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FREE EBOOK

SCIENCE PROJECTS AND KITS

Renewable Energy Models

Solar, wind and water power models that really work

INSIDE THIS BOOK

- Energy and how it changes form
- How a solar cell works
- Testing a small solar panel
- A solar car
- A solar street light with an LDR
- ...and 6 more chapters, practice questions and a glossary

Beginner to intermediate
Students of class 5 to 12

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Renewable Energy Models

Build working models of solar, wind and water power with small panels, toy motors and safe low-voltage batteries. Learn how a solar cell works, test a panel with a multimeter, make a solar car, an automatic street light, a water heater, a wind turbine and a water wheel generator, and explain biogas, tides, geothermal energy and smart grids in a viva.

WHO IT IS FOR	Students of class 5 to 12
LEVEL	Beginner to intermediate
SUBJECT AREA	Science projects and kits
WHAT IS INSIDE	11 chapters, practice questions with answers, and a glossary

HOW TO USE IT

Read one chapter at a time and try the examples as you go: on a computer, at your workbench or in your notebook. The boxes give tips, safety points and short activities. When you finish, test yourself with the practice questions and check your answers at the end. Words you may not know are explained in the glossary.



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Energy and how it changes form

Energy is the ability to do work: to move something, heat it, light it up or make a sound. You cannot see energy itself, but you can always see what it does. A fan turns, a bulb glows, a pressure cooker whistles.

Forms of energy

Form of energy	Everyday example
Light energy	Sunlight, a glowing LED
Heat (thermal) energy	A hot tawa, warm water
Electrical energy	Current flowing in a wire to a fan
Kinetic energy (energy of movement)	A moving bicycle, wind, a flowing river
Potential energy (stored because of height)	Water held high behind a dam
Chemical energy	Food, a cell, wood, petrol, cow dung
Sound energy	A ringing temple bell

Energy changes form

Energy is never made from nothing and never destroyed. It only changes from one form to another. This is the **law of conservation of energy**. Every model in this book is a chain of such changes, and you should be able to say your model's chain in one breath.

Model	Energy chain
Solar car	Light → electrical → kinetic
Wind turbine	Kinetic (wind) → kinetic (blades) → electrical → light (LED)
Water wheel	Potential → kinetic → electrical
Solar water heater	Light → heat

Model	Energy chain
Biogas plant	Chemical (waste) → chemical (gas) → heat (when the gas burns)

In every change, some energy turns into heat or sound that we did not want. The share of energy that comes out in the form we want is called **efficiency**. Most solar panels turn less than a quarter of the sunlight that falls on them into electricity. The rest warms the panel.

Renewable and non-renewable

Non-renewable sources are used up faster than nature can replace them. Coal, petroleum and natural gas are called **fossil fuels**, because they formed over millions of years from buried plants and tiny sea creatures. Burning them releases carbon dioxide, a gas that traps heat around the Earth, and smoke that dirties the air.

Renewable sources are refilled by nature: sunlight, wind, flowing water, plant and animal waste (biomass), tides and the Earth's inner heat. Here is why they matter:

- They will not run out.
- They make little or no smoke while working.
- They can be produced locally. A village with solar panels needs no fuel trucks.

They also have a problem. The sun sets and the wind drops, so we need ways to store energy and share it over a wide area.

REMEMBER

Renewable does not mean free of cost. Sunlight is free, but panels, wires and batteries must be bought and looked after.

TRY THIS

Write the energy chain for cooking rice in a pressure cooker on a gas stove. (Chemical energy in the gas → heat → kinetic energy of steam → sound in the whistle.)

How a solar cell works

A **solar cell** turns light straight into electricity, with no moving parts. A **solar panel** is many cells joined together behind glass or clear plastic.

What is inside a cell

A solar cell is a thin slice of **silicon**, an element found in ordinary sand, purified until it is extremely pure. The slice has two layers. A tiny amount of one substance is added to the top layer so that it has spare electrons (tiny charged particles). This layer is called **n-type**. A different substance is added to the bottom layer so that it is short of electrons. This layer is called **p-type**. The boundary where the two layers meet is the **junction**.

