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Alternative Energy Sources

Sally Morgan

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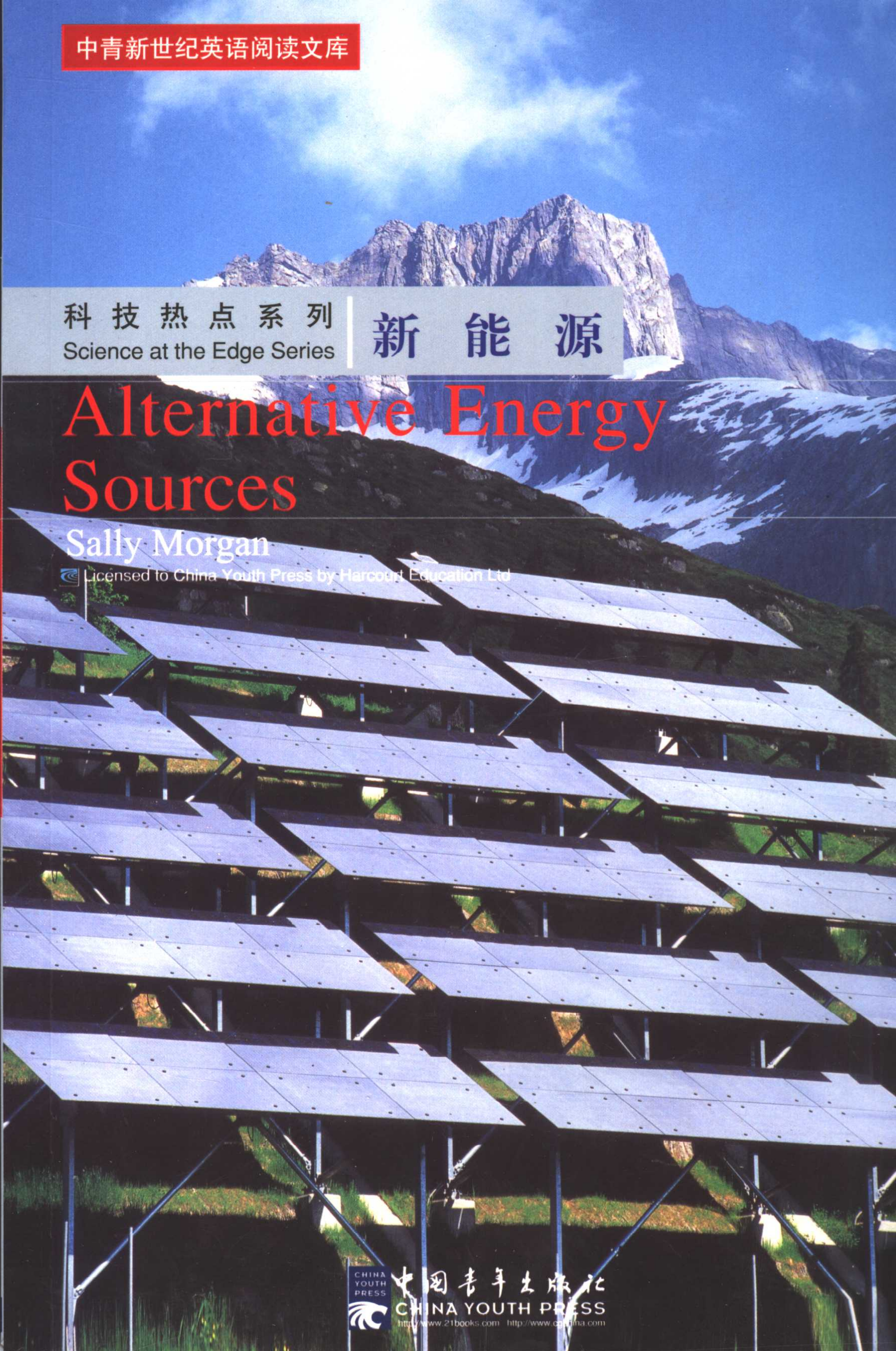

