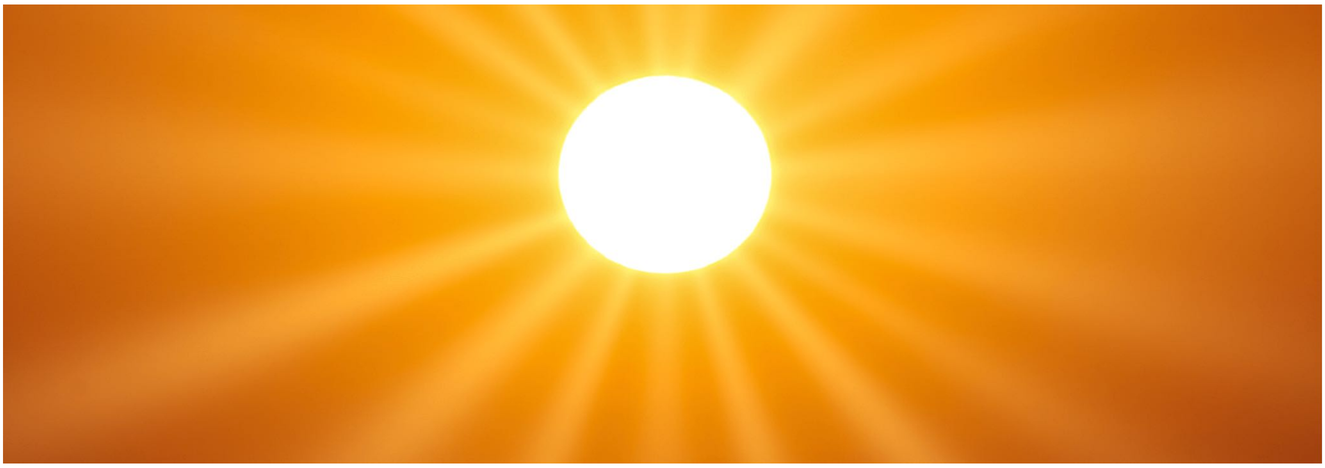
Solar power: teaching resource pack



This pack has been produced by The Young People's Trust for The Environment, in partnership with Essex County Council. It is designed to support primary school teachers with delivering lessons on photovoltaic solar panels and other sustainable energy sources.

The learning is broken into short 'bite-sized' pieces of information, together with suggestions for follow up activities. These are intended to be slotted into the timetable across a year in order to build learning in an incremental way. Activities have been themed into general learning areas: electricity, the sun and solar panels, renewable energy and more general ideas for living in a sustainable way.

The activity suggestions provided are designed to suit children from the Foundation Stage to Upper Key Stage 2 and can be used flexibly based on the teachers' knowledge of their learners' needs. It would be entirely appropriate to repeat activities or to re-visit them using one of the other activities provided in order to revise learning over the course of the year.

What is solar power?

There are four types of solar energy that we use for power:

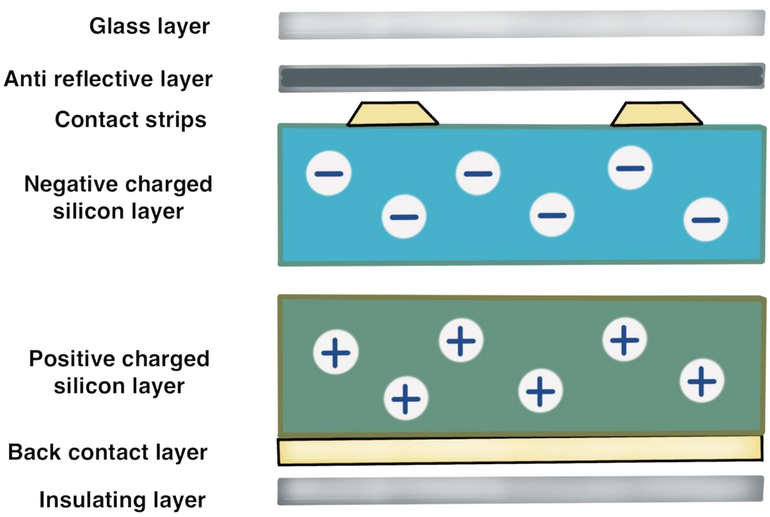
Passive solar gain - is the term used to describe the energy that is provided by a sun shining directly on to, for example, a house and warming it up. Clever design, such as large windows on south-facing walls and smaller ones on north-facing walls allow sunlight into a building to help heat it up.

Solar thermal - A solar thermal panel uses a black surface to absorb heat from the sun and transfers it into a fluid. This heated fluid, such as water, can then be used for washing or to heat a room.

Concentrated solar - in very sunny places, mirrors can be positioned to reflect the sun's rays on to a specific point in concentrated beams. This point has a fluid such as oil running through it, which can be heated to around 400 degrees centigrade, which is hot enough to make high pressure steam. This can, in turn, drive a generator to make electricity.

Photovoltaic cells - First used in space and now commonplace on devices from calculators to traffic signals, photovoltaic solar cells are able to convert light directly into electricity. These cells can be linked together in arrays and placed on our homes and schools to generate electrical power.

What are photovoltaic cells?



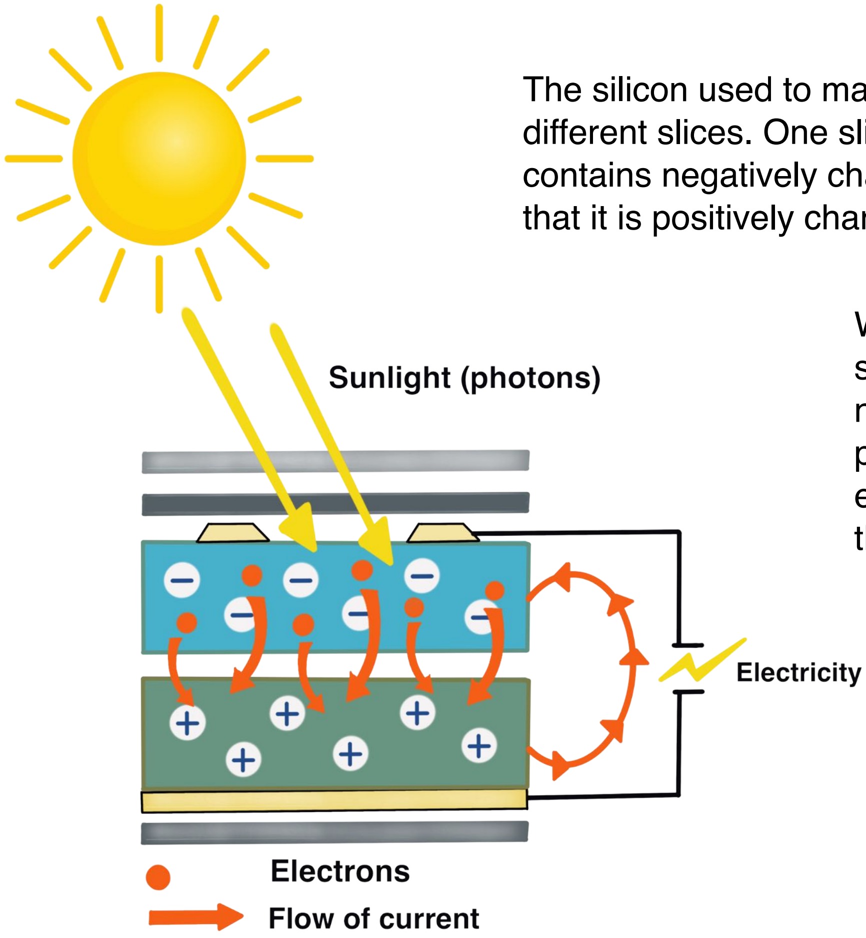
Photovoltaic cells are able to convert light from the sun into electricity to power electrical items. The power can be stored in batteries for use when the sun is not shining.

The cells are made of two layers of a semi conducting material, usually silicon. Silicon is made by heating sand to a very high temperature. So a solar panel can be a way to turn sunlight and sand into electricity! Amazing!

The silicon is treated with different chemicals so that it can create an electric current from photons when the sun shines on it.

How do photovoltaic cells work?

The silicon used to make photovoltaic cells comes in different slices. One slice of silicon is treated so that it contains negatively charged electrons and the other so that it is positively charged and has ‘holes’.



When the photons from the sunlight interact with the negatively charged electrons, they pass on some of their energy, exciting the electrons and letting them start to move about.

The negatively charged electrons start to move - travelling to the positively charged slice of silicon.

Once a flow of electrons all start travelling in the same direction, it creates electricity. The metal strips on the front of the cell and the metal contact on the back of the cell create a circuit that the electric current runs through.

What is a photon?

The prefix ‘photo’ comes from the Greek word for ‘light’. When you break a beam of light into its tiniest parts (particles), these are photons.

A photon can travel at nearly 300 million metres per second! This is called the speed of light. The sun is 92 million miles away from Earth, so photons take 8 minutes and 20 seconds to reach us after leaving the surface of the sun.

What is voltage?