When light falls on the cell, it gives energy to electrons and knocks them loose. The junction pushes these loose electrons one way only. If a wire joins the front and the back of the cell, the electrons flow round through the wire. That flow is an electric current. This is the **photovoltaic effect**: "photo" means light and "voltaic" means making a voltage.

The thin silver lines on the front of a cell collect the current. The blue or black colour comes from a coating that stops the cell reflecting light away.

Voltage, current and power

One silicon cell gives about half a volt (0.5 V) in good light, whatever its size. A bigger cell gives more **current**, not more **voltage**. So to get a useful voltage, makers join cells in series inside the panel. A small panel marked 6 V usually has about a dozen cells in a line.

A panel's label usually gives three numbers:

- **Voltage** in volts (V): how hard it pushes the current.
- **Current** in milliamps (mA) or amps (A): how much charge flows. 1,000 mA = 1 A.
- **Power** in watts (W): how much energy it gives each second. Power = voltage × current.

A panel marked 6 V and 1 W gives about $1 \div 6 = 0.17$ A, or 170 mA, in strong sunlight.

Panels in series and in parallel

In **series**, the + of one panel joins the – of the next. The voltages add up, but the current stays the same as one panel.

In **parallel**, + joins + and – joins –. The voltage stays the same as one panel, but the currents add up.

Two panels, each 6 V and 100 mA	Voltage	Current	Power
One panel alone	6 V	100 mA	0.6 W
Two in series	12 V	100 mA	1.2 W
Two in parallel	6 V	200 mA	1.2 W

The total power is the same either way. You choose the joining method that gives the voltage your model needs.

EXAMPLE

Arjun in Jaipur has two panels, each 6 V and 100 mA. His motor runs on 6 V but needs more current to start. He joins the panels in parallel: still 6 V, but now up to 200 mA.

REMEMBER

In a series panel, shade on even one cell cuts the current of the whole panel, like one slow walker in a single-file queue.

SAFETY

Small panels at these voltages are safe to touch, but glass panels have sharp corners and can break. Never connect any panel to the wiring of a house, a socket or a home inverter.

CHAPTER 3

Testing a small solar panel

A **multimeter** measures voltage, current and resistance. A basic digital one is enough for every test in this book.

Setting up the meter

1. Plug the black lead into the socket marked COM.
2. Plug the red lead into the socket marked V (for volts).
3. Turn the dial to DC volts. This is the V with a straight line next to it, not the wavy line, which means AC.
4. Choose the 20 V range if your meter has ranges.

Test 1: open-circuit voltage

Put the panel in direct sunlight with nothing connected to it. Touch the red probe to the panel's + wire and the black probe to its – wire. The reading is the **open-circuit voltage**. A minus sign only means the probes are the wrong way round. A 6 V panel often reads a little more than 6 V in bright sun with nothing connected.

Test 2: short-circuit current

1. Move the red lead to the 10 A socket.
2. Turn the dial to the 10 A DC current setting.
3. Touch the probes to the panel's wires. The reading is the **short-circuit current**.
4. Move the red lead back to the V socket straight away, so you do not forget.

SAFETY

Test 2 is safe only with a solar panel, because a panel can give only a small, limited current. Never connect a meter set to current straight across a battery or cell. That is a short circuit: it can blow the meter's fuse, overheat the battery and even start a fire.

Test 3: real power with a load

A panel gives its useful power when something is connected to it. Connect a 47 Ω (ohm) resistor rated 2 W across the panel. Measure the voltage across the resistor. Then work out the current with **Ohm's law**: current = voltage $\div$ resistance.

EXAMPLE

Neha in Lucknow reads 5.0 V across her 47 Ω resistor. Current = $5.0 \div 47 = 0.106$ A. Power = $5.0 \times 0.106 = 0.53$ W. Her panel is marked 1 W, so in that light it is giving about half its rated power.

