Shell Education Service

BIOMASS

alternative
energy

THERE ARE THREE SOURCES OF RENEWABLE ENERGY AVAILABLE TO US:

SOLAR ENERGY –
Energy from the sun (directly, or indirectly via wind, wave and biomass energy).

GEOTHERMAL ENERGY –
Energy from hot rocks underground.

TIDAL ENERGY –
Energy from gravitational effects in the solar system.

What is biomass?

Biomass is organic matter, mostly from plants such as wood, which can be used as a source of energy. The term includes animal waste (digested plant food) such a cow or pig dung. The size of the biomass energy resource is enormous. Every year, growing plants store enough energy to fuel the world for five years. The majority of this energy, about 90% of it, is stored in the wood of growing trees.

Biomass and the carbon cycles

There are two natural carbon cycles. One is the organic carbon cycle involving plant photosynthesis (see diagram) which cycles about 60 giga tonnes of carbon a year to and from the atmosphere. (One giga tonne is 10^9, one thousand million tonnes.) The other is the inorganic carbon cycle in which carbon dioxide, for example from volcanic activity, dissolves in rainwater. This solution reacts with rocks to form carbonates which are washed down to the sea by rivers. The shells of sea creatures contain calcium carbonate. When the creatures die, the remains fall to the seabed. In time, under the action of temperature and pressure, this calcium carbonate forms rock such as limestone. The process of rock formation and disintegration repeats itself – a cycle that takes millions of years to complete. It is estimated that geophysical actions cycle about 100 giga tonnes of carbon a year in this way.

Since the Industrial Revolution, the large scale use of fossil fuels has caused an accelerated increase in the amount of carbon dioxide entering the atmosphere. The result is an imbalance in the natural carbon cycles. Carbon dioxide is one of the so-called greenhouse gases. Increasing the amounts of these gases in the air raises the temperature near the earth's surface. This is called the enhanced greenhouse effect. Some scientists believe that this could be affecting the climate on earth. The combustion of fossil fuels, for example, adds about six giga tonnes of carbon a year to the atmosphere.

The scale of biomass energy

One TWh (terawatt hour) is the energy supplied by a large nuclear power station running at full power for two months.

The Earth receives 178,000 TW of energy from sunlight every year. Out of this 178,000 TW, plants use only 100 TW to make all the world's biomass each year. This still adds up to a lot of biomass energy. It is about 120,000 million tonnes of dry biomass each year. Of course, we use only part of this total for fuels or there would be no plants left.

All over the world, people use firewood and other kinds of biomass fuel. Biomass is already the fourth largest energy source worldwide – providing more primary energy than we get from hydroelectric or nuclear power. Since plants grow almost everywhere, there is great potential for us to increase our use of biomass in the future.

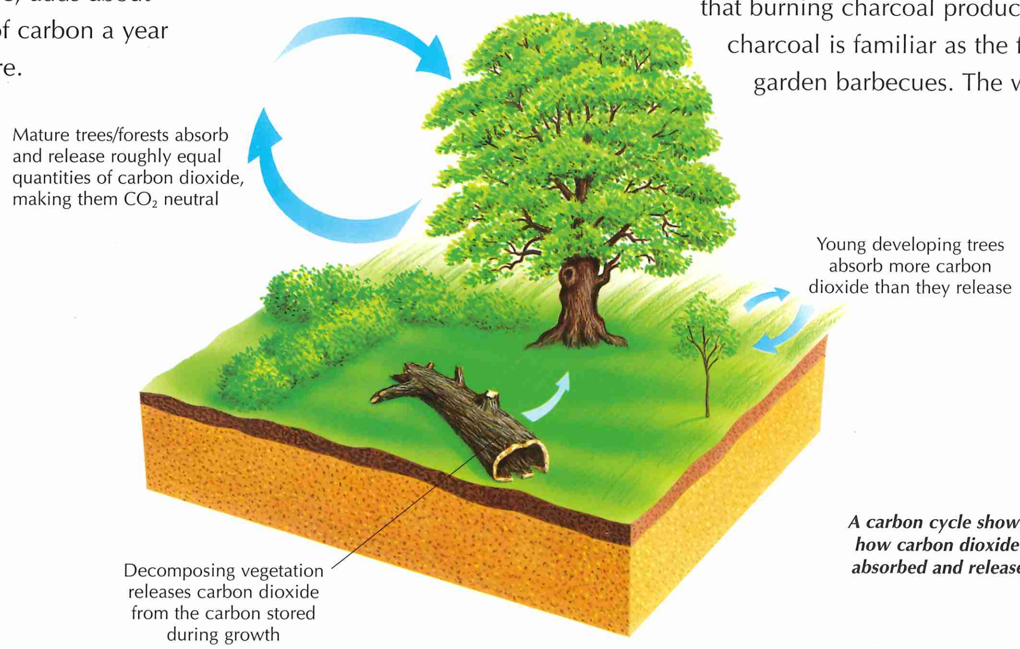
What kinds of biomass are available?

