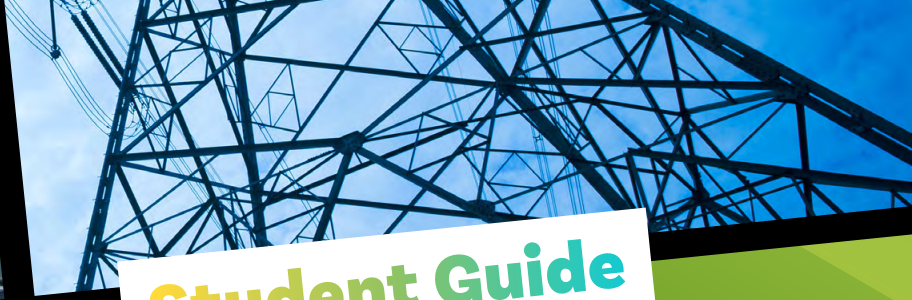
Royal Academy of Engineering



THIS IS ENGINEERING

Student Guide

POWER UP!

This STEM resource looks at different types of energy, energy in engineering, the importance of electricity and how this is generated. It investigates different types of renewable energy through a number of hands-on and practical activities.

Curriculum links

Science: Energy stores and transfers, Generating electricity
Maths: Problem solving using percentages, Area and perimeter
Design technology: Identify, solve and reformulate given design problems

CHANNELING OUR ENERGY

Time to think

- What does the word 'energy' mean to you?
- Share three sentences using the word energy in different ways.

Energy is a **conserved quantity** measured in **joules**.

Energy is stored in different ways and transferred from one store to another. The faster energy is transferred, the greater the power.

Where is energy stored?

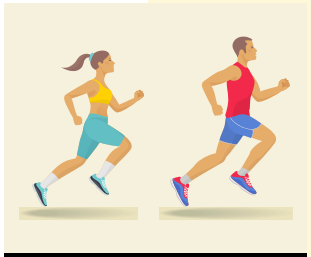
There are eight types of energy store:

1. A hot drink holds energy in a **thermal store**
2. A moving car or moving particles holds energy in a **kinetic store**
3. A stretched elastic band holds energy in a **elastic potential store**
4. A ball placed on a high shelf holds energy in a **gravitational potential store**
5. Batteries, petrol and food all hold energy in a **chemical store**
6. A thunderstorm holds energy in an **electrical store**
7. A magnet can hold energy in a **magnetic store**
8. A radioactive atom, nuclear bomb or the core of the Sun holds energy in a **nuclear store**.

Share a different example for each energy store.

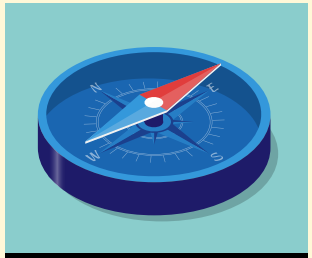

Thermal


Gravitational


Kinetic


Chemical


Nuclear


Electromagnetic


Electrical

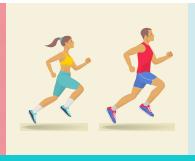
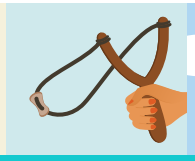

Elastic

Time to discuss

What might be happening in each example? Use your explanation for each example to tick each box that connects the energy store to the example. There maybe more than one energy store in each example.

Stretch and challenge

For each example, think of different states for the example. How does this affect the energy stores?

	 Thermal	 Kinetic	 Elastic potential	 Gravitational potential	 Chemical	 Electrical	 Magnetic	 Nuclear
Calculator								
Dry-cell battery								
Runner								
Explosion								
Hydro-electric dam								
The Sun								
Hot air balloon								
Catapult								
Your own example								

ENERGY CIRCUIT

We cannot create or destroy energy but we transfer (change) energy from one store to another. There are four ways of transferring energy:

- By **radiation** – such as light, microwaves or infrared waves
- By **heating** – because of a temperature difference
- By **mechanical working** – when a force moves through a distance
- By **electrical working** – when charges (electrons) move through a circuit

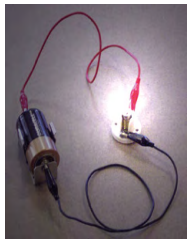
Visit each of the stations set up around your classroom/use the images shown to fill in the missing words about energy stores and transfers. The first one is completed for you as an example.

