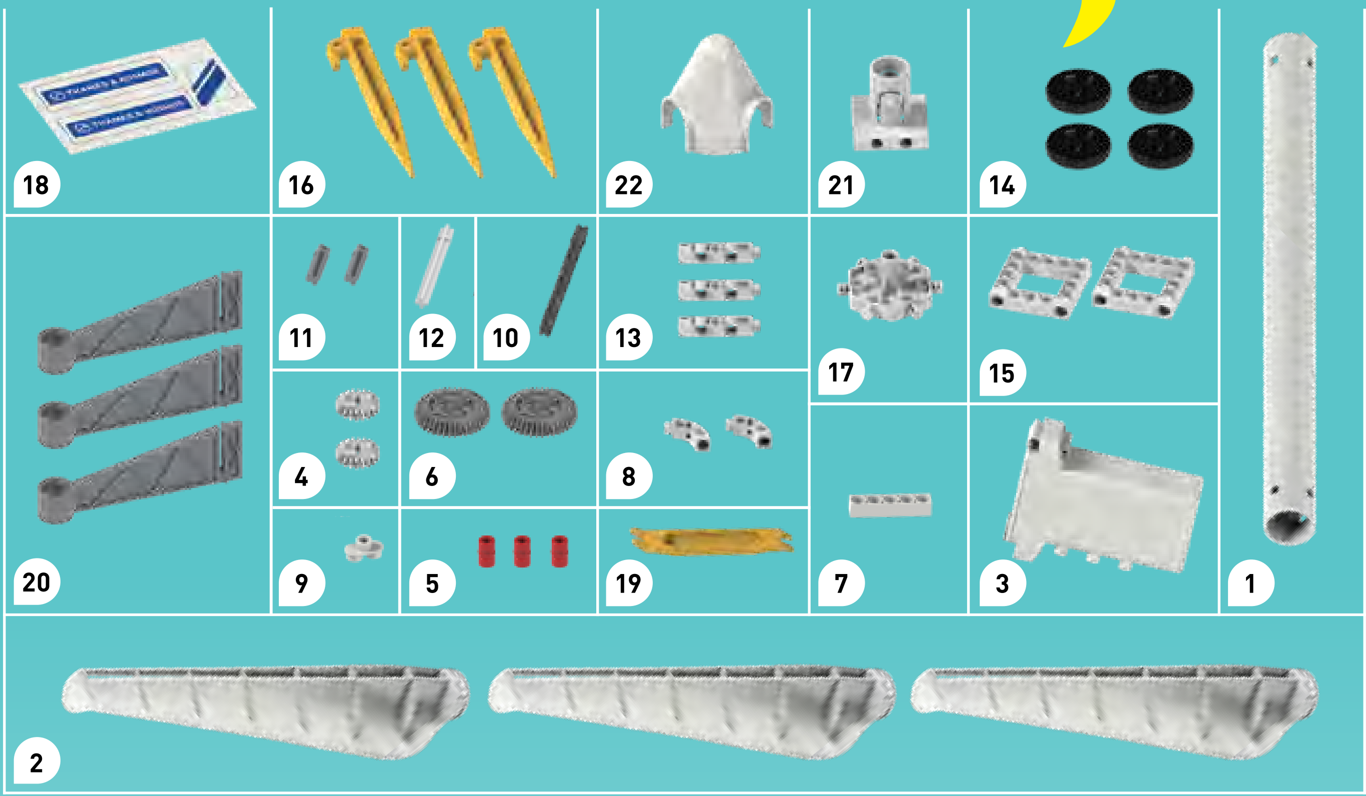
Good to know!
If you are missing any parts, please contact Thames & Kosmos customer service.

What's in your experiment kit:

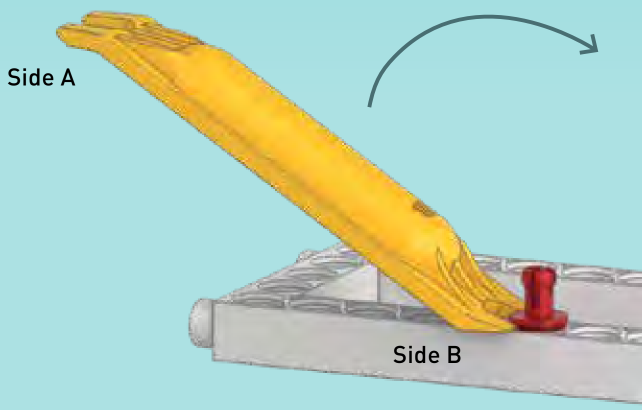


Checklist:

✓	No.	Items	Number	Type No.
◯	1	Tower	1	716028
◯	2	Rotor blade	3	722773
◯	3	Generator/motor and housing	1	722775
◯	4	Small gear wheel	2	716885
◯	5	Anchor pin	3	702527
◯	6	Medium gear wheel	2	716890
◯	7	5-hole rod	1	716875
◯	8	Curved rod	2	714285
◯	9	Two-to-one converter	1	714286
◯	10	Axle, 10 cm	1	716901
◯	11	Motor shaft, 2.7 cm	2	717962
◯	12	Axle, 7 cm	1	723292
◯	13	5-hole dual rod	3	716848
◯	14	Wheel	4	714006
◯	15	Square frame	2	716899
◯	16	Stake (set of 3)	1	722772
◯	17	Rotor blade hub	1	716038
◯	18	Sticker sheet	1	722771
◯	19	Anchor pin lever	1	702590
◯	20	Foot	3	722774
◯	21	Tower connector	1	716029
◯	22	Nose cone	1	716037

The parts not included in the kit are marked in *italics* in the YOU WILL NEED lists.

YOU WILL ALSO NEED:
1 AA rechargeable battery (1.2-volt, type HR6), fan, hairdryer, stopwatch, pencil, smartphone or tablet, compass



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TIP

YOU CAN FIND ADDITIONAL INFORMATION IN THE "CHECK IT OUT" SECTIONS ON PAGES 5, 11-14, 19-22, 27, AND 29-32

TIP

YOU WILL NEED TO USE THE ANCHOR PIN LEVER WHEN YOU WANT TO DISASSEMBLE YOUR MODELS. IT HAS TWO DIFFERENT SIDES FOR DIFFERENT PARTS.

Hooray! **Let's begin!**

627929-02-171120

WARNING

Not suitable for children under 3 years. Choking hazard — small parts may be swallowed or inhaled.

Warning: This toy is only intended for use by children over the age of 8 years, due to accessible electronic components. Instructions for parents or caregivers are included and shall be followed. Keep packaging and instructions as they contain important information.

Store the experiment material and completed models out of the reach of small children.

As a general rule:

Never dispose of batteries in the household trash.

Safety for Experiments with Batteries:

››› Never perform experiments using household current! The high voltage can be extremely dangerous or fatal!

››› One AA rechargeable battery (1.2-volt, type HR6, NiMH) is required, which is not included in the kit because of its limited shelf life.

››› Avoid short circuiting the battery. A short circuit can cause the wires to overheat and the battery to explode.

››› Different types of batteries or new and used batteries are not to be mixed.

››› Do not mix old and new batteries.

››› Do not mix alkaline, standard (carbon-zinc), or rechargeable (nickel-cadmium) batteries.

››› The battery is to be inserted with the correct polarity. Press it gently into the battery compartment (see page 9).

››› Non-rechargeable batteries are not to be recharged. They could explode!

››› Rechargeable batteries are only to be charged under adult supervision.

››› Rechargeable batteries are to be removed from the toy before being charged (or they must be charged as described in the instructions).

››› Exhausted batteries are to be removed from the toy (e.g., if no experiments are to be carried out with them for a prolonged period of time).

››› The supply terminals are not to be short-circuited.

››› Dispose of used batteries in accordance with environmental provisions, not in the household trash.

››› Avoid deforming the battery.

››› Do not expose the toy to extreme heat or long periods of direct sunlight; protect it from heavy, persistent rain and frost.

Notes on Disposal of Electric and Electronic Components

The electronic components of this product are recyclable. For the sake of the environment, do not throw them into the household trash at the end of their lifespan.

They must be delivered to a collection location for electronic waste, as indicated by the following symbol:

Please contact your local authorities for the appropriate disposal location.

SAFETY INFORMATION

This experimental kit is intended only for children over 8 years of age.

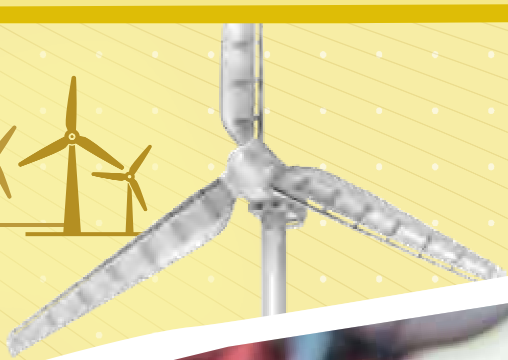
Dear Parents and Adults,

Children want to explore, understand, and create new things.
They want to try things and do it by themselves. They want to gain knowledge!
They can do all of this with Thames & Kosmos experiment kits.
With every single experiment, they grow smarter and more knowledgeable.

- Before beginning the experiments, read through the instructions along with your child, discuss the safety notes, and keep them on hand for reference. Check to make sure that the models have been assembled properly, and be ready to help with the experiments. Pay special attention to the insertion of the rechargeable battery (AA, 1.2-volt, type HR6).
- The wind turbine is suitable for indoor and outdoor use with the right amount of airflow. A scale for measuring wind speed, called the Beaufort scale, is given on page 12. To ensure that the turbine works properly, the wind force should be at least 2, but not more than 4, because the turbine could be damaged if the wind is too strong. Indoors, you can simulate the wind with the help of an electric fan or hairdryer.
- Please note the two different modes: input mode and output mode.
  Input (or charging) mode: Ensure that the button on the back side of the turbine is set to IN (according to the diagram next to the button) and that the rotor blades turn to the left. When the battery is charging, the light behind the button will turn red.
  Output (or stored energy) mode: To use stored energy (for example, to power your vehicle), ensure that the button on the back side of the turbine is set to OUT.
- To prevent damage to the device, do not switch to output mode (moving the button from IN to OUT) while it is being powered by the wind.
- Even though the wind turbine model is water resistant and can be used outdoors, it must be protected from the weather (mainly rain and frost), so that there is no damage to the electrical system and the other components. Therefore, it is best to bring it inside after every experiment. You can clean all the external parts with a wet cloth; do not use soap or any detergent-based products for this.
- If the wind turbine does not turn, check that the rotor blades have been assembled as shown in the instructions. Try adjusting the blades to different angles. The wind turbine works best when all three rotor blades are set to 3.

We hope you and your child enjoy experimenting while learning about the technology behind clean energy and all of its benefits!

Have fun!



Dyn-o-mite!
A bicycle dynamo generates electricity from the spinning tire!

Experiments with the Wind Turbine

For centuries, people have been building windmills to harness energy from the wind. Windmills convert the kinetic energy of the wind into rotary motion. Just like with a dynamo generator on a bicycle or a hand-cranked flashlight, this rotation can be used to generate electric power. First of all, let's take a good look at the parts of a modern-day windmill, called a wind turbine.

CHECK IT OUT

Measuring Instruments

The most important measuring instruments for wind turbines are the wind vane (or weather vane) for determining the direction of the wind flow, and the anemometer which shows how strong the wind is blowing.

ROTOR BLADES

At the top of a wind turbine's tower there is a hub to which the rotor blades are fixed. The shape of the rotor blades differs from turbine to turbine, but mainly they are shaped similar to an airplane's wing. There are usually three rotors per turbine.

HOUSING

The housing, or nacelle, is located behind the rotor blades. All the important energy conversion processes take place in the housing. To be able to use wind energy optimally, the housing and rotors can turn toward the direction of the wind.

Protecting the Turbine

Wind turbines have features designed to protect them from damage when the wind is too strong — for example, in a storm. If strong winds cause a turbine to spin faster than its maximum rated speed, the rotor blades will start to feather, or point into the wind, which reduces their contact surface area and slows them down. In some cases, the rotors can even be locked in place during a storm. Some blades are shaped in ways that reduce the lift forces at high wind speeds.

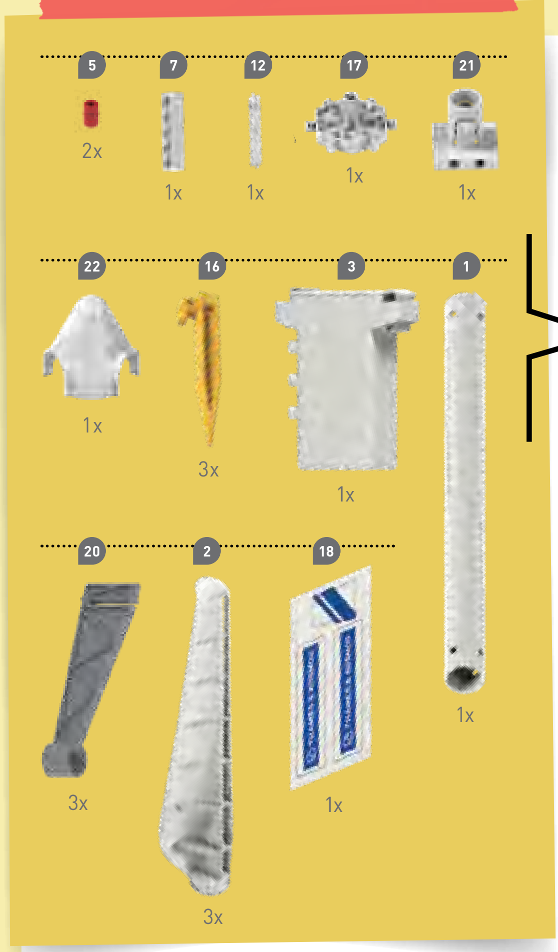
TOWER

If you are ever able to stand right next to a wind turbine, you'll see just how big it is in comparison. The height of the tower to which the housing is attached is between 40 and 180 meters (130 to 590 feet). This corresponds to a high-rise building with 13 to 60 floors.

