Bio-energy
what is bio-energy?

Biomass is plant and animal matter, such as wood, straw, sewage and waste food.

We can burn these natural materials to produce heat and electricity. The Earth's biomass is a huge store of energy, which is continually renewed by the sun through photosynthesis.

The power we produce from biomass is called **bio-energy**. People all around the world use wood, rice husks and other plant and animal material (biomass) as fuel to create heat (bio-energy) for use on a small scale.

Oil from oilseed rape can be used as fuel.

Photo courtesy of DEFRA. Crown copyright.

How does bio-energy work?

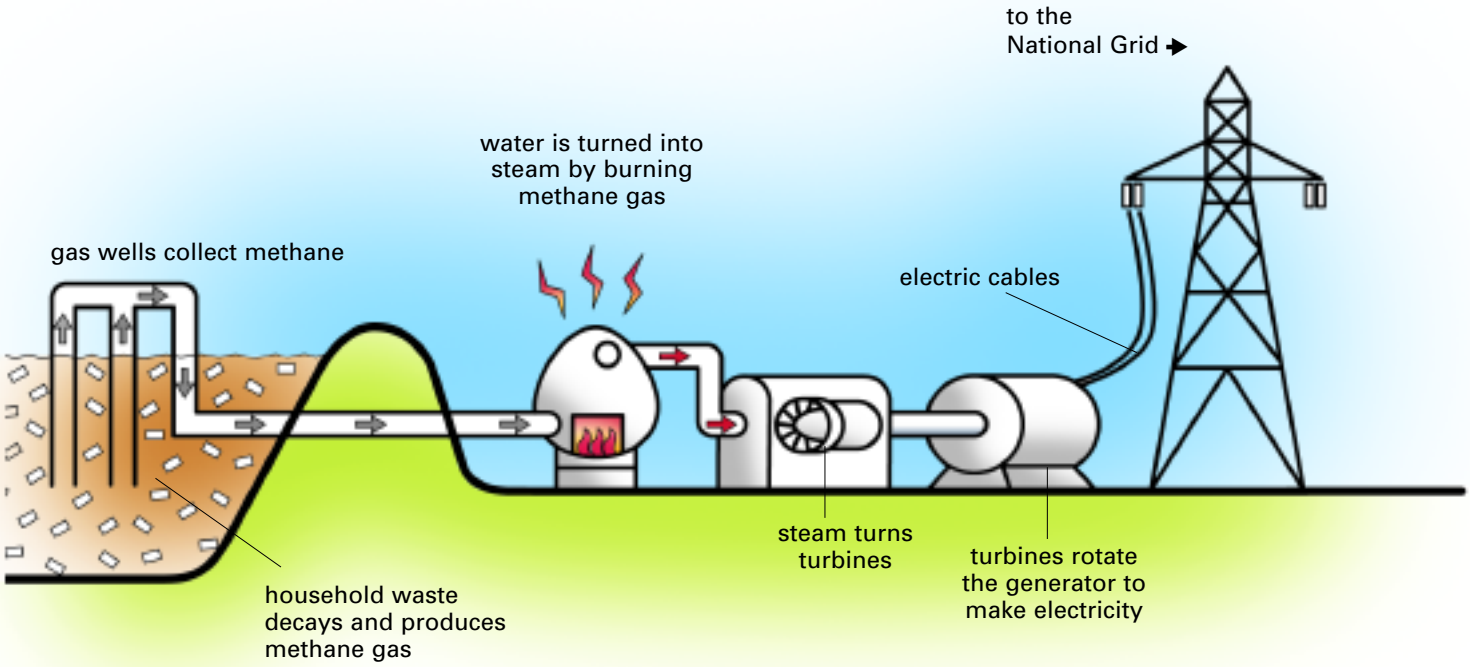
There are two main large-scale ways of generating bio-energy.

A farmer harvests trees for fuel.

Photo courtesy of NRE Slide Library/DTI

- **Energy crops** such as wood, oilseed rape and sugar beet are specially grown for fuel. A form of bio-diesel can be produced from vegetable oils. Other crops can be fermented to produce ethanol, a high-energy substance similar to petrol.

Using landfill gas to generate electricity



- **Waste** is an important source of bio-energy. Landfill sites, animal droppings and sewage all give off methane gas as they rot. Methane can be burnt to produce electricity and heat.

Advantages

- The fuel is cheap.
- It helps get rid of waste, which can cause smells and pollution.
- It is not using up limited resources like coal: biomass cannot run out.

Disadvantages

- Burning the fuel creates carbon dioxide, a greenhouse gas. However, if you grow crops that absorb the same amount of carbon dioxide from the air that is created by burning them, the effect on the environment is less harmful.
- Collecting waste in big enough amounts to generate energy can be difficult.
- If trees aren't grown especially for fuel, and re-planted, the result is deforestation.

To find out more about bio-energy, visit www.dti.gov.uk/renewables/schools

Geothermal energy

what is geothermal energy?

Coal miners know that the deeper you dig, the hotter it gets. This is because of the natural heat that exists deep within the Earth. We call this natural heat, geothermal energy.

There are two main ways to make use of geothermal energy.