Teacher note

Set stations up around your classroom with each of the mini experiments and give pupils a set amount of time at each station to work out the missing stores and transfers.

The experiments given are just examples, adapt these to use equipment that you have available in your school.

A light bulb connected to a cell (example)



ENERGY **CHEMICAL store** (in the battery)

TRANSFER → electrically in the wires

ENERGY **THERMAL store** (in the lamp)

TRANSFER → by radiation

ENERGY **THERMAL store** (in the room)

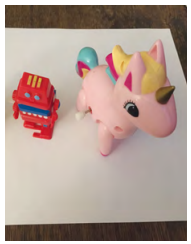
Hour glass

ENERGY _____ **store** (in the sand in the hourglass)

TRANSFER → _____

ENERGY _____ **store** (in the moving sand)

Wind-up toys



ENERGY _____ **store** (in your body)

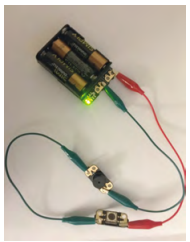
TRANSFER → mechanical

ENERGY **ELASTIC store** (in the wind up toy)

TRANSFER → _____

ENERGY _____ **store** (in the moving toy)

Buzzer connected to a battery pack and a switch



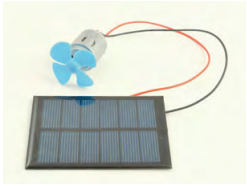
ENERGY _____ **store** (in the battery)

TRANSFER → _____ **TRANSFER** → _____

ENERGY _____ **store** (in the room)

Solar-powered fan

(do this outside if possible/near a window otherwise use a lamp)

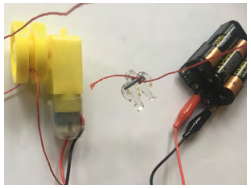


ENERGY _____ store → TRANSFER _____ → TRANSFER _____ → ENERGY _____ store

Yo-yo

ENERGY _____ store → TRANSFER _____ → ENERGY _____ store → TRANSFER _____ → ENERGY _____ store

An electric motor is used to raise a small mass attached to a piece of string



ENERGY _____ store → TRANSFER _____ → ENERGY _____ store → TRANSFER _____ → ENERGY _____ store

Lamp powered by mains supply and a black box with a thermometer inside

TRANSFER _____ → TRANSFER _____ → ENERGY _____ store

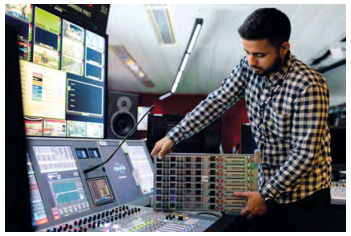
ENERGY IN ENGINEERING

Below are images of engineers at work in different industries.

What do you think is happening in each photo?

Match the image to the energy stores and/or transfer that you think is being represented. Each image could be matched to more than one energy store.

Explain your answers.











Energy stores

- Electrical
- Kinetic
- Magnetic
- Nuclear
- Thermal
- Gravitational
- Chemical
- Elastic

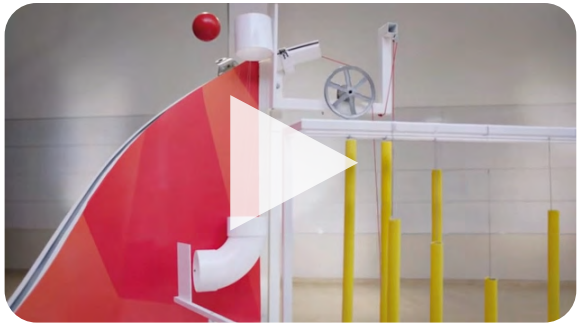
Energy transfers

- Heat
- Radiation
- Mechanical
- Electrical

RUBE GOLDBERG ENERGY EXPERIMENT

A Rube Goldberg machine is a machine designed to perform a simple task in an indirect and overly complicated way.

The machine usually consists of a series of unrelated devices; the action of each triggers the start of the next.