FOUNDATION

The foundation, or base, of the wind turbine is crucial for its structural integrity. You naturally want to prevent the turbine tower from falling over if the wind is too strong. For this reason, there are all sorts of structural technologies and measuring instruments for monitoring the foundation and housing. In this way, if necessary, engineers can respond quickly to structural issues.

ASSEMBLING THE WIND TURBINE



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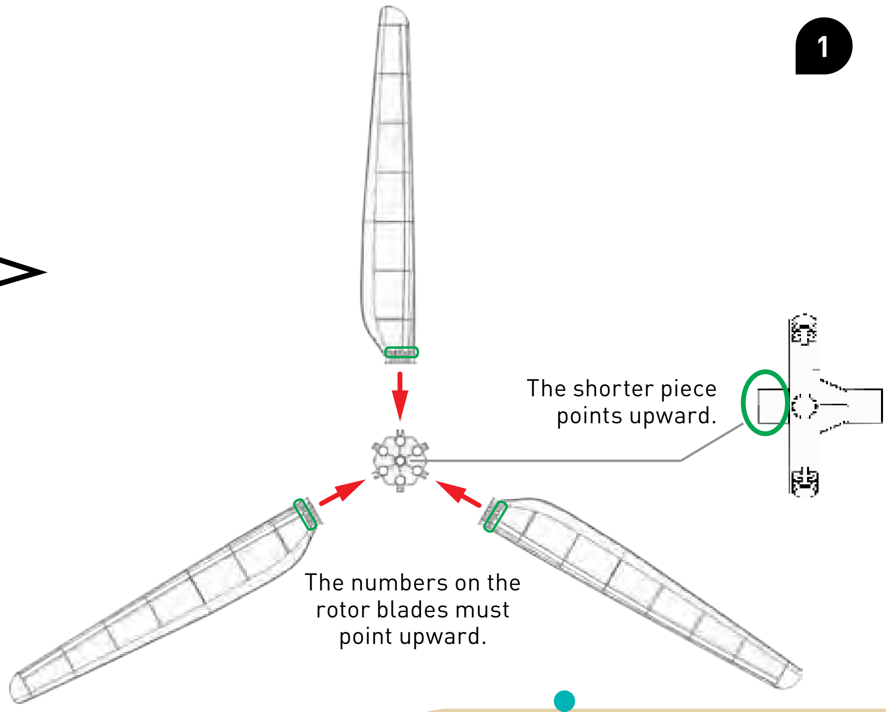

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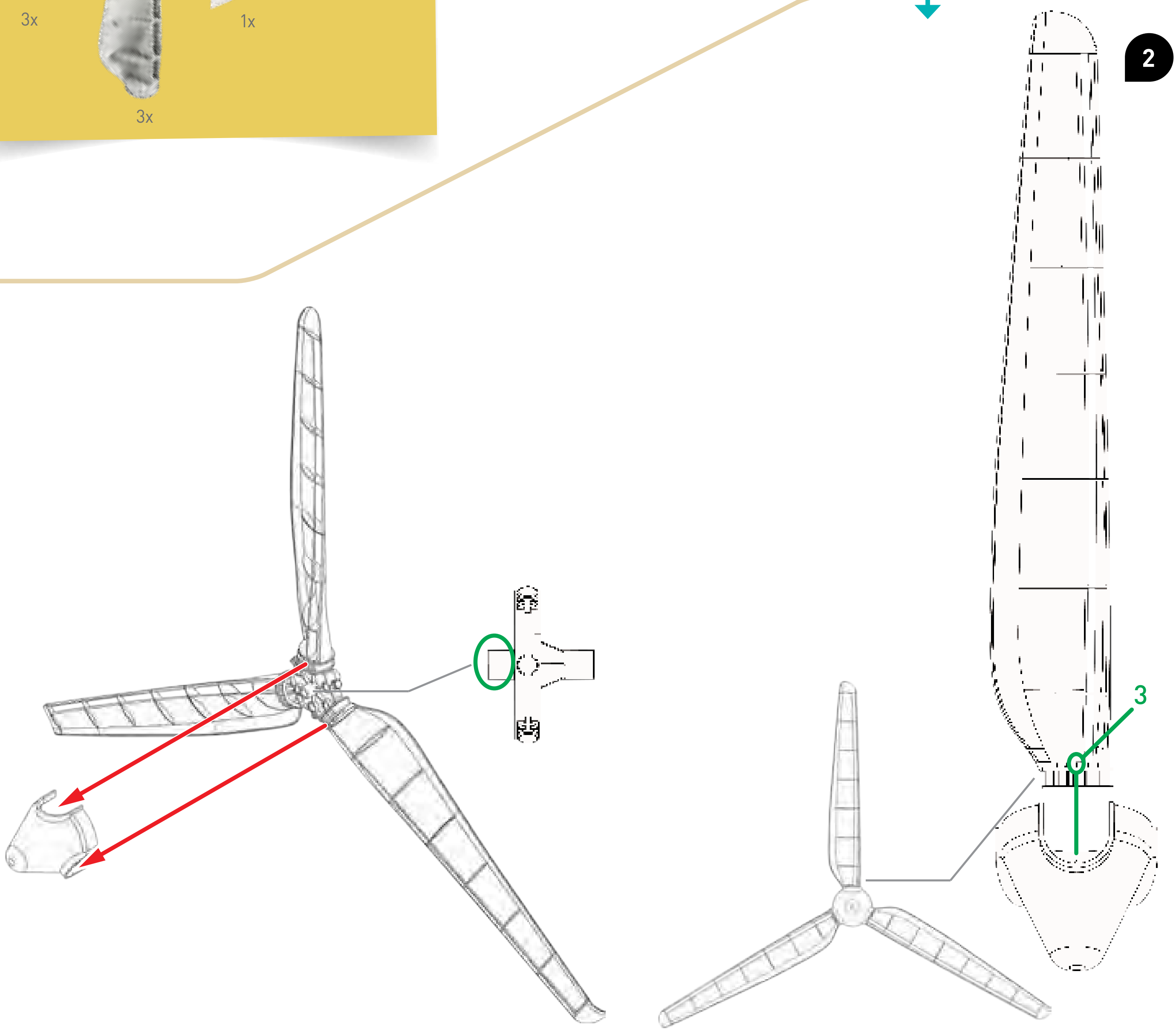

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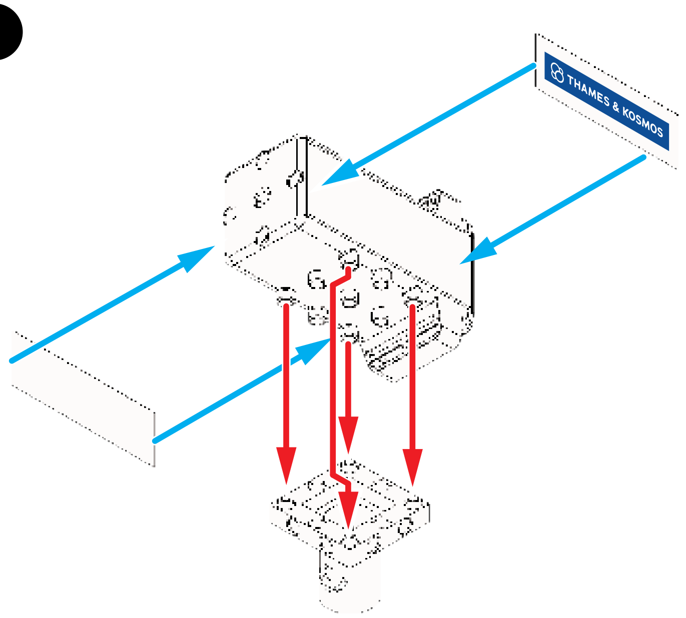

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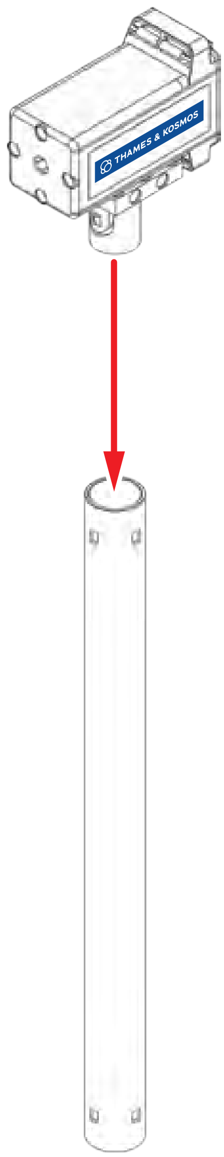

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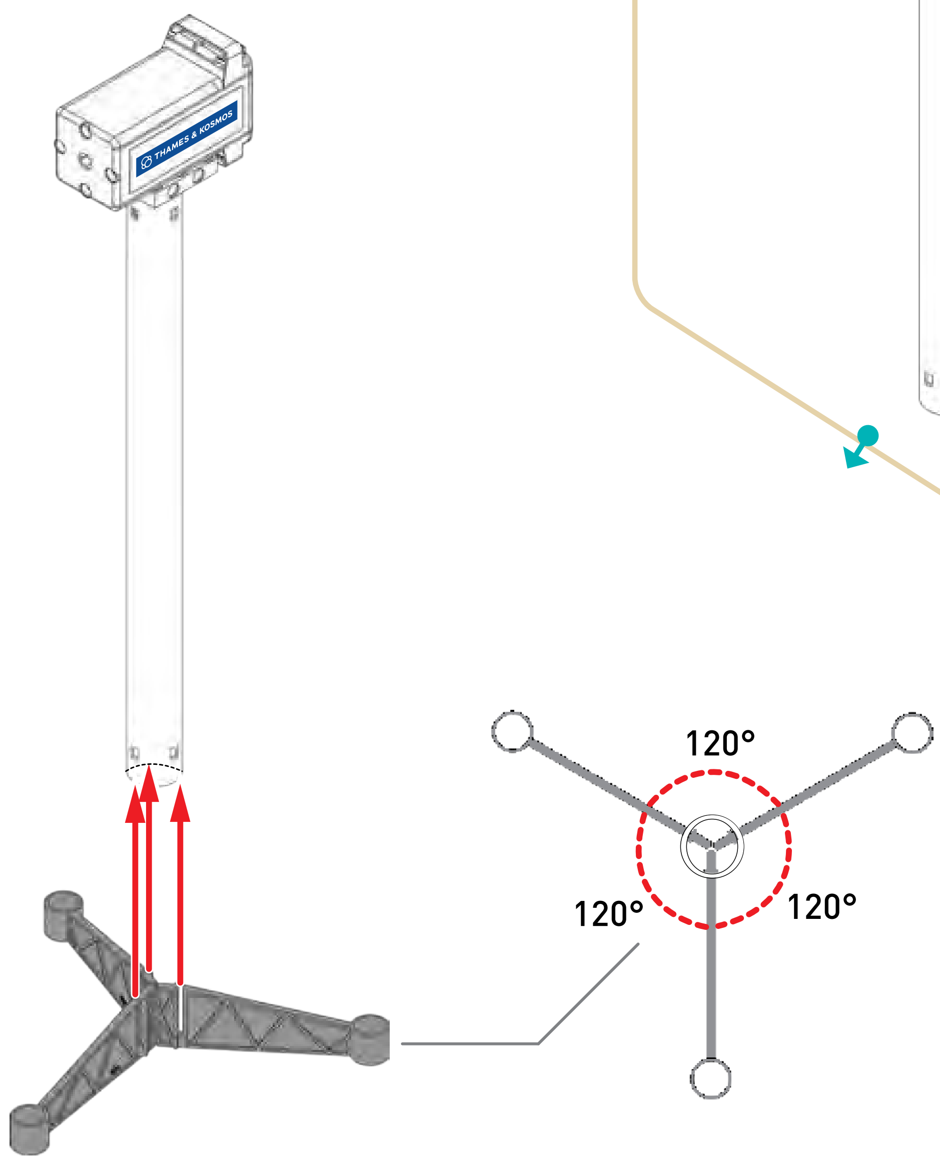