Voltage is what makes electric charge move. It is the ‘pressure’ from an electrical circuit’s power source that pushes charged electrons (the current) around a circuit allowing them to do work such as light a bulb. The greater the voltage of a power source, the more work it can do. For example, an AA battery typically has a voltage of 1.5 (1.5v) and a household power socket in the UK produces an average voltage of 230 (230v).

What is energy?

Energy is all around us in different forms. A simple definition of energy is "the ability to do work". When we eat food, it gives us the energy we need to keep warm, move, talk, think and do all the other tasks we need to. Energy is in everything in the world. It cannot be created or destroyed - but it can be changed from one form into another!

There are lots of different types of energy:

Chemical energy - this type of energy is stored in the bonds between molecules of different substances. Natural gas, coal and batteries all have chemical energy - and so does the food that we eat!

Electrical energy comes from tiny charged particles called electrons. This can happen naturally (such as with lightning) or can be made from other types of energy.

Gravitational energy - Very large objects such as the earth and the sun generate gravitational energy. When you drop something, it falls to the floor because of gravitational energy.

Heat energy - this type of energy is also sometimes called **'thermal energy'**

Light energy - this type of energy is usually called **'radiant energy'**

Sound energy - this is a type of energy released by vibrating objects such as a guitar string - or our vocal chords!

Kinetic energy is the energy of movement running, skipping, jumping, all of these are types of kinetic energy. This is sometimes called **movement or motion energy.**

Potential energy - potential is a bit like saying 'possible'. A ball at the top of a slope has potential energy just before it starts to move. A stretched spring also has potential energy. Potential energy is stored energy that is ready to be used.

Nuclear energy is generated by splitting atoms apart. Doing this generates huge amounts of energy. In the centre of the sun, atoms split apart regularly and this is what causes the heat and light that we get from the sun. We can also split atoms in nuclear power stations.

Although children aren't expected to have a sound grasp of energy transfer until KS3, it is helpful if they understand that energy is not created during any process, it is simply changing from one form to another. You may like to build "energy chains" with learners, tracing back the form of energy to it's source (usually the sun!) Try identifying a form of energy, such as 'electrical' and asking '…and before that?' 'kinetic' (the movement of the turbine) '…and before that?' 'chemical' (the fuel used in the power station) '…and before that?' 'heat and light' from the sun which helped the original organic matter to grow, before it became fuel!

Foundation Stage

There are plenty of opportunities to gain an early awareness of solar power through play and observation in the Early Years. As well as links to the learning goals for science and understanding of the world, there are countless opportunities for building communication skills during this topic, through group discussion and asking questions.

Learning about electricity

Understand that electricity powers some of the appliances in our homes:
Go on a hunt for items that run on electricity at school or at home. You might like to provide children with a basic outline of a house, so that the children can draw or stick pictures of the electronic appliances found in different rooms in the house.

Discuss daily activities that require the use of electricity, such as washing ourselves, our dishes or our clothes, cooking, using lights, watching television or playing on a computer. Make lists of the different activities we do in each part of our homes, or at school.

Explore a range of powered toys and games. Which need to be plugged into the mains and which run on batteries? Look at the ways that batteries are fitted into some of the powered toys at school and practise changing the battery. Show the children rechargeable batteries and explain that these can be used again and again. Explain in simple terms that batteries are a way of storing electricity.

Begin to understand the sun as a source of electricity: Show the children a small moving toy that is powered by the sun. How do they think it works? Explore what happens if the toy is placed in a sunny place or in a dark place. How is power reaching the toy? What happens if the solar cell is taped over? Gather ideas about what is making the toy move.

Know some similarities and differences between things in the past and now: As part of history topics, discuss the ways people carried out every day tasks in this country before they had electricity. If possible, bring in candles and a gas lamp to show the children. You might also look at a bucket and scrubbing board or a mangle. Children might enjoy beating a carpet outside using a carpet beater or a stick to get the dust off. Notice how long some of these tasks take! Which appliances do the children have at home to carry out cleaning tasks?

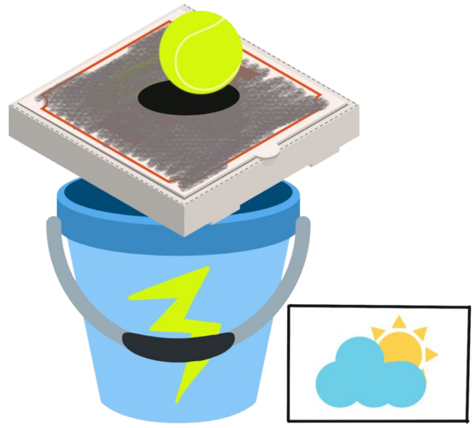
Which toys did children used to play with in the past? Ask the class to think of the toys and games they enjoy that don't need any power to make them work. Adults might bring in some favourite toys from the past that didn't need batteries or to be plugged in.

Explain some similarities and differences between life in this country and life in other countries: As part of geography work, discuss the idea that not all communities have ready access to electricity. How might this impact people's day? What activities / toys can people not do / use without electricity? If you have access to a forest school or outdoor area. You may like to link this activity to cooking outdoors over a fire.

Learning about solar power

Intended Learning: Understand some important processes and changes in the natural world around them, including the seasons and changing states of matter.

Talk about the sun and temperature in the context of the seasons and weather. Make a class weather board and record the temperature each day, noticing patterns over time.



Make a very simple ‘solar panel’ throwing game from a pizza box with a hole cut into it. Balance this over a bucket. Use yellow balls to represent sunlight / photons. Draw from cards with a selection of weather symbols on them. When the card shows sun and cloud, children can try to throw one ball into the bucket through the panel. If the card shows full sun, they can have three goes! Non sunny weather misses a turn. Which weather fills the bucket first? This can help children understand that solar panels work best on sunny days!

Explore the idea of the sun’s energy in simple observations. What do children notice about the temperature when they sit in the sun, compared with when they sit in the shade? Why do they think this happens?

Use ice cubes to explore the effect of the sun’s energy. Place an ice cube in full sunlight and another in a shady spot. What happens to the ice cubes? Why do the children think the the ice is melting? Which cube melts first?
Talk about shadows and notice how they are clearer on very sunny day. Draw round the shadows of objects and discuss what is causing them.

Learning about saving energy

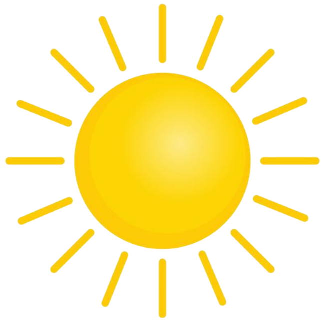
Intended Learning: Understand that our behaviours can have an impact on the environment.

Involve the children with activities that have a visible impact, such as going on a litter pick of the school grounds, or local area.

Explore the idea that lots of our waste can be recycled. Discuss which materials the children recycle at home and sort recycling regularly in class, explaining what will happen to the materials.

If there are toys in class that run on batteries, introduce the idea of rechargeable batteries. Support children with replacing batteries in the toys (with appropriate safety measures in place) and discuss the batteries that are in the charger. Where are they getting their new power from?

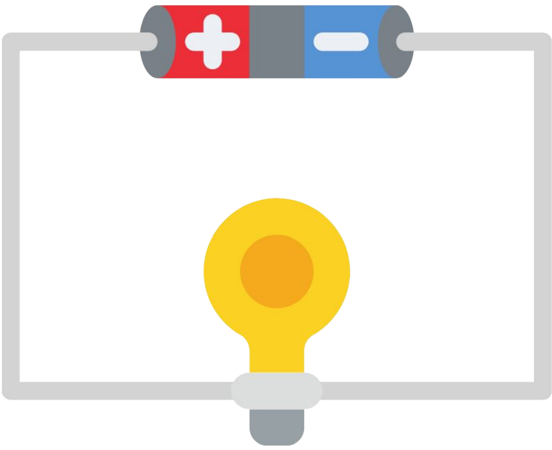
Key Stages 1 and 2



It's wholly appropriate for older children to have plenty of access to the practical exploration activities listed above, so teachers are encouraged to dip into those to ensure a secure basis for further learning.

Learning about electricity

Building circuits: Key to understanding the ways that we use electricity, is the concept of a simple circuit. If possible, it's ideal to have the equipment to build a simple circuits set up in the classroom throughout the year so that children can return to it repeatedly in spare moments to reinforce understanding.



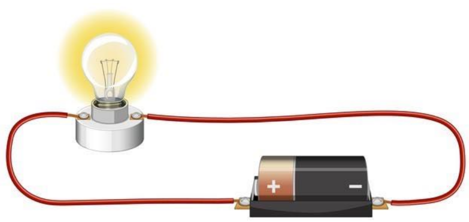
INITIAL TEACHING: Allow children to explore the components of a circuit in free play, having discussed safety requirements around batteries. Include some bulbs, motors and alarms in the materials available and allow children to explore ways to make them work.
Once the idea of a circuit is becoming secure, you can extend learning by adding new items to the kit and asking further questions. Kits such as the 'Electricity Blocks sets by EZBlocks are a great way to link circuit building with an understanding of the symbols used to draw circuit diagrams.
Include some small solar PV cells in the materials available. What do these replace in the circuit?
How many did it take to have the same effect as a battery?
Notice that adding more batteries makes a bulb brighter. Will this happen with more PV cells? Make the link to solar panels having multiple cells in an array.