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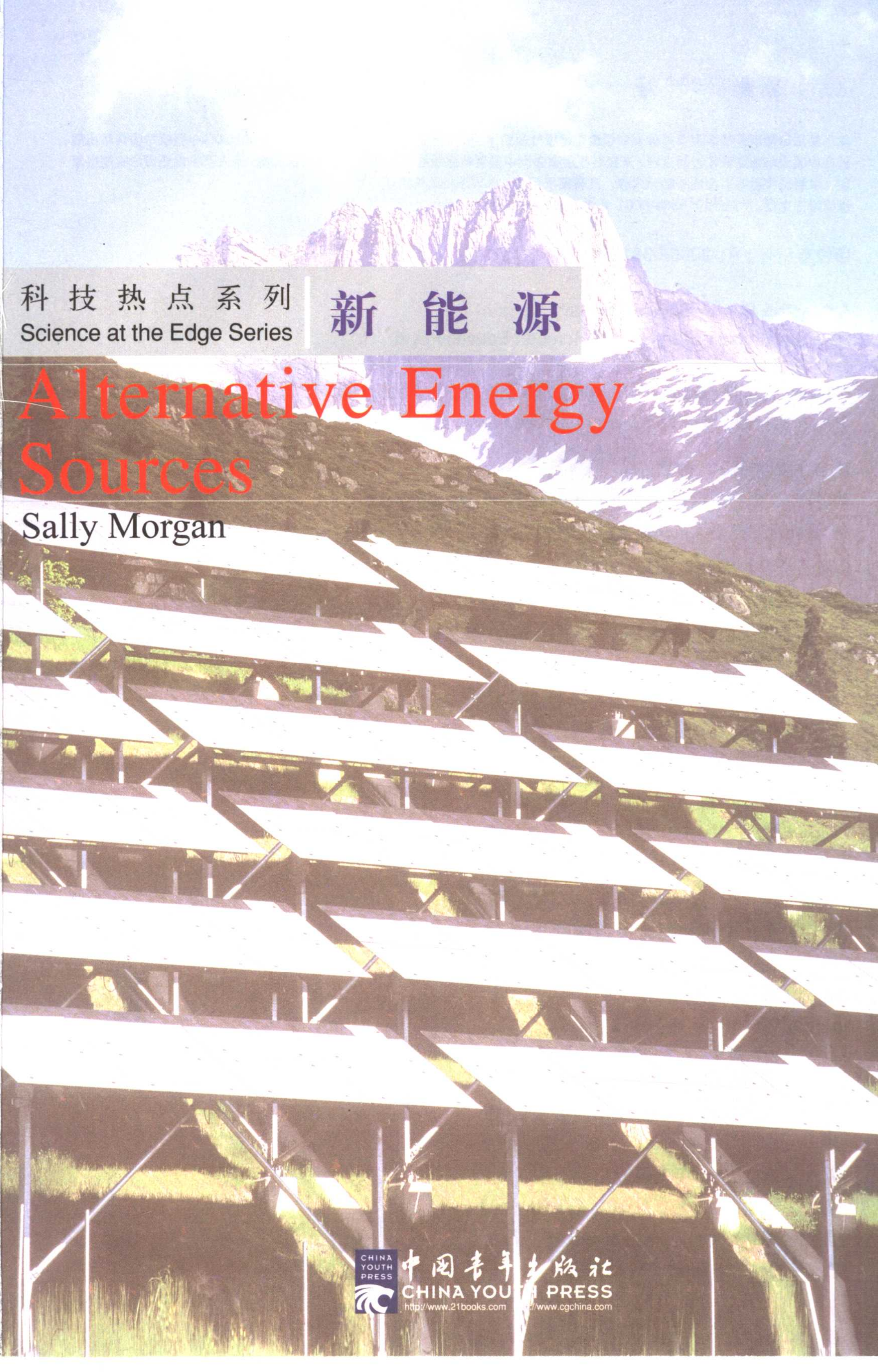

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Alternative energy sources

During 2001, the residents of California in the USA discovered what it would be like to live in a world where electricity was in short supply. The state suffered from periods of time when the supply could not keep up with the demand and entire districts had to survive without electricity for many hours. The Californian crisis was caused by a change in the way the power companies sold energy, but it was a very good illustration of how dependent people have become on a regular supply of electricity.

One of the immediate effects of this crisis was that many Californians turned to alternative energy sources that would give them independence from the power companies who had traditionally provided their energy. Many families rushed out and purchased solar panels to provide their homes with electricity and hot water.

Run on fossil fuels

The modern world is dependent on **fossil fuels** – oil, gas, coal and **peat**. Over the last two hundred years or so the quantities of fossil fuels extracted from the ground have escalated. Fossil fuels are used by power stations to **generate** electricity and to fuel our cars. They are essential to a modern lifestyle, but they have been used at the expense of the environment. Environmental damage is caused at every stage of extracting, processing and using these fuels. Coal is mined from the ground, while oil and gas are pumped out of the ground. Then they have to be transported around the world to where they are to be used. Finally, when they are burnt, these fuels release polluting gases into the atmosphere, causing **acid rain** and global warming.