- Use the water from naturally occurring underground reservoirs.
- Inject cold water into hot dry rocks.

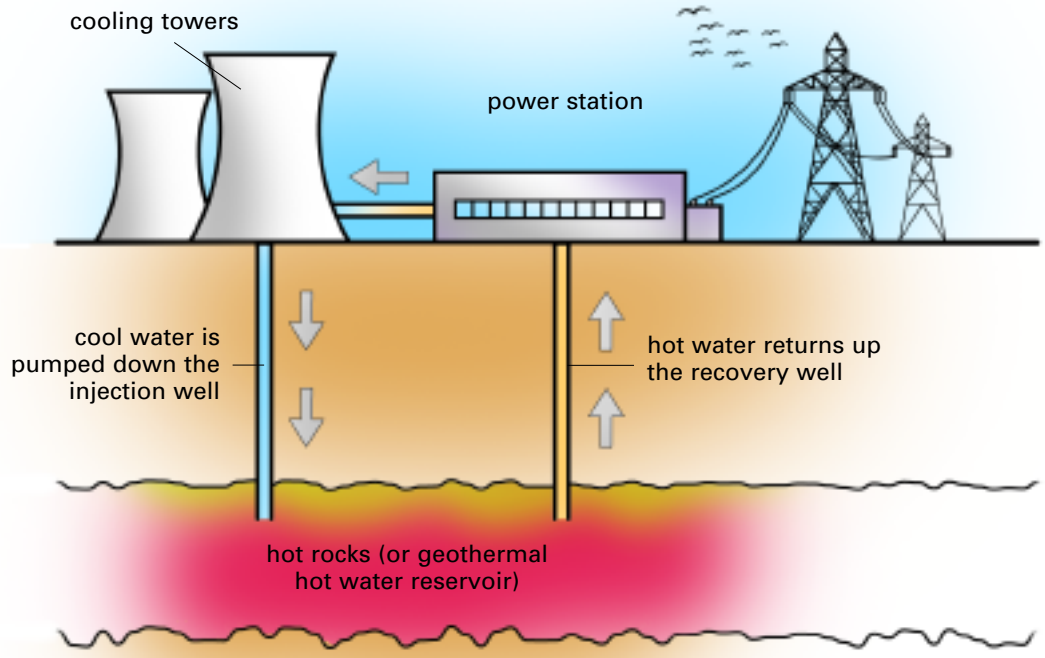
Old Faithful in Wyoming, USA, which erupts hot steam from far below the Earth's surface every 45 minutes.

Photo courtesy of www.pdphoto.org

How does geothermal energy work?

- In some areas of the Earth, geothermally heated underground water rises to the surface as **steam** or **hot springs**. If the hot water or steam doesn't rise to the surface on its own, we can drill boreholes to access it.
- Alternatively, cold water is pumped underground, where it is heated by hot dry rocks, and then returned to the surface. The hot water is then used in a steam turbine, or for direct heating.

Geothermal power plant



Where are geothermal power stations sited?

Places that are near a tectonic plate boundary (i.e. are volcanic), such as Iceland and Japan, have many places where boreholes can reach reservoirs of water at high enough temperatures and pressures to produce electricity.

The UK doesn't have any geothermal power stations that produce electricity, but lower-temperature reservoirs (far away from plate boundaries) are used for direct heating.

An example is the Southampton Geothermal District Heating Scheme, where water at 70°C is pumped up from a depth of 1800m, and provides heat to a number of buildings within 2km of the borehole.

Southampton Civic Centre uses heat from a geothermal well.

Photo by kind permission of Southampton City Council

Advantages

- Geothermal energy doesn't produce any pollution.
- Running costs for a geothermal power station are very low.

Disadvantages

- It is difficult to find suitable sites for geothermal power stations. The hot rocks have to be of a suitable type and depth, and the rocks above them have to be soft enough to drill through. There are hardly any sites in the UK.
- If not carefully managed, a borehole can 'run out of steam' and may not be useable again for several decades.
- Occasionally, dangerous gases and minerals can come out of a borehole, and it may be difficult to dispose of them.

To find out more about geothermal energy, visit www.dti.gov.uk/renewables/schools

Hydroelectricity

what is hydroelectricity?

This picture shows water being released under pressure, after it has turned the turbines inside the dam to generate electricity (Laggan Dam).
Photo courtesy of Roy Dyckhoff

When we use the energy in flowing water to produce electricity, we call it hydroelectricity.