Start to introduce the symbols for drawing basic circuit diagrams. Give examples, some with deliberate faults: - will these circuits work and if not, why not? Children draw diagrams for each other and play 'spot the mistakes'.

Introduce some conductive and non conductive materials and discuss the effects of adding them into a circuit. Which still allow the electricity to flow? Which don't? Link this to the materials used to make solar panels. Why wouldn't a solar panel be made from wood?

Create circuit builder games: Provide children with (or ask them to make) small cards with pictures of wires, bulbs and batteries or PV cells. There should be around twice the number of wire cards as other cards. There are many games you could play with this simple resource:

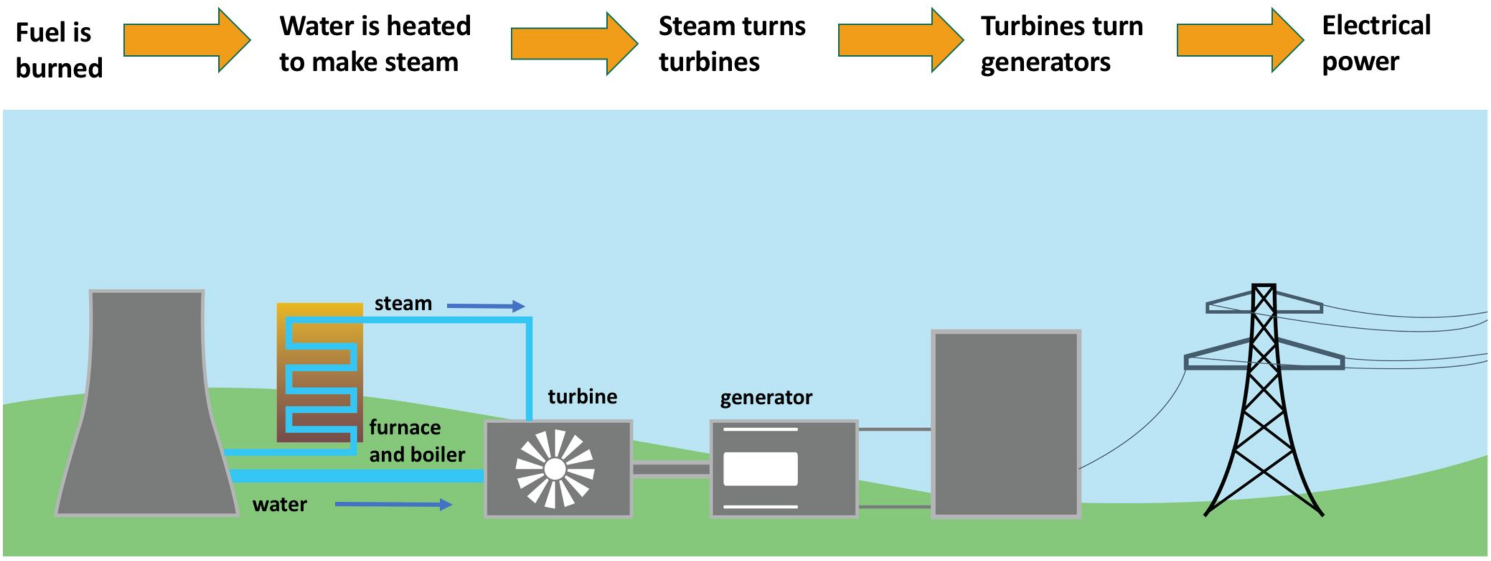
* All the cards are turned face down. Children work in pairs or groups, each turning over one card at a time until they have sufficient pieces to build a complete circuit. The player who shouts 'CIRCUIT!' and proves they have enough pieces, keeps those cards and the game continues.
* Call out different cards such as '2 bulbs, one cell, 3 wires' and see which team can build the circuit most quickly. Extra points for explaining whether circuits will work or not, or how bright the bulbs might be!



Where does electricity come from?

To understand how all the various energy resources end up being able to supply electricity to people's homes and businesses, children need some concept of what happens in a power station and, crucially, a basic understanding of what a turbine and a generator is. Apart from solar PV panels, most of our electricity comes from finding ways to spin turbines.

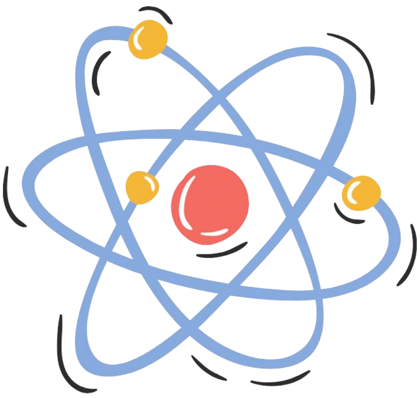
INITIAL TEACHING: Watch YPTE's video on How electricity is made
https://ypte.org.uk/videos/how-is-electricity-made



Most of the UK's electricity comes from burning fossil fuels. In a power station, coal is crushed to a fine dust and burnt. Oil and gas can be burnt directly. The burning fuel is used to heat a large volume of water to produce steam. The steam flows at pressure to turn a turbine, a bit like a large propeller. The turbine spins at high speed - up to 3,000 revolutions per minute - and this mechanical energy is used to spin a large magnet inside massive coils of copper wire. This generates a flow of electrons, through the copper wire, which is the electricity we use in our homes, schools, etc.
The steam that has passed through the power station's turbines has to be cooled, to condense it back into water before it can be pumped round again. This is what happens in the huge "cooling towers" seen at power stations.

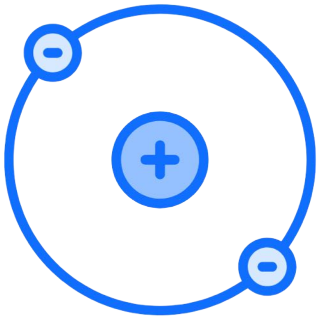
Remember - a generator doesn't **MAKE** energy - it simply changes it from one form to another!
When we clap our hands together - the movement we make is kinetic or 'movement' energy and when our hands clap together, that is changed into sound energy.
Generators can change mechanical kinetic energy from movement into electrical energy that we use to create heat, light and other types of energy in our homes!

Power station flow chart: Print out or draw symbols to represent the different parts of a power station: (In the case of a fuel powered station: energy source, heat, steam, turbine, generator, electrical power). Practise describing what each does. Work in pairs and groups to lay them out in order to build confidence. Use the cards as prompts to write flow charts and explanation texts.



But what IS electricity?
Just like everything else, electricity is made up of atoms. To help understand electricity, it can help to have a basic understanding of atoms. Atoms are the tiny building blocks that make up every part of our known world. In the middle of every atom is the nucleus. Every nucleus is made up of particles called protons and electrons which revolve round the nucleus in their shells. The protons have a positive charge and the electrons have a negative charge. They are attracted to one another. The positive charge of the protons is the same as the negative charge of the electrons, which makes the atom balanced when they have an equal number of protons and electrons. Neutrons have no electrical charge. The number of neutrons varies from atom to atom.

The electrons that are in the shells closest to the nucleus have a very strong attraction to the protons. Sometimes, the electrons that are in the shells furthest from the nucleus don't have such a strong attraction to the protons. They can be pushed out of their orbits (such as by photons!), which causes them to shift from one atom to another. These moving electrons are electricity.



Static electricity observation
You can use a ballon to demonstrate the way that charges attract and repel each other. Because everything is made of atoms, everything is made of charges, both positive and negative. When you rub a balloon on your hair, or on a wool jumper, the balloon starts to collect extra negatively charged electrons. If you hold two of these balloons together, these negative charges will repel each other! When you hold the balloon near a wall, the ballon now has more negatively charged electrons than the wall, so they will be attracted to the positively charged electrons of the wall and the ballon will stick! (When trying these activities, make sure you do it on a dry day as excess humidity in the air can affect the results.)

Remember opposite charges attract! Like charges repel! Positive charges are attracted to negative charges but positive charges repel other positive charges.

Learning about light bulbs.

* **There are different types of light bulbs that work in different ways**
* **Artificial light is very important to people in their daily lives**
* **Some lightbulbs are more efficient than others and waste less energy**
* **Companies sometimes design products so they will break, meaning that people have to buy more new things.**

Types of bulb:

Incandescent - an electric current is passed through a filament, usually made of tungsten, heating up until it glows.

Compact fluorescent LAMP (CFL) - Electricity causes mercury and argon fumes to produce invisible UV light. The UV light energises a fluorescent coating painted on the inside of the bulb and this emits visible light.

LED - Light Emitting Diodes - an electric current is passed through a semiconducting material. Electrons in the material move and release energy in the form of photons.

New incandescent bulbs are being invented that capture some of the leaking infrared radiation emitted and redirect it back to the filament. In effect, this recycles some of the wasted heat and uses it to make more light. This could end up being more efficient than LEd or CFL lamps in the future.
https://www.bbc.co.uk/news/science-environment-35284112

INITIAL TEACHING: Bring in a range of lightbulbs, or show pictures of different types, ideally including an incandescent bulb, an LED bulb and a Compact fluorescent lamp (CFL - the 'curly' bulbs!) Ask children what these are for and whether they know anything about the different types. One type of lightbulb is now being phased out in lots of countries. Why do learners think this might be?