Investigating light, angle and shade

Change one thing at a time and record both readings. Here are Neha's readings for a 6 V, 1 W panel around noon:

Condition	Voltage (V)	Current (A)
Facing the sun directly	6.9	0.16
Tilted 45° away from the sun	6.7	0.11
Lying flat on the ground	6.8	0.14
One cell covered with a strip of card	6.3	0.03
Behind a closed glass window	6.6	0.10
Under thick cloud	6.2	0.03

Look at the pattern. The voltage hardly changes while any light falls on the panel, but the current changes a great deal. Current is what tells you how much light the panel is getting.

TIP

In India, which is north of the equator, a fixed panel gives the most energy over a year when it faces south and is tilted at an angle roughly equal to your city's latitude: about 28° in Delhi and about 13° in Chennai.

CHAPTER 4

A solar car

In a solar car, everyone can see the energy change: sunlight goes in, movement comes out.

You need

- A small solar panel of about 6 V and 100 to 200 mA
- A small DC motor that starts on a low current (sold as a "solar motor")
- Four wheels (bottle caps or toy wheels) and two axles (bamboo skewers or thin metal rod)

- Two drinking straws, to hold the axles
- A light base of corrugated cardboard, sunboard or thin plywood, about 20 cm × 10 cm
- A small gear and a large gear, or two pulleys of different sizes and a rubber band
- Wires, tape, glue and a small slide switch

How to make it

1. Cut two pieces of straw a little wider than the base. Tape one across the underside at each end. These are the axle holders.
2. Push the axles through the straws. Spin them and check that they turn freely.
3. Fix a wheel on each axle end with glue. An adult should handle a hot glue gun.
4. Fix the motor at the back of the base. Fit the small gear on the motor shaft and the large gear on the rear axle, so the teeth mesh. (With pulleys, put the small pulley on the motor and the large one on the axle, joined by a rubber band.)
5. Mount the panel on top, flat or tilted towards the sun on a small card stand.
6. Wire the panel's + to the switch, the switch to one motor terminal, and the other motor terminal to the panel's -.
7. Test it in direct midday sun on a smooth floor. If it runs backwards, swap the two motor wires.

Why gears help

A small motor spins fast but has little turning force. Turning force is called **torque**. When a small gear drives a big gear, the big gear turns more slowly but with more force. If the motor gear has 10 teeth and the axle gear has 40, the axle turns once for every 4 turns of the motor, with almost four times the force. That extra force is what gets the car moving.

When it does not work

Problem	Likely cause	What to try
Hums but does not move	Car too heavy, or too little turning force	Lighter base, bigger gear on the axle
Does nothing in sun	Motor needs more current than the panel gives	A low-current motor, a second panel in parallel

Problem	Likely cause	What to try
Moves slowly	Panel at a poor angle, or wheels rubbing	Tilt the panel, check every wheel spins freely
Wheels slip	Smooth wheels on a smooth floor	Stretch a rubber band round each driving wheel

EXAMPLE

Kavya in Chennai tested her car at 9 a.m. and it would not start. At noon it ran well. She tilted the panel towards the morning sun and it started at 9 a.m. too. Her report explained why: more light on the panel means more current.

DID YOU KNOW

University teams from many countries build full-size solar cars and race them for about 3,000 km across Australia in the World Solar Challenge.

SAFETY

Skewers and wire ends are sharp. Never look straight at the sun while you angle the panel.

CHAPTER 5

A solar street light with an LDR

This model lights up by itself when it gets dark. In the day the panel charges a battery. At night a light sensor switches LEDs on.

You need

- A 6 V solar panel of about 1 W
- Four AA nickel-metal hydride (NiMH) rechargeable cells, 1.2 V each, in a holder (4.8 V in all)
- One 1N4007 diode
- One LDR (light dependent resistor)
- One BC547 transistor

- One 4.7 k Ω resistor and one 47 k Ω preset (a small adjustable resistor)
- Two or three white LEDs, each with its own 100 Ω resistor
- A slide switch, wires, a pole (a straw or thin pipe) and a base

Meet the LDR

An **LDR** is a resistor whose resistance changes with light. In bright light its resistance is low. In the dark it becomes very high. Check yours with the multimeter on a resistance (Ω) range: read it in room light, then cover it with your finger and read again. Write down your own numbers, because LDRs differ.