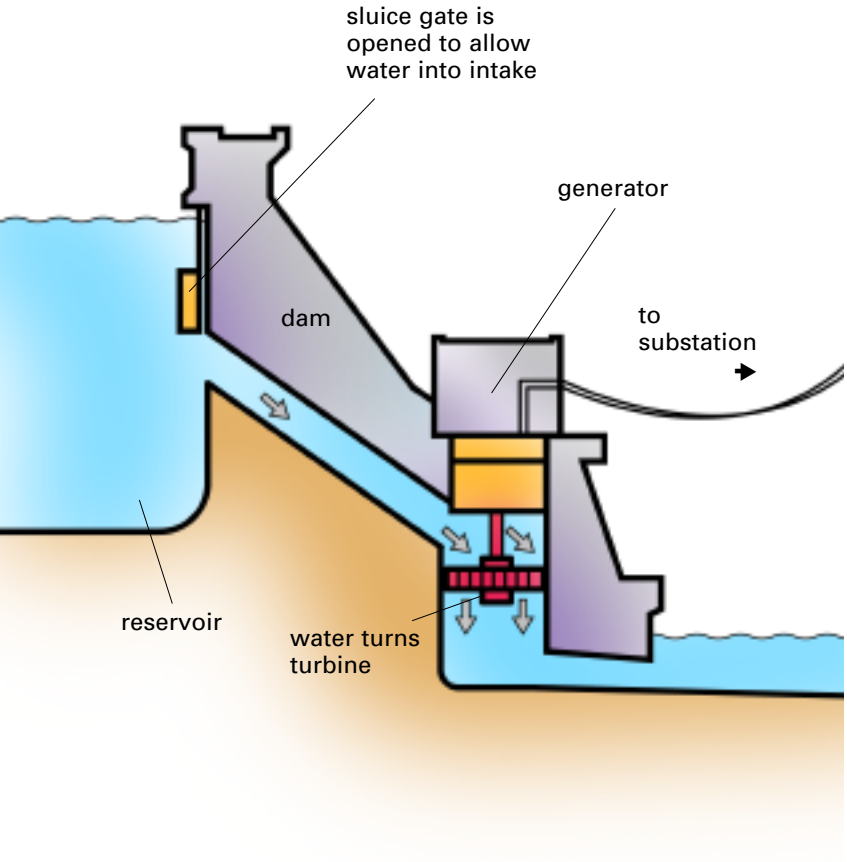
The name comes from the Greek word for water, 'hydro'. Hydroelectricity makes a major contribution to the world's energy supplies – more than any other kind of renewable energy resource.

How does hydroelectricity work?

There are two main ways of using the energy in flowing water to produce electricity.

- **Hydroelectric dams** trap flowing water, then release it again under greater pressure.
  - A river flowing through a valley is blocked by building a large concrete dam.
  - The valley is flooded by the river, creating a reservoir of water, like a man-made lake.
  - The water trapped in the reservoir is allowed to flow out through pipes, in the dam wall, under great pressure.
  - The flowing water turns a turbine, which then turns a generator. A generator is a machine that contains coils of wire and powerful magnets. When the wire coils are spun quickly inside the magnets, they produce electricity.
  - For example, in the Elan Valley in Wales, four dams hold 199 million tonnes of water. Not only is it the main water supply for Birmingham: the turbines also produce enough electricity to power nearly 11,000 homes.

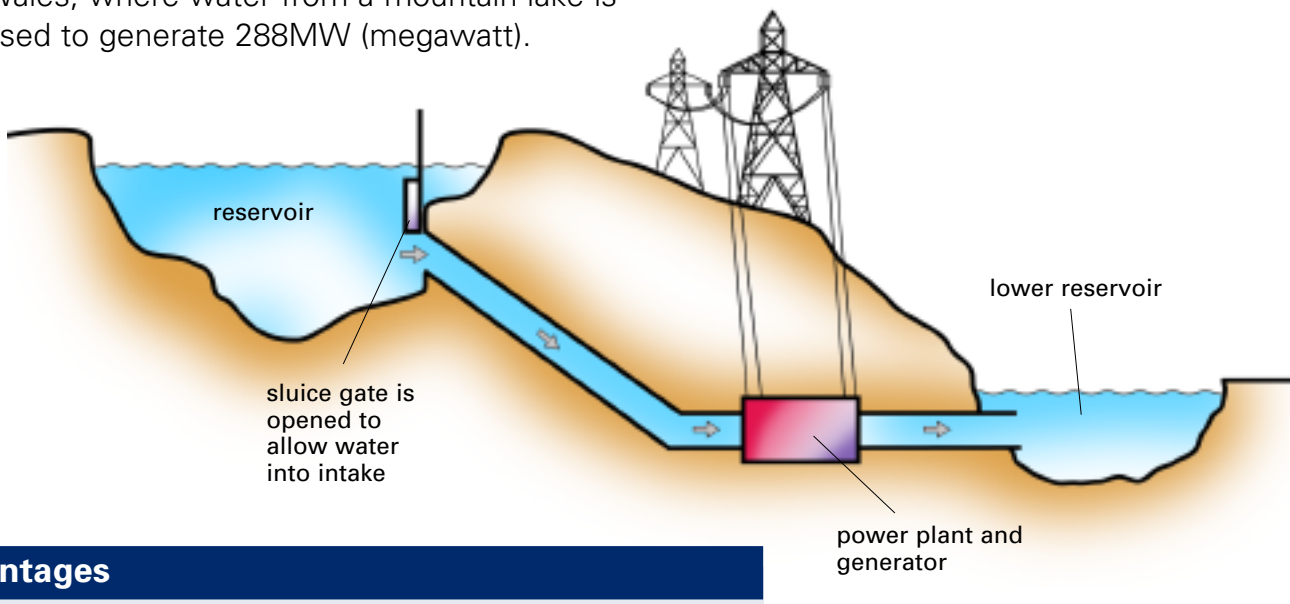
Hydroelectric dam



Dams depend on kinetic energy, which is the energy something possesses when it is moving. The bigger the height difference between the upstream and downstream water level (the 'head'), and the bigger the water flow through the turbines, the more electricity is generated.