Make sketches / diagrams of the different types of bulb and label the different types.

Give picture of a lightbulb outline and ask learners to draw a diagram of what they think is happening inside to make it light up.

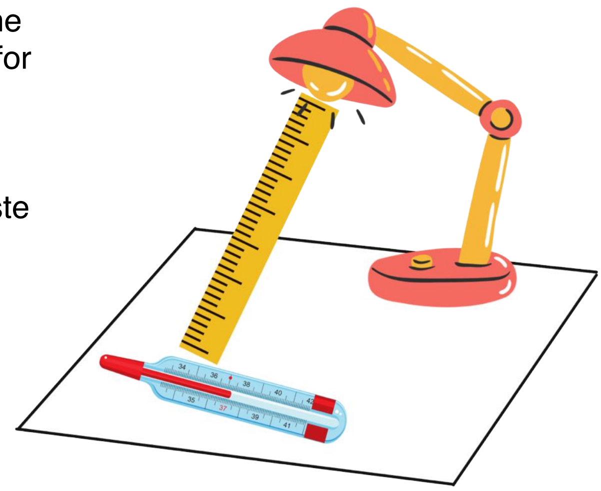
Some learners might like to research the different types of bulb to find out how they work. MANY different elements have been used to make filaments over the years with greater and lesser success. Finding out about these experiments is a great way to learn about trial and error in science, technology and design.

Look at the wattage of different bulbs (this is usually printed on the bulb) and calculate how much each bulb costs to run for different periods. See the section below on KiloWatt hours for an example calculation.

How many light bulbs are in your school / town? Predict and try to calculate (include street lights, car headlamps, LEDs inside computers, etc) Understand how widely they are used. List places lights / bulbs are used - Christmas lights, torches, vehicles

Consider a day without artificial light - what would it be like?

Old incandescent lightbulbs are very inefficient. Only about 5% of the energy that goes into them is converted into light; the rest is lost as heat. This means that some bulbs are more efficient than others and so are better for the environment as they don't waste as much energy doing their job.

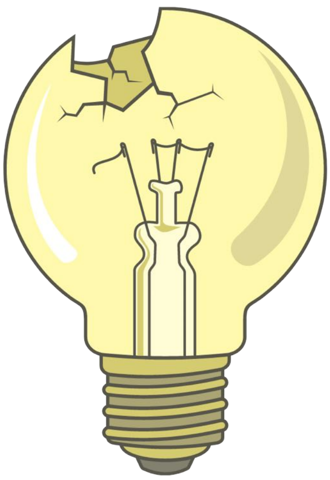


Design an experiment to find out which light bulbs waste the most energy as heat.

A simple test could be set up as follows:

Place a thermometer on a piece of white paper.
Position a lamp a set distance from the thermometer, using a ruler. Turn on the lamp and take temperature readings after a set time period (at least 5 minutes).
Repeat this test with different types of bulbs, allowing time between each bulb for the lamp to cool down, to see which is emitting the most heat.
Make sure that children understand that the lamp needs to be unplugged whilst the bulb is changed to avoid shocks.

A more complex experiment could be set up as an extension using a data logger to measure the light output of the bulbs in lumens, to better compare efficiency.



Planned obsolescence

The longest running lightbulb in the world has been running continuously for 110 years in a place called Livermore in California.

It has been possible to make long-running lightbulbs for over 100 years. However, in December 1924, a group of representatives from the world's top lightbulb manufacturing companies got together in a secret meeting and agreed to shorten the life of lightbulbs to 1000 hours. The 'Phoebus Cartel' also decided which companies could sell to which global zones and how many bulbs they were allowed to make.

Why do children think that manufacturers deliberately shortened the life of their lightbulbs?

Why would this only work if all the manufacturers agreed to it? You might like to research how the group made sure everyone stuck to the deal!

What impacts on the environment did this decision have? (Consider things such as the materials used, the waste created and the energy expended in manufacture)

Are there other products around today that are designed to make people need or what to replace them quickly? (Mobile phones are a key example).

Watch 'The Lightbulb Conspiracy' with UKS2 to better understand the problems of planned obsolescence.

"Watt" uses the most electricity?

INITIAL TEACHING: Show the label from an electrical appliance. Every electrical appliance has a power rating that tells you how much electricity it needs to work. This is usually given in Watts (W) or kilowatts (kW). 1000 w = 1kW.

Give children a set of pictures or words for electrical appliances (you can use this table to start you off). Ask them to sort the appliances to show which they think use the most electricity.

Either research the amount, look on labels of real products, or provide the answers. Was anyone surprised?

Point out that some appliances, such as fridge freezers, use less electricity, but are on all the time. A hair dryer uses a lot, but is not running all day.

Which appliances use most power in your classroom?

Appliance	Average power rating (Watts)
Fridge freezer	200 - 400
Games Console	45 - 190
Electric shower	7000 - 10,500
Laptop	20 - 65
Kettle	3000
Smart phone (charge)	2.5 - 5
Iron	1000 - 1800
Tumble dryer	2000 - 3000
Hair dryer	2000

Centre for Sustainable Energy

If you want to save electricity, it helps to focus on the things that use the most energy first!

Calculate how much it costs to use your appliances.

To find out the rate that you are paying for each unit of electricity, you'll need to look at a bill from your home or school's utilities supplier. One unit of electricity is equal to 1000 Watts of power used for 1 hour. This is called 1 Kilowatt hour, or 1kW/h. To find out how much an appliance costs to run per hour do the following:

1) Find out the cost you are paying per unit
2) Look at the label on the appliance you are using to find its power consumption in Watts. This might be on a label or sticker somewhere on the appliance. Look for its power consumption in Watts or kW (thousands of watts). This is how many Watts the appliance uses. An appliance with a power consumption of 1kW would use 1kW/h (1 kilowatt hour, or unit of electricity) every sixty minutes.
3) Work out the amount the appliance costs to run each hour:

Cost = unit cost in pence x power consumption in kilowatts.

To find out how much it costs to run over a week, multiply that by how many hours the device is used in a week.

Example:
How much would it cost to light a 100 watt bulb per hour if one unit of electricity costs 17.2p?

To change watts to kilowatts divide by 1000
100/1000 = 0.1

17.2p x 0.1 = 1.72p per hour to run.

If the light bulb is on for 4 hours every evening, how much will it cost a week?

1.72 x 4 hours = 6.88
x 7 days = 48.16 = 48p a week to the nearest penny.

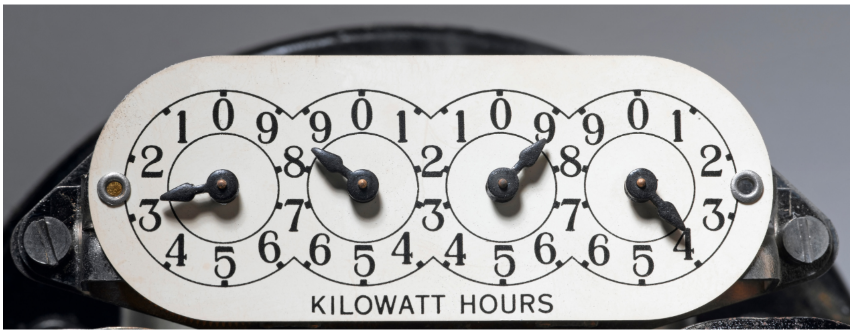
How much is this a year?

48.16 x 52 weeks = 2504.32p = £25.04 to the nearest penny.

Calculate your school energy use

Use information from your school energy bills to find out how much electricity you used over different time periods. You may even be able to access your school electricity meter so you can take readings and find out how many kWh the school is using in a day.

Compare the number of kWh used in a quarter (or a day) in the summer, with the amount used in the winter - why do you think there is a difference?

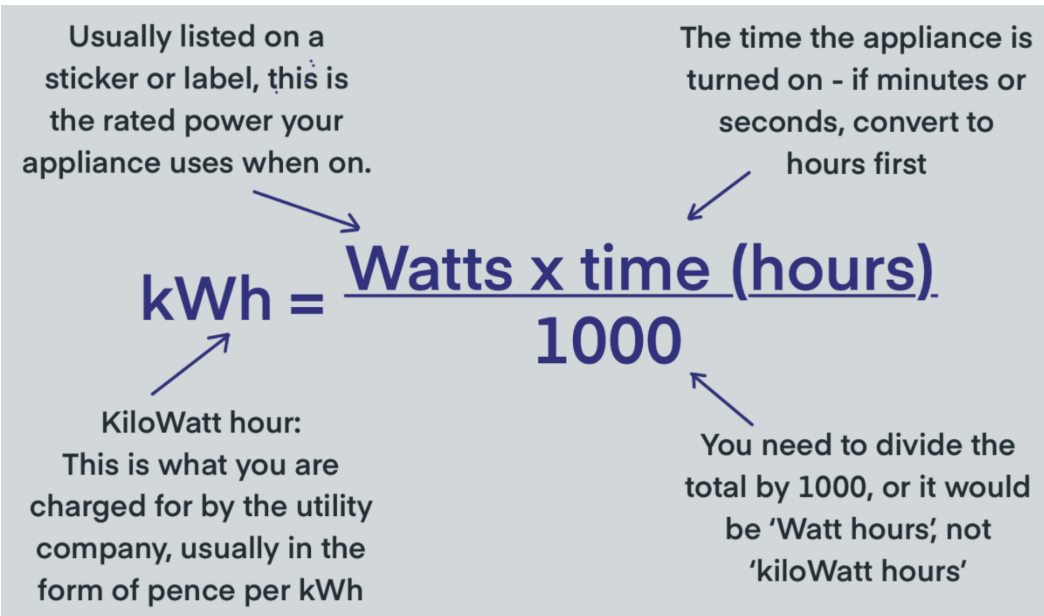


How much electricity are my solar panels generating?