The supply of fossil fuels will also eventually run out. Estimates of how long these fuels will last are uncertain, as new deposits are being found all the time. However, most experts agree that oil and gas will probably last between 30 and 50 years, while coal may last a couple of hundred years.

New energy sources

Over the last 100 years, people have learned how to use the energy locked up in fossil fuels. But there are other sources of energy. Each day, vast amounts of solar energy reach the ground. This energy is spread over the whole surface of the planet. The same is true for wind and wave energy. These forms of energy are less easy and more expensive to use than fossil fuels. However, when fossil fuels start to run out, people will need to find ways of using the energy from **renewable** sources. At some point in the future, all of the world's energy needs will probably have to come from such sources.

In September 2000, protesters against the high price of fuel, and the tax on it, **blockaded** British oil **refineries** and storage **depots**. Petrol tanker drivers were reluctant to break the blockade and so the British public experienced petrol shortages.

A fossil-fuelled world

Although there are many different sources of energy available, more than three-quarters of the energy used in developed countries comes from oil, gas and coal. These fuels are rich in carbon and **hydrogen**. They burn in air to form **carbon dioxide** and water, a process that releases heat energy.

Fossil fuel supplies

Fossil fuels were formed millions of years ago from the remains of plants and animals. There is a finite supply of these fuels and now they are being used up at a far faster rate than they are being formed. Soon they will run out.

Drilling for oil

Oil is formed under the sea from the remains of marine life. The oil formation process is similar to that of coal (see below). The remains become buried under layers of sediment, and the resulting high pressure and temperature cause them to turn into a black liquid with a high carbon content. Often, gas forms in the same place as the oil. The liquid oil moves towards the surface and becomes trapped under layers of **impermeable** rock. The pressure builds up as more liquid moves upwards.