- **Pumped storage** is not really a renewable energy source but a way of storing energy.
  - This system uses two reservoirs: one is much higher than the turbine and one is below it.
  - When electricity is needed, water is released from the top reservoir. It flows through pipes and turns the turbines to produce electricity.
  - When demand for electricity is low (e.g. at night), an electric pump is used to pump water back up to the top reservoir to be used again.
  - An example is the Dinorwig Power station in Wales, where water from a mountain lake is used to generate 288MW (megawatt).

Dworshak Dam, USA
Photo courtesy of US Army Corps of Engineers



Pumped storage

Advantages

- Once construction is completed, operating costs are very low.
- No waste or pollution is produced.
- Electricity can be generated constantly, because water can be stored and used as needed.

Disadvantages

- Dams are very expensive to build.
- Hydroelectricity sites are often remote, which leads to higher distribution costs.
- Suitable sites for large-scale projects are hard to find.

To find out more about hydroelectricity, visit www.dti.gov.uk/renewables/schools

Hydrogen fuel cells

what is a hydrogen fuel cell?

London is one of several European cities testing how well electric buses powered by fuel cells work.
Photo courtesy of Matthew Wooll

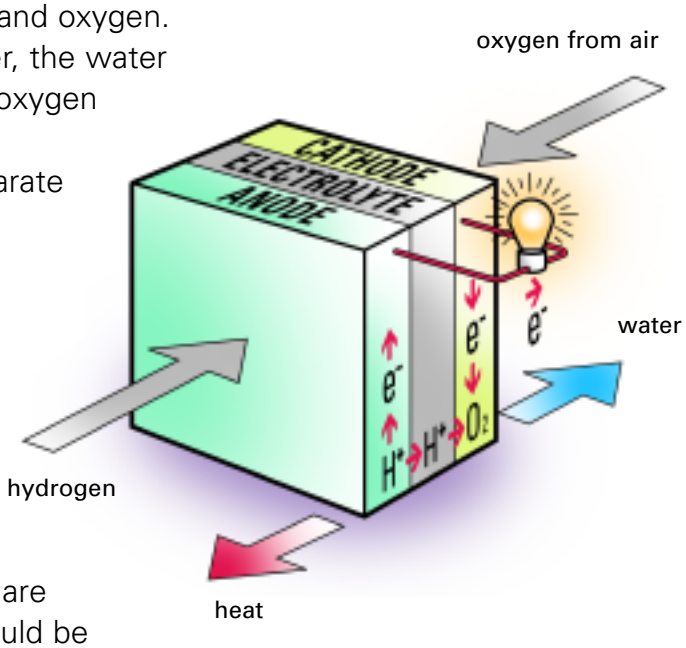
A hydrogen fuel cells works like a battery, but it uses hydrogen to make electricity. In other words, it converts hydrogen to electrical power.

Until recently, fuel cells were difficult and expensive to build, and were only used in very specialised areas such as on spacecraft and satellites.

Today we have the technology to produce cheaper and more efficient fuel cells than before, and many countries are testing them to see how well they work – for example, to power buses and cars, to heat water, supply electricity, even to provide clean water. But if we were to use them to replace other kinds of energy, fuel cells would need to be even cheaper and more efficient.

How does a hydrogen fuel cell work?

Water is a compound made from hydrogen and oxygen. If an electric current is passed through water, the water molecules split into separate hydrogen and oxygen molecules. The oxygen and hydrogen are released as gas and can be collected in separate containers. This process is known as **electrolysis**.



A fuel cell uses electrolysis in reverse. It converts hydrogen and oxygen into water, and produces electricity and heat in the process. This is all done without burning the hydrogen.

Fuel cells need hydrogen to work, and we need electricity to create hydrogen, so they are not a renewable energy resource. But it should be possible to use renewable resources to **produce** the hydrogen fuel. In Iceland there are plans to produce hydrogen using geothermal and hydroelectric power, which are both renewable sources of energy. The hydrogen will be used to power fuel cells to drive the country's cars.

Woking Park leisure centre is the first leisure centre in the UK to use hydrogen fuel cells for its energy needs. The fuel cells heat the swimming pool, provide clean water, and supply all of the centre's electricity. The system even makes chilled water for the building's air conditioning.

Photo courtesy of Woking Borough Council

Advantages

- There's no pollution: the only waste product is water and some heat, which can also be reclaimed.
- There's no noise.
- Fuel cells can be built in a huge range of sizes to suit almost any use.

Disadvantages

- Fuel cells rely on hydrogen, which has to be made. Most of the methods we use to produce hydrogen today use a lot of non-renewable energy, but this could change.
- It will be some time before hydrogen is as freely available as petrol is now.
- Hydrogen, like petrol, is flammable, but there are systems we can use to allow safe use.

To find out more about hydrogen fuel cells, visit www.dti.gov.uk/renewables/schools

Solar energy

what is solar energy?