Remember - if you have solar PV panels fitted to your school (or home), every kW/h of electricity they produce means one less kW/h that is being made from fossil fuels. It is also FREE electricity!

Your solar panels will come with a meter that tells you how many kiloWatt hours of electricity your panels are generating. This will be higher on sunny days than on cloudy days. Investigate the power consumption of your school appliances and can then calculate just what your panels are powering. Find out the standard unit cost of electricity in your area and you can calculate how much money they are saving you in free electricity.

It may be possible to get an energy monitor for use in your school or classroom. By looking at it, the children can see right away what impact is had on energy consumption by turning lights off and turning appliances off at the plug, rather than leaving them on stand-by.



Learning about solar power

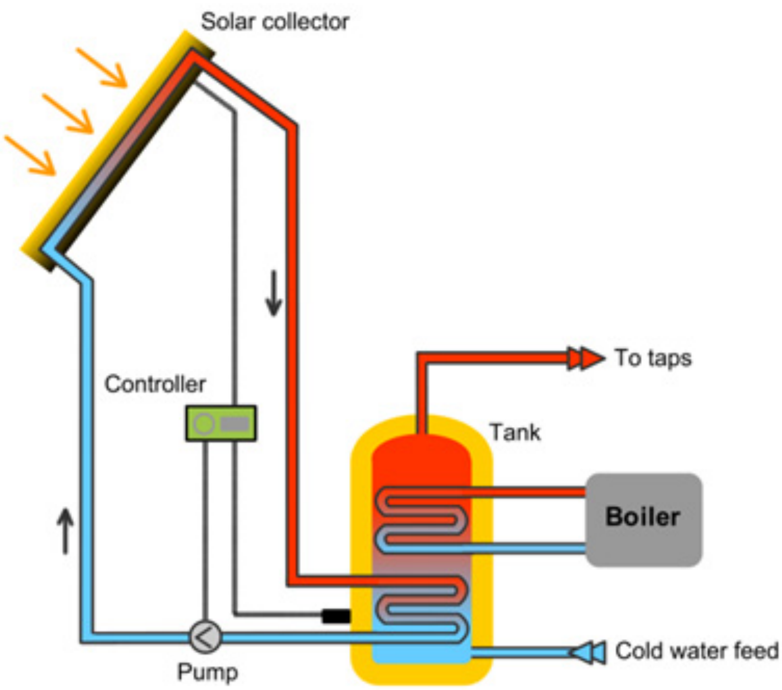
Learn about solar thermal

INITIAL TEACHING: It's possible to heat fluids up just by allowing the sun to shine on them. Light surfaces reflect more heat than dark surfaces. This is called the albedo effect.

You can explore this by taking two bottles of water (or use any sealed container). Cover one with white paper and one with dark black paper. The dark paper will absorb more heat from the sun than the white paper, which will reflect it off.

Leave the bottles in a sunny spot for an hour or two. The longer you leave them in the sun, the greater the effect will be. You should be able to feel the difference in temperature with your hand, but if you have a thermometer, you can measure how much warmer the black paper covered water is.

After observing this, embed learning by setting children mini challenges such as: how they could use this information:
* to heat a paddling pool up more quickly?
* to design a camping shower?
* to choose which t-shirt to wear on a hot day?



Solar thermal panels use the heat from the sun to heat water, or another fluid. This can then be used to heat people's homes or to provide the hot water for washing.

What is the sun made of?

The sun is a mass of gases that are burning at millions of degrees. To learn more about the sun - try this fun and very scientific song! The Sun Is a Mass of Incandescent gas: https://www.youtube.com/watch?v=3JdWISF195Y

Learn about Passive Solar Gain

INITIAL TEACHING: Ask children where the warmest country would be to build a house. If you lived in a very sunny country, where would you build a house to make it as cool as possible - in an open field, or in the woods? Why?
If you lived in a colder place, how could you design your house to gain maximum benefit from the sun's rays?

Provide children with boxes (cereal boxes are ideal - they need to be the same size) and challenge them to make a 'house' that uses the heat from the sun to keep it warm. Consider where the box needs to be positioned, what colour it should be and where any windows should be placed. Increase challenge by adding design parameters such as 'must have two windows and a door'. Test the designs by placing a thermometer inside and comparing the temperatures of the different 'houses' after a set period.

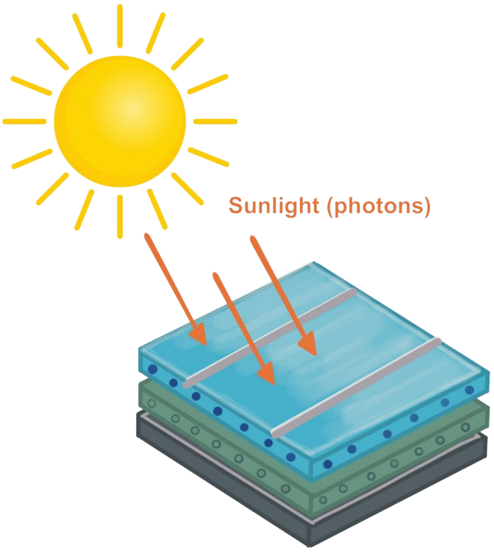
Learn about concentrated solar

For a simple demonstration of the way that concentrating the sun's rays can be useful for generating heat, try making this solar oven. On a sunny day, you should be able to use it to melt cheese, chocolate or marshmallows.

You will need:

*A pizza box
*Some aluminium foil
*sticky tape
*Scissors
*A pen or pencil
*A piece of wire (you can prop open the lid with a pencil if you don't have wire)
*A sheet of plastic film such as a file divider, some acetate or some food wrap.

First, you will need to cut a flap out from the lid of the pizza box. Next, stick your plastic over the hole you have just cut out. Cover the flap with the aluminium foil on the inside, to reflect heat on to your food when it is inside the 'oven' (You could use a mirror tile for a quicker effect). Line the box with more foil. Keep the shiny side of the foil outwards. Hold the flap of your oven open with a piece of wire, folded and taped into place. Adjusting the length of the wire will allow you to angle the flap so that the sun can hit the food inside. Place your completed oven in a sunny place. You can choose which sort of food to try melting. The steps are all available with linked photographs to follow here:
https://ypte.org.uk/downloads/home-learning-pack-energy-and-power



Learn about how PhotoVoltaic Cells work

Once children have the idea of electricity flowing through a circuit, and some idea of the properties of conductive and non conductive materials, they are better placed to begin thinking about the construction of photovoltaic cells themselves.

INITIAL TEACHING

If possible, take some small PV cells (such as those available online from hobby shops, or those found inside inexpensive solar garden lights) and allow children to dismantle them with supervision, in order to see the different layers.

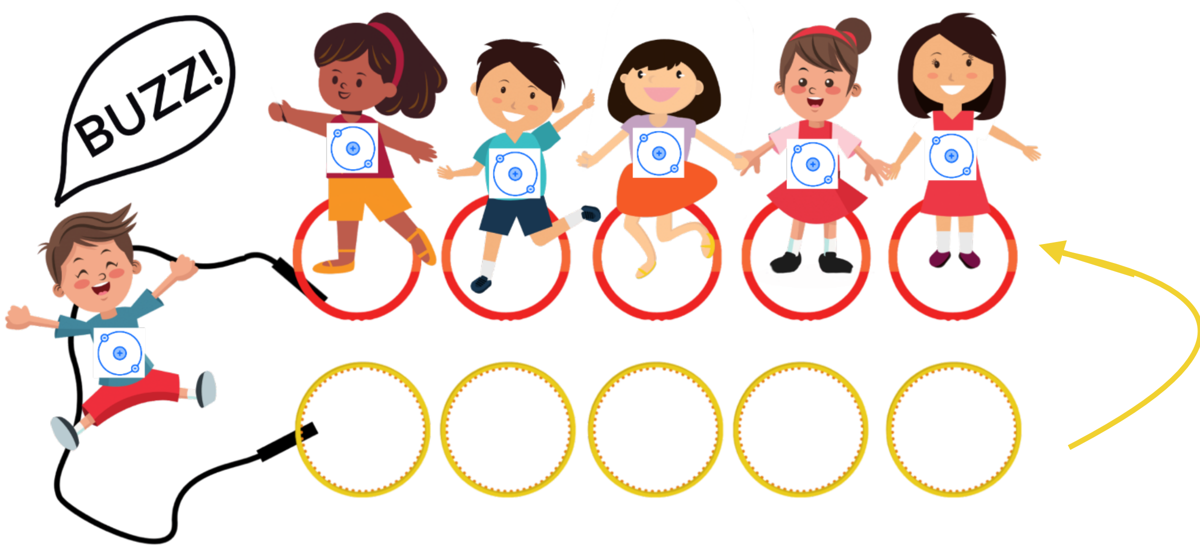
Show children diagrams of PV cells such as the one on the front of this resource pack and explain the function of each layer.