Connections

The charging part:

1. Join the panel's + to the end of the diode without a stripe. Join the striped end of the diode to the battery's +.
2. Join the panel's – to the battery's –.

The light part:

1. Join the battery's + to the switch. Call the switch's other side the "+ line". Call the battery's – the "– line".
2. Join the 4.7 k Ω resistor and the 47 k Ω preset in series, from the + line to the transistor's base.
3. Join the LDR from the base to the – line.
4. Join the transistor's emitter to the – line.
5. For each LED: + line $\rightarrow$ 100 Ω resistor $\rightarrow$ LED's long leg. Join every LED's short leg to the transistor's collector.

With its flat face towards you and its legs pointing down, a BC547 usually has its legs in the order collector, base, emitter from left to right. Check the maker's sheet for your part, because a few types differ.

How it works

The resistors and the LDR share the battery voltage between them, like two people sharing a load. In light, the LDR's resistance is low, so the base gets very little voltage and the transistor stays off. In the dark, the LDR's resistance rises, the base voltage rises above about 0.6 V, the transistor switches on, and current flows through the LEDs.

The diode is a one-way valve for current. At night the panel gives nothing, and without the diode the battery could slowly push current back through the panel.

Setting it up

Make the room dim, as at dusk, and turn the preset with a small screwdriver until the LEDs just come on. Point the LDR upwards and away from the LEDs. If the LEDs shine on the LDR, the light switches itself off, comes back on, and flickers.

SAFETY

Use NiMH cells as listed. Never use loose lithium-ion cells unless they come with a proper protected charging board and an adult is in charge. Never join the battery's + and – directly: even small cells get hot.

DID YOU KNOW

Real solar street lights work on the same idea. Many skip the LDR and use the panel itself as the sensor, because the panel's voltage falls at dusk.

TIP

A small panel charges slowly. Charge the cells fully with a proper charger before the exhibition, and use the panel to show that charging is happening.

CHAPTER 6

A solar water heater model

On many Indian rooftops you will see a solar water heater: black panels or glass tubes with a large tank above them. This model shows how they work.

How a real heater works

The sun heats water in black tubes called the **collector**. Hot water is lighter (less dense) than cold water, so it rises through a pipe into the tank. Cold water from the bottom of the tank sinks down into the collector to take its place. The water keeps circulating by itself, with no pump. This is called **thermosiphon** flow. The tank is wrapped in insulation so the water stays hot into the evening.

You need

- A shallow cardboard or wooden box, about 40 cm × 30 cm and 8 cm deep
- A thermocol sheet for insulation and black chart paper
- About 3 m of thin flexible plastic tube, painted matt black
- A clear acrylic sheet to cover the box (or glass, with an adult)
- A 1-litre plastic bottle for the tank, wrapped in cloth or thermocol
- Waterproof sealant or putty
- A thermometer and a watch

How to make it

1. Line the bottom of the box with thermocol, then black paper.
2. Lay the tube on the black paper in a zigzag and tape it down. Leave one end coming out near the top edge of the box and one near the bottom edge.
3. Cover the box with the clear sheet and tape the edges.
4. Prop the box up at a slope, facing the sun, with its "bottom" edge lower.
5. An adult makes two holes in the bottle: one near the bottom and one near the top. Push a tube end into each and seal them.
6. Place the bottle so that it is higher than the top of the collector. Join its bottom hole to the lower end of the collector tube, and its top hole to the upper end.
7. Fill the whole system with water, tilting it to push out air bubbles. Bubbles can block the flow.
8. Record the tank temperature every 15 minutes for two hours.

Sample readings

Time	Tank temperature
11:00	28 °C
11:30	32 °C
12:00	35 °C
12:30	38 °C
13:00	41 °C

Why it works

- Black surfaces absorb most of the light falling on them and turn it into heat.
- The clear cover lets sunlight in but stops the warm air escaping. This is the **greenhouse effect**.
- Insulation slows down heat loss from the tank.
- Thermosiphon flow carries hot water up to the tank without a pump.

