Introduction

Worldwide there is a range of energy resources available to us. These energy resources fall into two main categories, often called **renewable** and **non-renewable** energy resources. Renewable resources are also often called **alternative** sources of energy. Each of these resources can be used to generate electricity, which is a very useful way of transferring energy from one place to another such as to the home or to industry.

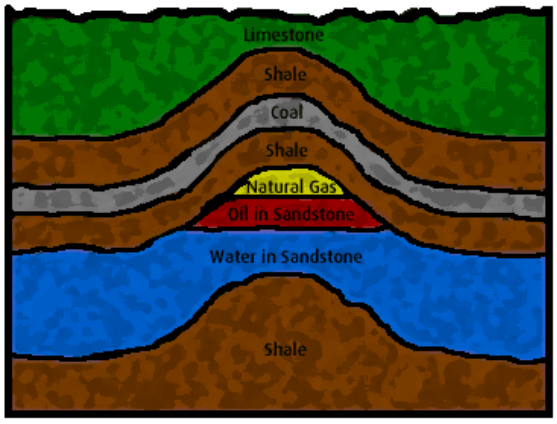
Non-renewable energy resources

These can be divided into two types: **fossil fuels** and **nuclear fuel**.

1. Fossil fuels

Fossil fuels are found within the rocks of the Earth's surface. They are called fossil fuels because they are thought to have been formed many millions of years ago by geological processes acting on dead animals and plants, just like fossils. Coal, oil and natural gas are fossil fuels. Because they took millions of years to form, they are called non-renewable. Once they are used up they cannot be replaced.

Pockets of oil and natural gas may become trapped between layers of non-porous rocks, deep underground.



A. Oil and natural gas

How were they formed?
Gas and oil were formed from the remains of small sea creatures and plants that died and fell to the bottom of seas. Over many millions of years, layers of mud or other sediments built up on top of these dead animals and plants. The pressure from these layers and heat from below the Earth's crust gradually changed the once-living material into oil and natural gas. Over time the layers of rocks in the earth's crust move and may become squashed and folded. The gas and oil may move through porous rocks and may even come to the surface. In some places, however, pockets of oil and gas can be found, because non-porous rocks have trapped them.

How were they formed? Going further
When reading or watching science fiction have you heard of 'carbon-based life forms'? Well that's us. All living things are made of complex molecules of long strings of carbon atoms. Connected to these carbon atoms are others such as hydrogen and oxygen. Oil and gas are chemicals that are made from molecules that contain just carbon and hydrogen. A simple molecule, called methane (CH_4), is the main component of natural gas.

Crude oil (oil obtained from the ground) is a sticky, gooey black stuff. It contains many different molecules, but all are made of carbon and hydrogen atoms.

Where can these fuels be found?

Natural gas and crude oil can be found in many places around the world, such as the Middle East (about 70 per cent of the world's known resources of oil), the USA and under the North Sea off the coast of the UK.

What are they like as fuels?

When gas and oil burn they produce mainly carbon dioxide and water, releasing the energy they contain. Crude oil is a mixture of different chemicals and is usually separated out into fuels such as petrol, paraffin, kerosene and heavy fuel oils. The oil-based fuels provide less energy per kilogram than natural gas. Both oil and natural gas produce carbon dioxide, which is a greenhouse gas.

How long will they last?

Oil and gas are non-renewable: they will not last forever. New sources of oil and gas are constantly being sought. It is thought that the current resources under the North Sea will last about another 20 years and the world resources will last for about 70 years. Estimates do vary, because we do not know where all the resources are and we do know how quickly we will use them. It is thought that with new discoveries these fossil fuels will last well into the next century.

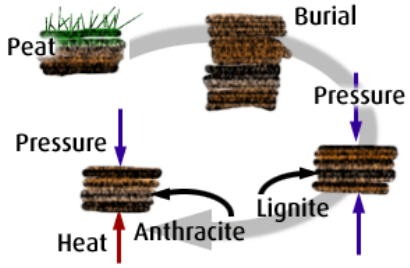
Advantages

These sources of energy are relatively cheap and most are easy to get and can be used to generate electricity.

Disadvantages

When these fuels are burned they produce the gas carbon dioxide, which is a greenhouse gas and is a major contributor to global warming. Transporting oil around the world can produce oil slicks, pollute beaches and harm wildlife.

B. Coal



How was it formed?
Coal was formed from plant material in ancient swamp forests. Millions of years ago trees and other plants grew quickly, and when they died they fell into the swamp. The water prevented the plant material from decaying completely and peat was formed. As time passed layer upon layer built up. The pressure from these layers and heat from below the earth's crust changed the material into coal.