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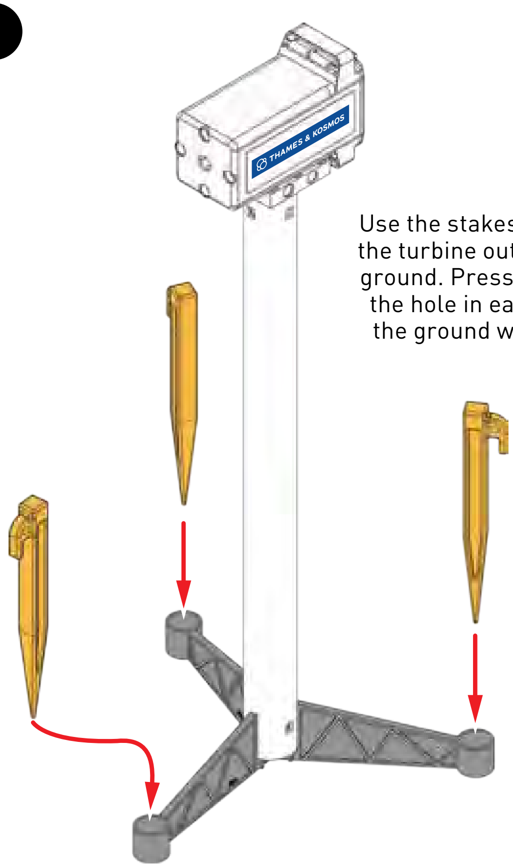
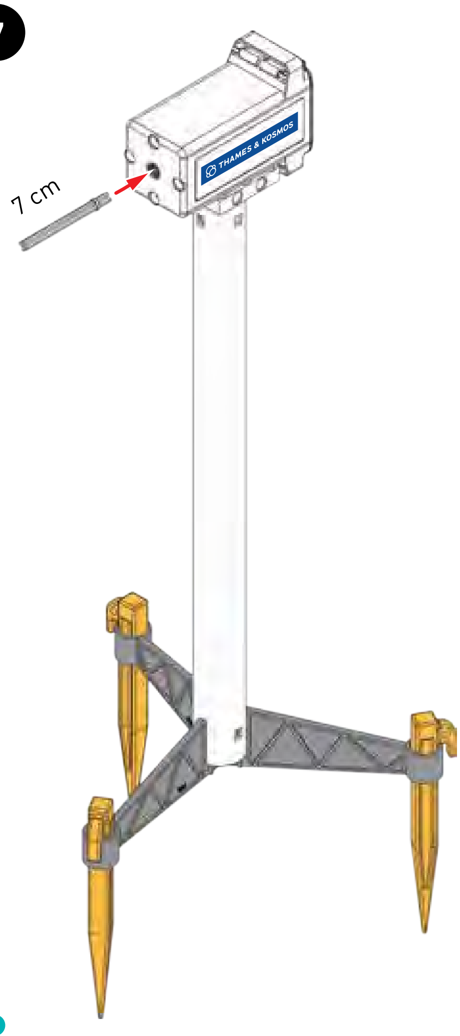


Use the stakes when installing the turbine outside on unpaved ground. Press a stake through the hole in each foot and into the ground with some force.

7



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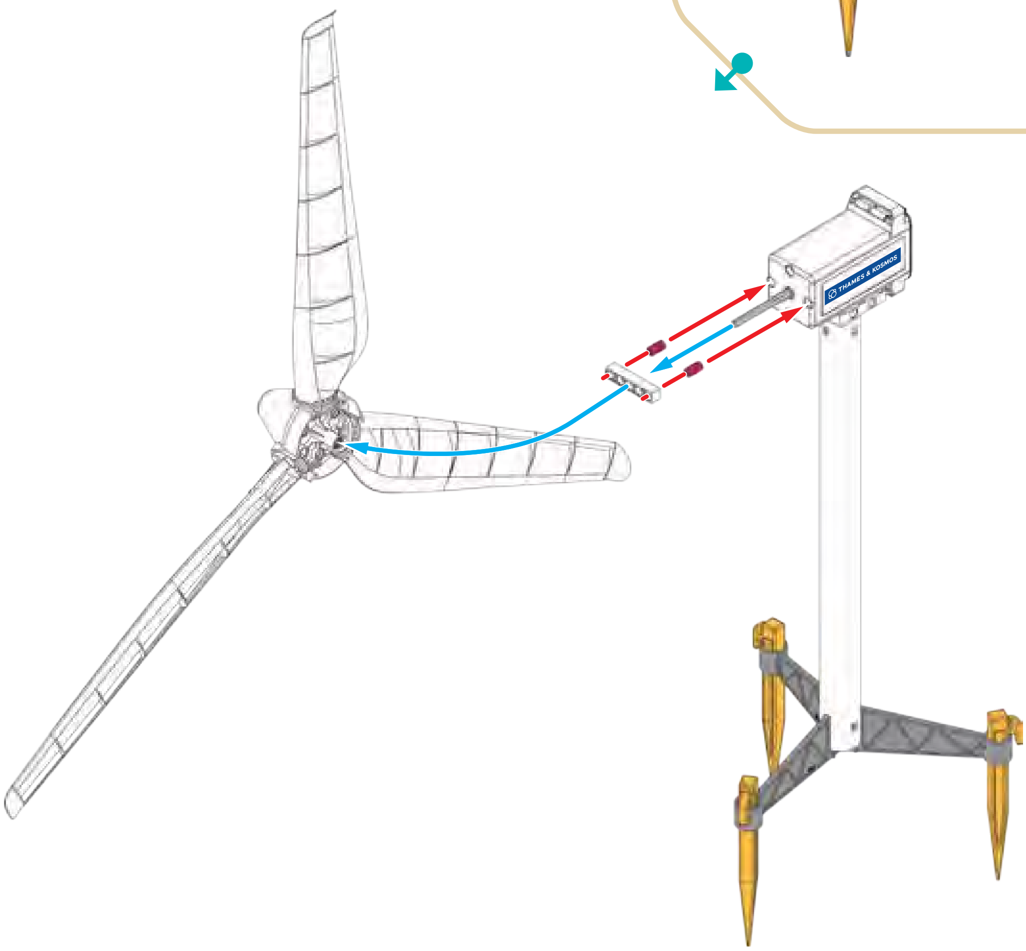

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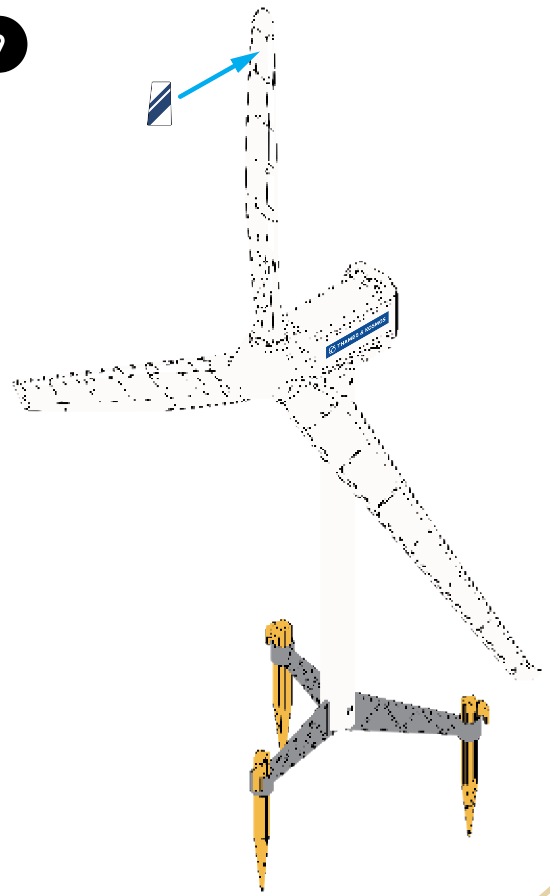

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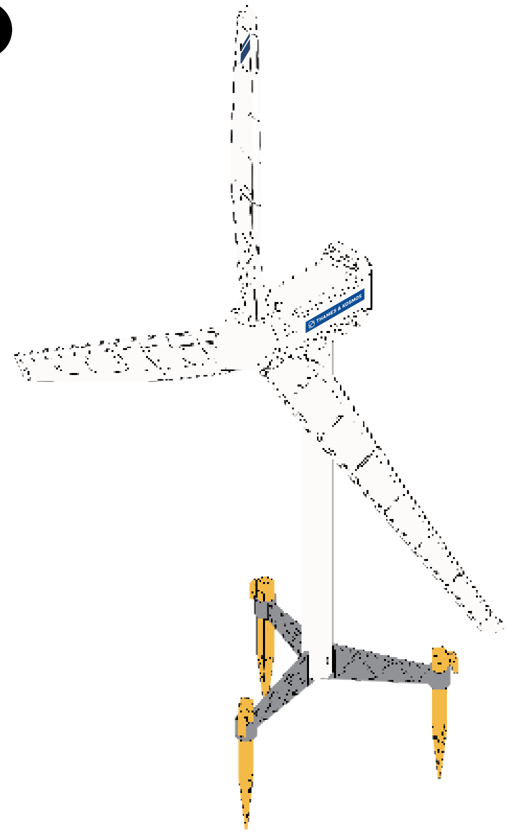
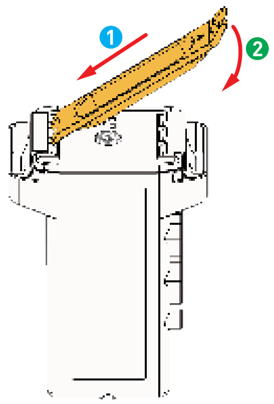
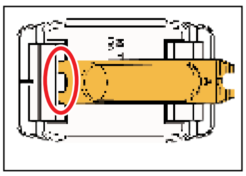
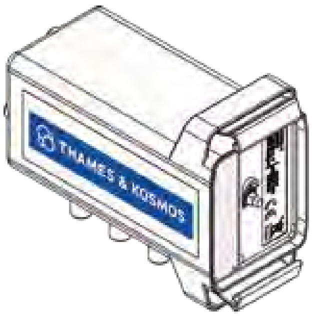
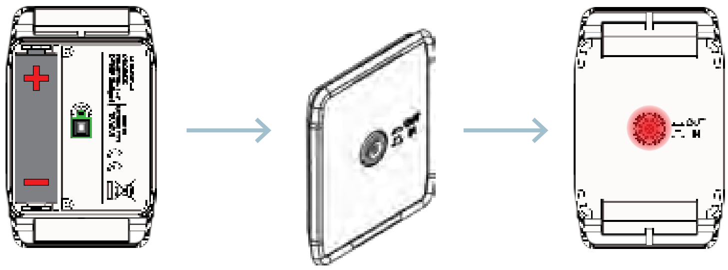






1. Insert side B of the tool under the clasp.
2. Pry the clasp open by pushing down on side A of the tool.





Open the battery compartment using side B of the anchor pin lever to release both of the clasps and removing the cover. Now insert one AA rechargeable battery (1.2-volt, type HR6) and close the battery compartment again. Keep the battery inserted during use.

WARNING! Never use a non-rechargeable AA battery in the battery compartment. Since a normal battery cannot be charged, there is a risk of overheating and explosion.

1. Press the button to alternate between the IN and OUT modes. When the button is set to IN, your turbine is in charging mode, used for storing electricity in the battery. When the button is set to OUT, that stored energy can be used; your generator becomes an electric motor powered by the energy stored in the battery.
2. In charging mode, an LED in the button turns red when the wind turbine turns counterclockwise, indicating that the battery is being charged.
3. To prevent damage to your turbine, do not switch it to output mode while it is being powered (rotated) by the wind.

EXPERIMENT 1

First test

You will need

- **Assembled wind turbine**
- **3 stakes**
- *AA rechargeable battery (1.2-volt, type HR6)*

Here's how

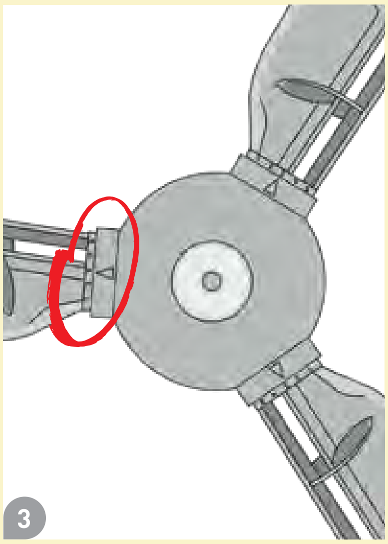
1. You can experiment with your wind turbine either indoors or outdoors. For setting it up inside, you will need an artificial wind force — for example, from an electric fan or hairdryer — of at least 2 on the Beaufort scale (see page 12). In addition, to prevent damage to your turbine, the wind must not be stronger than 4 on the scale.

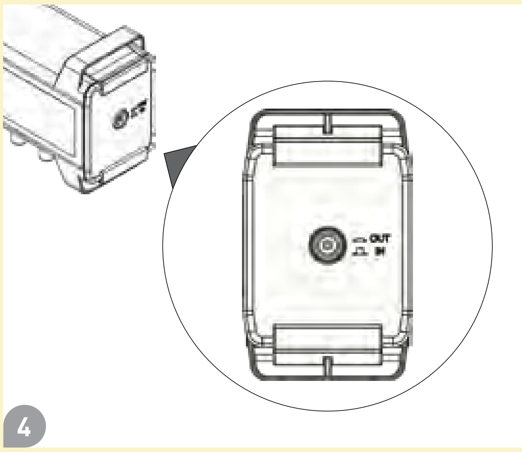
2. If you want to set up the turbine outside — for example, in your yard — you will need the three stakes included in the kit to anchor it in the ground. To do this, press the stakes with some force through the holes of the feet and into the ground. Now it should be secure and stable enough.

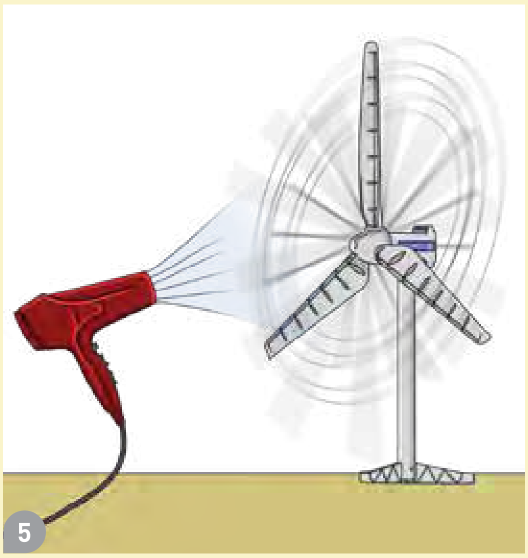
3. Set all three rotor blades so the arrows on the nose cone point to 3.