This advert by science-based technology company 3M used a Rube Goldberg machine for their advertising.

Watch the video on YouTube (www.youtube.com/watch?v=GEzcO3nfjZk) and describe the **energy stores and transfers** that are happening.

Energy stores	Energy transfers

Time to build

Make your own Rube Goldberg machine

Materials

- Glue
- Cardboard
- String
- Paperclips
- Marbles
- Dominoes

And anything you can recycle from home or school. Get creative!

ELECTRICITY EVERYWHERE?

Time to think

We rely heavily on appliances, devices and technology that are powered by electricity.

- How do we use electricity? Think of as many ways as you can.

In 1879 Thomas Edison was able to produce a reliable, long-lasting electric light bulb that revolutionised industry across the world!

- How has the way we have used electricity changed over the last 150 years?
- How do you think the we way use electricity will change in the next 50 years?

940 million people around the world have no reliable access to electricity*!

- Having no access to electricity has what sort of impact on people?
- What do you think affects access to reliable electricity?

This number has been slowly decreasing since 1990, but there is still a long way to go!

World leaders recognise that ending poverty and other deprivations go hand-in-hand with strategies that ensure everyone has access to affordable, reliable and sustainable energy.

Many have made a pledge to ensure that this happens as part of the **Sustainable Development Goals** www.un.org/sustainabledevelopment/sustainable-development-goals/.

*Source: https://ourworldindata.org/energy-access#what-share-of-people-have-access-to-electricity

SUSTAINABLE DEVELOPMENT GOALS

7 AFFORDABLE AND CLEAN ENERGY

Ensure access to affordable, reliable, sustainable and modern energy for all.

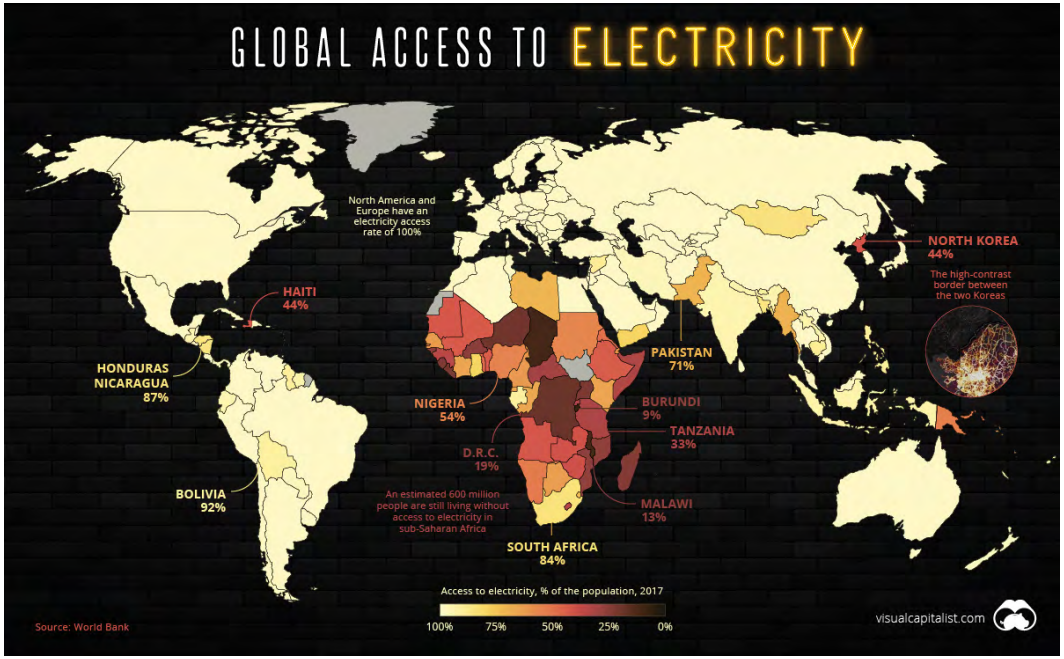


Image courtesy of www.visualcapitalist.com/mapped-billion-people-without-access-to-electricity/

HOW DO WE GENERATE OUR ELECTRICITY?