Biomass fuels are generally available to us as solids from a wide variety of sources but we can convert them into liquid and gaseous fuels.

Traditional sources of biomass energy

Wood. Wood was the major source of energy from the earliest times until the Industrial Revolution when coal very largely replaced it. In the developing world, wood often remains the major source of energy for heating and cooking. Dry fuels contain more energy per tonne than freshly cut material.

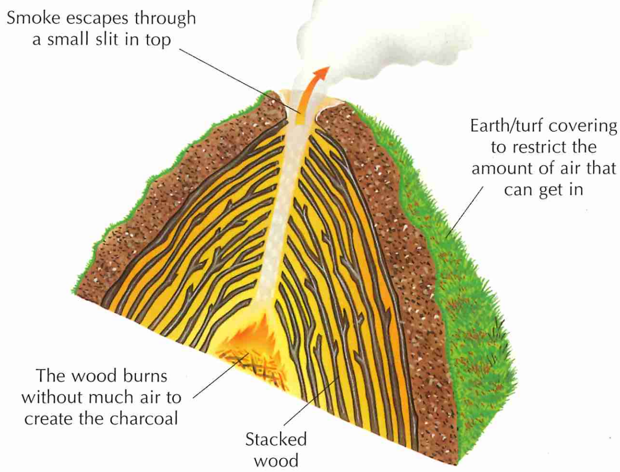
Charcoal. We make charcoal by heating wood in the absence of air (called pyrolysis). In Europe, the soil or turf-covered charcoal kilns date back over 5500 years. Charcoal was the fuel that bronze and iron age peoples used to smelt metals. They needed the high temperatures that burning charcoal produces. Nowadays, charcoal is familiar as the fuel used in garden barbecues. The wood contains



A carbon cycle showing how carbon dioxide is absorbed and released.

substances that are volatile, both gases and liquids. These are lost during traditional charcoal burning. Since these volatiles in biofuels can account for 75% of their energy content, charcoal burning is a very wasteful and polluting way to make fuel.

Cutaway view of a traditional charcoal kiln.



Farm wastes. Farm wastes have been used as fuels since the earliest times. The wastes include dried animal dung, crop residues, husks from milling food crops, straw and forestry wastes from thinning and felling trees. People have also been cutting and drying turfs of peat for thousands of years to make into fuel.

Drying dung in the sun in Bangladesh to replace firewood as fuel.

Modern sources of biomass energy

Industrial processing. This can produce large amounts of waste concentrated at one location. Such material can then be used as a fuel.

The Värnamo Biomass Plant in Sweden.

Agricultural waste. The waste from processing sugar cane is called bagasse. This fibrous material is suitable for firing boilers to raise steam and to generate electricity. Other agricultural wastes include coconut waste and rice husks, both produced in large tonnages but only available during particular seasons. Environmental concerns about straw stubble burning has meant that much more straw is now available as a potential fuel.

Animal waste. We can also use very wet wastes such as animal slurries from a cowshed. By processing them for a few days in large tanks called anaerobic digesters, we can obtain a useful fuel gas. The residue can be dried to give a fertiliser.

The fibropower power station at Eye in Suffolk, burns a dry mixture of poultry litter and wood shavings to generate electricity.

