Chem Factsheet

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Is Bio Ethanol Carbon Neutral?

A **carbon neutral** process is one that results in **ZERO net emissions of carbon dioxide** into the atmosphere.

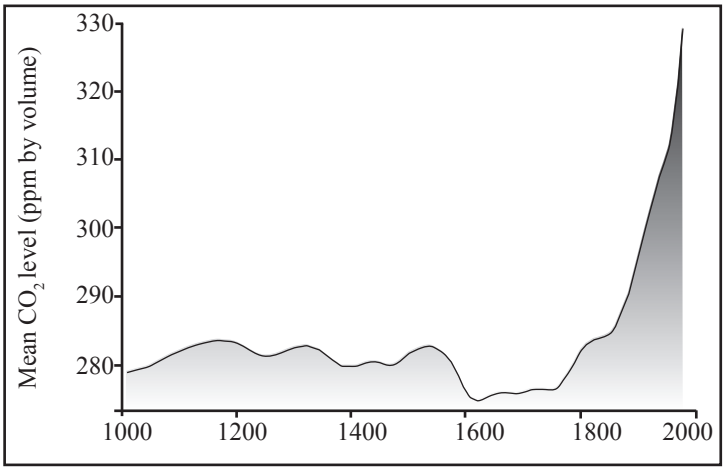
This concept has become very important since scientists identified carbon dioxide as a **greenhouse gas** and therefore responsible for **global warming** resulting in **climate change**.

A **greenhouse gas** is one which allows some of the heat energy from the Sun to be *retained* (the **greenhouse effect**) in the Earth's atmosphere (just like heat is retained in a greenhouse) keeping it at a temperature where life can exist. The average temperature of the Earth's surface should be about 14°C but, without the presence of greenhouse gases, and the consequent greenhouse effect, the whole of the Earth's surface would be covered in ice!

This shows that greenhouse gases are NOT a nuisance in themselves! In fact, they are essential for life to exist on Earth but, if their concentrations become too high, then more energy is retained in the atmosphere than is radiated out into space resulting in a net increase in atmospheric temperature – **global warming**. In truth, the levels of the greenhouse gas, carbon dioxide have probably already become too high as shown in the graph. This shows the dramatic increase in CO_2 levels since the start of the Industrial Revolution (ca. 1760) when the burning of coal and fossil fuels escalated to meet demands for energy.

NOTE: The concentration of atmospheric carbon dioxide is predicted to exceed 400ppm by volume for the first time ever by 2014.

Variations in atmospheric carbon dioxide during the last millennium



NOTE: Carbon dioxide is not the only greenhouse gas. Water vapour and methane (CH_4) are the other main culprits although many man-made substances such as hydrofluorocarbons (substitutes for ozone destroying CFC's – chlorofluorocarbons) also contribute.

Global warming is this average rise in temperature of Earth's atmosphere and its oceans. Earth's mean surface temperature has increased by about 0.8 °C since the early 20th century, with about two-thirds of the increase occurring since 1980.

Scientists are certain that **global warming** is primarily caused by increases in the concentrations of greenhouse gases (especially carbon dioxide) produced by human activities such as burning fossil fuels and burning living plants and trees during deforestation processes. Hence, the emissions of carbon dioxide need to be controlled.

NOTE: Scientists have made various predictions but, in 2007, their results were summarised by the Intergovernmental Panel on Climate Change (IPCC) suggesting that, during the 21st century, the global surface temperature is likely to rise by a further 1.1 to 2.9°C. However, they said it could be 2.4 to 6.4°C if CO_2 emissions are not controlled.

Climate change caused by **global warming** is predicted to vary from region to region around the globe. The effects will include a rise in sea levels and a change in the amounts and patterns of rain and snow fall resulting in more frequent extreme weather events such as heat waves, droughts and heavy rainfall. Also, some deserts are expected to expand and, in the Arctic, retreat of glaciers and thawing of the permafrost and sea ice have already been observed. This may well lead to some species becoming extinct (e.g. the polar bear).

Humans will also be under threat as crop yields are reduced in adverse weather and food-producing land is lost as a result of permanent flooding (called "inundation").

NOTE: As the levels of carbon dioxide increase, more and more becomes dissolved in the oceans. This causes the acidity of the oceans to increase as a result of the production of carbonic acid.
$CO_2 + H_2O \rightarrow H_2CO_3$
This does / will disrupt habitats and lead to the extinction of some species. e.g. corals.

Reducing carbon (dioxide) emissions

Although carbon dioxide is not the only problem, limiting its emissions has become a global priority. It is only by universal agreement and action that emissions can be reduced effectively.

Various approaches are being used or considered. Simple reduction in energy usage is the obvious way forward but this is very difficult if global economic development is to continue. Capturing carbon dioxide as it is emitted and either storing it (e.g. in vacant rock fissures) or converting it to a non-polluting form where it cannot add to global warming is another – much the same as when plants and animals were fossilised millions of years ago with the resulting carbon compounds being trapped in rock structures until humans intervened! Alternatively, carbon-free energy sources such as wind power, solar power, tidal power, hydrogen can be used. The use of **bio fuels**, rather than fossil fuels, is the priority for this Factsheet.

Biofuels

Simply, bio fuels are renewable fuels derived from living organisms or the products of living organisms. "Biogas" (a methane rich gaseous mixture) made from decaying manure and sewage by anaerobic bacteria, and naturally in landfill sites, is one common example.