Electricity needs to be generated from other sources of energy. This includes burning coal, natural gas, oil, nuclear power and other natural sources.

Large machines called **turbines** are turned very quickly to produce continuous power. This requires a lot of energy from high pressure steam, wind or moving water.

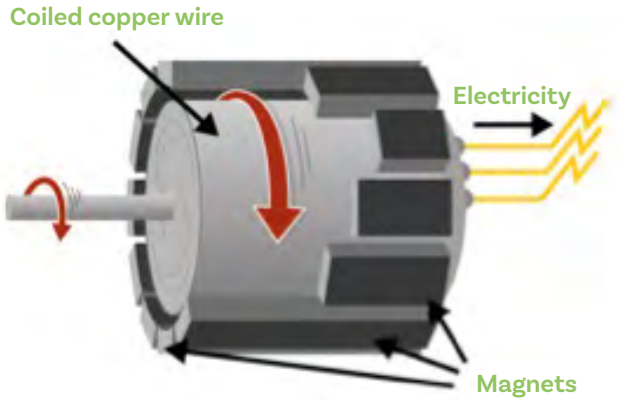
The spinning turbines cause large magnets to turn within copper wire coils – these are the **generators**.

Generators are machines for converting kinetic energy into electricity.

The moving magnets within the coil of wire cause electrons (charged particles) to move within the wire – this is the electricity!

Time to think

What energy transfers do you think are happening to generate electricity?