BedZED housing development near London uses passive solar design.
Photo courtesy of Bill Dunster Architects

Solar energy is energy from the sun. The sun is incredibly powerful. Each minute of the day, it delivers enough energy to the earth to meet global demand for a whole year.

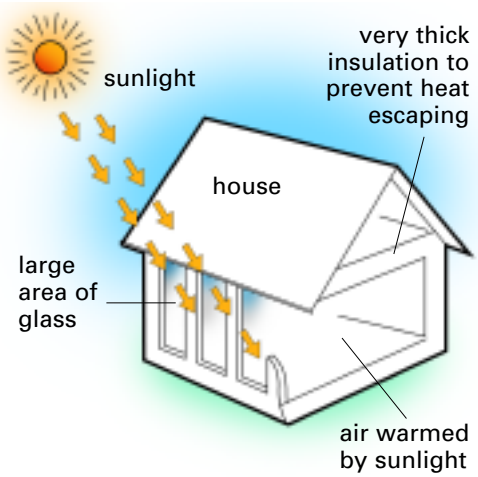
How does solar energy work?

Solar energy can be captured and used in three main ways.

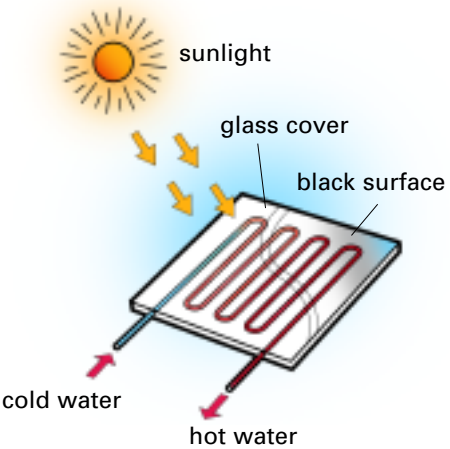
- **Passive solar design** involves designing buildings to make the most of the sun's natural heat, so that less electricity is needed to provide additional heat. For example, lots of glass is used to allow the sun's heat to warm rooms directly, and thick insulation holds in that heat.
- **Active solar heating** is a simple way of using the sun's heat to provide hot water for homes. Water is pumped through pipes into solar panels (called collectors) on the roof, and heated by the sun.

  The black, insulated base of the panels helps to trap heat. The heated water is then circulated through a heat exchanger to heat water for use in the home. It's surprisingly efficient, even in the chilly UK.
- **Photovoltaic cells** (PV cells) contain silicon, which convert energy from the sun into electricity. PV cells can be arranged in panels and can be fitted to almost anything, from your roof to your backpack. Experimental cars have been built where the body of the car is covered in PV cells, which generate electricity to power the vehicle.

Passive solar design



Active solar heating – solar collector



Sainsbury's is testing two solar-powered refrigerated trailers. The PV cells on the roof charge a battery, which powers the refrigeration system.
Photo courtesy of DTI

Direct and indirect solar energy

The sun actually gives us almost all the energy we use. It provides energy in two ways. We use the sun's energy **directly** to heat air and water for use in the home. We use it **indirectly** by burning fossil fuels. Millions of years ago, the coal, oil and gas that we burn today were plants and trees. They stored the sun's energy using a process called photosynthesis. When we burn these fossil fuels for fuel, the sun's energy is transformed into other kinds of energy that we can use. Even wind energy and tidal energy depend on the heat from the sun.

Advantages

- Once the solar power plant is constructed, running costs are very low.
- Solar energy can be used to generate electricity in remote places.
- No waste or pollution is produced.
- Energy is usually generated at or near where it will be used, keeping transmission and distribution costs to a minimum.

Disadvantages

- It doesn't work at night.
- Photovoltaic (PV) cells are very expensive (but they are getting cheaper).

To find out more about solar energy, visit www.dti.gov.uk/renewables/schools

Wind energy

what is wind energy?

Wind is created because some parts of the earth get more heat than others.

The warmer air rises and cooler air moves in to replace it. This movement of air is the wind.

