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Biofuels

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GCSE key words
Energy
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Burning fossil fuels releases extra carbon dioxide into the atmosphere, which contributes to global warming. However, burning renewable biofuels is part of the normal carbon cycle and does not contribute to an increase in atmospheric carbon dioxide. This article looks at the ways in which the energy stored in biofuels can be released.

Using vegetable oil as fuel in diesel engines is not a new idea. Rudolf Diesel's first engines were built to run on peanut oil in countries which had no petrochemicals industry.

Plants use water from the soil, carbon dioxide from the air, and mineral nutrients such as nitrate, sulphate and phosphate ions, also from the soil, to make carbohydrates, proteins and lipids (fats). Photosynthesis is effectively a type of chemical process called **reduction**. Plants release oxygen as part of this process; they also use hydrogen atoms from the water to make sugar.

The materials made by a plant form its **biomass**. Plant biomass is the immediate source of energy for all living things, not just animals but also the plant itself. Respiration releases the energy from carbohydrates. This process is the converse of photosynthesis and can be thought of as an **oxidation** process. It requires oxygen and releases carbon dioxide gas to the atmosphere; hydrogen atoms are also transferred back into the other by-product, water.

Combustion is also an oxidation process – to release the energy from a fuel, oxygen is needed as well as the fuel. Carbon dioxide and water are produced. Combustion therefore has the same starting materials and end-products as respiration:

organic matter + oxygen → carbon dioxide + water

Biofuel basics

When fossil fuels, such as oil, natural gas and coal, are burned, the carbon dioxide released has been out of circulation for a very long time, so any which is released in this way is in addition to that maintained by normal carbon cycling (see Figure 1).

When fresh biomass, such as wood or the residue of crops, is burned, the carbon dioxide that is released was in the atmosphere recently and is now returned to it. Other plants grown for harvesting as fuel then utilise this carbon dioxide.

Some crops grow very quickly, producing a lot of biomass in a short time (Table 1), and a number of crops are grown deliberately for energy production, rather than to provide food. Table 2 lists some examples.