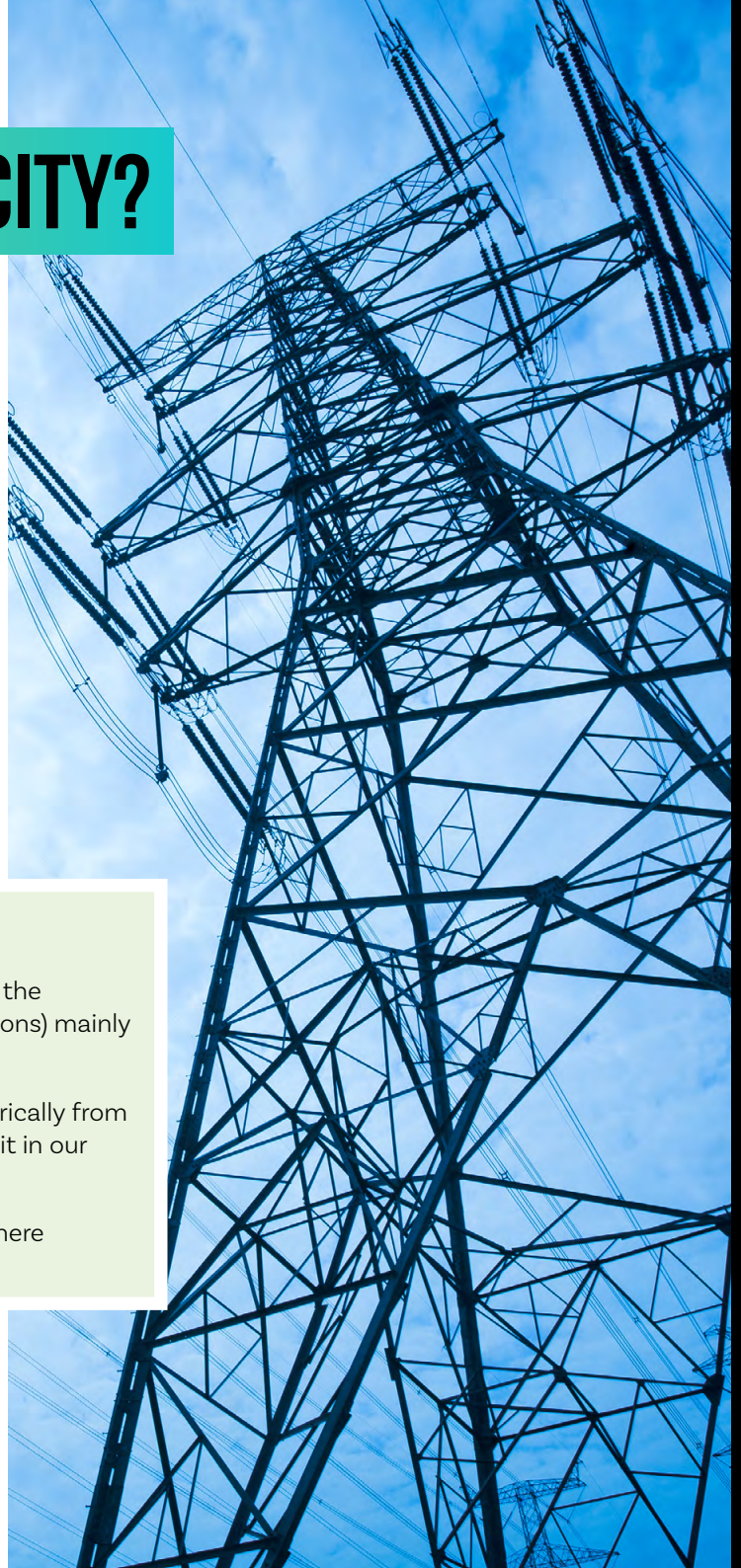
Generator

What do we mean by...

Electric current? An electric current is the movement of charged particles (electrons) mainly in a wire.

Electricity? Energy is transferred electrically from where it is generated to where we use it in our homes and schools.

Power stations? Power stations are where electricity is often generated.



HOW MANY ROWERS DOES IT TAKE TO POWER...?

Rowing machines are essentially energy-transfer machines: a pulley system which transfers the chemical energy in your muscles to kinetic energy in a fly-wheel.

Using an alternator (a small generator) we can power our own household appliances!

A rower from Team GB rowing squad can hold a steady pace of 1:56 per 500 metres.

Using the pace-to-Watts calculator (www.concept2.co.uk/indoor-rowers/training/calculators/watts-calculator), this equates to a power output of 224 watts.

If our device is roughly 45% efficient, how much power will one rower output?

If you recharged your phone every day for a year, it would need approximately 2,000 watts of power.

Approximately how many rowers would it take to generate this much power?

How many rowers does it take to power a house?

A team of rowers from the University of Nottingham (https://phys.org/news/2012-07-world-rowers-electricity-power-house.html) generated enough electricity to power a house for 24 hours.

If the average UK household consumes approximately **4,000 kWh** of electricity per day, how many rowers would be needed to power the house?

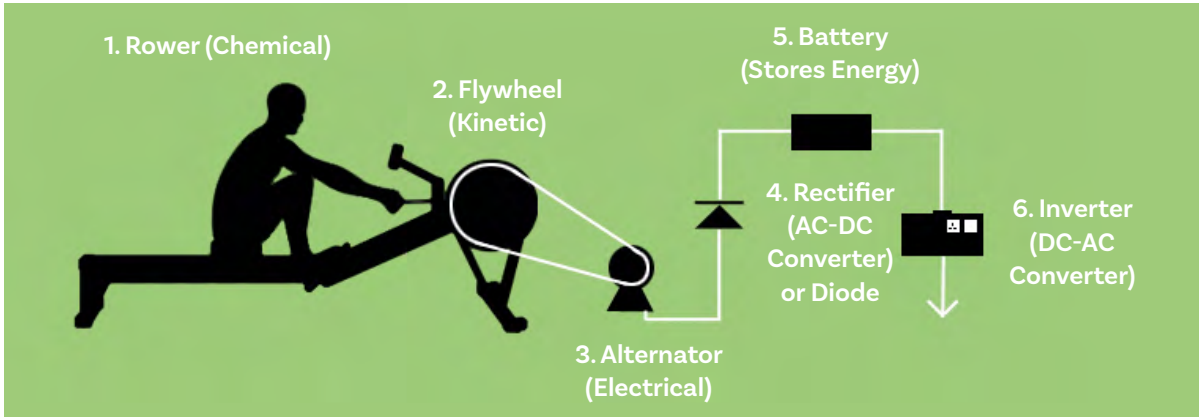


Image source: bangscience.org

Maddie Arlett
Team GB Women's rowing squad

Image courtesy of www.britishrowing.org

What do you mean by...

Power is the amount of energy being transferred per unit of time.

Power is measured in **watts**.

