

Combustion of fuels

Several waste products are released when fuels burn. These do not just disappear and they can harm the environment by contributing to global warming, global dimming and acid rain.

Complete combustion

Fuels burn when they react with oxygen in the air. If there is plenty of air, complete combustion happens. Coal is mostly carbon. During complete combustion, carbon is oxidised to carbon dioxide:

carbon + oxygen → carbon dioxide

Carbon dioxide is a *greenhouse gas*. Increasing concentrations of it in the atmosphere contribute to global warming.

Hydrocarbon fuels contain carbon and hydrogen. During combustion, hydrogen is oxidised to water (remember that water, H₂O, is an oxide of hydrogen). In general:

hydrocarbon + oxygen → carbon dioxide + water

The combustion of a fuel may release several gases into the atmosphere, including:



Clouds of smoke and other combustion products are emitted from chimneys

Incomplete combustion

If there is insufficient air for complete combustion, incomplete combustion (also called partial combustion) happens. Hydrogen is still *oxidised* to water, but carbon monoxide forms instead of carbon dioxide. **Carbon monoxide** is a toxic gas, so adequate ventilation is important when burning fuels.

Solid particles (particulates) are also released. These contain carbon and are seen as soot or smoke.

Particulates cause global dimming. They reduce the amount of sunlight reaching the Earth's surface.

Carbon dioxide dissolves in water in the atmosphere to form a weakly acidic solution. This means that rainwater is naturally slightly acidic. However, some of the products from burning fuels make rainwater more acidic than normal. This is acid rain.

Acid rain reacts with metals and rocks such as limestone, causing damage to buildings and statues.

Acid rain damages the waxy layer on the leaves of trees. This makes it more difficult for trees to absorb the minerals they need for healthy growth and they may die. Acid rain also makes rivers and lakes too acidic for some aquatic life to survive.