How was it formed? Going further

Coal mainly consists of carbon atoms that come from the plant material. It is a black solid that is reasonably soft. You can scratch it with a fingernail. It is not as soft as charcoal, however, and is quite strong. It can be carved into shapes. There are different types of coal. Some contain impurities such as sulphur that pollute the atmosphere further when they burn, contributing to acid rain.

Where can it be found?

Coal can be found in parts of the world that were once covered with swampy forests, such as the UK about 250 million years ago. There are large deposits in China, USA, Europe and Russia. South Africa also has relatively large deposits.

What is it like as a fuel?

When coal burns it produces mainly carbon dioxide, some carbon monoxide and soot (which is unburned carbon). Many coals when burned produce smoky flames. Their energy content weight for weight is not as great as oil. When coal burns it produces more carbon dioxide than oil.

How long will the supply of coal last?

The world has relatively large reserves of coal, more so than oil and gas. Estimates vary but suggestions are that supplies will last well into the next century.

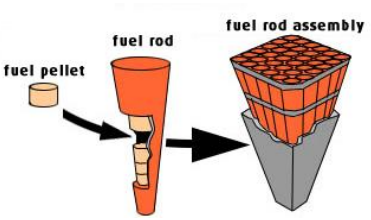
Advantages

Coal is relatively cheap, with large deposits left that are reasonably easy to obtain, some coal being close to the surface. It is relatively easy to transport because it is a solid.

Disadvantages

Some sources of coal are deep below the ground, as in the UK, and can be difficult, costly and dangerous to mine. Burning coal without first purifying it contributes to global warming, as well as to the production of smog (smoke and fog), which is harmful to health. It is a finite resource and will eventually run out.

2. Nuclear fuel



How is nuclear fuel made?
Nuclear fuel is made from naturally occurring radioactive materials, such as uranium, found in rocks. These materials are extracted and concentrated. They are formed into 'fuel rods'. When placed close together they set off nuclear reactions that generate heat. This heat is used to turn water into steam and generate electricity. The world's source of uranium and other radioactive materials is finite so it will not last forever. This fuel is classed as non-renewable, even though concentrating the fuel further can recycle some of the 'spent fuel'.

Radioactive materials are concentrated into fuel pellets and formed into fuel rods. The fuel rods are placed together in a nuclear reactor.

How is nuclear fuel made? Going further

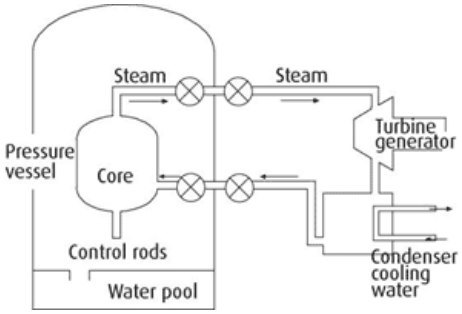
Some elements are naturally radioactive. That is to say, the nucleus in the atom may spontaneously break down to release energy and produce fast-moving particles, atoms of other elements. The fast-moving particles that are ejected can also strike other atoms, causing them to break down. Placing the atoms close together in a fuel rod means that atoms are more likely to be struck by these particles, and so produce more nuclear reactions. As the reactions proceed heat is produced. The task of a nuclear reactor is to control the reaction so that a steady flow of heat is produced.

Where can nuclear fuel be found?

There are deposits of the raw material uranium in some countries, such as Africa and Russia, and within North America. The raw material needs processing, however, before it can be used.

What characterises nuclear fuel?

The fuel is usually formed into rods. The fuel rods get hot during the process of radioactive decay. This heat is eventually used to turn water into steam. Because there is no burning involved, there are no polluting gases.



How long will the supply of nuclear fuel last?

The world supply of radioactive material will provide a source of energy well into the next century and beyond.

Advantages

Nuclear fuel does not produce greenhouse gases, so will not contribute to global warming. There is a relatively long-lasting supply of material.

Disadvantages

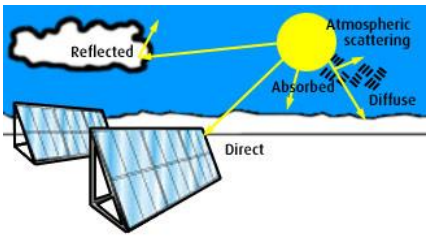
The waste remains radioactive for a long time (100+ years). If the reaction is not contained and controlled well, then the nuclear reduction could go out of control, as at Chernobyl in 1986. Radioactive material could then escape into the environment as it did in 1986. Radiation causes cancers.