Over time, provide children with different ways to revise learning and explain the understanding that they have developed:
*Draw and label diagrams of the PV cells
*Watch videos about how they work such as this one from TED Ex **https://youtu.be/xKxrkht7CpY**
*Build models of PV cells out of building blocks or recycled materials then explain what each layer represents and what their role is in making the cell work.
*Invent games (physical games or board games) where players move round as electrons and photons.

Solar Cell Buzz game: This game helps children to imagine what is going on inside a photovoltaic cell. You may like to set the following game up for the children to play, using the game itself to teach the workings of the cell. Alternatively, you could explain the workings of a PV cell in class, then ask children to devise a game to demonstrate their understanding.

On one side of a sport pitch or marked area, place a row of hula hoops with children standing still in each one being electrons. They should hold each other by the shoulder to show they are locked together and cannot move. Make ‘electron’ signs for them to carry or mark them with sashes or bibs. This is the N type silicon in the cell with extra electrons.

On the other side of the pitch, lay out another row of hula hoops on the floor. This is the P type silicon that has holes for the electrons to flow into. Joining the two sides is a skipping rope representing the wire that the electrical current will flow through.



Other children act as the photons travelling towards the solar panel. They play the part of the photons running from the sun as fast as possible to tag an electron. They could wear a yellow sash. You can use a picture or large ball to represent the sun, several meters away from the 'panel' area.

As each electron is tagged by a photon it becomes excited and is able to move- jumping up and running to the first available hoop on the opposite side. As the next electron arrives behind the first, and the hoops are filled the children representing the flow of electrons have to run along the wire and back to their original position where the photons can tag them again.

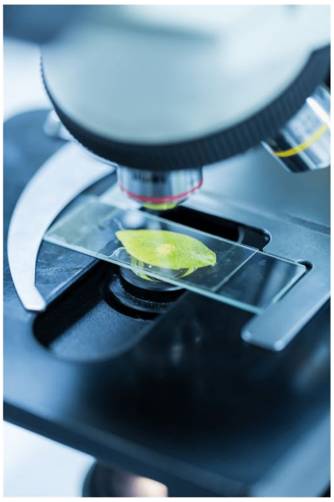
As the electrons travel along the skipping rope they shout "BUZZ!" to show they are now in a circuit producing electricity.

Check in at various parts of the game to ask players to explain what their role represents. Make sure that children have a turn to take different roles.
You may want to set up a series of play spaces next to each other with the resulting noise showing the additional electricity created by an array of cells!


Photo: Kris Krüg

Learn about a young solar inventor: This sequence of activities ideal for Upper Key Stage 2 helps to demonstrate that the way solar panels are arranged has an impact on their efficiency. It also shows that young people can be innovative and impactful when they link up areas of interest with creative thinking!

Aidan Dwyer was 13 years old when he became interested in the way that leaves grow on trees. During walks in nature, Aidan noticed that leaves seem to grow in certain patterns. When he thought harder about the reasons that plants have leaves, this led him to a discovery that made him a well known scientist.



Research Photosynthesis
- Watch videos about photosynthesis (such as **https://www.bbc.co.uk/bitesize/clips/z2k4d2p)**
- Study leaves close up with magnifying glasses, noticing the patterns of the veins.
- Make leaf rubbings and labelled sketches or diagrams of the leaves.
- Study different leaves under a microscope, or look online at images of leaf cells.
- Write explanation texts that explain how a leaf derives food from sunlight.

Investigate leaf patterns
- How do you think branches are arranged on the trunks of trees and leaves on the stems? Make a sketch to show how you think they might look.
- What purpose do the leaves of a plant serve? Remind children of previous work on photosynthesis.

* Take a walk in nature, or research trees online if this is not possible. Make sketches and scientific diagrams of branches and the ways they attach to the trunks of trees, and the way leaves attach to the stems
(There are opportunities here to study the difference between botanical drawing and more 'impressionist' art painting in a cross curricular link between art and science)
* Gather range of stems and notice position of leaves on the stems
* Make labelled diagrams

Key questions: WHY would it be important for the leaves on plants to grow in particular patterns?
WHAT could we learn from plants when it comes to solar power?

Research Aidan Dwyer and his invention / discovery
This discovery was made by a young person, simply because he was being observant and curious. Carry out research to find out more about his work and what he is working on now.

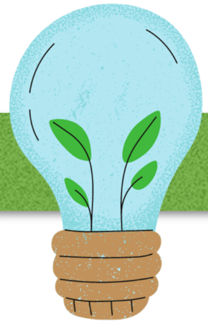
Build Photovolatic Arrays
Look at pictures of solar farms and houses with solar panels - what do you notice about how they are arranged?
Aidan Dwyer experimented with arranging PV cells in the patterns of branches on trees and the leaves on stems. Use PV cells from your solar kit, together with your research about plants, to build different arrays of panels.
Explore which array will generate the most electricity. You can do this by connecting the arrays to a device such as a motor to see how fast it spins, but it's also possible to connect your array to a USB charger for a very motivating real world example - which team can charge a phone most quickly with their array?! Can the children build arrays that are more effective than arranging the cells all laid out in the same direction, as they would be on a solar farm?

EXTENSION -
Learn about the fibonacci sequence - Aidan Dwyer noticed a link between the ways that branches and leaves were arranged on plants and the Fibonacci sequence. The Fibonacci Sequence is where each number is the sum of the two preceding ones:

0, 1, 1, 2, 3, 5, 8,13, 21, 34

This sequence of numbers is named after the Italian mathematician Leonardo Fibonacci, who introduced the sequence to Western European mathematics in 1202.
You might give students numbers from the pattern and see if they can work out the rule, or simply see how far they can continue the sequence.
Do some research to find out where else this pattern appears in nature.

Might this be the key to unlocking more answers in the hunt for sustainable power?



Learning about renewable energy

Solar power is not the only type of renewable or 'green' energy. You could also watch YPTE's video on renewable energy **https://ypte.org.uk/videos/renewable-energy**

Learning about wind power

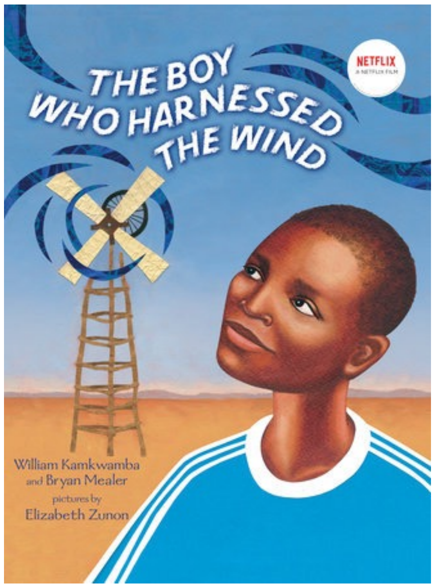
INITIAL TEACHING: The wind has been used as a source of power for centuries. The wind is formed because the sun doesn't warm everywhere in the atmosphere equally. Areas warmed by the sun create 'low pressure' zones as hot air rises. The colder air flowing in to the space created by hot air rising is what makes wind. Wind turbines can be used to generate electricity for use in our homes. The wind turns the propellor blades around a rotor which spins a generator to make the electricity.

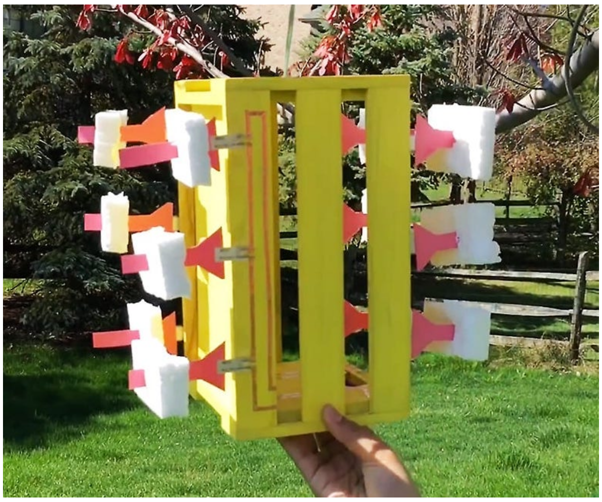
pros	cons
Renewable - the wind will not run out Produces no emissions The energy resource itself is free Wind farms can be built offshore Good value for money	The amount of electricity produced depends on wind strength If there is no wind, there is no electricity Wind farms can be noisy and spoil the view for people living near them High set up costs

Wind powered boats: Long before ships had engines, they travelled using only the power of the wind in their sails. The earliest wind-powered ships date back thousands of years to around 3000 BC! See if pupils can use recycled materials to build a simple boat. Even a small piece of card will float for a short time, but you can get inventive with upturned lids, take-away tubs and milk cartons cut in half. Sails could be made of paper or cloth and attached with a chop stick or twig and some modelling clay or taped on to a rolled up paper mast. Once children have constructed a boat, see whether they can power it along in a shallow bowl of water using only their breath, or a fan.