TRY THIS

Build two identical collectors, but leave the clear cover off one. Which heats faster? This turns your model into an investigatory project.

SAFETY

Check the water with the thermometer, never with your fingers. Tape the edges of any glass, and let an adult cut and handle it.

CHAPTER 7

A wind turbine model

How a real turbine works

Wind pushes on the blades and turns them. The blades turn a shaft connected to a **generator**, a machine that changes movement into electricity. Turbines stand on tall towers because the wind is stronger and steadier higher up, and they turn to face the

wind. Tamil Nadu and Gujarat are among India's leading wind power states, and the Muppandal area near Kanyakumari is one of the best known wind farm sites in the country.

A motor works backwards as a generator

A small DC motor turns electricity into movement. Spin its shaft by hand and it works the other way: it gives out a voltage. The faster you spin it, the higher the voltage. Test this before you build: set the multimeter to DC volts, join it to the motor, and twist the shaft between your fingers.

You need

- A small DC hobby motor (a 6 V or 12 V type works well)
- A bottle cap for the hub
- Stiff card or a plastic folder for the blades, and ice-cream sticks
- A tower: a wooden stick or PVC pipe about 50 cm tall, fixed to a heavy base
- Card for a tail vane
- A red LED, wires and a multimeter
- A table fan, switched on by an adult

How to make it

1. Pierce the centre of the bottle cap and push it firmly onto the motor shaft. Fix it with glue.
2. Cut four blades, each 12 cm × 4 cm, and glue each one to an ice-cream stick.
3. Cut slits round the edge of the cap and fix the sticks in them, so the blades stick out like spokes.
4. Twist every blade to the same angle, about 20° from flat. This angle is called the **pitch**.
5. Tape the motor to the top of the tower, with a card tail behind it.
6. Run the motor wires down the tower to the meter or the LED.
7. Stand the turbine 1 m in front of the fan and measure the voltage.

Experiments to try

Change one thing at a time and keep everything else the same. This is called a **fair test**.

What you change	Try these	What you record
Number of blades	2, 3, 4, 6	Voltage
Blade pitch	10°, 20°, 30°, 45°	Voltage
Distance from fan	50 cm, 1 m, 1.5 m	Voltage

A red LED needs about 2 V, and lights only when its long leg is on the + side. If it stays dark, swap its legs or move the turbine closer to the fan.

DID YOU KNOW

The power in the wind rises very fast with its speed. If the wind speed doubles, the power available becomes about eight times as much.

REMEMBER

A fan's breeze is uneven. Mark the turbine's position on the table with tape so each test is done at the same spot.

SAFETY

Keep fingers and hair away from the fan and the spinning blades. An adult should cut any PVC pipe. Never open the fan.

CHAPTER 8

A water wheel and hydro power model

How real hydro power works

Water stored high behind a dam has potential energy. When it is let out, it rushes down large pipes called **penstocks** and turns turbines connected to generators. The Bhakra Dam on the Sutlej and the Tehri Dam in Uttarakhand are well-known Indian examples. In hill areas, small hydro plants use the flow of streams.

How much energy does falling water have?

The potential energy of water, in joules, is $\text{mass} \times 9.8 \times \text{height}$, with the mass in kilograms and the height in metres. The 9.8 stands for the pull of gravity. One litre of water has a mass of about 1 kg.

EXAMPLE

In Ravi's model, 1 litre of water falls 0.3 m. Energy = $1 \times 9.8 \times 0.3$ = about 2.9 joules. In a dam with a 100 m drop, every litre gives up 980 joules. That is why dams are built tall.