Renewable energy resources

Some sources of energy are called renewable. This is because they will not run out. They include solar energy, geothermal energy, energy from the wind and waves, energy from tides and energy from biomass.

1. Solar energy

Every year the Earth receives about 300,000,000,000,000,000,000,000 kJ of energy. This is a lot of energy. This energy drives processes in the atmosphere that cause the wind and waves. Some energy is absorbed by green plants and used to make food by photosynthesis. So ultimately the Sun is the source of most energy resources available to us including fossil fuels. Scientists also try to use the energy of the Sun directly. This we call solar energy. 'Solar' means 'sun'.



How can the Sun's energy resources be used directly?

Solar energy can be used to heat a fluid such as water in solar collector panels. The simple types use flat collector panels that are mounted on the south facing roof or wall. The panels have a transparent cover to admit sunlight. Water circulates through channels or pipes inside. The inside is usually painted black, because black surfaces readily absorb heat. The water is heated, then the hot water is pumped to a heat exchanger that extracts the heat for use within the house.

Many of the Sun's rays are scattered by the Earth's atmosphere or reflected by clouds. But some solar radiation can be collected by special panels and used to heat water.

Solar energy can be used to generate electricity in photovoltaic (PV) cells. A PV cell may power your calculator. Photovoltaic cells are made of semiconductors, similar to those used to make computer chips. Until recently these cells were very costly to produce. They are getting cheaper and are currently about 10-15 per cent efficient.

Where can we use it?

The Sun's energy can be gathered anywhere, but obviously more can be gathered in areas on or near the Equator. In the UK the average amount of solar energy available is about 4,000 kJ per square metre. If less than a quarter of the population had solar panels this would save about 30 per cent of our annual energy demand.

Advantages

The energy resource is renewable, non-polluting and relatively maintenance free.

Disadvantages

There is less available energy in areas near the poles of the Earth. Cloud cover can reduce efficiency and PV cells are still quite expensive.

2. Geothermal energy

What is geothermal energy?
The temperature at the earth's core is over 70,000°C. The rocks not too far below the surface are also quite hot, perhaps 500°C about 1 km down. In some areas there are 'hotspots' where the temperature below the surface is higher. This is

usually near where the earth's tectonic plates meet. The existence of hot springs, geysers and volcanoes point to evidence of hot rocks below the surface. In some places there are reservoirs of hot water below the surface that can be tapped to provide energy.

Where can we use geothermal energy?

There are not many places that can currently exploit geothermal energy cost effectively. In Tuscany, Italy, a geothermal plant has been operating since the early 1900s. There are also geothermal power stations in the USA, New Zealand and Iceland. In Southampton (UK) there is a district heating scheme based on geothermal energy. Hot water is pumped up from about 1,800 metres below ground. The water is about 700 C and is used to heat a number of nearby offices and civic buildings.

Advantages

This source of thermal energy will not run out. It is renewable. The running costs can be very low. It can be non-polluting (as in Southampton).

Disadvantages

It can only be used in some areas around the world where the crust is thin, and hot rocks are near the surface. Sometimes the hot water that is pumped to the surface contains pollutants such as sulphur.

3. Wind and wave energy

A. What is wind energy?

Renewable energy from the wind has been used for centuries to power windmills to mill wheat or pump water. More recently large wind turbines have been designed that are used to generate electricity. The blades of these wind turbines are about 30 metres long. These new wind turbines are collected together in wind farms.

Huge turbines in a wind farm can generate enough electricity to supply a small town.

What is wind energy? Going further

When the Earth is irradiated by the Sun the ground absorbs some of this radiation. This heated ground warms the air above it. Hot air rises in what are called convection currents. The uneven heating of the earth's surface causes winds. For example, if the Sun's rays fall on land and sea, the land heats up more quickly. This results in the air above the land moving upwards more quickly than that over the sea (hot air rises). As a result the colder air over the sea will rush in to fill the gap left by the rising air. It is processes like these that give rise to high and low pressure areas, and thus to winds.

Where is wind energy used?

This energy can be harnessed in areas that are subject to reasonably consistent and strong winds. There may be large areas of flat land or those near coasts that are subject to prevailing winds. There are wind farms around the world. Because the UK is on the edge of the Atlantic Ocean it has one of the best wind resources in Europe. Offshore wind farms in coastal waters are being developed because winds are often stronger blowing across the sea. A 20-turbine wind farm can generate enough electricity (about 1MW) for a small town. Turbines can produce between 500kW and 1MW of electricity.

Advantages

This source of energy is non-polluting and freely available in many areas. Wind turbines are becoming more efficient. The cost of the electricity they generate is falling.