Build a model windmill: The first windmills were developed in the Middle East and China after sailors realised that wind could power more than ships! Early windmills were used to pump water and grind grain into flour. Use a recycled milk or juice carton to make a model of a windmill. If you attach the paper sails quite loosely, they should really spin in the wind. For detailed instructions on how to make this windmill visit: **https://ypte.org.uk/downloads/home-learning-pack-energy-and-power**

Find out about William Kamkwamba: When he was 14 years old, a severe famine in his native Malawi meant that William's family could no longer afford to send him to school. Refusing to give up on his studies, he attended a local library, where his interest in science led him to a book called 'Using Energy'. Working from a single photograph in that book, with no other instructions or help, William worked out how to build a wind turbine that could generate electricity for his village. His inspiring story is now the subject of a Netflix film and a book, both called 'The Boy Who Harnessed The Wind.





Find out about another young environmental inventor Maanasa Mendu who created a cheap way of generating electricity using **piezoelectric** material (material that generates a electricity from vibration).

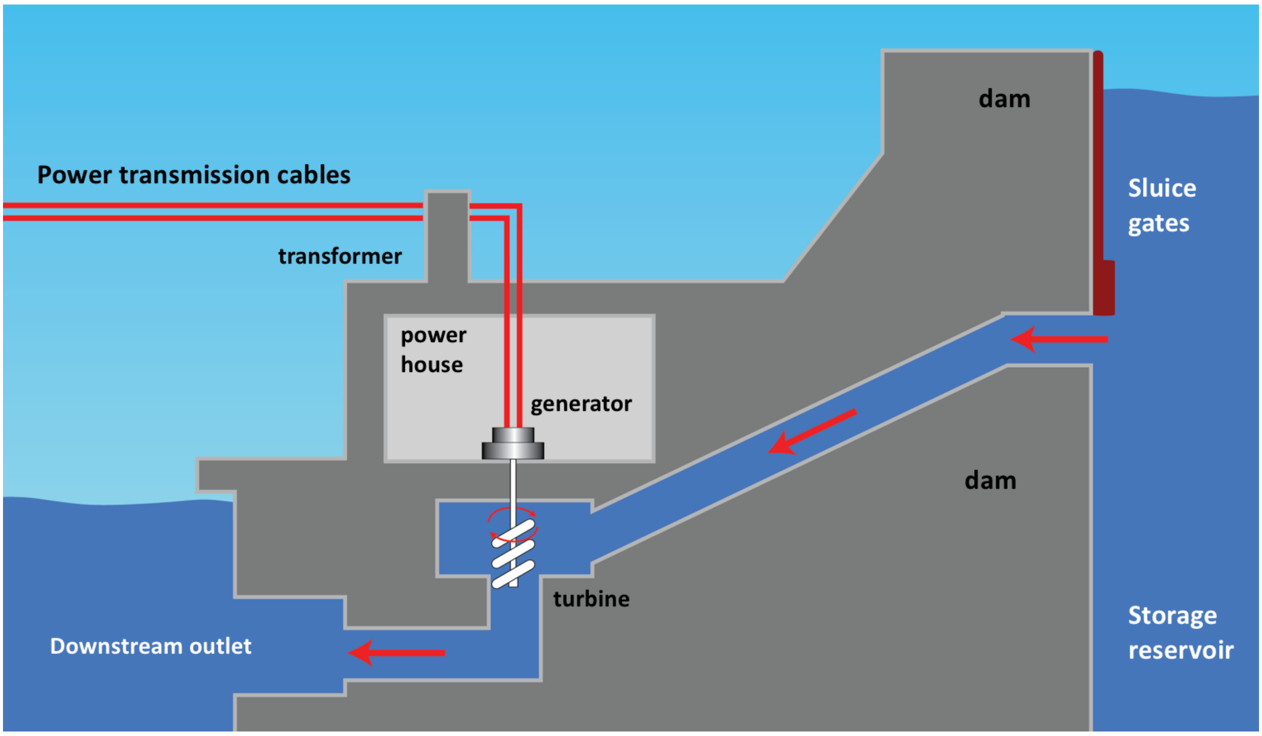
You can learn about her invention here: **https://youtu.be/z6HTkWEDexs**

EXTENSION -
Build a wind turbine:
Using a small DC toy motor (readily available online or in your science kit), children can work to develop their own wind turbine. You can also use a voltmeter to see how much electrical current the turbine produces (see this video clip: **https://youtu.be/_XSqPRl_Avk** for an explanation) and then challenge them to adapt the design to increase the turbine's output.

Learning about hydropower

INITIAL TEACHING: To create hydroelectric energy, a dam is built to trap water, usually in a valley where there is an existing lake. Water is allowed to flow through tunnels in the dam, to turn turbines and thus drive generators. The flow of water can be high pressurised, so can produce a lot of energy, but the building of the dams causes damage to plants and wildlife in the surrounding area.

pros	cons
Renewable - the water will not run out Produces no emissions once built The energy resource itself is free Reliable source of power Adjustable flow of water as needed (the dam can be opened and closed) Can create lakes	Building dams diverts natural waterways and has an impact on the environment and the animals and people who live in the area Limited possible locations Susceptible to drought High set up costs Risk of flooding in nearby areas



Above: diagram of hydroelectric dam.

Make a water powered turbine:

Give younger children plenty of opportunity to play in water trays with water wheels that clearly demonstrate that flowing water has the power to spin the wheel.

Older pupils can try to make their own water wheel that can lift a small weight on a string when the water wheel winds it up.

Use one cork, pierced through with a skewer. Cut slits in this cork using a craft knife (with supervision!). Insert 'slices' cut from a recycled plastic bottle to create the 'blades' of the propellor. Retain the neck of the bottle to use later.

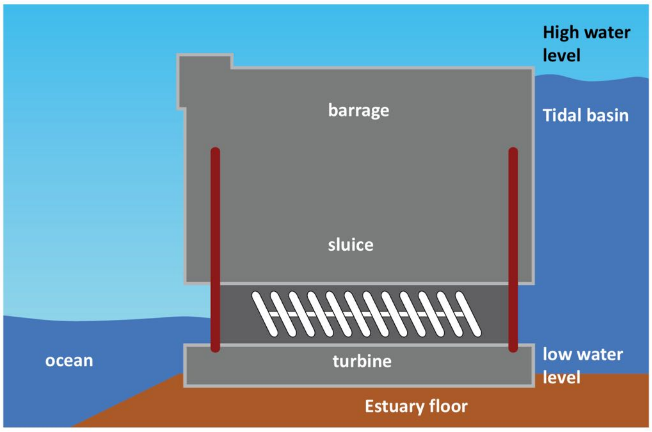
On one end of the skewer, poke a second cork. This one has a string or thread tied round it, which can be attached to a small object as a weight.

Mount the skewer over a funnel using tape, or two paper clips to balance it. Stand the funnel in the neck of the plastic bottle and place the whole turbine on a level surface, such as a tray, in a sink.

Turn on the tap, or pour water from a jug, allowing it to flow over the 'blades' of the propellor. Can you make the skewer spin so that the string winds round the cork and lifts the weight? This is one way of turning the power of the water into energy that we can use to do work.

Learning about tidal power

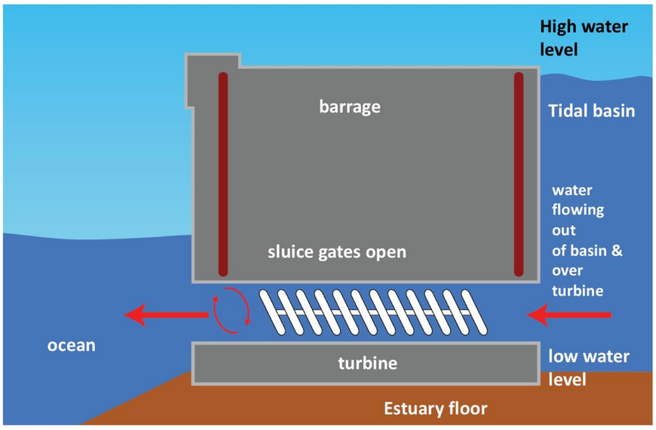
INITIAL TEACHING: Tidal energy is produced by the tides of the sea. These are created by the pull of gravity from the moon and the spin of the Earth. There are three main ways that tidal power can be used to generate electricity



Tidal Barrages - When the tide is high, a reservoir fills up. When the tide drops, a dam lets the water out. The moving water can spin the blades of turbines as it travels both in and out of the reservoir, to create electricity.