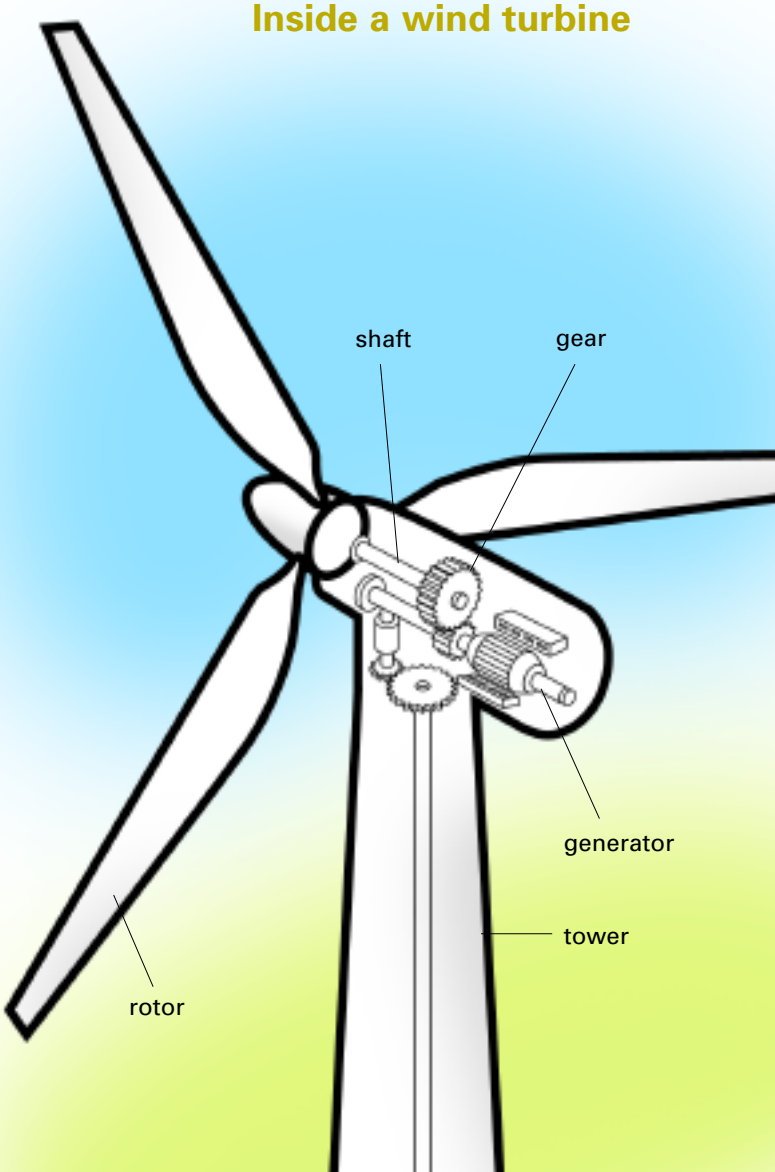
People have been using wind for thousands of years to pump water, mill grain and power sailing boats, amongst other things.

In the future we may develop even cheaper technologies, but today wind energy is one of the cheapest ways to produce electricity. There are over 1000 wind turbines at 89 sites in Britain. There are offshore wind farms at Blythe, North Hoyle and Scroby Sands. Most wind farms are located in the west of Britain, with the exception of Scroby Sands, off the east coast near Great Yarmouth.

Thanks to its position on the edge of the continent, Britain is the windiest place in Europe.

Out Newton Wind Farm, England
Photo courtesy of E.ON UK

Inside a wind turbine



How does wind energy work?

The force of the wind turns the rotor (which is like a huge propeller). The rotor is connected to a **generator**; this is a machine that contains coils of wire and powerful magnets. When the coils are spun quickly inside the magnets, they produce electricity.

To produce power, you need a wind speed of at least four metres per second (around 14KPH). Wind speed increases as you go higher above ground level, so wind turbines are usually mounted on tall towers. Wind speed also increases if there are no hills or buildings to slow it down. It is normally windier at sea than on land.

For commercial wind power stations, large numbers of turbines may be grouped together in **wind farms**.

Novar Wind Farm, Ross-shire, Scotland

This offshore wind farm is at Blythe, England.

Advantages

- Once the wind turbine is built, running costs are very low.
- No waste or pollution is produced.
- The land occupied by a wind farm can still be used for farming.
- Wind farms can become tourist attractions.

Disadvantages

- No wind, no power.
- Some people object because they feel wind farms spoil the view.
- Wind farms create a constant low-level noise.
- They can interfere with television reception and radar.

To find out more about wind energy, visit www.dti.gov.uk/renewables/schools

Wave energy

what is wave energy?

If you have seen the sea on a rough day, you will know that waves contain a lot of energy.

We can use this energy to produce electricity. Special machines have been designed to harness the power of the waves

Because of our position on the edge of the Atlantic, the UK has some of the best wave-power sites in the world.

The original source of wave energy is the sun. Waves are caused by wind, and the wind is caused by the uneven heating of the Earth's atmosphere.
Photo courtesy of NRE Slide Library/DTI

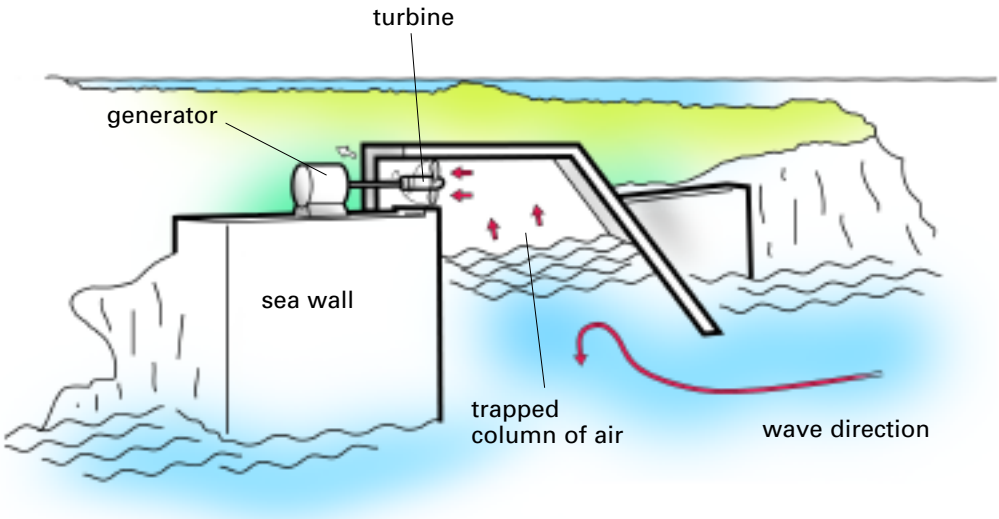
How does wave energy work?