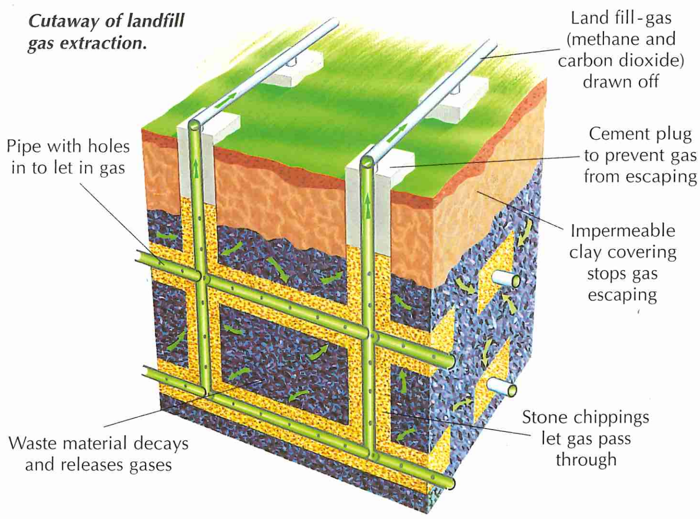
Forestry waste. Much forestry waste was left to rot in the past. The development of machines to harvest the waste and convert it into wood chips has changed this. The chips can be transported and dried for use in firing boilers.

Household waste. In industrialised countries this represents a major source of fuel. At present in the UK, most municipal waste is buried in landfill sites. These can be disused clay pits or quarries. This is an increasingly expensive and wasteful option.

There are two major ways to extract energy from household waste. One is to separate the combustible material before burial of the remainder. The other is to use the landfill site as a fuel gas producer.

Landfill waste. The raw waste can be incinerated directly, reducing the volume of the waste and so lowering disposal costs. The energy recovered can be used for district heating through a combined heat and power scheme, (called CHP).

Cutaway of landfill gas extraction.



If the raw waste is sorted first to remove things which cannot burn, such as metals and glass, the combustion is more efficient. Alternatively, the materials which will burn can be processed to give fuel pellets, known as refuse-derived fuel (or RDF for short).

When landfill sites are full they are capped to seal them. The absence of a supply of oxygen from the air creates anaerobic conditions. Under anaerobic conditions, natural micro-organisms convert wastes to a mixture of gases known as landfill gas. The two major components are carbon dioxide, which does not burn, and methane, the major component of natural gas. Originally the landfill gas was allowed to vent naturally to the atmosphere but this represented an explosion hazard. The next development was to collect and flare off the gas to reduce the danger. We now see landfill gas as a valuable resource. We can collect it and burn it to heat boilers or to generate electricity. The variable quality of landfill gas and the presence of impurities make it unsuitable for addition to the domestic gas distribution system.

Energy *crops*

In Europe some farmland has been taken out of use to reduce food production.This provides opportunities to grow energy crops specifically for their use as fuels. Fast-growing trees such as willow and poplar, or certain varieties of perennial grass, can all be grown as energy crops. For trees, the technique of coppicing is used. New growth is cut every three or four years for use as an energy crop. The trees sprout again and replace the cut material with new growth.

Coppice showing newly cut stumps and more mature trees in background.

Liquid *fuels* from energy crops

Most biomass fuels are used for heating and power but liquid fuels can also be produced for use in transportation. Ethanol is an alcohol which burns well and can be blended with conventional fuels such as petrol. Sugar cane and maize can both be used as the source of bio-ethanol. The crops are fermented to give a mixture of water and alcohol. This can be concentrated by distillation. In Brazil, millions of vehicles are powered by ethanol or ethanol-petrol mixtures. Vegetable oils can be used directly as fuels but they perform better after chemical treatment. We call this esterification. It involves chemically combining the oils with an alcohol, either methanol or ethanol. The resulting fuel can be blended with diesel for commercial use.

Environmental *effects* of using biomass

The growing and combustion of biomass fuels simply cycles carbon through the environment. If we can operate on a sustainable basis it will be carbon dioxide neutral, the atmospheric concentration will remain stable. There is a potential environmental gain that comes from the substitution of biomass fuels for fossil fuels. However, the substitution is not necessarily sustainable on a large scale.