4. Insert a rechargeable battery into the compartment in the housing. Set the switch on the backside of the housing to IN. The electricity generated will now flow into the battery and will be stored there. If the switch is set to OUT, then you can use the generator as a motor, which is powered by the energy stored in the battery.

5. If you want to test your wind turbine indoors, or if there is not enough wind blowing outdoors, you can use a fan or hairdryer to create some wind. Use the cold-air setting on the hairdryer. If the hairdryer doesn't have a cold-air setting, make sure your turbine doesn't heat up too much.







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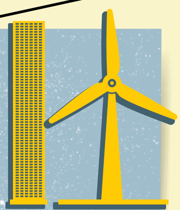


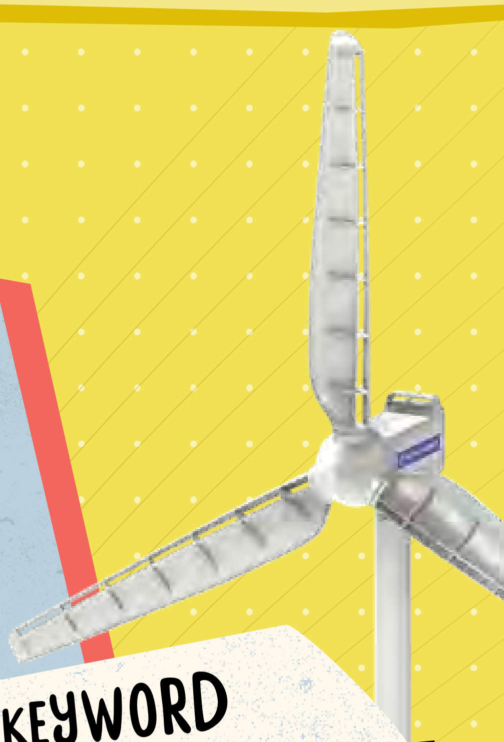
HEIGHT!

One of the tallest wind turbines in the world today is in Germany. It has a total height — the length from the foundation up to the top of a blade pointed straight up — of 264.5 meter (867 feet). This is as tall as a 90-story building. The tower alone is 178 meters (583 feet) tall. Taller wind turbines are being built each year. The taller the turbine, the more efficient it is.

WARNING! In this experiment kit, always use a rechargeable AA battery (1.2-volt, type HR6)!

CAUTION! Do not put your hands, or any other body part, in the way of the moving rotor blades.

CHECK IT OUT

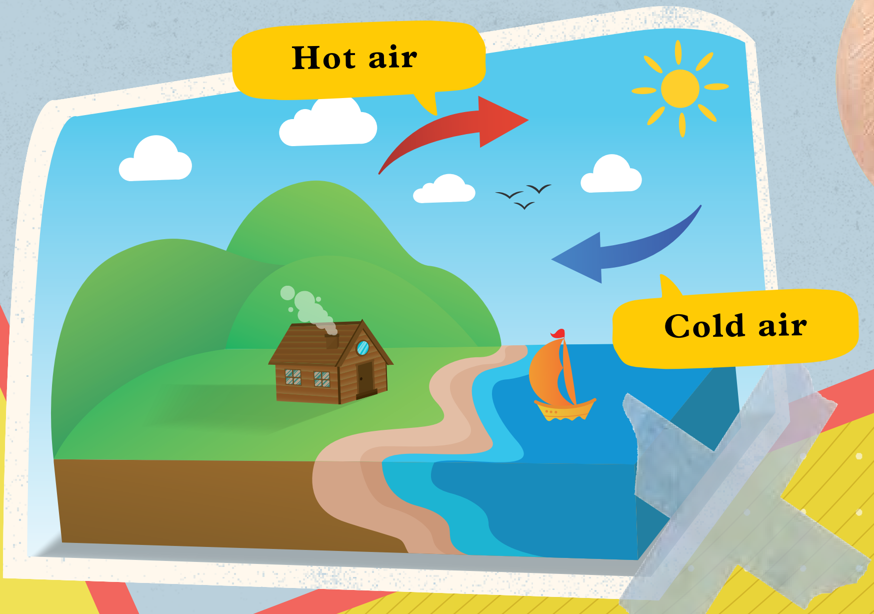


What Is Wind?

We have now explained how to assemble the wind turbine in detail and also how to test it on your own. But what exactly is wind, and how can it best be described?

WIND FORMATION

Our planet is protected by a layer of gases called the atmosphere, which blocks cosmic radiation and provides us with air for breathing. Wind is air that is moving predominantly in a particular direction. But how exactly does this air start moving? The engine that drives the wind is the sun. As the sun beams its rays on Earth, the air on Earth heats up and rises upward because of its lower density. Since the rising warm air has now left an empty space, cold air moves in to fill it up. We experience this air movement as wind.



KEYWORD

Density

Density is mass per volume. In other words, it describes how heavy something is with respect to its size. Suppose you have two balls of the same size. One of them is completely made of wood and the other is made of lead. Which ball has the greater density?

The lead ball is more dense. Both of the balls have the same volume, but the lead ball has a greater mass.

MEASURING WIND SPEED

When operating wind turbines, as well as in our everyday lives, it can be important to be able to measure and communicate how strongly the wind is blowing. To make sure that this information is standardized and comprehensible to everyone, agencies like the weather service use the Beaufort scale.

The Beaufort Scale

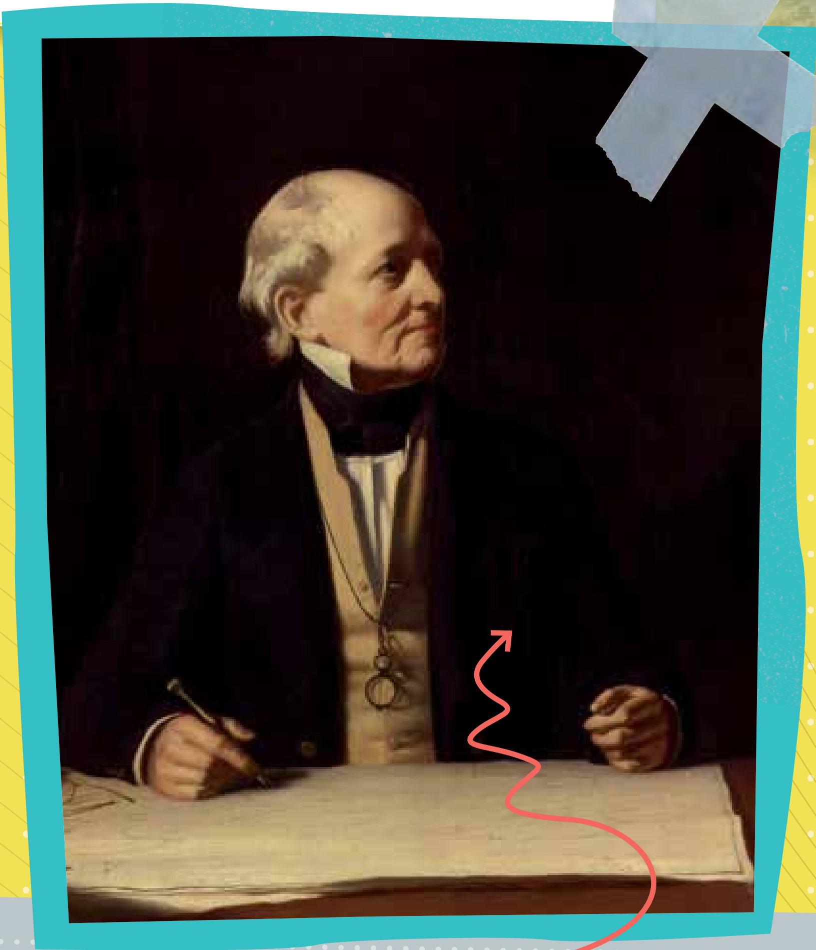
Wind force according to Beaufort scale	Wind speed km/h	m/s	Description	Effects on the land
0	< 1	< 0.3	Calm, still air	No air movement. Smoke rises vertically.
1	1 – 5	0.3 – 1.6	Light air, gentle draft	Smoke drifts slightly to the side, but pinwheels and wind vanes do not move.
2	6 – 11	1.6 – 3.4	Light breeze	Rising smoke clearly shows the wind direction. Leaves rustle and you can feel the wind in your face.
3	12 – 19	3.4 – 5.5	Gentle breeze	Pennants, leaves, and thin twigs move gently.
4	20 – 28	5.5 – 8.0	Moderate breeze	Branches move. Loose paper is swept around on the ground.
5	29 – 38	8.0 – 10.8	Fresh breeze	Large branches and small trees sway in the wind. The wind is clearly audible.
6	39 – 49	10.8 – 13.9	Strong breeze	Thick branches move. It becomes difficult to properly hold umbrellas.
7	50 – 61	13.9 – 17.2	High wind, moderate gale	Trees sway and you can feel resistance when walking into the wind.
8	62 – 74	17.2 – 20.8	Gale, gusty wind	Leaves and twigs are torn from trees. Even large trees can be moved around.
9	75 – 88	20.8 – 24.5	Strong/severe gale	Branches break. Bricks and chimneys can be damaged by the wind.
10	89 – 102	24.5 – 28.5	Storm, whole gale	Trees break or are even uprooted. Garden furniture is blown away and there is heavy damage to houses.
11	103 – 117	28.5 – 32.7	Violent storm	Severe damage to forests (wind breakage), roofs are torn off, vehicles are thrown out of their lanes, and thick walls are damaged.
12	> 117	> 32.7	Hurricane	Most severe storm damage and destruction, especially near the ocean.

Wind speed calculation

When you know the force of the wind according to the Beaufort scale, you can determine the wind speed with the following formula:

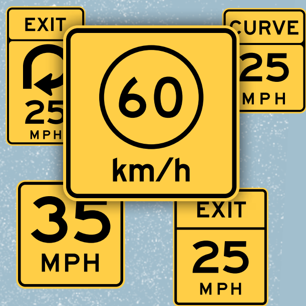
$$\mathbf{v} = 0.836 \times \mathbf{B}^{3/2}$$

Here **v** stands for the wind speed. For **B,** you must use the corresponding value from the Beaufort scale, which is a number between 0 and 12.



The Beaufort scale, which ranges from 0 (still air) to 12 (hurricane), was developed circa 1805 and is named after the Irishman Sir Francis Beaufort. Since the scale is named after Beaufort, it is assumed that he invented it, but that isn't the case. Beaufort was a hydrographer in the British Navy, where he standardized and spread the scale, but many others contributed to the development and usage of various scales which lead to what we now know as the Beaufort scale.

KEYWORD



SPEED!

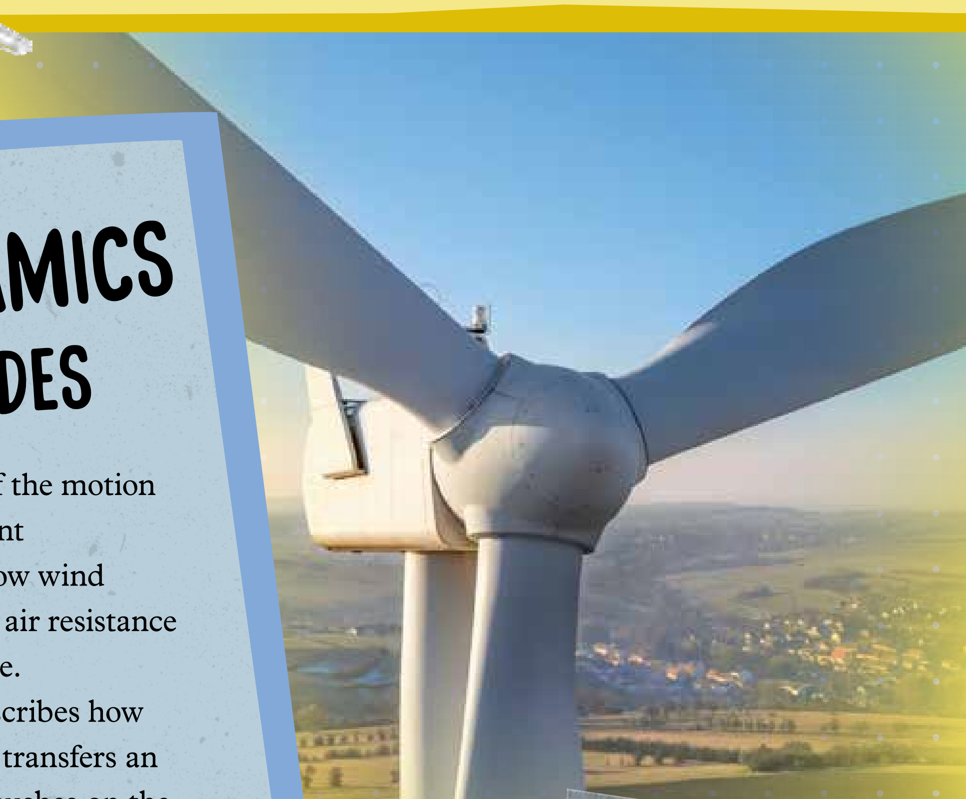
An object's speed is its distance traveled per unit of time. Speed is often specified in m/s (meters per second), in km/h (kilometers per hour), or in mph (miles per hour). 1 m/s corresponds to 3.6 km/h and 2.24 mph. When an anemometer measures wind speed, it is actually measuring the speed of the gas molecules in the air hitting it.