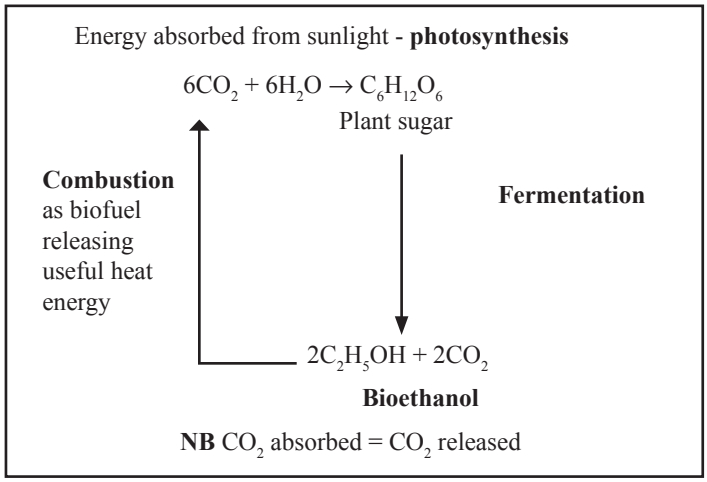
However, bio fuels fall into two main categories: **bio alcohols and biodiesels**. Bio alcohols, such as **bioethanol**, are produced by **fermentation** processes using yeast and bacteria to break down the starch in corn and other plants. To create **biodiesel**, oils already found in crops such as soybeans or rape seed, are treated with methanol or ethanol to turn them into biodiesel.

Bioethanol

Bioethanol is ethanol produced from living organisms or the products of living organisms. It is a **renewable energy source** and should not be confused with ethanol produced from non-renewable fossil fuels.

e.g. Crude oil → naphtha by fractional distillation
then naphtha → ethene (CH_2=CH_2) by cracking
then ethene to ethanol by catalytic (H_3PO_4) hydration
i.e. CH_2=CH_2 + H_2O → CH_3CH_2OH

The production and use of bio ethanol as a fuel can be seen as a cyclic process.



1. Plants such as sugar cane trap solar energy as chemical energy by the process of **photosynthesis** whereby carbon dioxide is removed from the atmosphere and combined with water to form glucose.
   $6CO_2$ + $6H_2O$ + Solar Energy → $C_6H_{12}O_6$ ------(1)
2. The glucose is **fermented** by yeast at about 37°C under anaerobic conditions to produce ethanol and carbon dioxide.
   $C_6H_{12}O_6$ → $2CH_3CH_2OH$ + $2CO_2$ -----(2)

NOTE: Ideally the carbon dioxide released will be captured to give a net reduction in atmospheric carbon dioxide

3. The ethanol is **combusted** as a fuel to provide useful energy
   $2CH_3CH_2OH$ + $6O_2$ → $4CO_2$ + $6H_2O$ + heat energy ------(3)
4. The carbon dioxide and water released in processes 2 and 3 can then be reused by plants to form more glucose by process 1.

NOTE: If equations (1), (2) and (3) are added together we get SOLAR ENERGY → HEAT ENERGY

Is bioethanol carbon neutral?

From the point of view of the chemical cycle (see above), it would appear that solar energy has been converted to heat energy with zero net release of carbon dioxide to the atmosphere. This should mean that the use of bio ethanol as a fuel is carbon neutral!

However, the overall manufacturing process must be looked at in detail to decide. In fact it is **NOT carbon neutral** but its **carbon footprint** is considerably less than simply burning the equivalent amount of coal or fossil fuel.

Additional processes, along with their energy requirements, need to be assessed. These include the possible use of fossil fuel energy to:

1. clear land on which to grow the fuel crops.
2. power machinery to plant, tend and harvest the crops
3. manufacture fertilisers to grow the crops
4. transport the crops to the manufacturing site
5. manufacture, build and maintain the structure of the manufacturing plant
6. maintain the (modest) operational temperature of the fermentation process
7. distil the aqueous ethanol produced to provide usable pure ethanol
8. transport the ethanol (or ethanol mixed with petroleum) to distribution points.

Some or all of these points will apply, meaning the bio ethanol is NOT completely carbon neutral. However, use of bio ethanol is estimated to reduce carbon emissions by up to 90% relative to the equivalent use of petrol. Furthermore this should be improved since some of the offending processes (1-8) involve emissions only during set-up, not as on-going processes.

Additional problems

Apart from carbon neutrality, or the lack of it, there are other drawbacks to this "miracle fuel" which include:

1. land that would otherwise be used to grow food is being used to grow fuel crops.
2. use of new land to grow fuel crops involves land clearance (possibly deforestation, especially significant in the rain forests) and loss of wildlife habitats, possibly leading to extinction.
3. materials which would otherwise be used as food are being converted to fuel.
4. bio ethanol is not as efficient as petroleum. Its energy content is only 70% of that of petrol but its cost is not proportionally less.
5. ethanol (because of mutual hydrogen bonding) absorbs water very strongly (it is said to be very hygroscopic). This means that bio ethanol is much more corrosive than petrol to engine parts.
6. because of the presence of stronger hydrogen bonds between molecules, bio ethanol is much less volatile than petrol causing possible ignition problems, especially in cold weather.

Summary

Bio ethanol is NOT the perfect carbon neutral and sustainable fuel that was at first envisaged because of the reasons discussed. However, it has the potential to become more and more so as science develops procedures to reduce or eliminate the practical and ethical problems. Perhaps one of the most hopeful developments will be the production of bio ethanol from cellulose (a non-food carbohydrate) derived from various grasses.

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