You need

- A small DC motor (as the generator)
- Eight plastic spoons and a thick bottle cap or cork for the hub
- A plastic container or shoebox lined with plastic, as the frame
- A tray or tub to catch the water
- A plastic bottle or jug of water
- A plastic bag and a rubber band to keep the motor dry
- A multimeter and a red LED

How to make it

1. Glue the spoons round the edge of the hub, evenly spaced, with all the bowls facing the same way. This is your water wheel.
2. Push the hub firmly onto the motor shaft and glue it.
3. Cover the motor body with the plastic bag, leaving the shaft and the wires out, and seal it with the rubber band.
4. Fix the motor to the side of the frame so the wheel hangs over the tray and turns freely.
5. Pour water from a height onto the spoons on one side of the wheel, away from the motor.
6. Measure the voltage while the wheel turns.

Experiments to try

Height of pour	Voltage (your readings)
10 cm	

Height of pour	Voltage (your readings)
20 cm	
30 cm	

Then keep the height the same and compare a thin stream with a thick one. A higher drop and a bigger flow both turn the wheel faster and give more voltage.

SAFETY

This model has no battery and makes only a small voltage, so it is safe. Still, keep the multimeter dry, wipe up spills at once, and never work near a wall socket. Work outdoors or over a tub.

TRY THIS

Try six spoons instead of eight, or cups instead of spoons. Which wheel turns fastest from the same height?

CHAPTER 9

Biogas, tidal and geothermal energy

These three sources are hard to build as working models, so a clear concept model with good labels is the right choice. A **concept model** shows how something works without doing the real job.

Biogas

When cow dung, kitchen waste or crop waste rots without air, bacteria (tiny living things) break it down and give off **biogas**. Biogas is mostly **methane**, a gas that burns with a clean blue flame, plus some carbon dioxide. Rotting without air is called **anaerobic digestion**. The leftover slurry is good manure for fields. Many Indian villages use small "gobar gas" plants for cooking.

Part of a biogas plant	Its job
Inlet tank	Dung and water are mixed into a slurry

Part of a biogas plant	Its job
Digester	A closed tank, usually underground, where bacteria make the gas
Gas holder (dome or drum)	Collects the gas at the top
Gas pipe and valve	Carries gas to the stove
Outlet	Used slurry flows out to be used as manure

A balloon demonstration. With an adult, outdoors, wearing gloves: half-fill a plastic bottle with fresh cow dung mixed with an equal amount of water. Stretch a balloon over the neck and tape it. Keep it in a warm, shady place. Over the next week or two the balloon slowly swells as gas forms. Measure round the balloon with a thread each day and record it.

SAFETY

Never try to light the gas. Methane catches fire easily. Keep the bottle outdoors, let it out of the balloon in the open air, and wash your hands well. Put the slurry on a garden or compost pit when you finish.

Tidal energy

The pull of the Moon and the Sun makes the sea rise and fall, usually about twice a day. These are **tides**. A tidal power station traps water behind a wall called a **barrage** across a bay. As the tide comes in and goes out, the water flows through turbines in the wall. France has run a tidal station at La Rance since 1966. In India, the Gulf of Khambhat and the Gulf of Kutch in Gujarat have been studied as possible sites.

Concept model: a long tray with a card wall across the middle and a small water wheel in a gap in the wall. Tilt the tray one way, then the other, to show the "tide" flowing both ways and turning the wheel each time.

Geothermal energy

The inside of the Earth is extremely hot. In some places hot rocks lie close enough to the surface to heat underground water into steam, which can drive turbines. This is **geothermal energy**. Iceland uses it widely. India has hot springs such as Manikaran in Himachal Pradesh, and the Puga Valley in Ladakh has been studied for geothermal power.

Concept model: a cut-away box showing coloured layers of earth, a pipe going down to red "hot rock", steam rising up a second pipe to a turbine, and cooled water being pumped back down.

REMEMBER

Say clearly that a concept model shows the idea. Judges respect honesty more than a model that pretends to do more than it can.

CHAPTER 10

Smart grids and measuring output

What a grid is

The **grid** is the network of power stations, wires and substations that carries electricity to homes, shops and factories. The supply must match the demand every second. Renewable sources make this harder: solar power is strongest at noon, but many homes use the most electricity in the evening, and the wind can drop at any time.