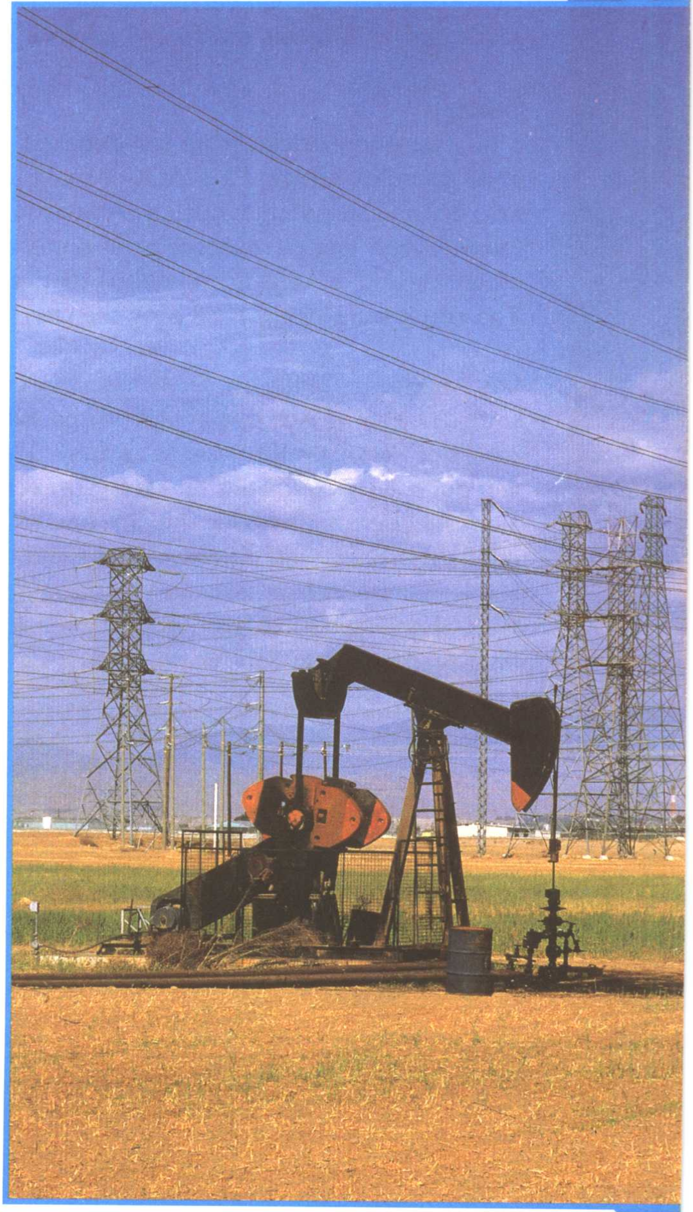
Coal formation

The process of coal formation starts with a build-up of dead plant matter, which becomes buried in swampy or waterlogged conditions. The lack of oxygen in the ground prevents bacteria from completely breaking down the plant matter. This decaying matter is buried deeper by more plant material and by sediment. These layers press tightly together, causing the pressure and temperature to increase. Gases and liquids escape to the surface, leaving a solid material behind. Peat develops within hundreds of years and contains about 60 per cent carbon. Millions of years later, the peat turns into **lignite**, a low-grade brown coal with 70 per cent carbon. Eventually, the lignite turns into **anthracite** coal. This is a high-quality coal that is 95 per cent carbon.

Although oil is formed under the sea, many of the world's oil fields are located on land. This is a result of changes in sea levels and movements in the Earth that have 'uplifted' rocks, causing them to lie above water.

The oil and gas is reached by drilling wells, sometimes several kilometres long, through the overlying rock. When the drill breaks through the rock above the oil, pressure is released, and the oil spurts out of the well. To prevent this from happening, engineers place special valves at the top of the well. When there is not enough pressure to push oil to the surface, water or gas can be pumped into the well to force the oil out. The crude oil that comes out of the ground has to be taken to refineries to be processed before it can be used.

Oil companies are now searching for new oil and gas fields in some of the world's most inhospitable places, such as the frozen ice fields of Siberia and Alaska and the Arctic Ocean. Once all the oil fields are depleted, the energy companies may turn their attention to oil shales. These are rocks that have oil inside them. However, removing oil from rock is very expensive and produces a lot of waste.



A 'nodding donkey' **rig** pumps oil to the surface in an onshore oil field in California, USA.

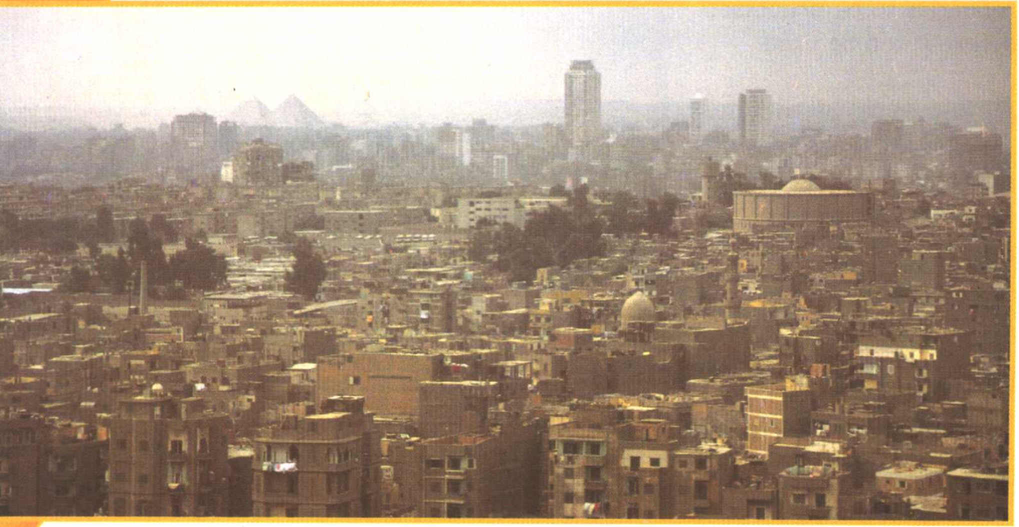
Air pollution

Fossil fuels produce a number of pollutants when they are burnt, in addition to carbon dioxide and water. Coal often contains sulphur, which is released as **sulphur dioxide** – one of the chemicals that causes acid rain. When petrol and **diesel fuels** are burnt in engines, gases such as **nitrous oxide** and **carbon monoxide** are released.

Smog

The gases and particles from car **exhaust** pipes can create photochemical **smog**. This form of smog is particularly common in hot, dry and sunny cities such as Athens in Greece, Cairo in Egypt and Mexico City. The car exhaust pipes pump out gases such as nitrous oxide, carbon monoxide and ozone that react together in the sunlight. The result is a smoggy haze over the city.