One watts is equal to one joule (energy) per second.

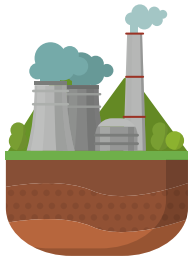
Kilowatt hour (kWh) is a measure of **energy**.

For example if you switched on a 100 watt light bulb, it would take 10 hours to reach 1 kWh of energy.

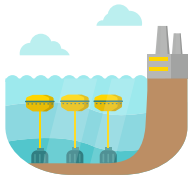
A 1000 watt drill needs 1000 watts (1 kWh) of power to make it work and uses 1 kWh of energy in an hour.

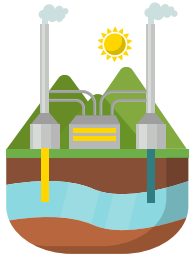
RESOURCES THAT GENERATE ELECTRICITY

Sort the resources into renewable and non-renewable

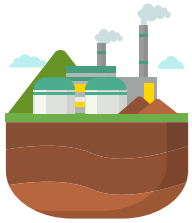

Nuclear


Wind

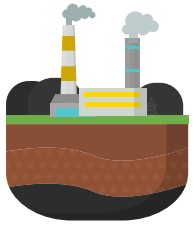

Wave

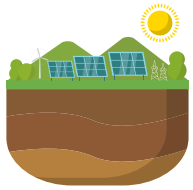

Geothermal


Tidal


Biomass


Oil


Coal


Solar


Hydroelectric

Time to research

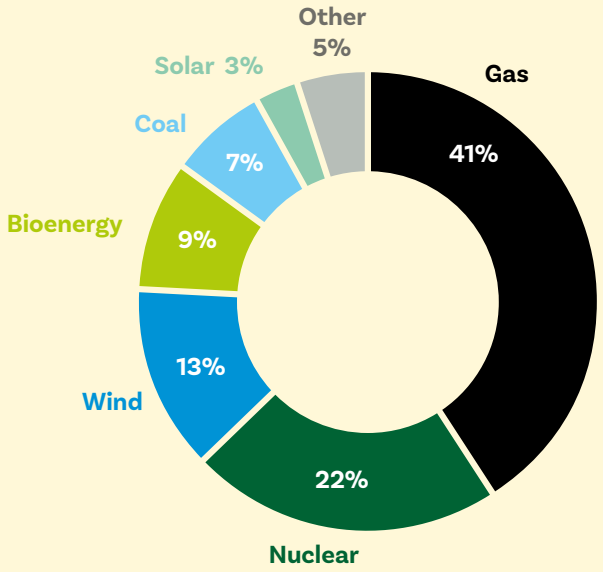
In small groups, choose one renewable and non-renewable from the group above.

- How does it generate electricity?
- Where is it often used?

Time to calculate

The average annual electricity consumption of a household is approximately 3,500 kWh.

Calculate how much electricity is generated from each resource using the chart (right).



UK electricity generation

Proportion of total electricity generated from different sources in the 12 months ending September 2017

Source: Department for Business, Energy and Industrial Strategy, Energy trends: electricity, tables 5.1 and 6.1

SOLAR POWER

In less than 15 seconds the Sun can provide as much energy to Earth as humans use in one day!

That is enough energy to melt a bridge of ice four kilometres wide, two kilometres thick, and extending the entire way from the Earth to the Sun, in one second.

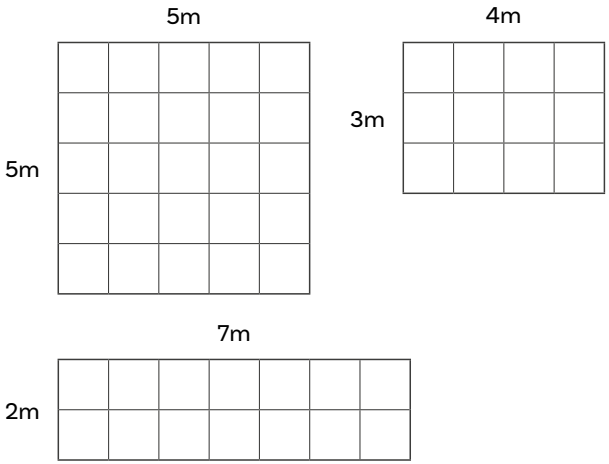
Solar panels use sunlight to generate electricity.