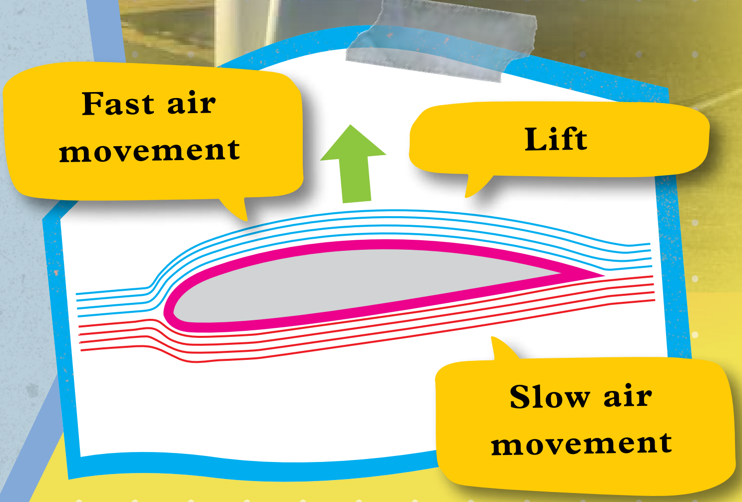
THE AERODYNAMICS OF ROTOR BLADES

Aerodynamics is the scientific study of the motion of air. In general, there are two different aerodynamic principles that explain how wind turbines are powered by the wind: the air resistance (or drag) principle and the lift principle.

The air resistance principle describes how when the wind hits the rotor blades, it transfers an impact force. The wind basically just pushes on the blade to turn it. In this very direct type of power generation, the efficiency is very poor. So this technology — which was used in most traditional windmills for centuries — today has been almost completely replaced by turbines that work according to the lift principle.

The shape of the rotor blades on this newer type of turbine is similar to that of an airplane's wing. Because of the special cross-sectional shape of the blade (and an airplane wing), which is longer on one side than the other, wind takes longer to flow past the blade on one side than on the other. This means that there are more air molecules on the shorter side, where the air flow is slower. Thus, the air density and the air pressure are higher on this side and lower on the side with the faster moving air. This pressure differential results in a lift force that pushes on the blade from the high pressure side to the low pressure side, which causes the blades to move and turn around the axis.

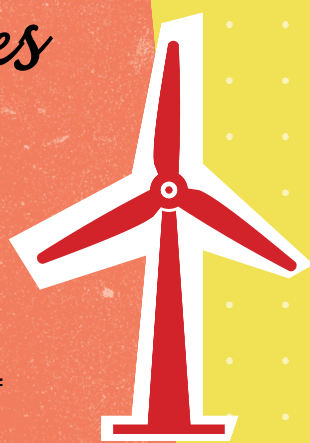




KEYWORD

Rotor blades

Have you ever noticed that most wind turbines have exactly three rotor blades? This is because a three-bladed design results in the greatest efficiency and operates very quietly. When there are more than three blades, the air turbulence generated by the movement of one rotor blade has a negative effect on the movement of the following rotor blade, resulting in less efficient operation.

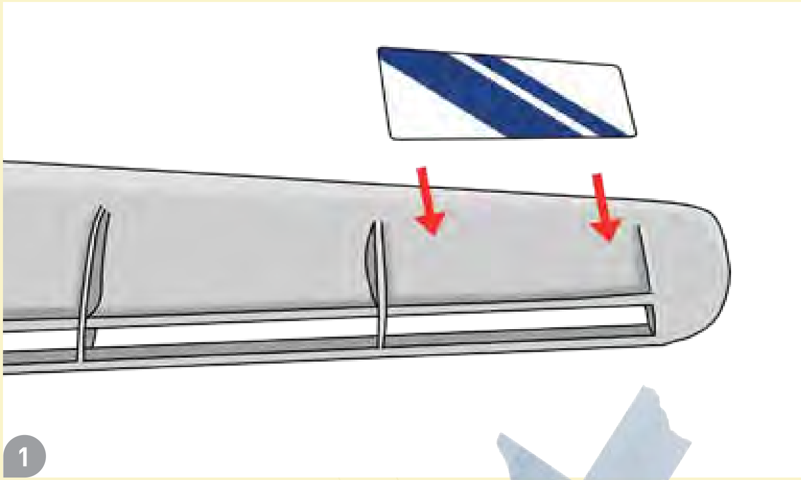


EXPERIMENT 2

Optimizing the rotor blade angle

You will need

- **Completely assembled wind turbine**
- **Sticker for the rotor blade**
- *Fan or hairdryer*
- *Stopwatch*
- *Pen and paper*
- *AA rechargeable battery (1.2-volt, type HR6)*



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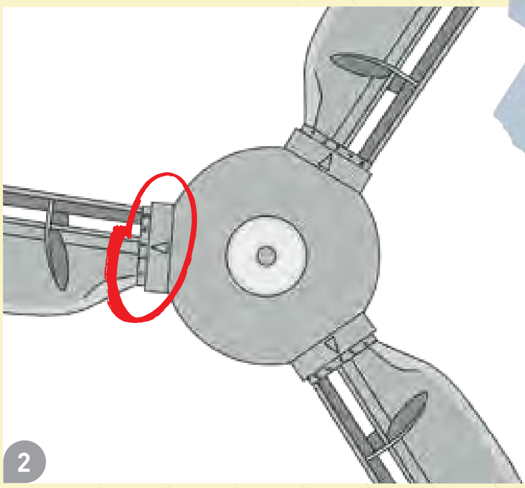


2

Here's how

1. Position the fan or hairdryer at a fixed place in front of your wind turbine. Now adjust the speed of the fan and watch the rotor blades. Do they move at different speeds? If you mark one of the rotor blades with the sticker, you can count the rotations per minute more easily by watching how many times the marked blade passes a certain position in its rotation.
2. Now keep the fan at a fixed speed setting and change the angular positions of the turbine's rotor blades. Start by setting the three blades to the lowest setting (1) and test the turbine. Count the rotations per minute and record the number in the table below.
3. Test each different angle setting by increasing the angle setting by one increment each time. Always make sure that you adjust all three rotor blades to the same setting. Record the number of rotations per minute for each respective angle setting in the table. Can you determine the setting at which the turbine spins the fastest?
4. Now experiment and see what happens if the angle settings of the rotor blades are not all set to the same number.

WHAT'S HAPPENING?

The number of rotations per minute is an indicator of the performance of your wind turbine. The faster the rotor blades are spinning, the more electricity is produced by the electric generator inside the turbine (to a point). Every turbine has a unique optimal setting depending on the shape of the rotor blades. To keep the speed of the rotor constant despite varying wind speeds, the rotor blades of large wind turbines are twisted along the length of the blade.

ANGULAR POSITION	ROTATIONS PER MINUTE
1	
2	
3	
4	
5	

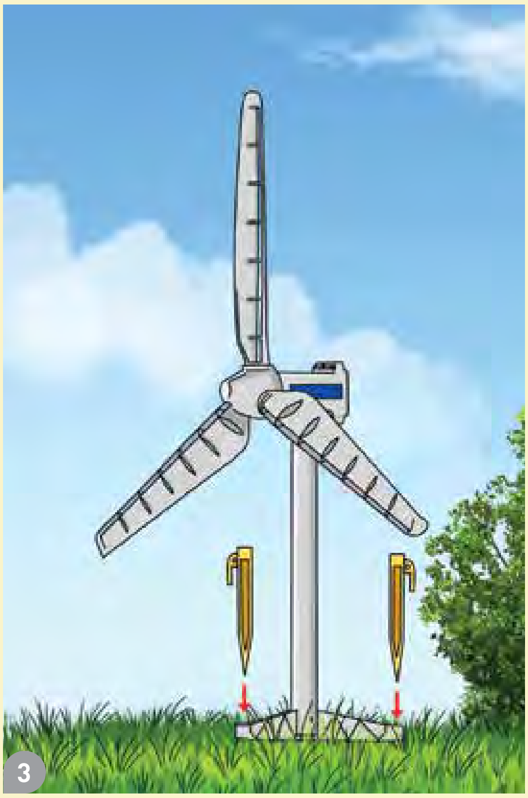
Finding the best location

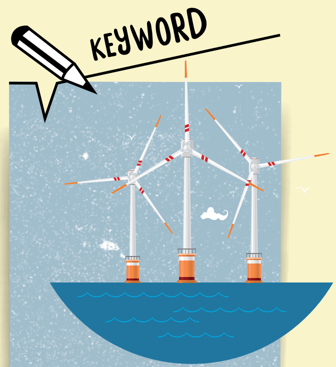
You will need

- **Assembled wind turbine**
- **3 stakes**
- *AA rechargeable battery (1.2-volt, type HR6)*

Here's how

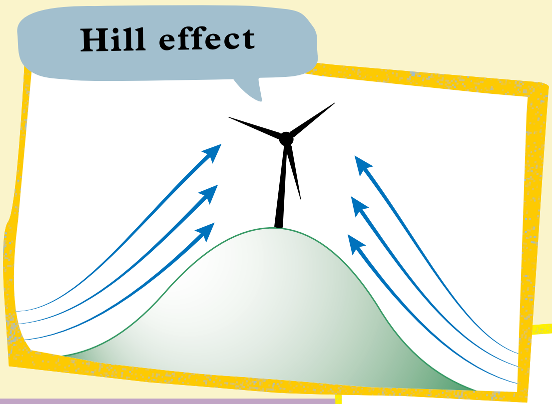
1. Now that you are somewhat familiar with your wind turbine, you can do some initial experiments outside. Before attempting this, take a look out your window and at the weather forecast. Make sure the wind is not blowing too strongly or too weakly. The ideal conditions would be a light breeze on the Beaufort scale (see page 12).
2. Consider potential locations for your wind turbine. How about the highest point in your yard, a narrow alley between houses, or on a hilltop in a park? Would it make sense to install it in a forest?
3. With adult supervision, choose a location and install your wind turbine. Anchor it with the stakes firmly in the ground so that it does not get blown over.

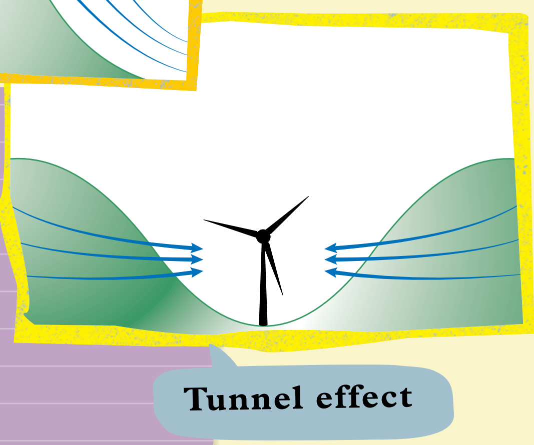




OFFSHORE!

Offshore wind turbines (turbines that are situated at some distance from the shoreline) are particularly efficient, as the strongest and steadiest winds are found near the coast where the open ocean allows wind to blow without any obstacles.





WHAT'S HAPPENING?

When the wind reaches a hill, it cannot go through it; it has to go over it. And so the wind gets accelerated. This is perfect for your wind turbine. The same thing happens between two obstacles, like the parallel outer walls of two houses. In a "wind tunnel" like this, the wind is accelerated. If, for example, the general wind speed is about 6 m/s, then with clever placement in an alley or on a hilltop, a speed of 9 m/s could be obtained. It is worth thinking carefully in advance about which location in your area will be the best location for your turbine. And if you are not sure which spot would work best, you can do some trial runs in different locations. The results of these trials will help you decide where to set it up more permanently.

EXPERIMENT 4

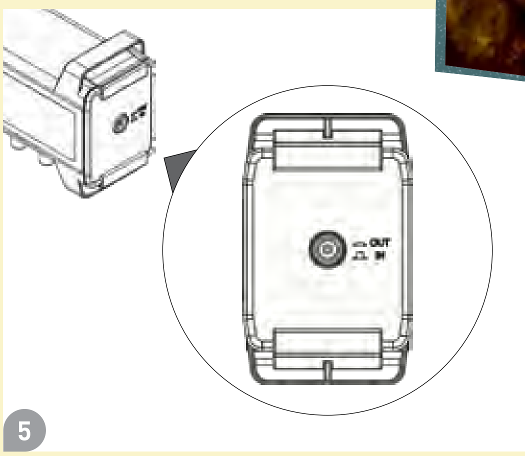
Wind prediction

You will need

- **Your wind turbine installed outside**
- **Beaufort scale (page 12)**
- *Smart phone or tablet with internet access*
- *Compass*
- *AA rechargeable battery (1.2-volt, type HR6)*

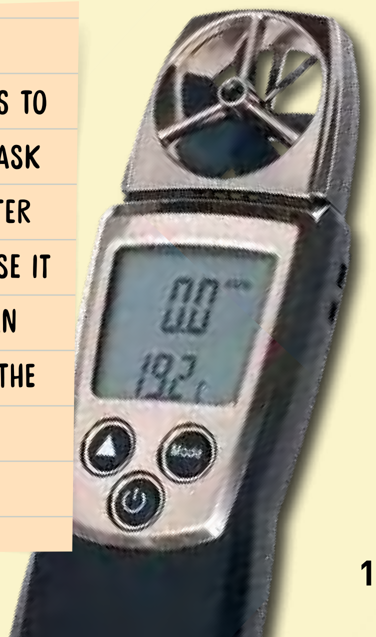
Here's how

1. To run your wind power plant in the best possible way, it is helpful to do a little research about your area's wind speed and the wind direction. With supervision from an adult, you can use the internet to do this. There are web pages where you can find wind data from tens of thousands of weather stations around the world. Type search terms like "wind force" and "wind direction" and your location into a search engine to find them.
2. With the help of a compass, you can now position your wind turbine optimally for the prevailing wind direction in your area.
3. If there is no weather station near you, or if you don't have access to the internet, you can examine your environment first-hand by looking at clues in nature. By observing the motion of the trees and the grass, you can just as easily determine the wind direction.
4. To determine the wind force, you can use the Beaufort scale on page 12.
5. Once you have found the optimal location and conditions, you can now set up and leave your turbine to charge the rechargeable battery. Insert the rechargeable battery into the compartment in the housing and set the switch on the back of the housing to IN mode. The electricity generated by the turbine will now flow into the battery and charge it.