What makes a grid smart

A **smart grid** uses sensors, smart meters, communication and computers to balance supply and demand automatically. It can:

- Store spare solar power in batteries during the day and use it in the evening.
- Let homes with rooftop panels send their spare power into the grid.
- Show families how much electricity they use each hour.
- Find a fault quickly and send power round it by another route.

A smart grid model

Make a "smart town" on a board: three cardboard houses, each lit by an LED with its own resistor and switch, and two sources, a solar panel and a battery pack (for example four AA NiMH cells, 4.8 V, so that the panel takes over in sunlight). Join each source to the town's + line through its own diode, so that neither source can push current backwards into the other.

To demonstrate:

1. In sunlight, show the panel lighting the houses.
2. Cover the panel ("night") and show the battery taking over.
3. Switch all three houses on together ("evening peak") and show on the multimeter how the current rises. Set the meter to current and join it in series in the + line, never straight across the battery.
4. Explain how a real smart grid would store daytime power for that evening peak.

Measuring output properly

Quantity	Unit	Meaning
Voltage	volt (V)	The push on the current
Current	ampere (A), milliamp (mA)	How much charge flows each second
Power	watt (W)	Energy given each second; volts $\times$ amps
Energy	watt-hour (Wh), kilowatt-hour (kWh)	Power $\times$ time; 1 kWh is the "unit" on an electricity bill

EXAMPLE

Imran's street light uses 0.3 W. In 10 hours it uses $0.3 \times 10 = 3$ Wh. His panel gives about 0.5 W, so it needs about 6 hours of good sunlight to replace that energy.

Take each reading three times and work out the average. If Imran's turbine reads 2.1 V, 2.3 V and 2.2 V, the average is $(2.1 + 2.3 + 2.2) \div 3 = 2.2$ V. Then draw a line graph, such as time across the bottom and temperature up the side, so the pattern is easy to see.

TIP

Write units with every number in your table. "2.2" means nothing to a judge; "2.2 V" tells the whole story.

CHAPTER 11

Presenting your model and answering questions

A two-minute talk

1. **Name and aim:** "This is a wind turbine model that changes wind energy into electricity."
2. **Principle:** the science idea, in one sentence.
3. **Energy chain:** say it while pointing to each part.
4. **Demonstration:** show it working and read the meter aloud.
5. **Results:** point to your table and graph.
6. **Real use:** where this is used in India.
7. **Limits and improvements:** what you would do next.

Exhibitions are often indoors, where light is far weaker than sunshine. Bring a short video of your solar model working outside, and your written readings. A bright torch held close to the panel will still move the meter reading.

Your chart

Use a clear title, a large labelled diagram, your readings table with units, one graph and a short list of uses. Keep the words few and big.

Viva questions and answers

Question	A good short answer
Why does your panel give less in the evening?	Less light reaches it, so it gives less current.

Question	A good short answer
Why use a diode in the street light?	So the battery cannot send current back through the panel at night.
How can a motor make electricity?	Spinning its coil past its magnets produces a voltage.
Why are wind turbines tall?	The wind is stronger and steadier higher up.
What gas is mostly in biogas?	Methane.
What is the main problem with solar and wind power?	They vary with the weather and time of day, so we need storage and a good grid.

REMEMBER

If you do not know an answer, say so honestly and say how you would find out. That is a scientist's answer.

CHECK YOURSELF

Practice questions

1. What is energy?
2. Write the energy chain for a wind turbine lighting an LED.
3. Name three fossil fuels and give one reason they are called non-renewable.
4. What happens at the junction of a solar cell when light falls on it?
5. About what voltage does one silicon solar cell give, and does a bigger cell give more voltage?
6. Two panels of 6 V and 100 mA are joined in series. What voltage and current do you get?
7. The same two panels are joined in parallel. What voltage and current do you get?
8. A panel is marked 6 V and 1.2 W. What current does it give in strong sunlight?
9. Why is it safe to measure short-circuit current on a solar panel but not on a battery?