Los Angeles in California, USA, has suffered badly in the past from smog. The smog was due in part to the exhaust fumes from millions of cars, but also from the local geography. The city lies by the coast and is surrounded by mountains. In certain weather conditions, the smoggy air would be trapped over the city, and air quality would fall steadily until atmospheric conditions changed and the smoggy air was replaced by cleaner air. A hazy layer can still be seen over Los Angeles, but the level of pollutants has fallen dramatically due to new legislation and improved pollution control on cars.



Heavy traffic and local industry contribute to the smog that hangs over Cairo in Egypt.

Acid rain

Coal-fired power stations release sulphur dioxide, especially those burning lignite coal. This gas, together with nitrous oxides from vehicle exhausts, reacts with water in the air to form weak acids. These acids create acid rain – rain that has a lower pH than normal. Acid rain erodes and damages the outside of buildings and statues, especially those made of limestone.

Acid rain falling on conifer forests in mountainous areas of Scandinavia, North America and central Europe has caused long-term damage to the trees. The soils become more acid and this causes **toxic** compounds, such as **aluminium**, to be released. The first signs of damage are a tree's needles turning brown and whole branches dying. Increased acidity in the soil damages trees' roots, and this reduces their ability to take up water and nutrients. The trees become more **vulnerable** to frost and disease. Eventually, they die.

Lakes are also vulnerable. The **acidic** rainwater drains off soils into the lake, causing it to become more acid. Aluminium in the water causes the **gills** of fish to produce more mucus, and this prevents them from obtaining sufficient oxygen from the water. In extreme cases, all life in the water may die.

Global warming

Burning fossil fuels releases carbon dioxide. Carbon dioxide is described as a 'greenhouse' gas, because it traps heat in the atmosphere. The presence of some greenhouse gases keeps the Earth at a temperature of approximately 15°C, which allows life to survive. A recent increase in the use of fossil fuels has caused the levels of carbon dioxide in the atmosphere to increase, too. More carbon dioxide means that more heat is trapped, and this has caused the average global temperature to rise. This is called global warming.

The effects of global warming are uncertain, but it is likely that the increasing temperatures will disrupt climates around the world, causing some regions to have lower rainfall and other regions to have more. The warmer temperatures will cause ice caps and **glaciers** to melt, which, combined with the expansion of water in oceans, will cause sea levels to rise, flooding low lying areas which are heavily populated. Extreme weather events such as droughts and storms could also become more common.

Extraction and transport

Every stage in the process to extract and process fossil fuels can harm the environment. Coal is mined, either from the surface in huge open cast mines (also called strip mines) or by underground tunnels. Open cast mining eats up hectares of countryside, leaving behind huge holes that have little use and produce dust and other discharges into the atmosphere. Lignite is a poor quality coal that is taken from open cast mines. When burnt, it releases a lot of sulphur dioxide, which creates acid rain. Mining produces large quantities of waste, which is usually dumped in piles called spoil heaps. Water runs off these heaps, and the drainage from these areas can carry pollutants into rivers and lakes.

Wells are dug into the ground to bring the oil to the surface. There can be local damage from spills, but most of the damage occurs during its transportation. Some of the largest tankers carry up to 500,000 tonnes of crude oil and many only have a single hull. Any damage to the hull results in an oil spill. In the past, there have been numerous tanker accidents in which hundreds of thousands of tonnes of crude oil have been spilt into the sea. The oil causes widespread damage to local populations of birds, mammals and invertebrates, and also damages

Brown coal (lignite) is stripped from the ground in central Europe, creating huge holes. Power stations burn the coal. It is poor quality and releases sulphur dioxide, a gas that causes acid rain.

In 1989 the oil tanker *Exxon Valdez* ran aground off the coast of Alaska, **rupturing** its tanks. The disaster created a huge oil slick and terrible environmental damage. The clean-up operation cost billions of dollars.

coastlines. Large quantities of oil also enter the water every year when tankers clean out their tanks, or from minor spills in ports.

Changes ahead

Energy demands are increasing all the time. Approximately one third of the world's population lives without electricity, relying solely on battery power and kerosene lamps and candles. These people's governments want to supply them with electricity in order to improve their standard of living. To provide electricity to all these people would mean building thousands of new power stations in order to greatly increase the current energy generating capacity. This would severely deplete the remaining supplies of fossil fuels, and send carbon dioxide **emissions** soaring out of control.