TIP

DO YOU KNOW SOMEONE WHO LIKES TO SAIL, BOAT, OR WINDSURF? IF SO, ASK THEM IF THEY HAVE AN ANEMOMETER AND IF THEY WILL ALLOW YOU TO USE IT FOR YOUR EXPERIMENTS. WITH AN ANEMOMETER, YOU CAN MEASURE THE WIND MORE PRECISELY.



Energy

How is electric current generated from the spinning movement of the turbine? What happens to the energy after it is produced in a wind turbine or in another power plant? Let's take a look at how the generated energy can be stored and transported until it reaches consumers like us.

CHECK IT OUT

Energy Production

The winds blowing around our planet can produce tremendous forces depending on their speeds. The energy that we can extract from the wind is actually the energy of gas molecules (the very small particles of air) in motion, known as kinetic energy. When a moving gas molecule hits the rotor blade of a wind turbine, the rotor blade starts to turn from the force of the impact. The kinetic energy is converted into rotational energy, also known as angular kinetic energy.

To convert the rotational energy into electrical energy, a generator is required. A generator is a machine that turns kinetic energy into electrical energy (electricity). The rotating wind turbine causes a magnet to rotate inside an electromagnetic coil — a coil of wire wound in a spiral. When a magnetic field moves near a coil, an electric voltage, and thus electric current, are produced in the coil. The faster the magnet turns, the more electric current (electricity) is produced.

KEYWORD

Energy!

At some point, you may have heard someone make a statement like "that's how energy is made." But as precise researchers, we must always bear in mind that, strictly speaking, energy can neither be created nor can it be destroyed. Energy can only be converted from one form of energy to another form of energy. This is an important law of physics, called the law of conservation of energy.

TRANSMISSIONS

The electric voltage obtained from the wind turbine at any one moment also depends greatly on how fast the wind turbine is turning at that moment. But you cannot just supply any voltage into a power grid, because it might get damaged. Rather, engineers must make sure that the voltages match. To do this, a mechanical transmission is installed between the rotor and the generator which regulates the number of rotations so that the electricity generated has the right voltage.

ENERGY TRANSPORT

Once the generated electricity is fed into the power grid, it still has a long way to go before it can be used by consumers at home. The power grid is somewhat similar in its hierarchical structure to our road networks, except that in the power grid, it is electricity that is being transported, rather than vehicles. In this way, imagine that there are large, well-developed highways, called supergrids, to which all of the large-scale power plants, like nuclear power plants and coal-fired power plants, are connected. These major lines transport electricity with a voltage of 220,000–380,000 volts (for comparison, mobile phones run on just 5 volts). These main lines go to regions and cities and then are split into lines that have lower and lower voltages (see the list below). Between these individual power sectors, the voltage must be transformed again and again. But why go to all this effort?

- SUPERGRID: 220,000-380,000V
- HIGH-VOLTAGE GRID: 110,000V
- MEDIUM-VOLTAGE POWER GRID: 1,000-50,000V
- LOW-VOLTAGE GRID: 120-240V (CONNECTIONS TO HOMES)

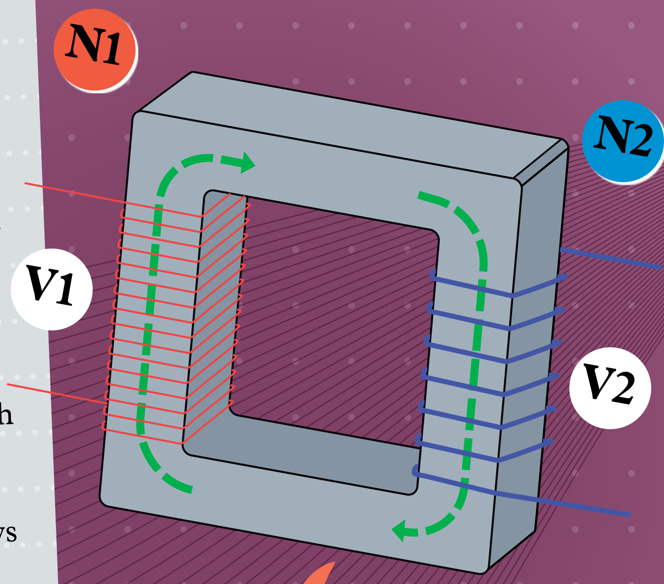
When electric current flows through a conductor, such as a metal wire, the conductor opposes, or pushes against, the electric current — somewhat like

the idea of friction between two objects. Then, the electricity slows down, electrical energy is lost, and the conductor heats up a little. This phenomenon is called electrical resistance, and is measured in ohms, named after the physicist Georg Simon Ohm. Obviously, the goal is to keep the loss of electrical energy to a minimum when electricity is transported. You may have already guessed: The best way to keep the electrical resistance low is to make the voltage as high as possible!
But how does such a transformer work exactly?

TRANSFORMERS

Generally speaking, a transformer consists of two coils, which are wires that are wound into spirals. The number of loops in a coil is referred to as the number of turns, denoted by the symbol N.

Refer to the diagram of a transformer to the right. If a voltage V1 is applied to one coil (red coil) with a specified number of turns N1, a magnetic field builds up in the coil. If this magnetic field (green arrows) flows through the core (gray square) to the second coil (blue coil), a voltage V2 can now also be tapped there. This process is called induction. Now, if the number of turns of the two coils differs from one another, the value of the two voltages will also differ. To achieve a desired voltage V2 in the second coil, you only have to adjust the number of turns N2 in the second coil.



Cool!

This is how a transformer works.

KEYWORD

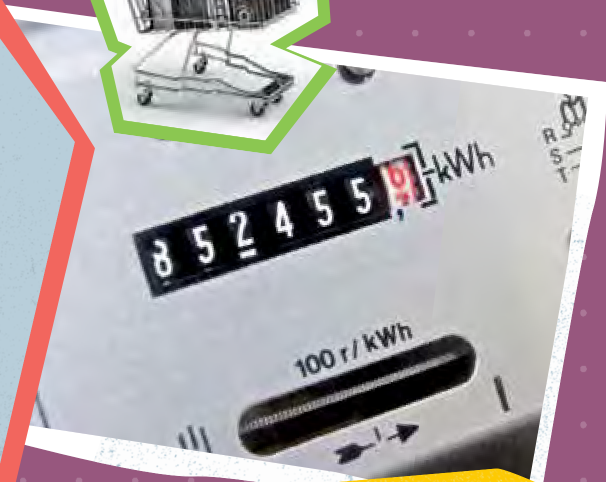
DC AC

Alternating voltage!

ALTERNATING CURRENT, AS OPPOSED TO DIRECT CURRENT, IS REQUIRED TO CREATE THE MAGNETIC FIELD IN A TRANSFORMER, MAKING IT POSSIBLE TO TRANSFORM (OR TO CONVERT) VOLTAGE IF ALTERNATING VOLTAGE IS PRESENT. THEREFORE, ALTERNATING VOLTAGE IS USED FOR POWER GRIDS WORLDWIDE.

CHECK IT OUT

ENERGY CONSUMPTION



To be able to use electricity from the socket in the wall, the voltage must be adapted to the input requirements of the respective device (for example, mobile phones typically need 5 V and laptops typically need 19 V). For this reason, there are transformers inside most power adapters, which are devices used to charge mobile phones, laptops, and so on.

CALCULATING ELECTRICITY CONSUMPTION

For vehicles, power is measured in horsepower (hp); for electricity, the unit used to measure power is the watt (W). 1000 watts corresponds to 1.34 hp. Since both of these units are measurements of power, they can be converted into each other. If you want to talk about the consumption or the amount of energy that was obtained over a period of time, then the unit used is the kilowatt hour (kW·h). 1000 watts are equal to 1 kilowatt; 1 kilowatt of power sustained for 1 hour is equal to 1 kW·h.

Here's an example: A family of four in a single-family house uses about 11,000 kW·h of electricity per year. If a solar panel with an area of 18 square feet generates 0.3 kW in strong sunlight, then it would need to operate for 36,667 hours to produce 11,000 kW·h of electricity for the family. There are maybe only 2,000 to 3,000 hours of sunlight per year, so you would need maybe 12 to 18 of these solar panels on the house.

KEYWORD

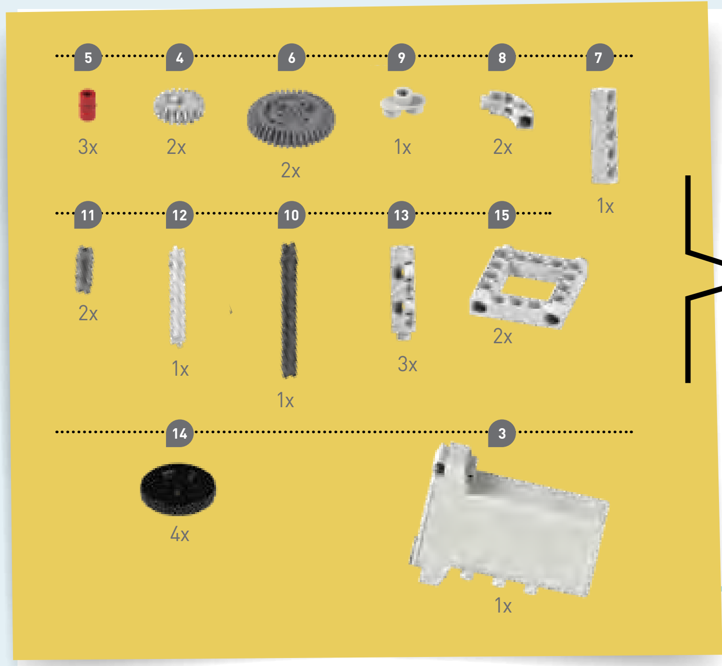
Sockets!

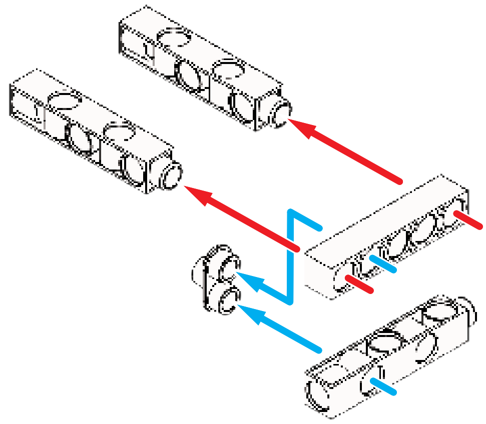
If you plug something into a wall socket in your home, then the socket delivers alternating current at 60Hz from the power grid (this means that the electricity changes direction 60 times a second) and 120 volts. This is uniform across the United States and Canada. In most of Europe, it is 50Hz and 230 volts. This differs around the world.

Electric Vehicles

If your wind turbine has been charging the rechargeable battery, you can remove the housing from the turbine and build an electric car, with the generator acting as its motor! You can find the assembly instructions on the next three pages, followed by additional information on electric vehicles, including their benefits and drawbacks.