There are two main types of wave-energy generator.

- **Fixed devices** are fixed to the sea bed or the seashore, for example the LIMPET (Land Installed Marine Powered Energy Transformer) on the Scottish island of Islay. The strong concrete walls set half in and half out of the water trap a column of air inside the machine. As the waves rush in, the air is forced upwards and spins the turbine. As the wave retreats, air is sucked back through the turbine, causing it to spin again. The turbine is connected to a generator, which produces electricity.

  The LIMPET was the world's first large wave power machine. It can supply electricity to about 350 homes. Inside the LIMPET is a Wells Turbine: this special turbine turns in the same direction regardless of which way the air moves, allowing the generator to be turned by both incoming and retreating waves.

LIMPET at Islay, Scotland
Photo courtesy of Wavegen



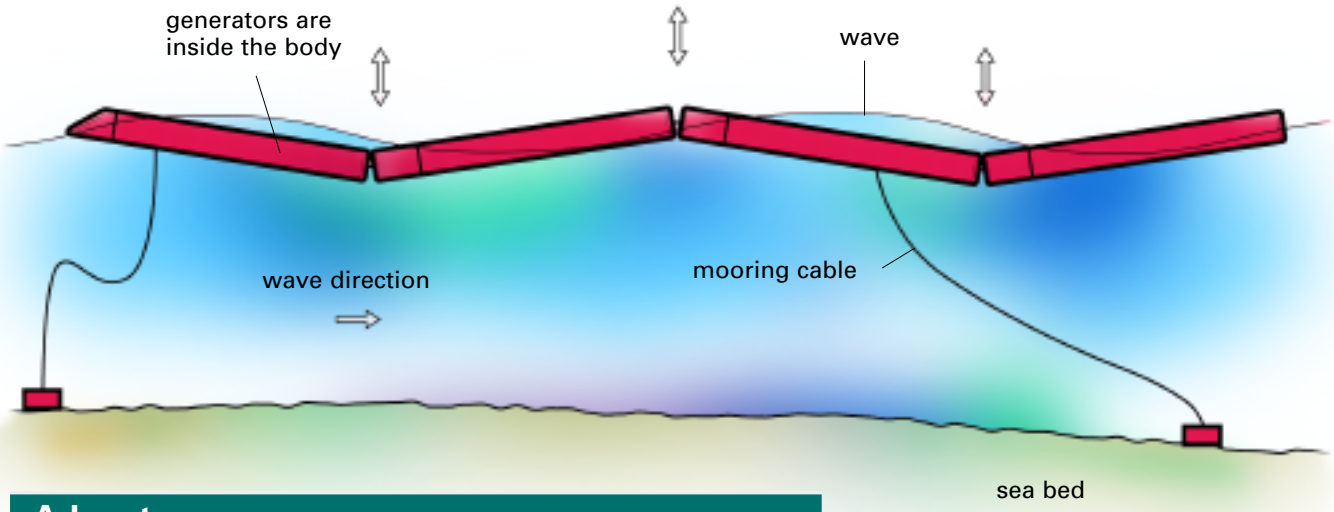
The LIMPET

Pelamis near Orkney, Scotland
Photo courtesy of Ocean Power Delivery

- **Floating devices** or **barrages** are generally found offshore. A good example is Pelamis, a wave-power project off the Scottish coast. It is a series of giant metal tubes joined together with flexible hinges. The movement of the waves causes sections of the snake to move up and down. Each hinge is connected to a pump, which pumps oil through a hydraulic motor as it moves. The motor generates electricity as it spins.

Pelamis first began generating electricity in 2004. Its location was chosen for ideal waves, the depth of sea, and to avoid passing ships. It is fixed to the sea bed by strong cables. Pelamis is Greek for 'sea snake'.

Pelamis



Advantages

- Once constructed, running costs are very low.
- No waste or pollution is produced.
- Wave-energy generators are capable of producing large amounts of energy.

Disadvantages

- Wave-energy generators are only effective where they are exposed to strong waves.
- They can be noisy.
- Wave-energy generators may be a hazard to ships and leisure craft.

To find out more about wave energy, visit www.dti.gov.uk/renewables/schools

Tidal energy

what is tidal energy?