- Biomass fuels currently cost more to produce than fossil fuels.
- Liquid biomass fuels produce some different combustion products to petrol or diesel. This does not mean, however, they are significantly 'cleaner' fuels. The annual sustainable yield of liquid biofuels from good agricultural land is very low. In reality, there is a limit to how much land could be allocated for this purpose. Every hectare set aside for biofuel production is a hectare less for growing food.
- The large scale growth of energy crops will change the landscape and can also have more subtle effects. Unless care is taken, the crops can cause changes to the local water table and increase the demand for nutrients from the soil.

In the UK, biomass fuels currently provide less than 1% of the supply of primary energy.In parts of the developing world the proportion approaches 100%.

Economic aspects of biomass energy:

- Biomass fuels are best suited for heat and power.
- Although production costs are not falling as rapidly as for other renewables such as photovoltaics, they seem certain to fall further in the future because of the economies of scale.
- If we use the same amount of land for energy crops as we use to grow softwood for papermaking, we could provide up to 30% of worldwide electricity demand.
- Liquid biofuels are not cost-competitive with petrol or diesel. The production cost of biofuels is at least three times higher than the production cost of fuels derived from crude oil.
- Some countries do not have large oil resources of their own but can still produce biofuels.
- Only 2% of the world's biomass generated each year is currently being used in fuels. Estimates suggest this could increase to 8% by the middle of the 21st century.

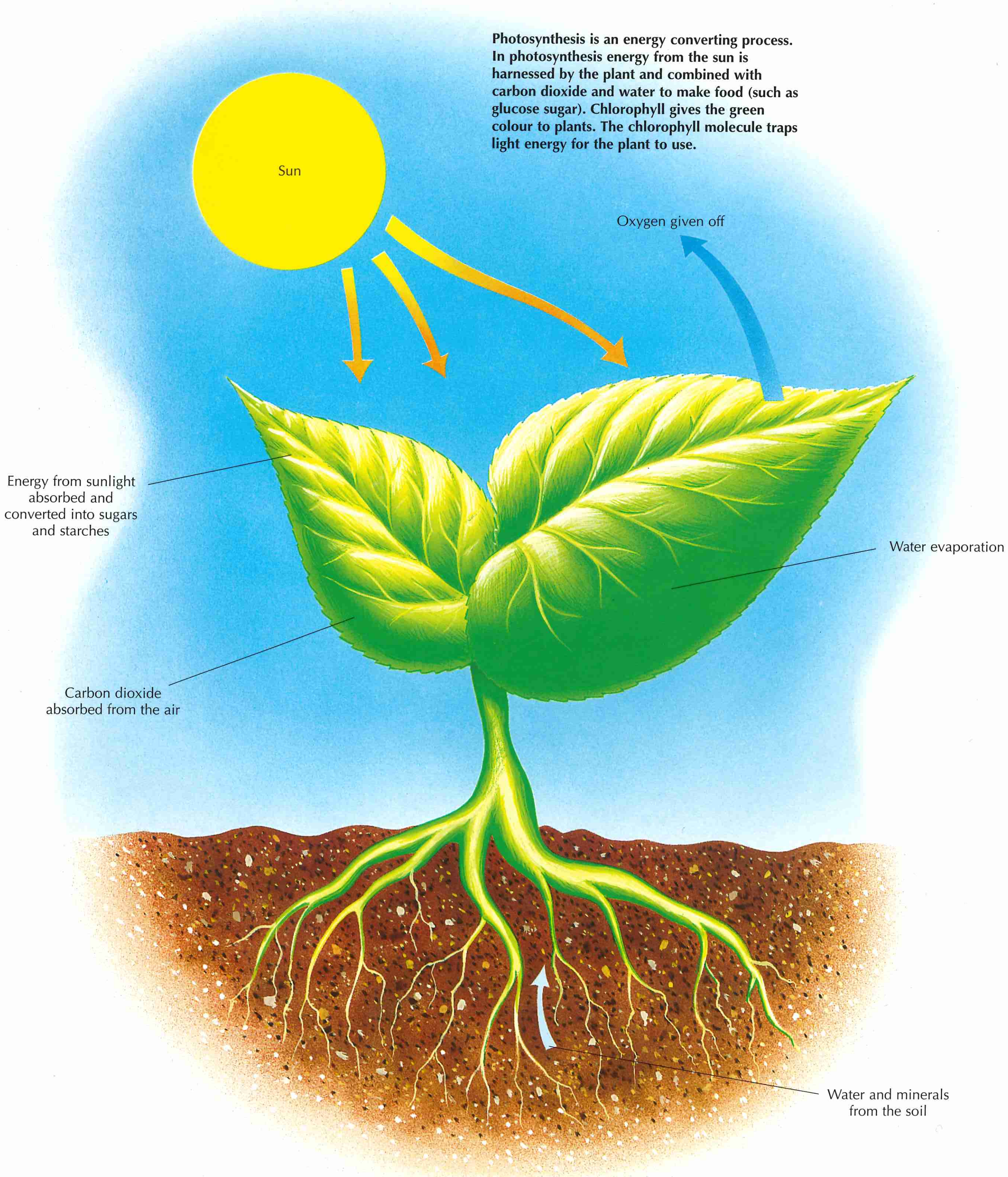
The *sun* is the source of biomass energy