ASSEMBLY OF THE CAR





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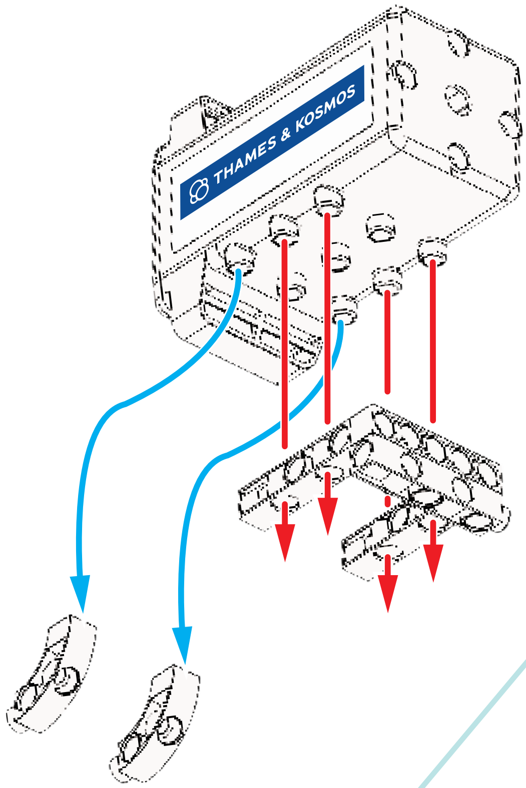

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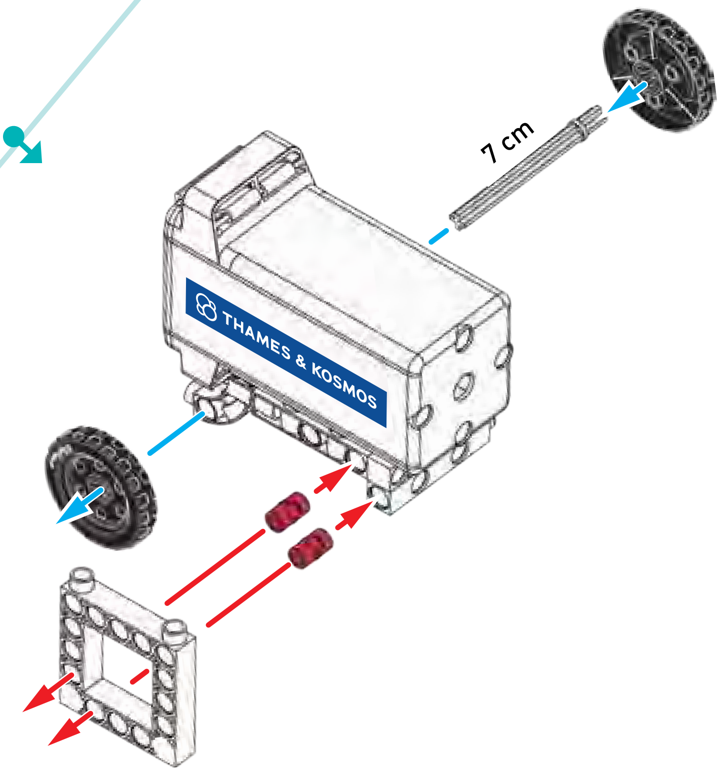

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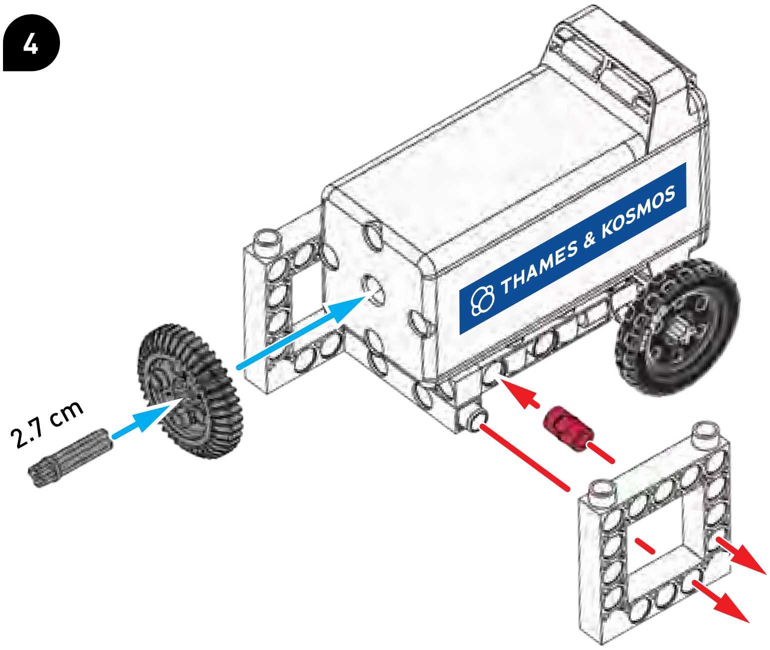

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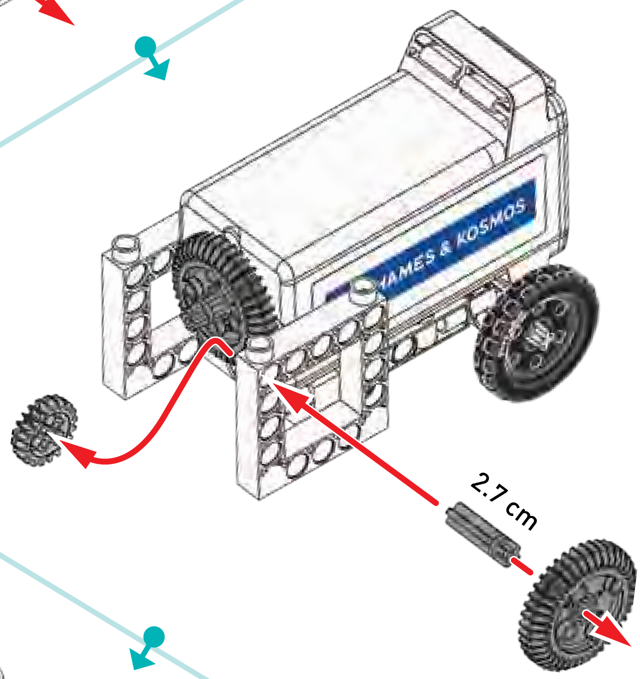

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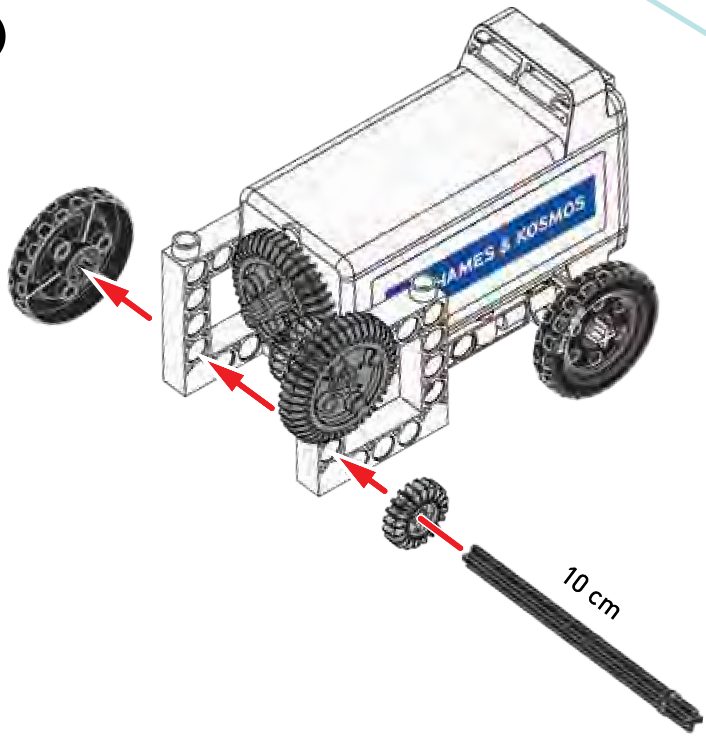

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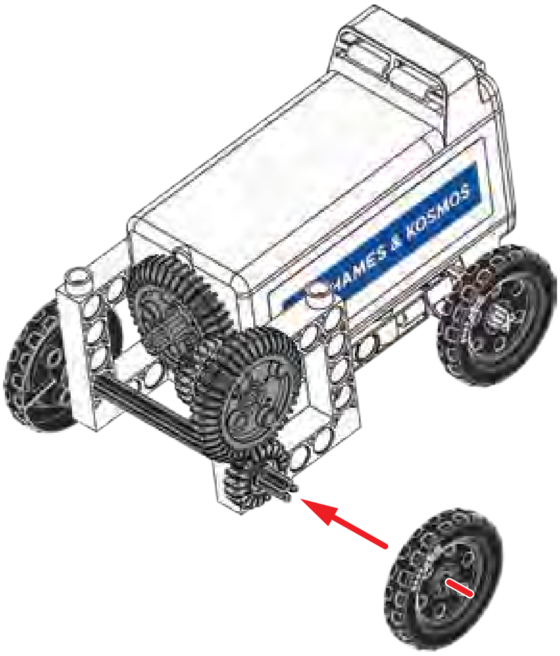
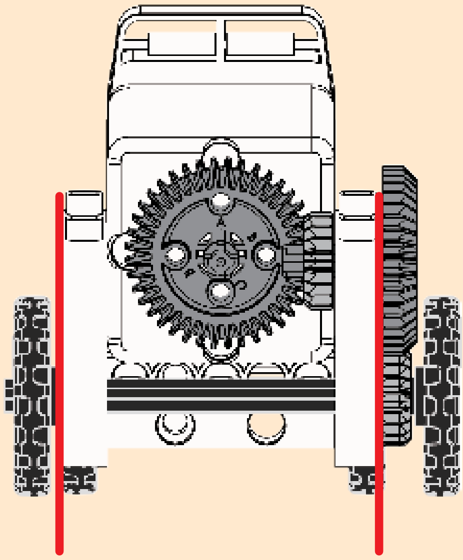
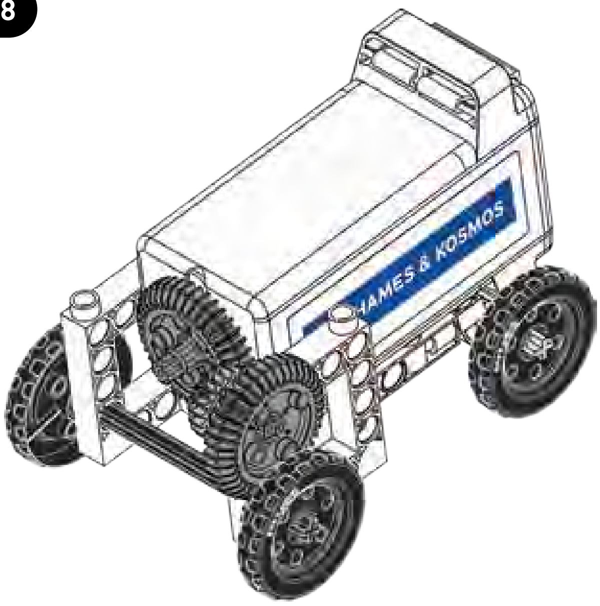
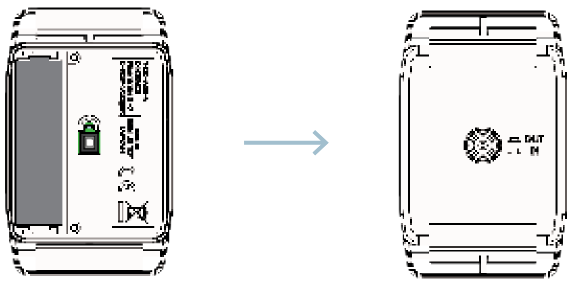




Do not push the gears or wheels too firmly against the frame. If you do, they won't be able to spin freely. The red line shows you where you have to leave about 1 mm of space between the wheels and frame.

8





Keep the battery inserted during assembly.

Press the button and switch the mode to OUT. Watch as the stored energy from the battery is used to turn the car's wheels.

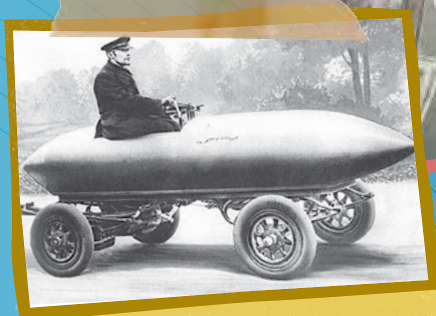
CHECK IT OUT

Electric vehicles offer us many advantages. We have high hopes that they will contribute to the clean energy transition. Here are a few advantages offered by electric vehicles:

- + They don't produce harmful exhaust gases.
- + They are much quieter and could be helpful in reducing noise pollution.
- + They are low-maintenance (since these cars don't have a combustion engine, there is no clutch and no transmission).
- + In theory, you can charge an electric car at home.

However, the development of electric vehicles has a long way to go. So here are a few of the drawbacks of electrical vehicles that are currently being researched and solved:

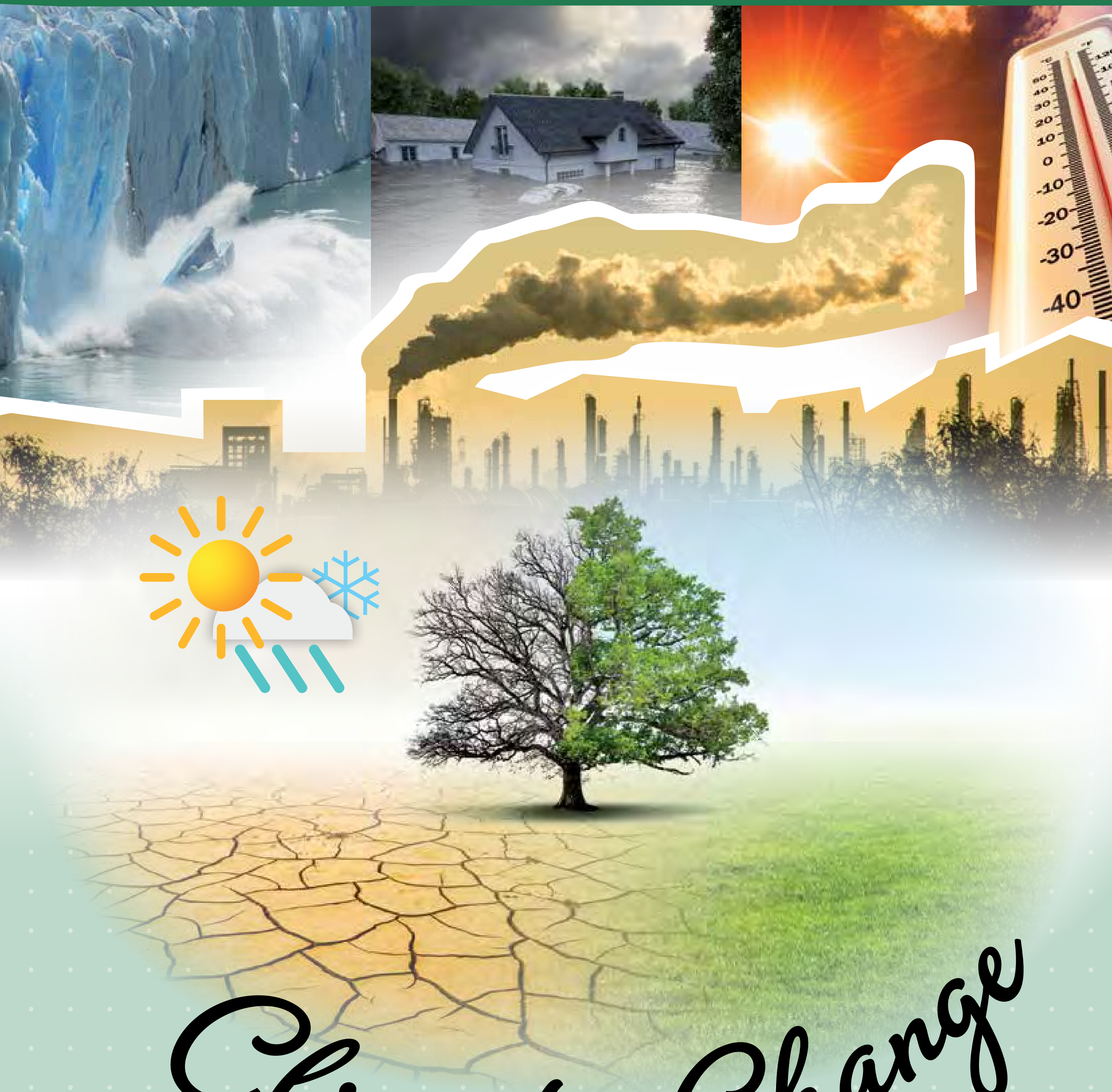
- – The purchase prices are too high.
- – It takes a long time to charge an electric car (mainly compared to filling a car with gasoline).
- – Adequate infrastructure with charging stations is still not available.
- – The mileage range is much lower compared to cars with combustion engines (that is, cars that run on gasoline or diesel fuel).