Solar panels now convert around 19% of the Sun's light to power. On a clear, sunny day, one square metre of earth will receive around one kilowatt of power.

Time to calculate

1 kilowatt = 1,000 watts

How many watts of power will be generated from a solar panel measuring one square metre? How many watts of power will be generated from each of the solar arrays shown below?



Time to investigate

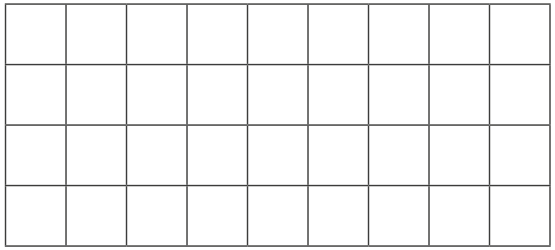
You have been given 36 square metres of solar panels.

On a clear, sunny day, approximately how much energy would these solar panels produce?

One way to position the solar panels is shown below.

For your design, consider different arrangements for your solar panels so that they can be used in different settings.

How many other arrangements can you create? What is the perimeter of the solar panel arrangement below? Which arrangement would have the smallest perimeter? Which arrangement would have the largest perimeter?



***Teacher note:** divide a piece of A4 paper into 36 equal size pieces so young learners can 'tinker' with this activity.

Stretch and challenge

You are not restricted to positioning your panels in rectangles.

- What other arrangements can you make?
- How does this affect the perimeter of the solar panels?

WIND POWER

Electricity generated from wind turbines is low-carbon and becoming less expensive.

Wind is the UK's strongest source of renewable energy and in 2019 made up approximately 20% of the UK's electricity with many on and off-shore wind farms opening.

Time to build

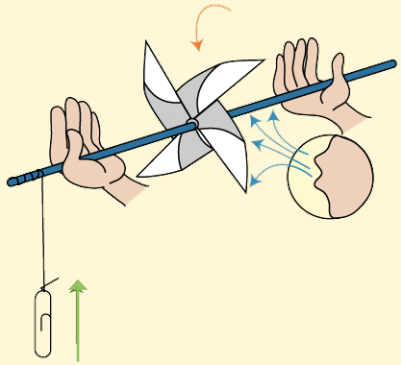
Design and build a wind turbine that will lift a paperclip attached to a piece of string.

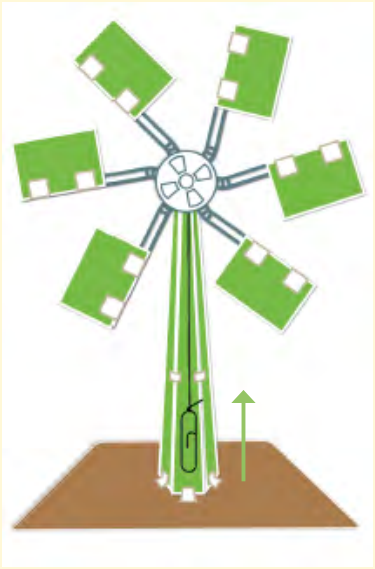
Test different designs.

- Which are most affective?
- Why do you think?

Materials

- Recycled cardboard
- Recycled card
- Paperclips
- String
- Sticky tape
- Straw
- Any other materials you can find at home or at school





What energy stores and transfers are happening?

Tip: Use a cotton reel as the centre piece of your wind turbine.

Time to research

How does a wind turbine generate electricity?
Research different types of wind turbines.

BIOMASS

Biomass energy is the use of organic material to generate energy. Think about stuff made in nature – like wood pellets, grass clippings and even poo!

It is considered a renewable energy source as we can keep growing more plants and trees. However it is not an infinite resource as there is only so much land and water to grow plants.

Biomass is sometimes thought of as the original source of energy – discovered when we realised wood could burn!

There are number of ways electricity can be generated, but most common is **combustion**.

Agricultural waste or woody materials are burnt to heat water and produce steam which spins turbines.