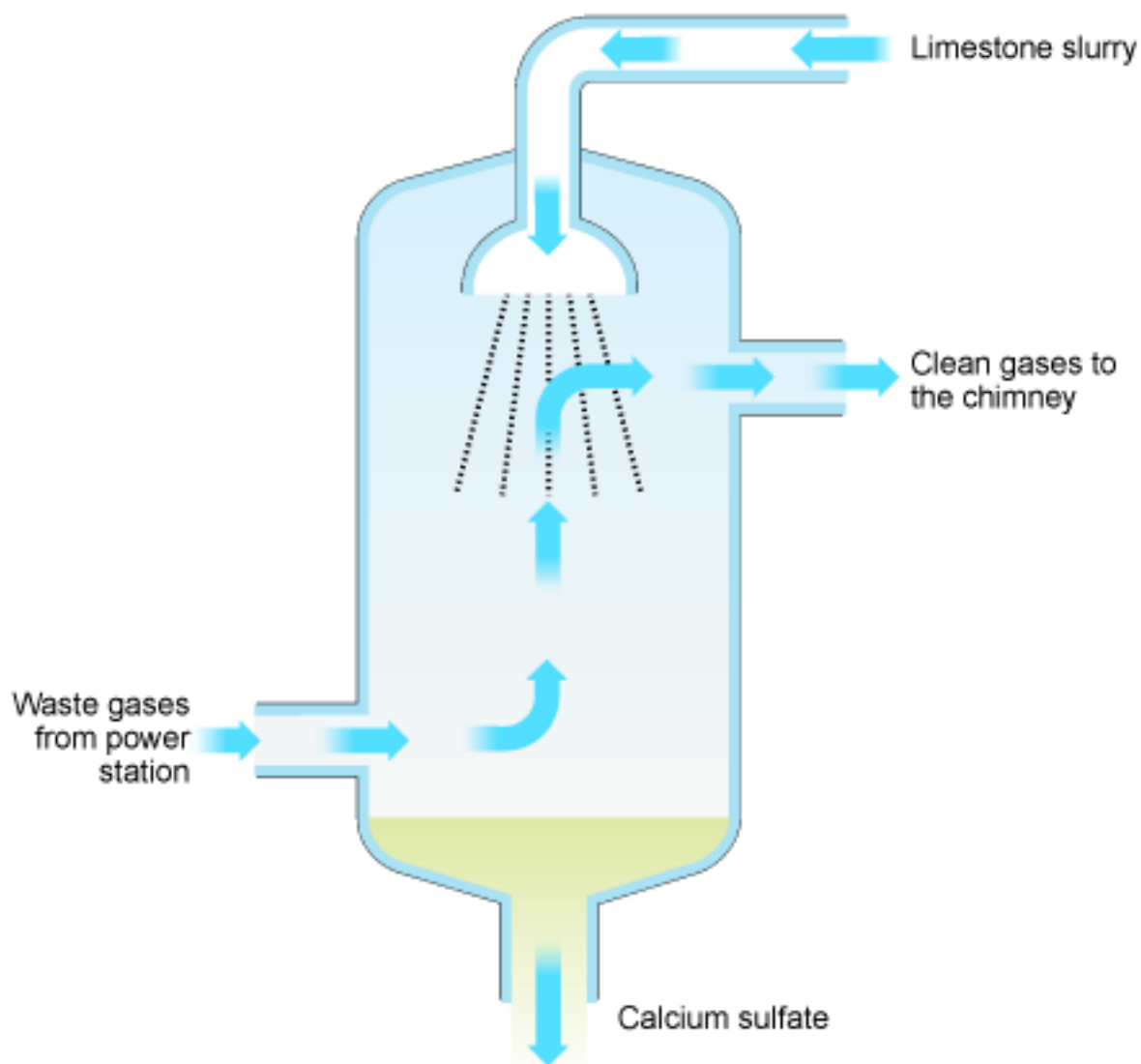
Sulfur dioxide

Coal and most hydrocarbon fuels naturally contain some sulfur compounds. When the fuel burns, the sulfur it contains is oxidised to sulfur dioxide:

sulfur + oxygen → sulfur dioxide

This gas dissolves in water to form an acidic solution. It is a cause of acid rain.

Sulfur can be removed from fuels before they are used. 'Low sulfur' petrol and diesel are widely available at filling stations to use in vehicles. In power stations, sulfur dioxide can be removed from the waste gases before they are released from chimneys. The waste gases are treated with powdered limestone. The sulfur dioxide reacts with it to form calcium sulfate. This can be used to make plasterboard for lining interior walls, so turning a harmful product into a useful one.



The process of removing sulfur dioxide

Oxides of nitrogen

At the high temperatures found in an engine or furnace, nitrogen and oxygen from the air can react together. They produce various oxides of nitrogen, often called NO_x . These also cause acid rain.

Coal and crude oil are *non-renewable* resources. They take so long to form that they cannot be replaced once they have all been used up. This means that these fossil fuels are likely to become more expensive as they begin to run out. Petrol, diesel and other fuels produced from crude oil make a range of harmful substances when they are burned, including:

- carbon dioxide
- carbon monoxide
- water vapour
- particulates (solid particles)
- sulfur dioxide
- oxides of nitrogen or NO_x .

Biofuels are fuels produced from plant material. They have some advantages and disadvantages compared to fossil fuels.

Biodiesel

Biodiesel is made from rapeseed oil and other plant oils. It can be used in diesel-powered vehicles without needing any modifications to the engine.

Bioethanol

Ethanol, C_2H_5OH , is not a hydrocarbon because it contains oxygen as well as hydrogen and carbon. However, it is a liquid fuel that burns well. Bioethanol is made by fermenting sugars from sugar cane, wheat and other plants. It cannot be used on its own unless the engine is modified. However, modern petrol engines can use petrol containing up to 10 percent ethanol without needing any modifications, and most petrol sold in the UK contains ethanol.

Ethical concerns

There are ethical issues surrounding the use of biofuels. For example, crops that could be used to feed people are used to provide the raw materials for biofuels instead. This could cause food shortages or increases in the price of food. There are other economic issues surrounding the use of biofuels, including:

- **human resources** - more people are needed to produce biofuels than are needed to produce petrol and diesel
- **increased income** - for farmers
- **lower fuel prices** - biofuels limit the demand for fossil fuels, helping to reduce increases in fuel prices.

There are environmental issues surrounding the use of biofuels. Biodiesel naturally contains little sulfur. For example, it may be said that they are **carbon neutral** – the amount of carbon dioxide released when they are used is the same as the amount absorbed by the plants as they grew. If so, this would reduce the production of this greenhouse gas. However, while biofuels produce less carbon dioxide overall, they are not carbon neutral. This is because fossil fuels are used in their production, for example in making fertilisers for the growing plants.

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