The way forward is to use renewable sources of energy that provide electricity without causing massive damage to the environment. At the same time, people will have to use fossil fuels more efficiently to ensure that the supply lasts as long as possible – for example, by making cars travel further on a litre of petrol, and improving the efficiency of power stations.

Making and storing electricity

The electricity generation process involves a number of energy changes, regardless of the initial energy source that is used. Traditionally, electricity has been generated using fossil fuels, especially coal. More recently, power stations have started to use oil and gas as their source of energy. Oil-fired power stations are common in oil producing countries, such as Indonesia. Gas burns more cleanly and efficiently than coal. It releases half as much carbon dioxide and more than 1000 times less sulphur dioxide per unit of energy.

Burning fossil fuels in power stations

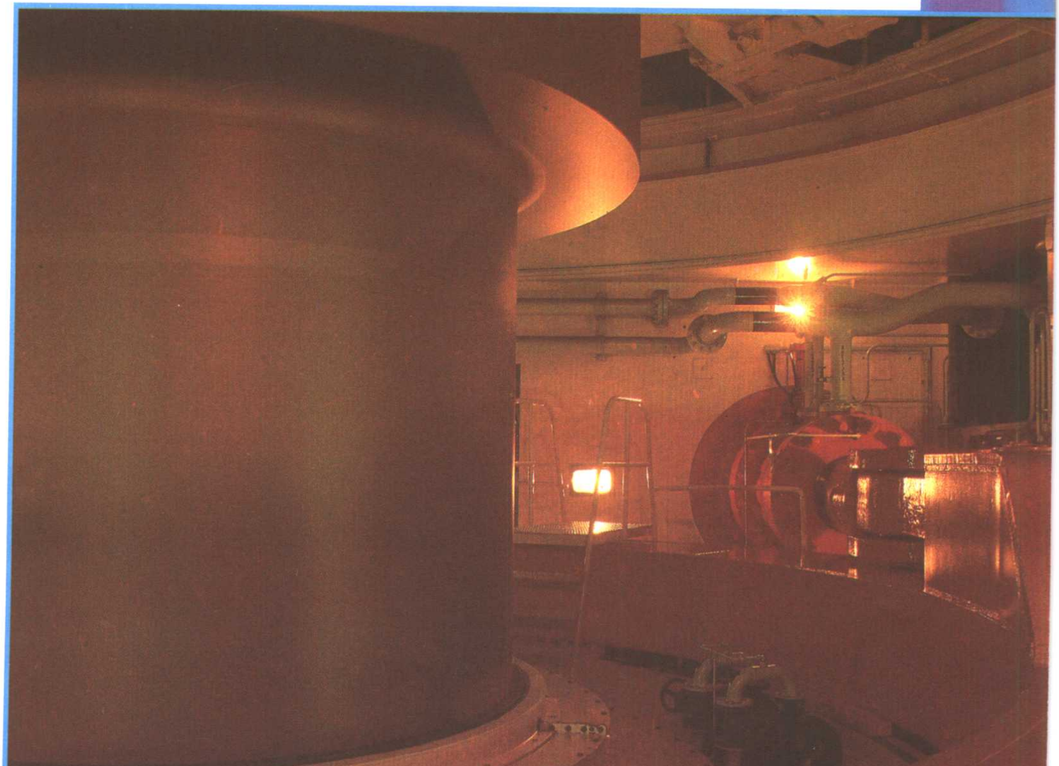
The heat released from burning fossil fuels is used to boil water to produce steam. The steam is heated to very high temperatures so that it is at high pressure and can turn huge steam **turbines**. Some of the energy of the steam is transformed into movement, or **kinetic energy**, as the turbines spin. The turbines are connected to the coils of large **generators**. The coils carry a current and act as **electromagnets**. As the turbines spin, they produce an electric current in the fixed coils surrounding them. This is fed into a power supply grid and carried to wherever in the network it is needed.

Power stations cannot store **surplus** electricity, so electricity generation has to match demand. The power companies have to judge how much power will be required. During periods of hot weather, electricity demand may increase as more people use air conditioning to keep their homes and offices cool. If power companies' estimates are wrong, people may experience power cuts.

Power stations are not very efficient, and between 50 and 70 per cent of the energy contained in the fossil fuel is wasted. Some of the heat energy will heat the surrounding air and escape through the boiler chimneys. The heat energy locked up in the steam cannot all be transferred to the spinning turbines. Although the steam is cooler when it leaves compared to when it enters the turbines, it is still warm. The steam is carried to the cooling towers, where it cools sufficiently to **condense** back to water. The warm water is then emptied into a nearby river or sea, where it can cause **thermal** (heat) pollution. Warm water holds less oxygen than cold water. The addition of a large quantity of warm water can cause animals, such as fish, to '**suffocate**', as they are unable to extract enough oxygen from the water.