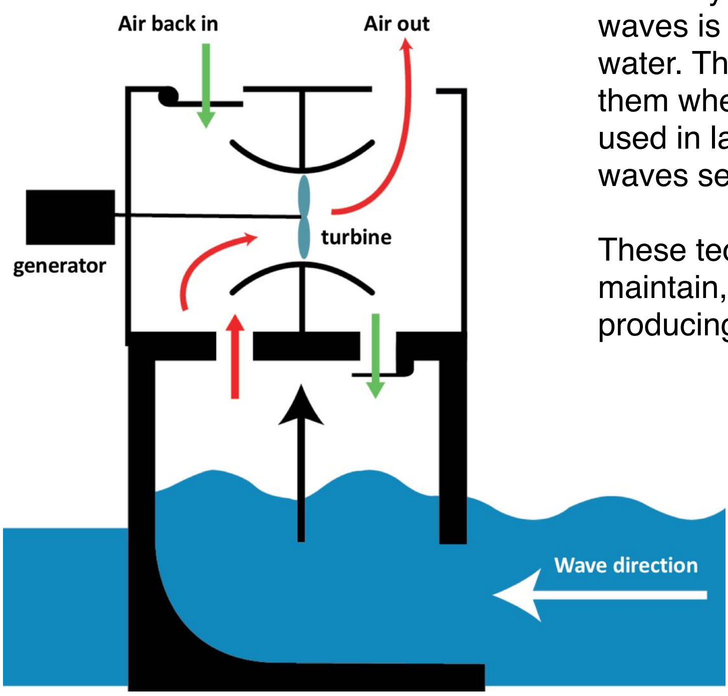
Tidal Fences - These are not as large as a tidal barrage. Several turbines stand up like a fence between two areas of land. When the tide moves in and out, the water spins the turbines and generates electricity.

Tidal Turbines - These are separate turbines which can be placed on their own anywhere there is a strong tidal flow.



Learning about wave power:

INITIAL TEACHING: Wave power is energy from the movement of the waves in the sea. These are caused when the wind blows the surface of the water. (Some waves are also caused by gravity, like with the tides). There is an enormous amount of energy stored in waves. If we could find an efficient way to harness wave energy, we'd have enough free electricity to power all of our needs… but for now, we're still waiting for people to invent the technology that will make that happen.



One way that we are able to capture energy from the waves is to place floating turbines on the surface of the water. The turbines spin as the waves push air past them when they flow in and out. A similar method is used in large tubes, where the rising and falling of the waves sends pressurised air through a turbine.

These technologies are expensive to build and maintain, so they are not yet a cost effective way of producing electricity.

This video explains some of the problems scientists and engineers face when they try to generate electricity from the waves: **https://youtu.be/PMRiKmgxrh0**

Create a wave: As we have seen in previous learning, apart from solar PV panels, our other methods of generating electricity rely on spinning turbines. This is what makes it so hard to generate power from the waves. Ask a pupil to volunteer to be spun round (either whilst standing, or perhaps on an office chair!) Ask a line of children (represent a flow of water) to pass the volunteer, each giving them a little push to keep them spinning. When the flow of water (or wind) is moving sideways like this, it's not too hard to spin a turbine. Next, ask a line of children in chairs to create a wave by each standing up and sitting down in succession. Notice that, in this case, the water is NOT moving in a line. Using this up and down motion to spin the turbine is harder to achieve.

pros	cons
Renewable – waves and tides will not run out	Hard to 'scale up' energy production over a large area
Waves and tides are predictable	People who live far from the sea don't really benefit.
Produces no emissions	Setting up and maintaining the technology is very expensive and we don't know how long it would be able to last for
The energy resource itself is free	Can disturb marine life and shipping lanes
Doesn't damage the land	
High energy potential	
Lots of ways to harness the energy	

Where does our power come from?

Conduct a survey to find out which energy suppliers provide the electricity for school and in pupils' homes. Carry out research to find out what percentage of this energy came from renewable sources in the past year. If you have solar panels at school, you can work out what percentage of your electricity they generated in a year!

Pros and cons of energy resources

Children can make a table to list the types of energy sources that they learn about through the year. They should include a column for the type of resource (such as coal, wind, or hydropower) and then a column for the pros and one for the cons of each.

Use the information to support discussion and debate about the benefits of different energy sources.

Roleplay: Take on the roles of different characters and consider how they might feel about different kinds of energy use. Imagine:

* A child whose asthma is very badly affected by smoke and traffic pollution.
* A person whose view from their garden has been blocked by a wind farm.
* A businessperson who is very rich from selling oil.
* An environmental campaigner who is concerned about climate change.
* A person who lives by a river which is about to be diverted to build a hydroelectric dam.
* An inventor who is building a turbine designed to capture wave energy.

Hot seat discussions between different pairs and groups of people. Are there people who are in agreement over some aspects of an energy source but not others? Are there people who cannot agree at all? Who gets to decide which energy source is used?

Some issues with batteries

One of the challenges facing us as we move towards greener energy (such as electric cars and a greater use of solar power) is the issue of energy storage.

Solar power is useful when there is bright sunlight, but to store power for use in the dark and on days when the weather is cloudy, we need huge battery banks. It's important to have a stable supply of electricity - we'd be quite annoyed if we kept having power cuts in our homes, but a power outage at a nuclear power plant could be a disaster.

Stable electricity from renewable sources is hard to achieve, so different methods are used to try and store energy when it is being produced, to use when supply is lower. Pumped water storage uses reserves of electricity to pump water from a low reservoir to a higher one. This allows the energy to be stored (as potential gravitational energy). When it is needed, the water can be released to flow back down to the lower reservoir, past turbines, that generate more electrical energy.

Another type of storage is achieved with banks of huge lithium-ion batteries. These are used to hold energy as chemical energy until it is needed, when it can be converted to electrical energy. Some of the biggest battery storage plants in the world are the Hornsdale Power Reserve in Australia and the Moss Landing Storage System in California (both use lithium-ion Megapack battery storage built by TESLA).

These giant batteries are like much larger versions of the ones needed to run electric vehicles. The lithium that the batteries use is mined from the ground and, whilst they can be recharged a certain number of times, eventually they will run down and stop working. What will we do with all of the used up batteries? What will be the effect of so much lithium mining? As we move towards 'greener' power, these are some questions we will need to ask, if we are not to store up problems for the future.

Left: TESLA Megapacks being installed in Moss Landing, California (image: teslarati.com)

The Chemetall Foote lithium mine in Clayton Valley, Nevada, US.

Learning about saving energy

INITIAL TEACHING: Electricity is valuable and we should try not to waste it. Lots of electricity is still made using fossil fuels which harm the environment. The more efficient we can be with electricity, the better it is for the planet - and the more money we save to spend on other things!

Keep an energy journal: Challenge pupils to record their electricity consumption over a typical week. (This might vary in the summer, compared with the winter, so you might want to repeat the activity in different terms - this might also show improvements!) Younger children might just record the electrical appliances that they use, whilst older pupils can try to calculate how many kiloWatt hours of energy they have consumed.

Make an energy pledge: Having taken note of their journal findings, children think about which activities they can reduce in order to save the most power. This might include:

- Taking a shorter hot shower
- Turning appliances off at the plug when not in use
- Making sure lights aren't on in empty rooms
- Turning the heating down by one degree

Children can then record any actions they have taken to reduce their energy use in school or at home and can calculate how much electricity they have saved.

Walk or Cycle to school:

Cars burn fuel to make them go (unless they are electric) and this creates harmful emissions. Take part in a walk or cycle to school campaign to encourage those pupils who can to travel to school by foot, bicycle or scooter.

Have an up cycled clothing fashion show!
Find out about the impact of Fast Fashion on the planet. The fashion industry uses lots of electricity and causes huge amounts of pollutants to enter the atmosphere each year. Yet many people love buying brand new clothes and their old ones are just thrown away to rot in landfill.
Learn to mend and up-cycle clothes in DT lessons and host a second hand swap shop at school. Host a fashion show for children to show off their recycled or up-cycled clothing looks and make second hand fashion cool at school!

Recycled art lessons.

Plastic production uses an enormous amount of electricity and waste plastic harms the environment. How can we use art to draw people's attention to environmental issues?

Expand on children's understanding of recycling and energy conservation by studying the work of artists who use recycled plastics and other found items to make commentaries about the environment.

Artist Steven McPherson works in found plastics. He has been collecting found plastic debris for over 15 years, turning a litter picking and recycling habit into an art form.

Use Steven's scrap books of found paper and card ephemera as inspiration for class or personal repositories of found objects.

Study the piece "Ritual Objects" (2019) and discuss the idea of this work as art. What is a ritual? Why do people practise them? At what point does something stop being rubbish and start being ritual, or art? Children could gather their own items (with appropriate measures in place to clean any found items - perhaps setting up and area for soaking and sterilising) and then work in available time slots to produce small 'ritual' objects. Display these altogether and notice the power of many small items making a bigger impact as a group. Does this help make something art? Is this a bit like the effect of many pieces of rubbish having a big impact all together in nature?

Explore Steven's piece " Variables - Patterns' (2010). Here, differently coloured plastics have been arranged based on the average temperature for the summer that year. In what ways might a piece of art like this be used to talk about climate change?

Washed Ashore is a project started by artist Angela Hazeltine Pozzi. The group she runs makes enormous statement pieces from marine debris that has been washed ashore. A series of excellent learning resources are provided here: **https://www.washedashore.org/curriculum/** and would lend themselves to a year long project, possibly culminating in a whole school recycled creature being built from gradually gathered recycling.