KEYWORD

Invention (of electric cars)

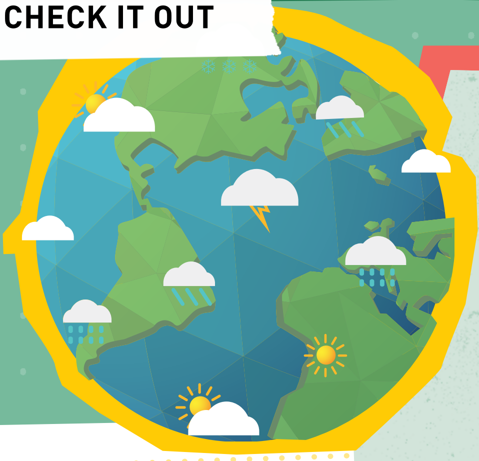
The first electrically powered cars were already available by the end of the 19th century, a time when cars were very new and rare. But the electric engine could not keep up with the performance of the combustion engine, which was developed in the 1920s, and the electric car was dismissed for many decades.



Climate Change

You have probably read the words "climate change" in newspaper or magazine articles. Maybe you have heard them on TV, in school, or in a discussion between adults. Today, "climate change" is an increasingly important term, but what does it mean?

CHECK IT OUT



What is climate change?

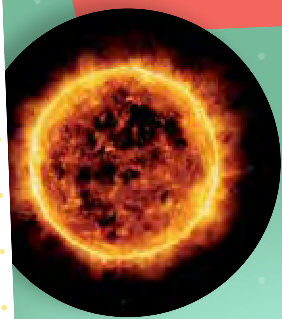
Climate is not the same as weather. Climate refers to the general weather conditions averaged out over a long period of at least 30 years, whereas weather describes the condition of the atmosphere at a specific time and place. Climate change refers to when the average weather changes considerably during this long time period, and it is something we are currently experiencing.

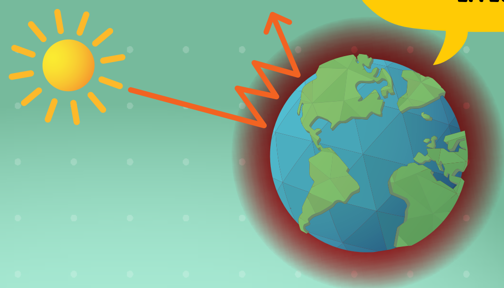
On one hand, there are many natural factors that are always present and very normal, like volcanic eruptions and ocean currents (see below). However, we have learned that we humans have a big impact on our climate and its evolution.

NATURAL FACTORS

The sun is Earth's largest source of energy. It keeps us warm with its rays and provides for a pleasant temperature in most parts of the planet. When you observe the sun more closely, you can see spots on its surface that are somewhat darker than the rest of the sun. These spots emit less energy. However, the number of sunspots is not always the same; it changes at regular intervals.

The fewer the spots on the sun, the greater its energy emission activity, and thus the greater the temperature on Earth at these times.



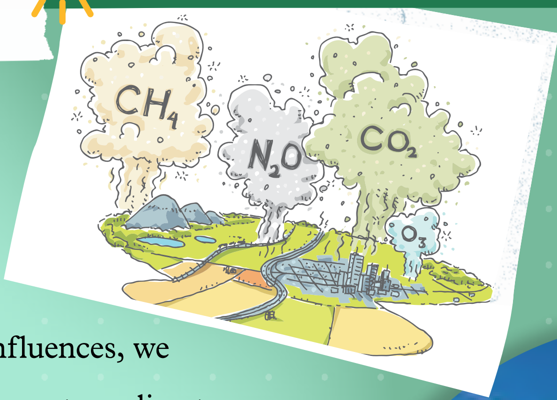


SIMPLE DIAGRAM OF THE GREENHOUSE EFFECT

In addition, there are greenhouse gases in our atmosphere like steam, carbon dioxide (CO_2), and methane (CH_4), that are released by natural processes happening on Earth (volcanic eruptions, evaporation, and so on). It is because of these gases that heat radiation cannot escape into space through the atmosphere; rather it gets absorbed by the atmosphere or reflected back to Earth, like a greenhouse traps in heat. The temperature on Earth increases due to this greenhouse effect as well.

CHECK IT OUT

Human Factors



In addition to these natural influences, we humans also have had a big impact on climate, particularly since industrialization. Our cars and factories release enormous quantities of CO_2 and CH_4, which amplify the greenhouse effect in the atmosphere.

There are many renewable energy sources for the future

Consequences of global warming

Global warming leads to extreme weather conditions such as severe storms and long heat waves. To slow down this change, there are global agreements in which countries have jointly agreed to reduce the emission of CO_2. In this context, so-called renewable energies are especially important. We will investigate different renewable energy options in more detail on the following pages.

ENERGY TRANSITION

In order to protect our atmosphere, it is important to obtain energy in the cleanest way possible. Power plants that run on fossil fuels (such as coal, crude oil, or natural gas) produce many waste gases (mainly CO_2) as by-products. Nuclear power plants leave behind harmful radioactive waste that will continue to exist for thousands of years. In addition, these raw materials are not endlessly available, as they will slowly be exhausted. That is why scientists have turned to sources of energy that are continuously available for the foreseeable future — in other words, renewable. These sources mainly include our sun, the wind, water, plants (biomass), and the heat from inside of the Earth (geothermal power). Replacing unclean sources of energy with renewable sources is known as energy transition.

Renewable Energies

WIND

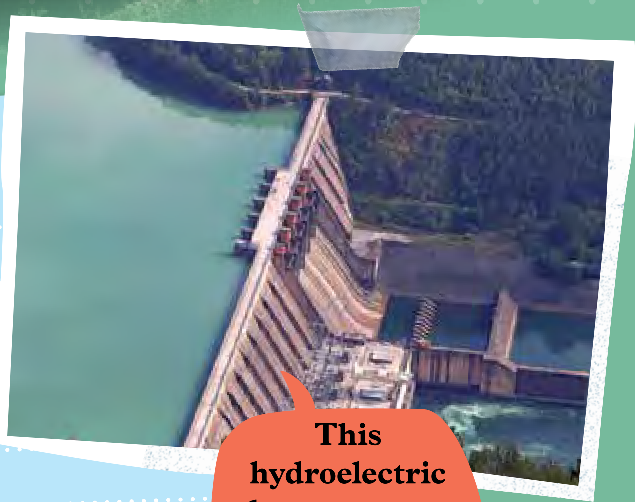
You have probably seen at least one of the hundreds of thousands of large wind turbines installed all around the world. They are hundreds of feet tall and easy to spot. As you have seen firsthand in this kit, the force of the wind can be converted into electrical energy using the generator in a wind turbine.

The Sun

The sun's rays can be converted to electrical energy with the help of solar cells. Solar panels are becoming increasingly common. Take a look around your neighborhood or city and you will probably spot solar panels on roofs or in fields nearby. With the right systems in place to efficiently store the generated energy, we could cover all our energy needs with solar energy. The sun supplies us with sufficiently abundant energy, but unfortunately only during the daylight hours.

WATER

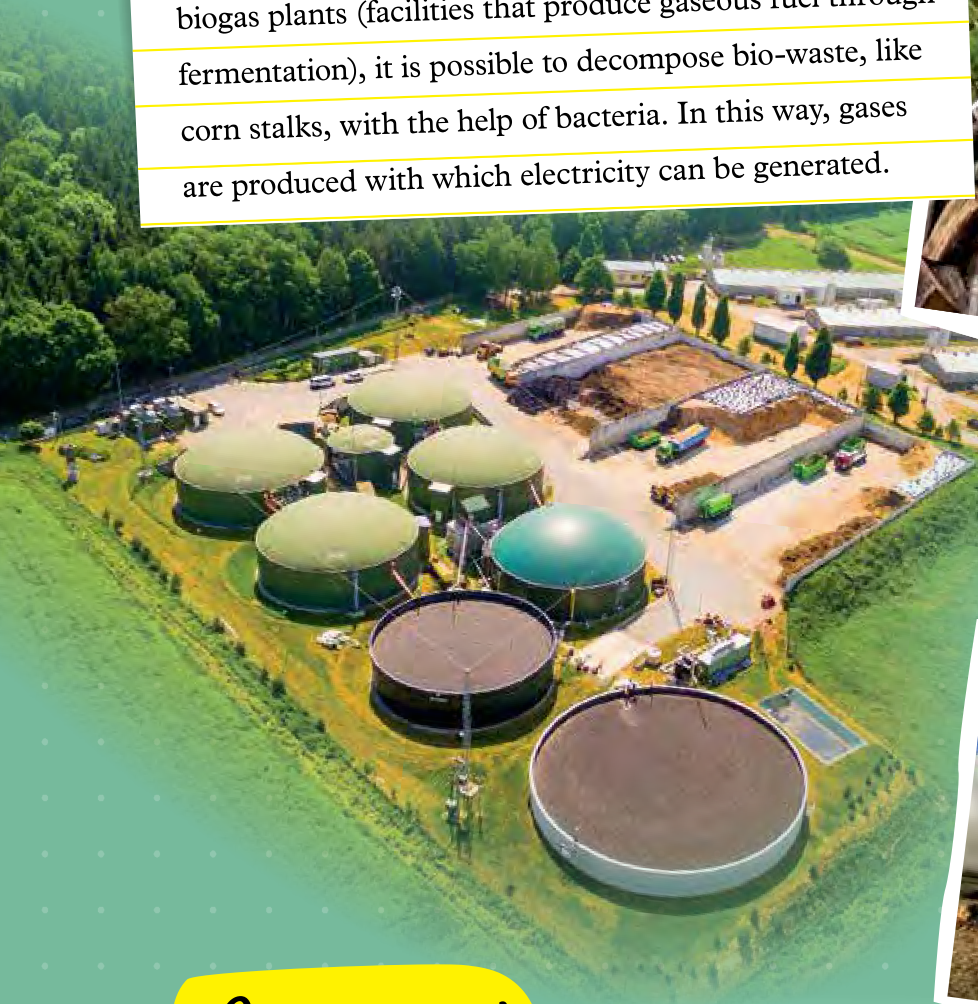
JUST AS A WIND TURBINE IS ROTATED BY MOVING AIR, A WATER TURBINE IS ROTATED BY MOVING WATER. GRAIN MILLS AND SAW MILLS WERE RUN ON THE POWER FROM WATERWHEELS FOR THOUSANDS OF YEARS. NOWADAYS, ELECTRICAL ENERGY IS PRODUCED BY WATER TURBINES THAT TURN AN ELECTRIC GENERATOR.



This hydroelectric dam generates electricity from flowing water.

BIOMASS

Lots of energy is released from burning biomass such as plants and wood. If new plants and trees are planted, the use of biomass can be sustainable. In addition, using biogas plants (facilities that produce gaseous fuel through fermentation), it is possible to decompose bio-waste, like corn stalks, with the help of bacteria. In this way, gases are produced with which electricity can be generated.



Hot stuff!
Heat from Earth's interior

Geothermal Energy

The interior of our Earth is very hot (approximately 5,000 °C). This tremendous heat means that a lot of energy exists down there. Geothermal energy means making this geothermal heat useful to people. To do this, very deep holes are dug in the ground and flooded with water. This water boils and rises up as steam and powers thermal power plants. Geothermal energy can also be used on a smaller scale in homes, with heating devices called heat pumps.

Conception and text: Anna Nolde
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Technical product development: Dr. Petra Müller; Genius Toys Taiwan Co., Ltd.

Manual design concept: Atelier Bea Klenk, Berlin
Manual layout: Oliver Gibler, Studio Gibler, Stuttgart
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