Is generating energy from biomass a good use of land and resources?

Making the case

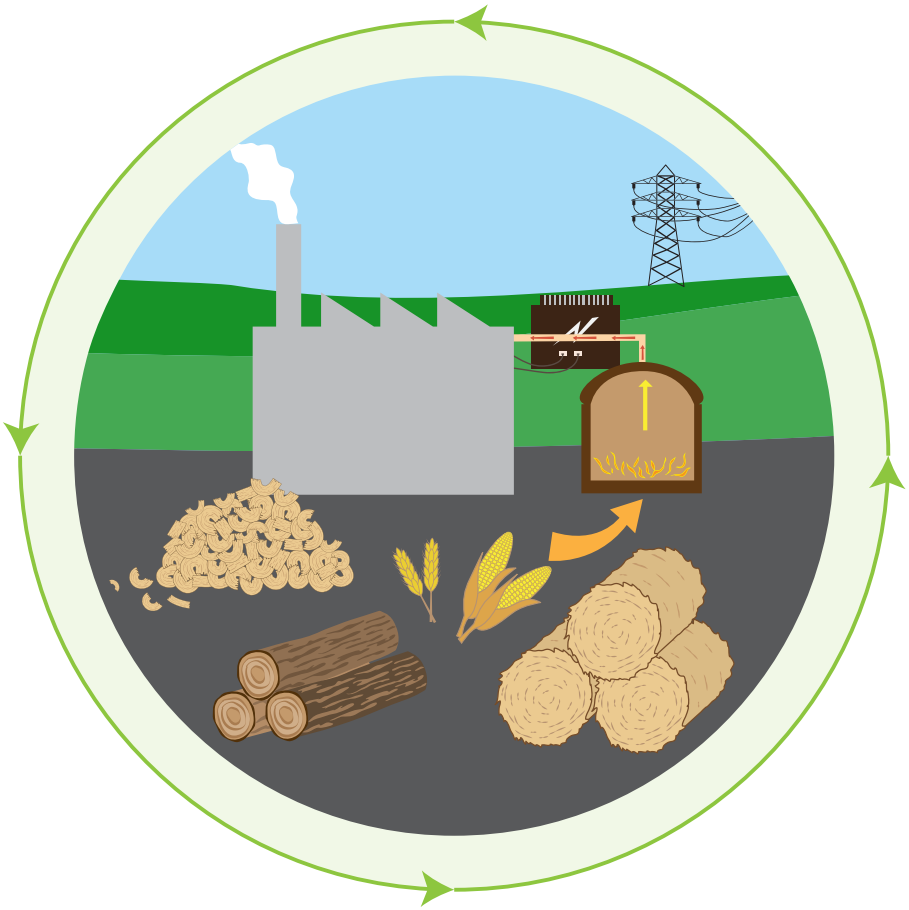
You are working as part of team deciding on how much to invest in biomass energy.

Divide your class or group into two groups.

One group to research advantages of biomass and the other group disadvantages.

Present a convincing argument in under one minute around whether we should use biomass or not.

Biomass energy



NOTES

Royal Academy of Engineering

The Royal Academy of Engineering is harnessing the power of engineering to build a sustainable society and an inclusive economy that works for everyone.

In collaboration with our Fellows and partners, we're growing talent and developing skills for the future, driving innovation and building global partnerships, and influencing policy and engaging the public.

Together we're working to tackle the greatest challenges of our age.

What we do

Talent & diversity

We're growing talent by training, supporting, mentoring and funding the most talented and creative researchers, innovators and leaders from across the engineering profession.

We're developing skills for the future by identifying the challenges of an ever-changing world and developing the skills and approaches we need to build a resilient and diverse engineering profession.

Innovation

We're driving innovation by investing in some of the country's most creative and exciting engineering ideas and businesses.

We're building global partnerships that bring the world's best engineers from industry, entrepreneurship and academia together to collaborate on creative innovations that address the greatest global challenges of our age.

Policy & engagement

We're influencing policy through the National Engineering Policy Centre – providing independent expert support to policymakers on issues of importance.

We're engaging the public by opening their eyes to the wonders of engineering and inspiring young people to become the next generation of engineers.

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