Combined heat and power plants

Some power stations, called combined heat and power plants (CHP), try to make use of the waste heat. They pipe the waste hot water to surrounding businesses and homes to provide heating. There are many such units in Germany, and many small towns are benefiting from this cheap energy source. However, this is only possible with small and medium-sized power plants that are built close to towns. In many countries, especially the UK, power stations are located in more remote locations and so this energy source would not be practical.



Water is a renewable source of energy. The turbine room at the Itaipu Dam in Brazil lies deep inside the dam. The falling water spins the turbines and this, in turn, produces electricity.

Storing energy

Electricity is usually generated at a level that meets demand, as it is difficult to store surplus energy. However, it is possible to store smaller amounts of energy for personal and domestic uses. Batteries and **fuel cells** both produce electricity by using **electrochemical** reactions. **Flywheels** store energy as they spin.

The battery

A convenient store of energy is the electric cell or battery. These are used everyday to power torches, radios, toys and many other appliances. The most common form of battery contains carbon and **zinc** separated by a solution of **ammonium chloride**. When the battery is connected to an electrical circuit, its stored chemical energy is changed into electrical energy. The battery continues to produce an electric current until all the chemicals have reacted with each other. Then, the battery is said to be 'flat'. Batteries containing **nickel** and **cadmium** (Nicads) can be recharged by passing a small electric current through the battery for several hours. This makes them last much longer.