Disadvantages

To be efficient wind turbines need to be linked together in wind farms, often with about 20 turbines. This looks unsightly, and can be noisy. The wind farms also need to be sited reasonably close to populations so that the electricity generated can be distributed. Winds are intermittent and do not blow all the time.

B. What is wave energy?

Waves are caused by the action of winds on the sea. Waves can be many metres in height and contain a great deal of energy. This energy can be harnessed to drive turbines that generate electricity. Wave energy collectors are of two main types. The first type directs waves into man-made channels, where the water passes through a turbine that generates electricity. The second type uses the up and down movement of a wave to push air.

Where can we use it?

Wave energy can be harnessed in coastal areas, close to the shore. There has been one such device working on the island of Islay in Scotland since the early 1990s, producing 75kW of electricity.

Advantages

This is a non-polluting source of energy, relatively quiet to operate and does not affect wildlife.

Disadvantages

The turbines can be unsightly. Wave heights vary considerably so they would not produce a constant supply of energy.

4. Energy from the tides: tidal power

What is tidal power?
The tides are caused by the gravitational pull of the Moon, and to a lesser extent the Sun, on the oceans around the world. The difference between high tide and low tide can be many metres. If, at high tide, water can be trapped behind a barrage and then let out as the tide ebbs, this water can be passed through a turbine that can generate electricity.

Where can it be used?

Barrages are built in river estuaries that have large tidal ranges, such as the River Severn in the UK.

Advantages

The rise and fall of the tide is constant, and does not depend on the weather. The production of electricity in this way is relatively cheap.

Disadvantages

Present designs do not produce a lot of electricity, and barrages across river estuaries can change the flow of water and so the habitat for birds and other wildlife.

5. Energy from rivers: hydroelectric power

What is hydroelectric power?
Rivers flow from relatively high areas of land (e.g. hills or mountains) to the sea. Flowing rivers have kinetic energy. If a dam is built across the river then water can be allowed to flow in a controlled way through a turbine that generates electricity.

A dam across a river can provide a cheap, constant source of hydroelectric power for large communities.

Where is it used?

Hydroelectric power schemes exist in many countries. They can be built in areas where there are fast-flowing rivers. These are often hilly or mountainous regions where rivers flow down steep slopes. On flatter land rivers flow more slowly. In these slower flowing rivers very large artificial dams have to be built to create reservoirs. The reservoir then provides a

'head of water' that can be allowed to fall through a turbine. Most people live on flatter land so most hydroelectric schemes require large dams and flood a lot of land.

Advantages

The river flows continually and provides a constant source of energy. Once built the supply of electricity is relatively cheap.

Disadvantages

A good site for a hydroelectric scheme, such as a mountainous region, is not always near towns. The building of large dams floods large areas and causes damage to existing habitats. Changing the flow of a river will affect the water supply to lands nearer the sea. This may cause problems of irrigation for crops.

6. Energy from biomass

What is biomass?
Biomass is material from living things. This could be plant material, animal material or even bacteria. Plant material such as wood or hay can be burned to provide heat to raise steam and so generate electricity in a power station. Animal waste (e.g. animal slurries from the cow shed) can be treated to provide gases that can be burned to generate electricity. Landfill sites emit gases (mainly methane) that can also be used to provide energy. Some plant materials such as sugar cane and maize (sweetcorn) can be fermented to produce alcohol. Alcohol can be used in cars as a substitute for petrol. Crops can be grown as energy crops rather than food crops. Oil seed rape (the fields of yellow flowers you see in the UK in summer) produces oil. About 32 per cent of the seed is oil. After treatment with chemicals it can be used as a fuel in diesel engines. The fuel is called RME (Rape Methyl Ester). Fast-growing trees such as willows can be farmed for energy.

Where is it used?

About 200 years ago biomass in the form of wood was the major source of energy. In many parts of the developing world biomass (not always from trees) is still the major source of energy. In Brazil large numbers of cars run on alcohol rather than petrol. In the Western world, people are developing ways of using biomass as an alternative to fossil fuels. There is a large biomass plant in Sweden and in the UK attempts are being made to develop a power station that will run solely on wood from a nearby farm.

Advantages

Biomass is a renewable resource - for example, trees can be re-grown or coppiced. Energy can be extracted from wastes. They can be used in similar ways to fossil fuels. They are readily available worldwide.

Disadvantages

They are no more environmentally friendly than fossil fuels because they recycle carbon into the atmosphere when they are burned. Carbon dioxide, which is produced when these fuels are burned, is a major cause of the greenhouse effect.