10. A $47\ \Omega$ resistor across a panel has 4.7 V across it. What are the current and the power?
11. In a solar panel test, which changes more with light: voltage or current?
12. Why does a solar car usually need gears or pulleys?
13. In the street light, what happens to the LDR's resistance at night, and what does the transistor then do?
14. What is thermosiphon flow?
15. Give two reasons why the solar water heater model has a clear cover and a black inside.
16. What is a fair test? Give one example from the wind turbine model.
17. One litre of water falls 2 m. About how much potential energy does it lose?
18. What is biogas mostly made of, and why must you never light the gas in the balloon demonstration?
19. How does a tidal barrage make electricity?
20. What is a smart grid? Give two things it can do.

ANSWER KEY

Answers

1. Energy is the ability to do work, such as moving, heating or lighting something.
2. Kinetic energy of the wind → kinetic energy of the blades → electrical energy → light energy.
3. Coal, petroleum and natural gas. They took millions of years to form, so once burnt they cannot be replaced in our lifetime.
4. Light knocks electrons loose and the junction pushes them one way, so a current can flow through an outside wire.
5. About 0.5 V. No: a bigger cell gives more current, but about the same voltage.
6. 12 V and 100 mA, because voltages add in series.
7. 6 V and 200 mA, because currents add in parallel.

8. Current = power ÷ voltage = $1.2 \div 6 = 0.2$ A, or 200 mA.
9. A panel can give only a small, limited current. A battery can give a very large current, which can blow the meter's fuse, overheat the battery and cause a fire.
10. Current = $4.7 \div 47 = 0.1$ A. Power = $4.7 \times 0.1 = 0.47$ W.
11. Current changes much more; the voltage stays nearly the same while any light falls on the panel.
12. A small motor spins fast but with little turning force. Gears trade speed for more turning force (torque) so the car can start moving.
13. The LDR's resistance becomes very high, the base voltage rises, and the transistor switches on and lights the LEDs.
14. The flow of water by itself, without a pump, because hot water is lighter and rises while cold water sinks.
15. Black absorbs most of the light and turns it into heat; the clear cover lets sunlight in and traps the warm air (greenhouse effect).
16. A test where you change only one thing and keep everything else the same. Example: changing only the number of blades, with the same fan, distance and blade pitch.
17. Energy = $1 \times 9.8 \times 2 =$ about 19.6 joules.
18. Mostly methane. Methane catches fire easily, so lighting it is dangerous.
19. Water is trapped behind a wall across a bay; as the tide comes in and goes out, the water flows through turbines in the wall, which drive generators.
20. A grid that uses sensors, smart meters, communication and computers to balance supply and demand. It can store daytime solar power for the evening and let homes send spare power into the grid.

WORD LIST

Glossary

Anaerobic digestion

the breaking down of waste by bacteria without air, which produces biogas.

Barrage

a wall built across a bay or river to hold back water, used in tidal power stations.

Biogas

a fuel gas, mostly methane, made when waste rots without air.

Collector

the part of a solar water heater that absorbs sunlight and heats the water.

Diode

a part that lets current flow in one direction only.

Efficiency

the share of the energy put in that comes out in the useful form.

Fair test

an experiment in which only one thing is changed at a time.

Fossil fuel

a fuel such as coal, petroleum or natural gas, formed over millions of years from buried living things.

Generator

a machine that changes movement into electrical energy.

Geothermal energy

energy from the heat inside the Earth.

Greenhouse effect

the trapping of heat behind a clear cover, or by gases around the Earth.

LDR (light dependent resistor)

a resistor whose resistance is low in light and high in the dark.

Methane

the main gas in biogas; it burns with a blue flame.

Multimeter

an instrument that measures voltage, current and resistance.

Photovoltaic effect

the production of a voltage when light falls on a solar cell.

Pitch

the angle at which a turbine blade is set.

Renewable source

an energy source that nature refills, such as sunlight or wind.

Short-circuit current

the current a panel gives when its two wires are joined through a meter set to current.

Smart grid

a power network that uses sensors, meters and computers to balance supply and demand.

Thermosiphon

the natural circulation of water caused by hot water rising and cold water sinking.

Torque

turning force.

Watt-hour (Wh)

a unit of energy; one watt used for one hour.



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