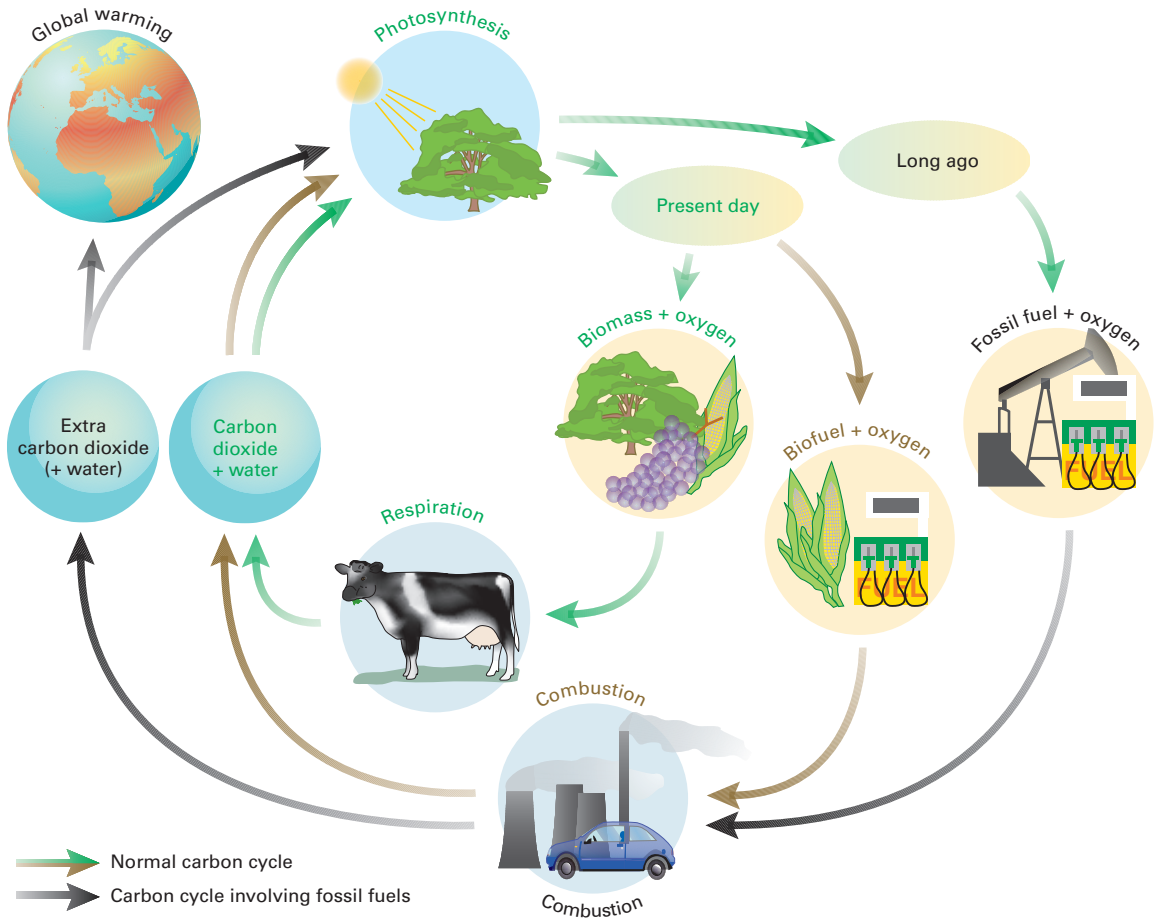

Figure 1 *The carbon cycle and fuels*

Another way to make a biofuel is to use bacteria to decompose organic materials under anaerobic conditions and release methane, an inflammable gas. This biogas, produced by microbial respiration, can be used as a fuel to power the generation of electricity in sewage works, for example.

Although many diesel cars can run on biodiesel, some with particular makes of injector pump cannot — so don't try putting biodiesel in the family car without thorough research!

Table 1 *Fast-growing biomass crops*

Type of plant	Annual yield of dry matter (tonnes per hectare)
Wood produced by short rotation coppicing of willow or poplar	10
Giant grasses, such as *Miscanthus*, reed canary grass or switchgrass	60

Biofuel for cars

Each of the energy crops in Table 2 can be converted to a liquid fuel that can be used to power vehicles. The main way in which this is produced is by fermentation, followed by distillation, to produce **ethanol**. The crops contain sugar, either as individual sugar molecules or in the polymers, starch or cellulose. Sugar and starch are used in most instances:

- stage 1: starch/cellulose is broken down to sugar, involving the use of acid
- stage 2: sugar → ethanol + carbon dioxide, using yeast

- Log on to **http://bioenergy.ornl.gov/papers/miscanthus/miscanthus.html to find out more about a fast-growing biomass crop.**

Table 2 *Energy crops*

Energy crop	Examples	Fuel use	Alternative uses
Cellulose/ lignin crops	Wood, straw	Combust directly as heating fuel	Digest cellulose to sugar and use this to make ethanol, which can be blended with petrol
Starch crops	Barley, wheat, maize and rice seeds, potatoes	Use to produce ethanol, which can be blended with petrol	Straw from cereals can be burned
Sugar crops	Sugar cane, sugar beet	Use to produce ethanol, which can be blended with petrol	
Whole plants	Maize, *Miscanthus*, reed canary grass, coppiced willow, poplar	Combust directly as heating fuel	Convert to methanol or ethanol, which can be blended with petrol
Oil crops	Sunflower, olive, palm, oilseed rape	Combust directly as heating fuel	Add to transport fuel to make biodiesel

Box 1 Biodiesel: a case study

Was that a whiff of doughnuts when that car went past? Maybe the driver was someone like Steve Dewar. Although Steve has an ordinary diesel-engined car it can also use biodiesel. Steve uses waste cooking oil from a local café to make biodiesel. Chip shop and curry restaurant oils are not suitable, but filtered doughnut frying oil is fine.

Waste cooking oil is normally sent to landfill sites or put down drains. It was used for pet food, but since there is a risk that it could contain animal products it can no longer be used for this. So, as well as helping his pocket, biodiesel also reduces the waste problem — something that Steve cares deeply about.

Steve learned about biodiesel from a friend and researched how to make it on the internet. One big advantage of biodiesel in the past was that it cost less than conventional diesel. It also has a higher cetane rating (a measure of how easily it ignites), produces cleaner emissions — no oxides of nitrogen, sulphur dioxide or particulates — and makes car engines run better.

The price advantage has almost disappeared because home biodiesel makers now have to pay more fuel tax on their oil — 47p per litre. Commercial companies which can prove their biodiesel meets European standards pay less fuel tax, but there aren't many commercial producers yet. Biodiesel is popular in Germany and there is a growing band of backyard biodiesel producers in the UK.

The science of making biodiesel

Waste cooking oil consists mainly of triglycerides. The process uses methanol and sodium hydroxide to split the triglyceride molecules into glycerol and fatty acids. The fatty acid products are the fuel element. Glycerol can be composted, recycled and used to make other products.

Making biofuel

A small-scale biodiesel plant

● **Log on to www.greenfuels.co.uk and click on biodiesel. Look at both sections. You can download a PDF that describes the process of making biodiesel in detail.**

The ethanol can then be blended with petrol (usually between 5% and 22% ethanol). Brazil has over 300 distilleries, and the fuel derived from sugar cane there is called gasohol. In the USA, Spain and France, maize and other cereal crops are used as the feed-stock. The organism involved in ethanol production is often a variety of yeast; experiments are also being conducted in Canada and Scandinavia with other microbes that can digest woody material, releasing sugar from lignin and cellulose.

The other plant product that can be used as a fuel is the oil produced by plants within their seeds or fruits. The seeds, such as those of sunflower, rape or palm, or fruits, such as the olive, are crushed to release the oils. The oils can be used in two ways. They can be added directly to diesel fuel as a supplement or they can be converted to **biodiesel** (see Box 1).

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