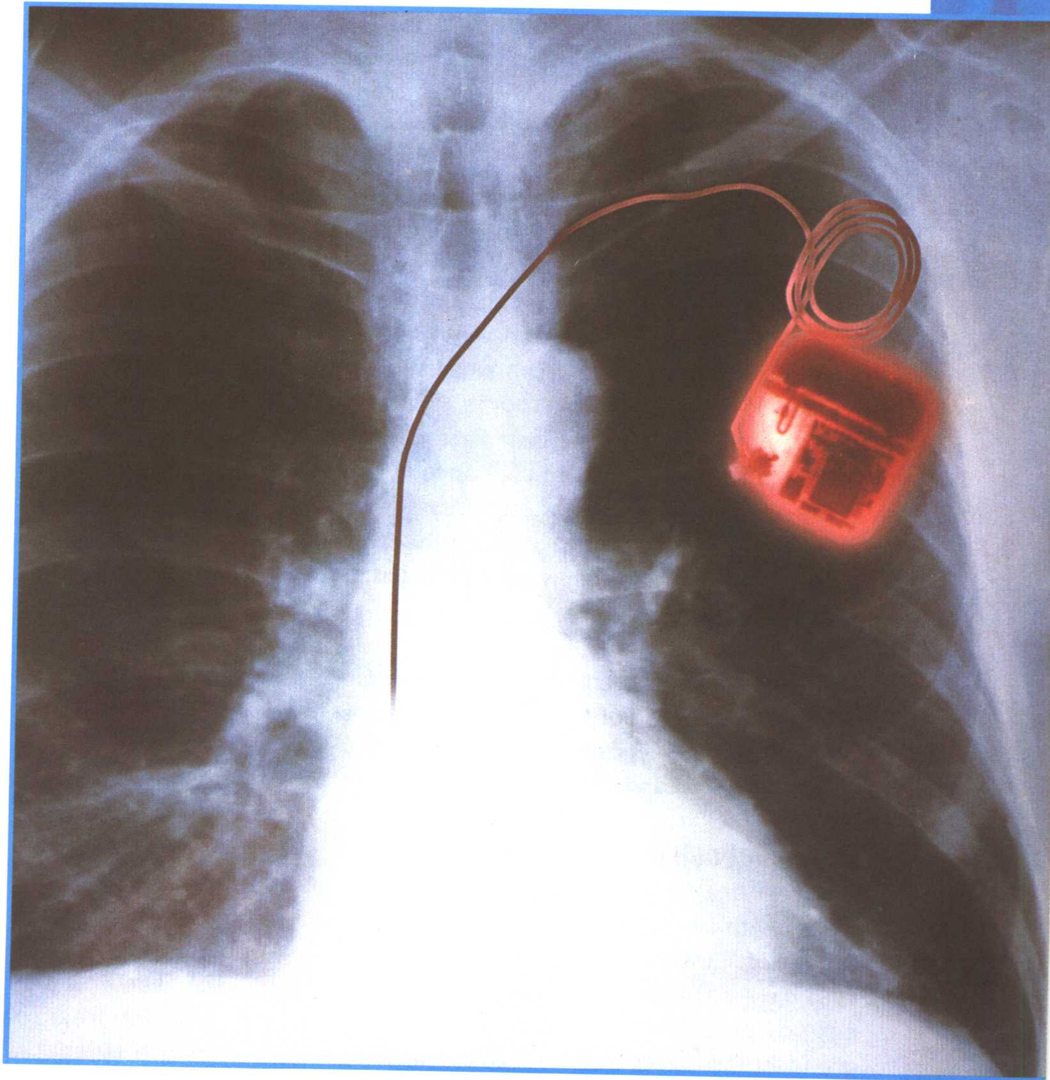
Flywheels

Space stations use **photovoltaic** panels and fuel cells as their source of energy. This energy is then stored in batteries. These batteries are large and expensive and have to be replaced every five years. But new space stations and satellites may use flywheels to store the energy. These can last up to twenty years. Flywheels are used in engines, but now scientists are designing even more efficient versions. When energy is used to spin a flywheel, the energy is converted to kinetic energy. The flywheel stores the energy mechanically in the form of kinetic

Powered by air

When air is pumped into a tyre, it becomes **compressed** and is under great pressure. When the **valve** is released, the air rushes out with some force. This idea could be used on a much larger scale by power stations. When a power station produces too much electricity, it is usually wasted. Some of this surplus electricity could be used to pump air into underground chambers, such as old salt mines, oil wells or even natural caves. The surplus electricity would be used to force the air into the chamber under pressure. When the demand for electricity became high, the air could be released to power air-driven turbines.

energy. The faster the flywheel spins, the more energy it stores. This energy can be converted to electricity. The new flywheels will be as small as just fifteen centimetres across, and made of extremely strong, yet lightweight, materials. They will spin up to 600,000 times each minute, and can store eight times more energy than a battery of the same mass.



An artificial heart pacemaker is made of **titanium** and contains a tiny generator powered by batteries. These tiny batteries are designed for the very specialized job of keeping the heart beating at the right speed. The pacemaker is inserted under the skin of the chest wall and is connected to the heart. The batteries last a long time and they can be changed under local **anaesthetic**.

Fuel cells

It is possible that in the near future, car engines, batteries in laptops and even power stations could be replaced by fuel cells. Fuel cells date back to 1839, but until recently, only the US National Aeronautics and Space Administration (NASA) made use of them.

All fuel cells are energy converters, and work on the same basic principle. They have two **electrodes** separated by an **electrolyte**, a substance that conducts electricity. A fuel such as hydrogen enters at one electrode and oxygen enters at the other. They undergo a reaction, which produces an electric current. When the fuel is hydrogen, the only waste product is pure water.

Fuel cells have many advantages. They convert energy far more efficiently than conventional power sources: for example, a fuel cell is twice as efficient as a car petrol engine and produces virtually no pollution. Furthermore, they contain no moving parts, so do not produce any noise or vibration. An operating fuel cell is therefore very quiet and does not suffer from wear and tear. However, there are a number of problems to overcome. Currently, fuel cells are very costly, although this is due to the fact that only small numbers are being manufactured. The price will fall once large quantities are produced. There are also problems of reliability with some fuel cells. In addition, some larger fuel cells have a poor power to weight and volume ratio. This means that for their weight or volume, they produce relatively small amounts of power.

> *'There's no other technology around like fuel cells. They are basically black boxes, you put fuel in one end and get electricity out the other, with great fuel efficiency and low emissions.'*
>
> Edward Gillis, Electric Power Research Institute, California

Using fuel cells

Fuel cells are already being used in some buses and cars. The fuel cell works with an electric motor that converts the electrical power from the fuel cell into a force to turn the wheels. Buses powered by fuel cells have been tested in Canada, Germany and the USA. The first fuel cell-powered cars are now appearing. These cars are emission free, so are ideal for places such as California, USA, where there are strict emission laws. Larger systems are being tested in small power stations and houses. A police station in Central Park, New York, USA, is using a large fuel cell to provide its electricity and heating. It cost more than US$1 million to install, but this was cheaper than having to lay