Plants use the energy from the sun to convert carbon dioxide and water into carbohydrates (such as glucose) and oxygen. This process is called photosynthesis. Carbohydrates provide the plant with an energy store. Carbohydrates in our diet supply us with energy as well. The energy stored in the plant is released on burning (imagine the warmth of a log fire) or when the plant dies – and carbon dioxide and water return once more to the atmosphere.

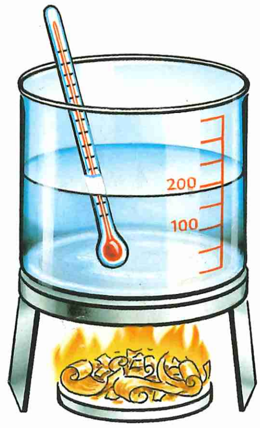
We still use ancient biomass energy. The fossil fuels of oil, natural gas and coal all have their origins in living plant organisms – and like living plant organisms, fossil fuels also release carbon dioxide when they burn.

The important step in *photosynthesis* looks like this:

Photosynthesis is an energy converting process. In photosynthesis energy from the sun is harnessed by the plant and combined with carbon dioxide and water to make food (such as glucose sugar). Chlorophyll gives the green colour to plants. The chlorophyll molecule traps light energy for the plant to use.



Activity 1



Moisture content and combustion of biofuels

Compare the energy content of freshly cut wood with that of a similar sample that has been air dried. You must make it a fair test by using:

- same mass of wood each time
- same size pieces (surface area effects). Note that wood shavings are easier to light than large pieces.
- same procedure to measure the heat output on combustion.

Place 200ml of cold water in a glass or metal container, supported on a tripod.

Weigh out 10g of the fuel being tested into a fireproof dish.

Measure the water temperature at the start and the highest temperature reached.

Ignite the fuel below the container of water.

Measure the time taken to reach the maximum temperature.

How does the moisture content affect the performance of the fuel?

What are the problems with making accurate measurements, how could you solve them?

Temp (°C)	Time (mins)

Activity 2

Making a liquid biofuel, ethanol

Fermentation requires days or even a few weeks to reach completion. Anaerobic respiration of yeast produces the alcohol called ethanol, together with carbon dioxide gas. The rate of production of the gas gives a measure of the progress of the fermentation.

Using a commercial wine kit, or simply a mixture of water, sugar and yeast, set up a fermentation jar (1). This works best under warm conditions, about 40° Celsius. You must stop air getting into the fermentation jar by using a water-filled airlock or a simple bunsen valve.

When fermentation ends, distil a sample of the mixture to recover the ethanol (boiling point 78° Celsius) (2).

Burn a 5ml sample of ethanol in a saucer (3).

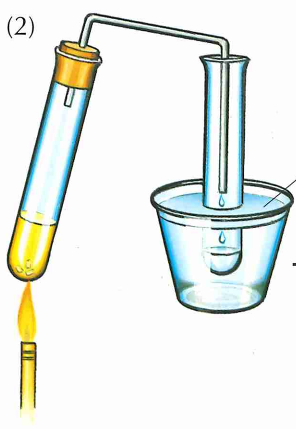
Observe the flame colour, the ease of lighting and evidence of complete combustion – no smoke or soot.

What residue remains?

(1)

sample →

(2)



sample →

(3)