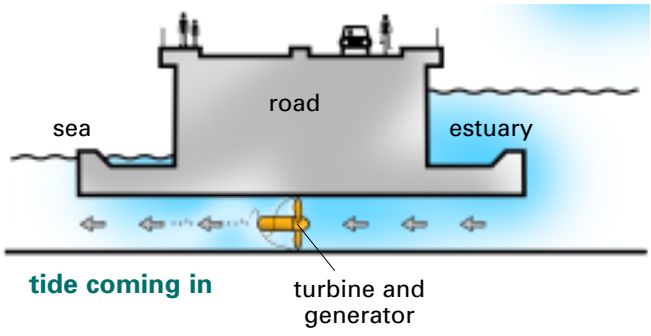
Around the coast of the UK, the sea level rises and falls twice daily. This rising and falling of the sea is caused by the pull of the moon.

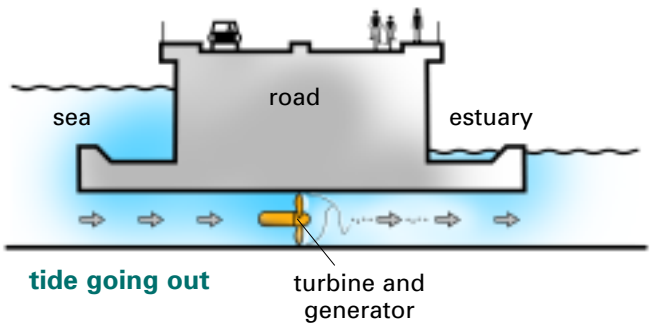
If we place barrages or dams in places where the tide moves in and out, and the difference between high and low tides is at least 5 metres, we can use this powerful movement of water to make electricity.

Today there is only one major tidal power station in operation in Europe. This is the 240MW (megawatt) barrage on La Rance river in France.

In Britain, the high tidal ranges near the Severn estuary could be used for a barrage. A barrage across the Severn could supply as much as 5 per cent of the UK's electricity needs, but it would be very expensive. There are currently no plans for a Severn barrage.

Tidal barrage





Tidal barrage at La Rance, France
Photo courtesy of EDF Médiathèque / G. Halary

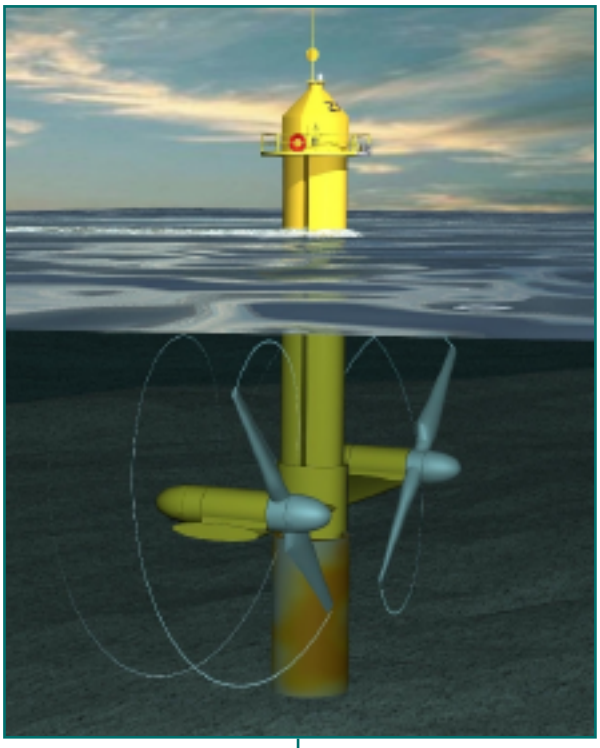
How does tidal energy work?

Tidal energy relies on the flow and ebb of the tide, caused by the gravitational pull of the moon. There are two main ways to harness tidal power.

- **A tidal barrage** is a giant wall (dam) that is built across a river estuary or a bay on the coast. Gates and turbines are built in along the dam wall. The gates are opened to allow the tide to flow in, and turn the turbines, which turn the generators to produce electricity. At high tide, the gates are closed and the water is held until the tide level outside the gates has dropped. Then the water is released to run through the turbines and turn the generators as it escapes. So electricity is generated by water flowing both in and out of the dam.

- **A tidal stream generator** (also known as a marine turbine) works like an underwater wind turbine. Instead of using the rising and falling movement of the tides, tidal stream generators make use of the fast sea currents that flow as tides move in and out. Sea currents turn turbines, which turn the generators that generate electricity. These can be used in **tide races**: places where the tide speeds up to 4–6 knots as it passes through a narrow gap.

  Marine turbines avoid the damage to the environment that barrage schemes can cause. The turbines turn quite slowly, so they do not affect sea life. Tidal barrages can affect sea life, such as fish that migrate up rivers from the sea.



Marine turbine
Image courtesy of Marine Current Turbines

Advantages

- Running costs are very low.
- No waste or pollution is produced.
- The technology is very reliable.
- No fuel is required.
- The amount of electricity and the time when it is produced is totally predictable.

Disadvantages

- There are only a few suitable places for tidal energy projects.
- Tidal stream technology is at a very early stage of development.
- Tidal schemes are expensive to install compared with other renewable energies.
- Damming bays or inlets can affect the environment over a large area.
- Barrage schemes will only provide energy for about 10 hours each day, as the tide moves in and out.

To find out more about tidal energy, visit www.dti.gov.uk/renewables/schools